D4.2
Requirements definition for Brake by Wire and safety concept

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Abstract:	Gathers the final requirements for brake system and for electronic control and communication, as well as a thoughtful risk analysis and verification plan. Last but not least, a technical and safety concept for brake systems will be presented.
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Executive Summary

The main objective of WP4 of Safe4RAIL (S4R) is to develop a concept for a new railway braking system based on electronic devices and communication systems with high integrity safety performances to demonstrate the Safe4RAIL new TCMS embedded platform consistency.

In D4.1 (see [1]) the state of art of brake systems has been described.
D4.2 includes the brake system requirements specification, the safety requirement allocation, the risk analysis and new brake system concept electronic control specification.

System Requirements definition has been done with a joint work with CONNECTA (CTA) WP5, which is developing the innovative device EDV (Electronic Distributor Valve) using electronic control with high integrity safety performances. Cooperation has been necessary to benefit from the specific brake systems competencies available inside the CTA team. Cooperation between S4R and CTA has been extended to Safety Analysis where S4R has, among its partners, specific safety competencies.

The deliverable, after definition of the structure of the brake system functions and sub-functions, provides a detailed specification of the brake system functional requirements and generation process used to develop the specification.

On the basis of the functions implemented by the Brake system, a first Safety Analysis is developed at a functional level providing as results a set of countermeasures, recommendations and applications requirements.

The deliverable provides the base for the future work to be done in the next phase to get the final objective of anew brake system electronic control concept specification.

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Chapter 1 Introduction

Safe4Rail WP4 main goal is to provide the demonstration of the results of Safe4RAIL new TCMS embedded platform. This demonstration can be done by the implementation on the new TCMS platform for the safety related functions controlling the brake system of a train.

A general analysis of brake system was already done in the previous task D4.1 (see [1]).

A cooperation is established for this task and deliverable with CTA-WP5 to grant the competencies in brake system engineering necessary to make the analysis of brake system functions and define independently requirements for the control. Inside CTA-WP5 car-builders, brake suppliers and national operators are involved in the development of an innovative solution for brake system inside the Shift2Rail project.

This CTA innovative solution consists of developing a sub-system that is in charge of certain functionalities of the brake system. These functionalities are selected with the goal to replace as much pneumatic components as possible (less precise and more expensive in terms of materials and Life Cycle Cost (LCC)) with a device integrating simple pneumatic components and safe electronic control.

The selection process is described in document in [2].

Objectives and scope of the two projects are not the same, but the joint work and process can provide S4R WP4 with the necessary requirements about brake system control.

1.1 Objectives

The main objective of WP4 - Brake by Wire is to develop a *concept* for a new railway brake system control based on electronic devices and communication systems with high integrity safety performances (see §Executive Summary of [1]).

The objectives of CTA WP5 are (see §2 of [2]):

(1) Performance improvement in safety relevant braking functions resulting in optimisation of the braking distances in safety braking.

(2) On board system optimisation, reducing the number of sophisticated pneumatic components, improving overall LCC.

(3) Use of communication standards carrying high SIL related information coordinated with other TCMS WPs.

(4) Validation of non-railway EN standards to be used in railways safety related application.

Based on above, S4R WP4 and CTA WP5 have the common goal to extend the use of electronic control technologies for functionalities which are till now covered by pneumatic technologies, even if the final objectives are different:

S4R WP4 shall develop the brake system electronic control in line with the future generation TCMS platform defined by S4R WP1 and WP2.

CTA WP5 will develop an innovative sub-system of the brake system, called Electronic Distributor Valve (EDV), based on CTA WP3 new TCMS platform and on custom proprietary architecture solution market oriented in shorter times if compared with the S4R one.

S4R WP4 objective is also to provide feedback requirements to IMP - Integrated Modular Platform system which other WPs are developing, based on the result of the implementation of the general principles of the platform to the brake system practical application.

Being the final objectives different, S4R WP4 shall adapt its *scope* to CTA one, maintaining in any case the final objective of being a demonstrator of the feasibility of the new S4R TCMS embedded platform.

1.2 Scope

CTA scope is **the innovative brake sub-system EDV**, selected by the process described in [2] and composed of high safety integrity level electronic control unit and pneumatic actuators and sensors, controlling the *adhesion dependent friction brake force* applied by *service brake and emergency brake* main functions (see §4.3 in [3]).

S4R scope is a new **electronic control concept** able to implement high safety level functionalities.

CTA restriction of the scope to adhesion dependent friction brake force control and service and emergency brake is a limitation of the type of brake force controlled and of the main functions considered, but it is not a limitation in defining a brake control architecture and consequently is coherent with the general objective of S4R.

The scope of S4R can be therefore considered the following one:

- Adhesion dependent friction brake control,
- Service and emergency brake related functions,

which is aligned to the CTA one.

1.3 Work method with Connecta

S4R D4.2 had the following objectives:

- to gather the final requirements for the brake system electronic control and communication,
- to complete the safety concept for brake systems, defining through the Hazard Analysis the set of safety requirements,
- to take into account any requirement, also safety one, coming from any system breakdown development decision external to the electronic control,
- connection with communication requirements specification for the safety Ethernet infrastructure (TCMS) from WP1 & WP2.

The scope of above activities is limited by what specified in §1.2.

The above activities require both brake system functions and overall architecture definition, in order to identify the borders between electronic control and other devices.

CTA, in parallel task T5.2, develops brake system functional structure only, while the brake system architecture definition is demanded to T5.4 (see §2 Note 1 of [3]).

S4R has not competencies to define autonomously an overall brake system architecture.

The objectives of T4.2 are then redefined as follow, for which cooperation between CTA and S4R is required:

- to gather the requirements for the brake system functionalities inside the above mentioned scope, identifying interface information with other sub-functions or technical systems of the train;

- to complete the safety concept for brake systems, defining through the Preliminary Hazard Analysis (PHA) the set of safety requirements for the brake system functionalities inside the above mentioned scope.

The requirements shall specify **the whole set of brake system sub-functions inside the defined scope**, whatever the brake system sub-function or the technical system of the train is in charge of.

In the following work and deliverable D4.4 (S4R T4.3 D4.4) CTA and S4R cooperation shall permit:

- to define brake system architecture identifying the border of electronic control and the interfaces;
- to check the consistency of defined brake architecture with functional and safety requirements defined in this deliverable;
- to arrive to a final definition of functional and safety requirements related to sub-function performed by electronic control and its interfaces.

Once these activities are finalized S4R will have all the information to proceed autonomously with the brake system electronic control concept definition based on IMP.

Further limitation in the scope could be defined (for example to consider only emergency brake functions).

The last activity part of the objectives of T4.2:

- connection with communication requirements specification for the safety Ethernet infrastructure (TCMS) from WP1 & WP2,

is moved as well to D4.4, involving Electronic Control architectural aspects.

1.4 Conclusion

The main objective of S4R WP4 is the development of a *concept* for a new railway braking system based on electronic devices and communication systems with high integrity safety performances based on S4R integrated platform.

The scope for the development can be limited by the boundaries defined with CTA and the requirements definition work can be jointly done.

The joining points of the CTA-WP5 and S4R-WP4s, starting from which each WP will define its own electronic control architecture, are:

1. brake system functions and sub-functions structure,
2. requirements of the set of brake system sub-functions inside the defined scope and related interfaces information,
3. system safety requirements,
4. brake system architecture,
5. electronic control requirements allocation and related interfaces.

The joint starting point guarantee the consistency of the two research activities.

In this document the first 3 steps are developed.

S4R, starting from the outcome of above cooperation, in the following task will:

1. filter and propagate the requirements for electronic controls, taking in account the boundaries about electronics and the brake system safety analysis;

2. defines the architecture of an electronic control of brake system based on S4R new TCMS platform;
3. defines the concept for an electronic sub-system part of the above defined architecture, focused on the brake system functionalities inside the scope;
4. develop the electronic sub-system concept on the new TCMS platform.

Chapter 2 Brake system functional structure

Brake system functional structure is the result of the process followed by CTA in [2] and [3].

In [2] a top down process defines the brake system functional structure: starting from the definition of the main goal given to brake system by European directive [1] §4.2.4.1 requirement (1).

“The purpose of the train braking system is to ensure that the train's speed can be reduced or maintained on a slope, or that the train can be stopped within the maximum allowable braking distance. Braking also ensures the immobilisation of a train.”

It is analysed how this goal is propagated to main functions and from main functions, to their sub-functions in the conventional brake system.

The main brake system functions, described in §3.4.2 of [2], have the following main goals:

- BSM - Brake System Management:
  it has the goal to manage the Brake System initialization and configuration at train power up or coupling/uncoupling and to manage the operative mode of the Brake system during operation.

- SB - Service Brake:
  It is used by the driver and technical systems (actors) to apply an adjustable retarding force to the track (directly or by the wheelset) with the following goals:
  - Reduce the speed of the train;
  - Maintain the speed of the train on a slope;
  - Immobilize *temporary* the train at standstill on a certain slope.

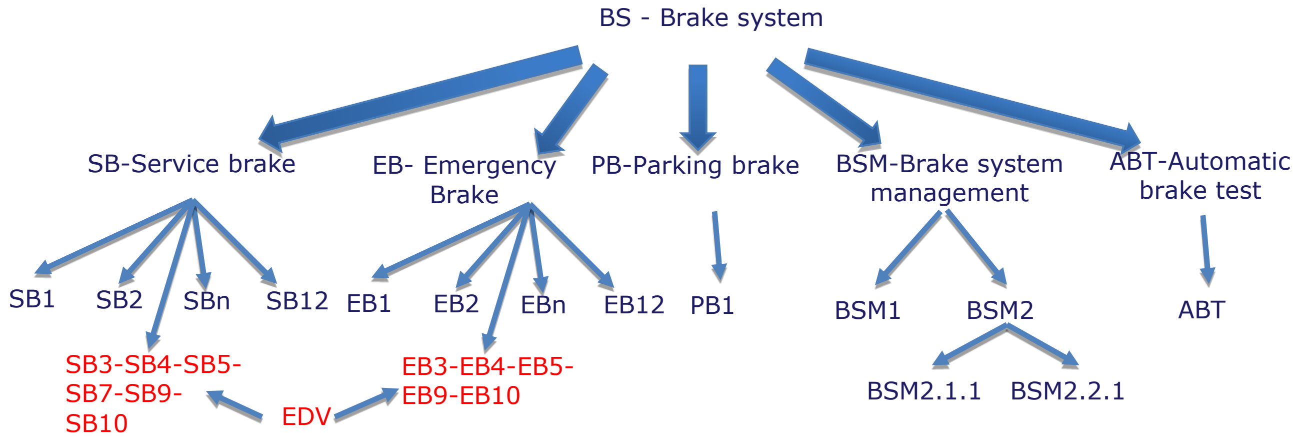
- EB - Emergency Brake:
  It is used by the driver and technical systems (actors) to apply a predefined retarding force to the track (directly or by the wheelset), with the goal to stop the train in a predetermined distance in line with guaranteed performances considered by signalling system model.

- PB - Parking Brake:
  it is used by the driver and technical systems (actors) to apply a force to the track (directly or by the wheelset), with the goal to keep the train stationary for an *indeterminate period of time*, at a certain load condition, on a certain slope and without energy available on board.

- LAM - Low Adhesion Management:
  it has the goal to maximize the train brake performances in case of reduced adhesion of the rail which can induce sliding of the wheelset on the track. This function provides both protection against sliding and increase of the available adhesion between wheelset and track in low adhesion conditions.
  The LAM - Low Adhesion Management main function is a common function for Service Brake and Emergency Brake, for this reason in the following revision of the structure done in [3] it became a sub-function.

The sub-functions are described by the title and requirements in §3.4.4 of [2].

As result of [2] , a preliminary list of sub-functions which can be allocated to the innovative device EDV is identified among the emergency and service brake sub-functions. In [3], starting from conventional train brake system functional structure, the possible improvement given by EDV innovative solution is analysed and a new functional structure is defined including the new functionalities possible with the implementation of the innovative solution (see §4.2 of [3]). The final list of sub-functions in charge of EDV is defined.



The brake system functional structure is the following:

2.1 BSM - Brake System Management sub-functions

BSM1. Train topology and brake system integrity
BSM2. Brake operating modes management
- BSM2.1. Service brake management
  - BSM2.1.1. Service brake normal mode
  - BSM2.1.2. Service brake degraded mode
  - BSM2.1.3. Service brake towing mode
- BSM2.2. Emergency brake management
  - BSM2.2.1. Emergency brake normal mode
  - BSM2.2.2. Emergency brake degraded mode
  - BSM2.2.3. Emergency brake towing mode

2.2 SB – Service brake sub-functions

SB1. Service brake train deceleration request
- SB1.1. Driver request acquisition
- SB1.2. Technical system request acquisition

SB2. Service brake request transmission
SB3. Train load calculation
- SB3.1. Load acquisition
- SB3.2. Train load calculation

SB4. Train service brake force calculation
SB5. Service brake blending
- SB5.1. Detection of the service brake availability of all types of brake
  - SB5.1.1. Dynamic service brake availability detection

SB5.1.1.1. Adhesion dependent dynamic service brake availability detection (ED brake)
SB5.1.1.2. Adhesion independent dynamic service brake availability detection (Eddy current brake)
SB5.1.2. Friction service brake availability acquisition
SB5.1.2.1. Adhesion dependent friction service brake availability detection (Disc/tread brake)
SB5.1.2.2. Adhesion independent friction service brake availability detection (MTB)
SB5.2. Train service brake force calculation on different types of brake
SB5.2.1. Train dynamic service brake force calculation
SB5.2.1.1. Train adhesion dependent dynamic service brake force calculation (ED brake)
SB5.2.1.2. Train adhesion independent dynamic service Brake force calculation (Eddy current brake)
SB5.2.2. Train Friction Service Brake Force Calculation
SB5.2.2.1. Train adhesion dependent friction service brake force calculation (Disc/tread brake)
SB5.2.2.2. Train adhesion independent friction service brake force calculation (MTB)
SB5.3. Train service brake force request on different types of brake
SB5.3.1. Dynamic Service Brake Force Request
SB5.3.1.1. Adhesion dependent dynamic service brake force request (ED brake)
SB5.3.1.2. Adhesion independent dynamic service Brake force request (Eddy current brake)
SB5.3.2. Friction Service Brake Force Request
SB5.3.2.1. Adhesion dependent friction service brake force request (Disc/tread brake)
SB5.3.2.2. Adhesion independent friction service brake force request (MTB)
SB5.4. Achieved adhesion dependent dynamic service brake force detection (ED brake)
SB5.5. Service brake force application
SB5.5.1. Dynamic service brake force generation
SB5.5.1.1. Adhesion dependent dynamic service brake force generation (ED brake)

1. Reference adhesion dependent dynamic service brake force pilot command generation
2. Adhesion dependent dynamic service brake force application

SB5.5.1.2. Adhesion independent service brake force generation (Eddy current brake)

1. Adhesion independent dynamic service brake force pilot command generation
2. Adhesion independent dynamic service brake force application (Eddy current brake)

SB5.5.2. Friction service brake force generation

SB5.5.2.1. Adhesion dependent friction service brake force generation (Disc/tread brake)
1. Adhesion dependent friction service brake force pilot command generation
2. Adhesion dependent friction brake force application

SB5.5.2.2. Adhesion independent friction service brake force generation (MTB)
1. Adhesion independent friction service brake force pilot command generation
2. Adhesion independent friction brake force application

SB6. Service brake energy storing and distribution
SB6.1. Pneumatic energy storing and distribution
SB6.2. Electric energy storing and distribution
SB7. Holding brake
SB8. Service brake Traction cut off
SB9. Service brake state and fault detection and indication
SB9.1. General service brake function state and fault detection and indication
SB9.2. Adhesion dependent dynamic service brake state and fault detection and indication (ED brake)
SB9.3. Adhesion independent dynamic service brake state and fault detection and indication (Eddy Current brake)
SB9.4. Adhesion dependent friction service brake state and fault detection and indication (Disc/tread brake)
SB9.5. Adhesion independent friction service brake state and fault detection and indication (MTB)
SB10. Service Brake isolation
SB10.1. Adhesion dependent dynamic service brake isolation (ED brake)
SB10.2. Adhesion independent dynamic service brake isolation (Eddy Current)
SB10.3. Adhesion dependent friction service brake isolation (Disc/tread brake)
SB10.4. Adhesion independent friction service brake isolation (MTB)
SB11. Energy supply
SB11.1. Service brake high voltage electric energy supply
SB11.2. Service brake low voltage energy supply
SB11.3. Service brake pneumatic energy supply
SB12. Service brake kinetic energy transformation
SB12.1. Service brake kinetic energy transformation in electric energy
SB12.1.1. Kinetic energy transformation in electric energy
SB12.1.2. Electric energy recovery
SB12.1.3. Electric energy dissipation
SB12.2. Service brake kinetic energy transformation in thermal energy
SB13.1.1. Kinetic energy transformation in thermal energy
SB13.1.2. Thermal energy dissipation
LAM1 Wheel slide protection
LAM1.1 Speed detection
LAM1.2 Adhesion dependent reference brake force reduction/restoring
LAM1.2.1 Adhesion dependent dynamic reference brake force command reduction/restoring (ED brake)

LAM1.2.2 Adhesion dependent friction reference brake force command reduction/restoring (disc/tread brake)
LAM1.2.3 Brake force reduction timeout (watchdog)
LAM2 Adhesion improvement (Sanding)
LAM2.1 Adhesion improvement request
LAM2.1.1 Adhesion improvement manual request
LAM2.1.2 Adhesion improvement automatic request
LAM2.2 Adhesion improvement manual request transmission
LAM2.3 Adhesion improvement generation
LAM3 Adhesion management state and fault detection and indication
LAM3.1 General adhesion management sub-function state and fault detection and indication
LAM3.2 Wheel slide protection state and fault detection and indication
LAM3.3 Adhesion improvement state and fault detection and indication

2.3 EB - Emergency brake sub-functions

EB1. Emergency brake train deceleration request
EB1.1. Driver request acquisition
EB1.2. Technical system request acquisition
EB2. Emergency brake request transmission
EB3. Train load calculation
EB3.1. Load acquisition
EB3.2. Train load calculation
EB4. Train emergency brake force calculation
EB5. Emergency brake blending
EB5.1. Detection of the emergency brake availability of all types of brake
EB5.1.1. Dynamic emergency brake availability detection
EB5.1.1.1. Adhesion dependent dynamic emergency brake availability detection (ED brake)
EB5.1.1.2. Adhesion independent dynamic emergency brake availability detection (Eddy current brake)
EB5.1.2. Friction emergency brake availability detection
EB5.1.2.1. Adhesion dependent friction emergency brake availability detection (Disc/tread brake)
EB5.1.2.2. Adhesion independent friction emergency brake availability detection (MTB)
EB5.2. Train emergency brake force calculation on different types of brake
EB5.2.1. Train dynamic emergency brake force calculation
EB5.2.1.1. Train adhesion dependent dynamic emergency brake force calculation (ED brake)
EB5.2.1.2. Train adhesion independent dynamic emergency Brake force calculation (Eddy current brake)
EB5.2.2. Train Friction Emergency Brake Force Calculation
EB5.2.2.1. Train adhesion dependent friction emergency brake force calculation (disc/tread brake)
EB5.2.2.2. Train adhesion independent friction emergency brake force calculation (MTB)

- EB5.3. Train emergency brake force request on different types of brakes
  - EB5.3.1. Dynamic Emergency Brake Force Request
    - EB5.3.1.1. Adhesion dependent dynamic emergency brake force request (ED brake)
    - EB5.3.1.2. Adhesion independent dynamic emergency Brake force request (Eddy current brake)
  - EB5.3.2. Friction Emergency Brake Force Request
    - EB5.3.2.1. Adhesion dependent friction emergency brake force request (Disc/tread brake)
    - EB5.3.2.2. Adhesion independent friction emergency brake force request (MTB)
- EB5.4. Achieved adhesion dependent dynamic emergency brake force detection (ED brake)
- EB5.5. Emergency brake force application
  - EB5.5.1. Dynamic emergency brake force generation
    - EB5.5.1.1. Adhesion dependent dynamic emergency brake force generation (ED brake)
      - EB5.5.1.1.1. Reference adhesion dependent dynamic emergency brake force command generation
      - EB5.5.1.1.2. Adhesion dependent dynamic emergency brake force application
    - EB5.5.1.2. Adhesion independent emergency brake force generation (Eddy current brake)
      - EB5.5.1.2.1. Adhesion independent dynamic emergency brake force command generation
      - EB5.5.1.2.2. Adhesion independent dynamic emergency brake force application
  - EB5.5.2. Friction emergency brake force generation
    - EB5.5.2.1. Adhesion dependent friction emergency brake force generation (Disc/tread brake)
      - EB5.5.2.1.1. Adhesion dependent friction emergency brake force pilot command generation
      - EB5.5.2.1.2. Adhesion dependent friction brake force application
    - EB5.5.2.2. Adhesion independent friction emergency brake force generation (MTB)
      - EB5.5.2.2.1. Adhesion independent friction emergency brake force command generation
      - EB5.5.2.2.2. Adhesion independent friction brake force application

EB6. Emergency brake energy storing and distribution
- EB6.1. Pneumatic energy storing and distribution
- EB6.2. Electric energy storing and distribution

EB7. Actual Emergency Braking Power Calculation
- EB7.1. Emergency Braking power calculation
- EB7.2. Emergency Braking power indication to driver
- EB7.3. Emergency Braking power transmission to technical systems

EB8. Emergency brake Traction cut off

- EB9. Emergency brake state and fault detection and indication
  - EB9.1. General emergency brake function state and fault detection and indication
  - EB9.2. Adhesion dependent dynamic emergency brake state and fault detection and indication (ED brake)
  - EB9.3. Adhesion independent dynamic emergency brake state and fault detection and indication (Eddy current brake)
  - EB9.4. Adhesion dependent friction emergency brake state and fault detection and indication (Disc/tread brake)
  - EB9.5. Adhesion independent friction emergency brake state and fault detection and indication (MTB)
- EB10. Emergency Brake isolation
  - EB10.1. Adhesion dependent dynamic emergency brake isolation (ED brake)
  - EB10.2. Adhesion independent dynamic emergency brake isolation (Eddy/current brake)
  - EB10.3. Adhesion dependent friction emergency brake isolation (Disc/tread brake)
  - EB10.4. Adhesion independent friction emergency brake isolation (MTB)
- EB11. Energy supply
  - EB11.1. Emergency brake high voltage electric energy supply
  - EB11.2. Emergency brake low voltage energy supply
  - EB11.3. Emergency brake pneumatic energy supply
- EB12. Emergency brake kinetic energy transformation
  - EB12.1. Emergency brake kinetic energy transformation in electric energy
    - EB12.1.1. Kinetic energy transformation in electric energy
    - EB12.1.2. Electric energy recovery
    - EB12.1.3. Electric energy dissipation
  - EB12.2. Emergency brake kinetic energy transformation in thermal energy
    - EB12.2.1. Kinetic energy transformation in thermal energy
    - EB12.2.2. Thermal energy dissipation
- LAM1 Wheel slide protection
  - LAM1.1 Speed detection
  - LAM1.2 Adhesion dependent reference brake force reduction/restoring
    - LAM1.2.1 Adhesion dependent dynamic reference brake force command reduction/restoring
    - LAM1.2.2 Adhesion dependent friction reference brake force command reduction/restoring
    - LAM1.2.3 Brake force reduction timeout (watchdog)

- LAM2 Adhesion improvement
  - LAM2.1 Adhesion improvement request
    - LAM2.1.1 Adhesion improvement manual request
    - LAM2.1.2 Adhesion improvement automatic request
  - LAM2.2 Adhesion improvement manual request transmission
  - LAM2.3 Adhesion improvement generation
- LAM3 Adhesion management state and fault detection and indication
  - LAM3.1 General adhesion management sub-function state and fault detection and indication

LAM3.2 Wheel slide protection state and fault detection and indication
LAM3.3 Adhesion improvement state and fault detection and indication

2.4 PB – Parking brake sub-functions

- PB1. Parking brake command generation
  - PB1.1. Driver request acquisition
  - PB1.2. Technical system request acquisition
- PB2. Parking brake train command transmission
- PB3. Parking brake force generation
  - PB3.1. By train command
  - PB3.2. By local command (manual application)
- PB4. Parking brake energy supply
  - PB4.1. Pneumatic energy supply
  - PB4.2. Parking brake low voltage electric energy supply
- PB5. Parking brake energy storing and distribution
  - PB5.1. Parking pneumatic energy storing and distribution
  - PB5.2. Parking electric energy storing and distribution
- PB6. Anti-compound
- PB7. Actual Parking Braking Power Calculation
- PB8. Parking brake state and fault detection and indication
  - PB8.1. Parking brake applied status
  - PB8.2. Parking brake released status
  - PB8.3. Local parking brake state (applied/released/faulty/isolated/no info)
- PB9. Monitoring Parking brake applied at speed detection and speed reduction request
- PB10. Parking brake manual release
- PB11. Parking brake isolation

2.5 ABT – Automatic Brake test sub-functions

- ABT1. Automatic Brake Test request generation
  - ABT1.1. Driver request acquisition (only in brake test mode)
  - ABT1.2. Technical system request acquisition (only in brake test mode)
- ABT2. Check of preconditions of brake test
- ABT3. Automatic Brake test commands transmission
- ABT4. Continuity test
  - ABT4.1. Service brake command continuity
  - ABT4.2. Emergency brake command continuity
  - ABT4.3. Parking brake command continuity
- ABT5. Adhesion dependent friction brake test (Disc/tread)
- ABT6. Adhesion independent friction brake test (MTB)
- ABT7. Adhesion dependent dynamic brake systems test (ED brake)
- ABT8. Adhesion independent dynamic brake systems test (Eddy current brake)
- ABT9. Braking power calculation
- ABT10. Pneumatic energy supply test
- ABT11. Wheel Slide Protection test
- ABT12. Adhesion improvement management test

Chapter 3 Brake system functional requirements specification

This chapter describes the requirements generation process jointly done by S4R and CTA.

3.1 Requirements sub-set definition

CTA, to reach its scope, identified in §4.3 of [3] the following sub-functions managing the adhesion dependent friction brake application which are allocated to the EDV device:

SB3	Train load calculation
SB4	Train service brake force calculation
SB5.1.2.1	Adhesion dependent friction service brake availability detection (Disc/tread brake)
SB5.2	Train service brake force calculation on different types of brake
SB5.3.2.1	Adhesion dependent friction service brake force request (Disc/tread brake)
SB.5.5.2.1.1	Adhesion dependent friction service brake force pilot command generation
SB7	Holding brake
SB9.4	Adhesion dependent friction service brake state and fault detection and indication (Disc/tread brake)
SB10.3	Adhesion dependent friction service brake isolation (Disc/tread brake)
LAM1	Wheel slide protection
LAM2.1.2	Adhesion improvement automatic request
LAM3.2	Wheel slide protection state and fault detection and indication
EB3	Train load calculation
EB4	Train emergency brake force calculation
EB5.1.2.1	Adhesion dependent friction emergency brake availability detection (Disc/tread brake)
EB5.2	Train emergency brake force calculation on different types of brake
EB5.3.2.1	Adhesion dependent friction emergency brake force request (Disc/tread brake)
EB5.5.2.1.1	Adhesion dependent friction emergency brake force pilot command generation
EB9.4	Adhesion dependent friction emergency brake state and fault detection and indication (Disc/tread brake)
EB10.3	Adhesion dependent friction emergency brake isolation (Disc/tread brake)

The above identified set of sub-functions is not enough to arrive to a clear definition of the EDV requirements.

The EDV sub-functions need information coming from other brake system sub-functions and technical system as inputs. The content of this information can be described by the requirements of other sub-functions not allocated to EDV and of involved technical system, which shall be also generated to have precise understanding of the information meaning.

These additional requirements are the ones completing the global view of the **control process of the adhesion dependent friction brake force** and permitting S4R to have all requirements necessary to reach its objective on the defined scope.

Based on above, **for every function/sub-function of the brake system, requirements relevant for the control of the adhesion dependent brake force** (emergency or service) have been generated.

The definition of all requirements linked to the adhesion dependent friction brake force provides also the complete flow of events necessary to do a consistent system level safety analysis, which is described in next Chapter 4.

Requirements about PB and ABT functions are intentionally ignored, because they are not included in the scope.

BSM function requirements are instead considered since they impact the service and emergency brake management at train level.

3.2 Function interfaces and data information definition

Any data exchanged and used in the functional model, reported as data, information or parameter, is specified as a single requirement under the Requirements Classification as “data”.

The term “parameter” refers to invariant configuration numbers, defined and validated during dimensioning/design phase.

3.3 Requirements classification

The requirements can be classified depending on the requirements definition phase of the top down process and on the type of requirements.

- Top – down process:
    - ➢ System requirements: these are the requirements linked to the system functionalities, they are the top level requirements.
    - ➢ Architectural requirements: these are the functional requirements which are propagation of the chosen architecture of the brake system, implementing the functionalities described by system requirements in a coherent way.
    - ➢ Technical requirements: these are the requirements propagation of the system and architectural requirements to devices implementing them. In S4R project they correspond to Electronic Control (EC) requirements and they include functional, architectural, technical requirements of electronic control propagating the above system and architectural requirements allocated to EC.

  This document specifies system requirements only.

- Type:

  Requirement types are defined by the content of the requirement:

  a) Functional requirements:

They are requirements describing specific behaviours, what a certain actor does with certain defined input information. It has always as result an output which will be an input to other requirements.

b) Interface data requirements
The interface data requirement provides a simple and clear definition of, interface information or parameter being actor input or output of any requirement to provide common understanding of the requirements itself (see §3.2 for interface information or parameters requirements).

c) Safety requirements
Requirements are object of safety analysis, providing recommendation or mandatory requirements.
These requirements are subsequent to requirements definition and generate a reiteration of the requirements generation process to take in account them in the system design. Final objective is to transform all safety requirements into functional requirements.

Other types of requirements will be present once that the system design will deal with the technical aspects: environmental requirements, dimension requirements, communication requirements, etc..

At this stage all the requirements defined are at the same level, there is no parent/son relation between them, even if existing.

3.4 Requirements format

Among the attributes proposed in §4.2 of [4] , following one will be used in this document:

- Requirement ID: automatic code given by Polarion to the requirement;
- Requirement text: requirement description;
- Requirement identification: “speaking” code, parallel to Polarion automatic code, mentioning the brake system sub-functions which the requirement describes;
- Requirement classification – Level: in this document all requirements are at System level;
- Requirement classification – Type: type of requirement among:
    - Functional
    - Definition
    - Safety
- Main Function: report the main function of brake system at which the requirements refer to;
- Rationale: any justification of the requirement or comment;
- Actor: actor in charge of the requirement. The actors can be users, other technical system of the train, any brake system function or sub-function (see §3.7);
- Input information: the input information used to implement the functionality by the actor;

- Output information: the information which is the output of the requirement.

3.5 Requirements management

Relevant information for the Requirements management process that has been adopted:

- requirements are traced in Annex 3 .
- requirements are imported on the requirements manager Polarion to support the following work to define and link together lower V process level requirements.
- a reqif file format is available for any exportation need.
- key requirements information is available in Annex 2 .

3.6 Requirements propagation plan

Requirements reported in this deliverable are:

- system level,
- functional,
- related to the scope defined in the previous chapters.

Future development for the Requirements definition will done according to these V process steps:

- System Architecture
- Electronic Control
- Electronic Control architecture
- Electronic Control Items:
    - hardware
    - software
    - IMP

3.7 Requirements actors

Every requirement is in charge of one and only one of the following possible actors:

- Dimensioning (responsible for parameters, see §3.2).

- Brake system functions and sub-functions:
    - any of the functions/sub-functions listed in Chapter 2.

- User:
    - Driver
    - Train staff
    - Brake test operator
    - Maintenance staff
    - Preparation service staff

- Train Technical system (other than brake system):
    - Railway track
    - Wheel/Wheel set
    - Traction

- Electrical energy supply
- Pneumatic energy supply
- Passenger Alarm
- ATP on board
- ATO on board
- ETCS on board unit
- Odometry
- Macrophones and horns
- TCMS
- GSM/WLAN
- Vehicle coupler
- Vigilance control on board unit
- Driver HMI (displays, Touch and hw buttons)
- Diagnostic system
- Maintenance tools
- Diagnostic tool
- Thermostat
- Environmental condition
- Car Body
- Door
- Bogie

3.8 Functional requirements definition

The functional requirements are defined working on the following sources:

- Applicable functional requirements reported in previous S4R document [1] and CTA document [2],
- European regulation [1], standards [9] and standard [10] applicable functional requirements,
- Assumption done in defining the functional structure,
- Assumptions and best practices coming from experience on conventional trains and oriented to innovative solution.

In next paragraphs the assumptions and best practices used in defining the requirements are described to provide an explanation of the requirements specified formally in Annex 2 and Annex 3 .

In § the brake system level base concept used in defining requirements are described, in §3.8.6 assumptions done for different sub-functions, based on above mentioned concepts and best practices are resumed.

3.8.1 Brake system base concept

The main function of brake system is defined in §4.2.4.1 (1) of [1]:

"The purpose of the train braking system is to ensure that the train's speed can be reduced or maintained on a slope, or that the train can be stopped within the maximum allowable braking distance. Braking also ensures the immobilization of a train".

The main function of the brake system is then **to generate a force** so that a deceleration is applied at the mass of the train and the train reduces the speed or stops in a certain stopping distance, or the train is immobilized on a maximum slope.

It means that it is needed: brake request, brake request transmission and brake force application functionalities. All functionalities are inside these 3 categories of functions.

Not only functionalities are involved in requirement definition, but also

- physical aspects (dynamics and kinematics),
- dimensioning principles,
- main brake system safety principle,

shall be considered in requirements definition.

The three main functions of brake system are then defined by TSI as follow:

- Service brake: "ensures that the train's speed can be reduced or maintained on a slope" and "ensures the *temporary* immobilization of the train";
- Emergency brake: "ensures the train can be stopped within the maximum allowable braking distance";
- Parking brake: "ensures the *permanent* immobilization of the train".

Note: the immobilisation requirement is divided in temporary and permanent immobilisation in TSI §4.2.4.2.1 (13).

3.8.2 Dynamic and kinematic

In this chapter physical concepts that are described in [14]are considered, adopting a different formality with the goal to be more understandable.

All the brake requirements turn around these main physical figures:

- Mass (m)
- Slope (i)
- Force (F)
- Deceleration (a)
- Speed (v)
- Space (s)
- Time (t)

Mass, Speed and Slope are the 3 key physical input information by which brake system is able to control the speed and stop the train in a predefined stopping distance in front of a brake request.

⇒ Mass measurement is one of the brake system sub-functions.

⇒ Train speed measurement is considered an external input of the brake system function.

⇒ Slope information:

- It is optional in **service brake**, to have a service brake deceleration independent from the slope.

- It is not considered in **emergency brake** because it is supposed that the longer stopping distances are considered by signalling.

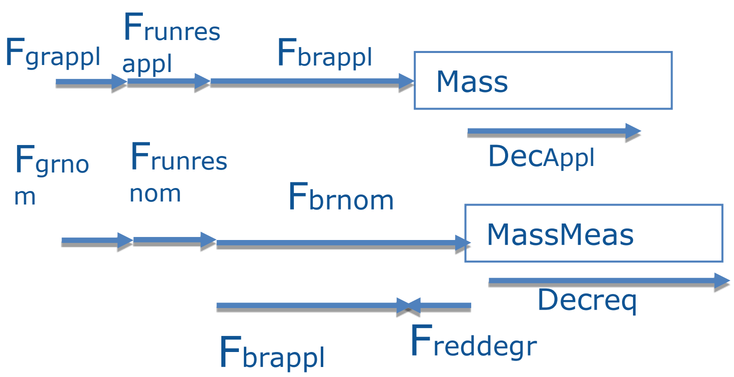
Force, speed, deceleration and space are linked together by physical constraints represented by dynamics and kinematic of the train.
The forces applied to the train are:

- Braking force,
- Running resistance force,
- Gravity force.

In the requirements the forces/deceleration “applied” are the real forces/deceleration applied at the train.

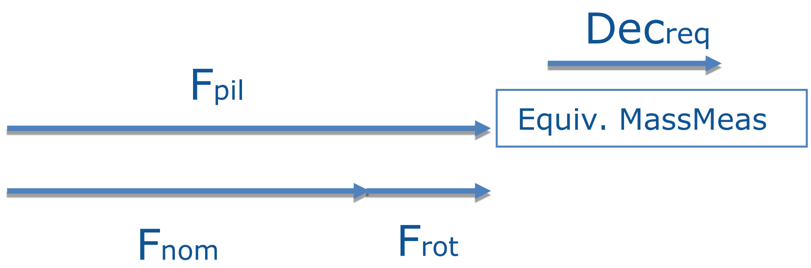
The forces/deceleration “nominal” are the *expected* forces/deceleration to be applied based on *request.*

The difference between nominal and applied is the degradation of the force due to degraded environmental condition (wet pad, sliding) / degraded dissipation condition (high pad/disc temperature, high rheostat temperature, ...) or failures.



F_{grappl} : Gravity force applied
$F_{runresappl}$: Running resistance force applied
F_{brappl} : Braking force applied
Mass : Train Mass
DecAppl : Deceleration applied at the train
F_{grnom} : Gravity force nominal
$F_{runresnom}$: Running resistance force nominal
F_{brnom} : Braking Force nominal
MassMeas : Train mass measured
Decreq : Requested deceleration
$F_{reddegr}$: Reduction of force due to degraded condition

Rotating mass is considered by piloting to the force generation sub-function SB/EB5.5 a force equal to the nominal one + the force necessary to brake the rotating mass:



Fpil	: Piloted braking force,
Frot	: Force braking the rotating mass,
Equiv. MassMeas	: Train equivalent mass measured (measured mass + rotating equivalent mass).

Note: the rotating mass brake force request is provided by both adhesion dependent type of forces. The priority is automatically given to dynamic brake by the feedback of dynamic brake force to friction brake force provided by sub-function SB/EB5.4 (see §3.8.11 last sentences).

Constraints are present:

- Mass: running order mass< mass < maximum mass;
- Slope: 0 < slope < maximum slope of the line;
- Speed: 0 < speed < max speed of the train;
- Deceleration: maximum limits applicable by brake system (linked to limit of forces on the tracks), contractual limits, operational limits (adjustability, minimum value acceptable), maximum jerk;
- Force: maximum force applicable by brake system dimensioning constraints, maximum force applicable due to adhesion limits, force availability.

The constraints can be speed dependent.

The kinematic of the train is given by the formulas provided by following formula in case of constant deceleration in every speed interval:

$$S = V_0\,\mathrm{t}_{eq} + \frac{v_0^2 - v_1^2}{2a_1} + \frac{v_1^2 - v_2^2}{2a_2} + \cdots + \frac{v_n^2}{2a_{n+1}}$$

Where

S : stopping distance

V_0 : initial speed

t_{eq} : equivalent time

a_{n+1} : deceleration in the speed interval n+1

v_n : initial speed in the speed interval n+1

v_{n+1} : final speed in the speed interval n+1

If a linearly variable deceleration is considered the formula can be the following:

$$S = V_0\,\mathrm{t}_{eq} + \left(\frac{v_1}{-k_2} - \frac{k_1}{{k_2}^2} * ln|k_1 - k_2 v_1|\right) - \left(\frac{v_0}{-k_2} - \frac{k_1}{{k_2}^2} * ln|k_1 - k_2 v_0|\right)$$

Where

$$a(v) = k_1 - k_2 * v$$
$$v_1 < v_{in} \leq v_0$$

3.8.3 Brake force types

The brake force is obtained by the single or contemporary application of the 4 types of forces:
- Adhesion dependent dynamic brake,
- Adhesion independent dynamic brake,
- Adhesion dependent friction brake,
- Adhesion independent friction brake.

Where adhesion dependent are the forces transmitted to the rail by the wheels.

Emergency brake can use all 4 types.

Service brake can use the first 3 types.

Parking brake can use friction types.

The adhesion dependent friction brake force is supposed to be piloted by pneumatic energy (conventional solution).

All forces are linked together by dimensioning constraints on:
- Adhesion,
- Performances,
- Forces,
- Energy.

3.8.4 Brake dimensioning constraints

3.8.4.1 Adhesion

The adhesion dependent brakes are linked together by the wheel rail adhesion limits.

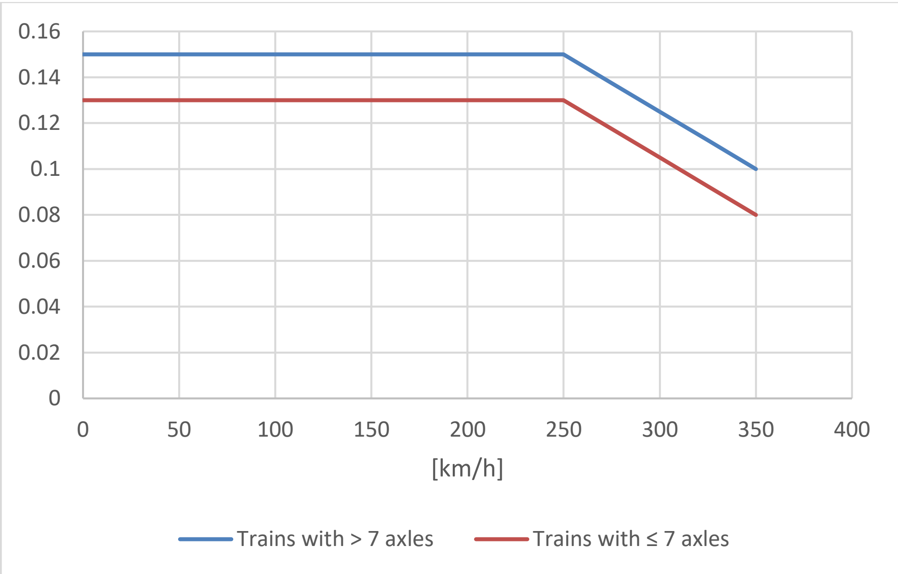


Figure 1 – TSI Adhesion limits

3.8.4.2 Service brake performances constraints

The service brake request is a *deceleration* request (speed regulation), having the following characteristics:

- mass independent: at same request same performance with different mass;
- speed dependent: at same request the performance can be different at different speed;
- slope dependent: at same request different performance with different slope (optionally independent with slope external information available);
- failures independent: at same request, same performance achieved in nominal or degraded condition (until the dimensioning and blending rules permit it);
- environmental/dissipation condition dependent: at same request, the performances are different at different environmental/dissipation condition.

The service brake performance is then a deceleration, but defined by a range:

- low deceleration: operational constraint,
- high deceleration operational and LCC constr.

For every request of service brake the deceleration shall stay inside a predefined range of deceleration.

The range is defined by two «parameters», representing the deceleration limits for *maximum* service brake request (100%):

- Max Service brake low deceleration,
- Max Service brake high deceleration.

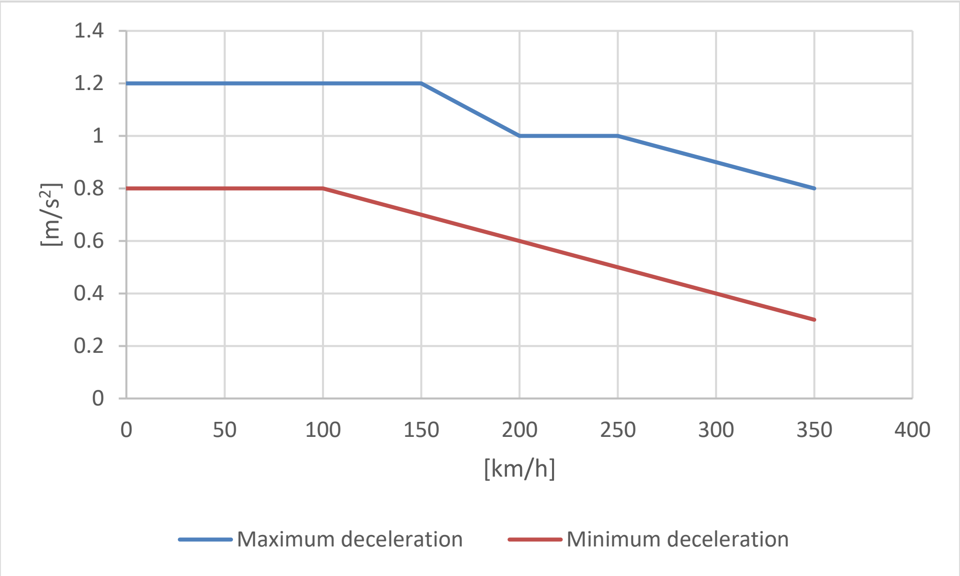


Figure 2 –Maximum service brake deceleration range (example)

Intermediate deceleration request limits are defined proportionally.

Force is defined consequently considering the train mass measured.

In nominal condition the performances are at the high, if failures happen the blending logic maintain the high performances until it is possible by available force, then the deceleration start to decrease till to reach the low performances. Below the low the train cannot run.

The low deceleration limit can be 0, it is a design choice.

3.8.4.3 Emergency brake performances constraints

The emergency brake request is the request to stop the train in a *guaranteed stopping distance on level track*. It has the following characteristics:

- mass independent: the guaranteed stopping distance shall be the same at different mass of the train;
- speed dependent: the guaranteed stopping distance is different at different initial speed;
- Slope dependent: the guaranteed stopping distance is different with different slope;
- worst single failure tolerant: the guaranteed stopping distance is fulfilled also with the worst single failure happening during emergency brake;
- Degraded environmental/dissipation condition independent: the guaranteed stopping distance is fulfilled also with Degraded environmental/dissipation condition.

The emergency brake performance is then a stopping distance.

The emergency performance is defined by a new **braking power concept.**

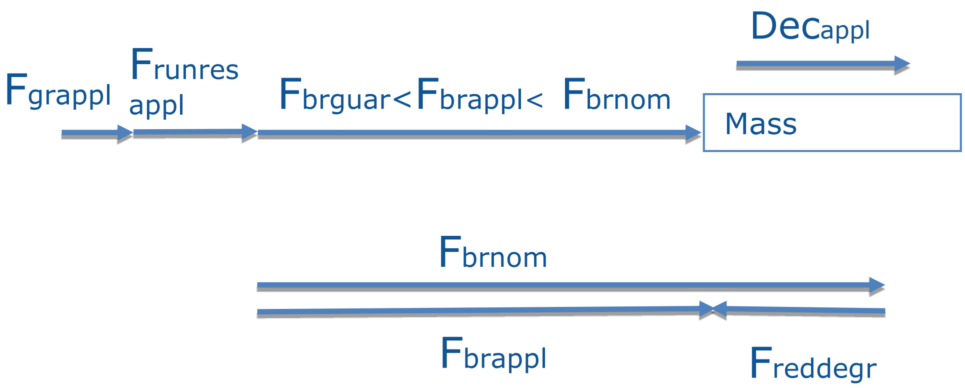
This braking power concept joins the brake mass percentage concept still often used for train < 200 km/h and the guaranteed deceleration concept that was introduced to manage high speed trains.

As the braked mass and the mass of the train define the brake mass percentage which, by formula on UIC544-1 leaflet, permit to calculate the nominal stopping distance of the train and the ratio between the braked mass and the mass of the train univocally identify the stopping distance, the new concept permits to do the same, but using instead of mass and braked mass and brake mass percentage the following information:

- Maximum equivalent time,
- Nominal maximum deceleration,
- Braking power.

The braking power is the ratio between the guaranteed deceleration and the nominal maximum deceleration.

- Guaranteed deceleration: deceleration *guaranteed* by emergency brake according tests and dimensioning evaluation in following condition:
  - on a flat track,
  - with maximum train mass,
  - with worst single failure happening during braking and active isolation,
  - with worst degraded environmental condition/dissipation condition.
- Nominal maximum deceleration: nominal deceleration of the train according tests by the emergency brake in following condition:
  - on a flat track,
  - with maximum train mass,
  - without any failure and isolation,
  - without degraded environmental condition/dissipation condition.



The guaranteed deceleration is the deceleration, *proportional to the maximum one*, which has at any speed a deceleration value lower than the one measured during test or evaluated by dimensioning in degraded condition.

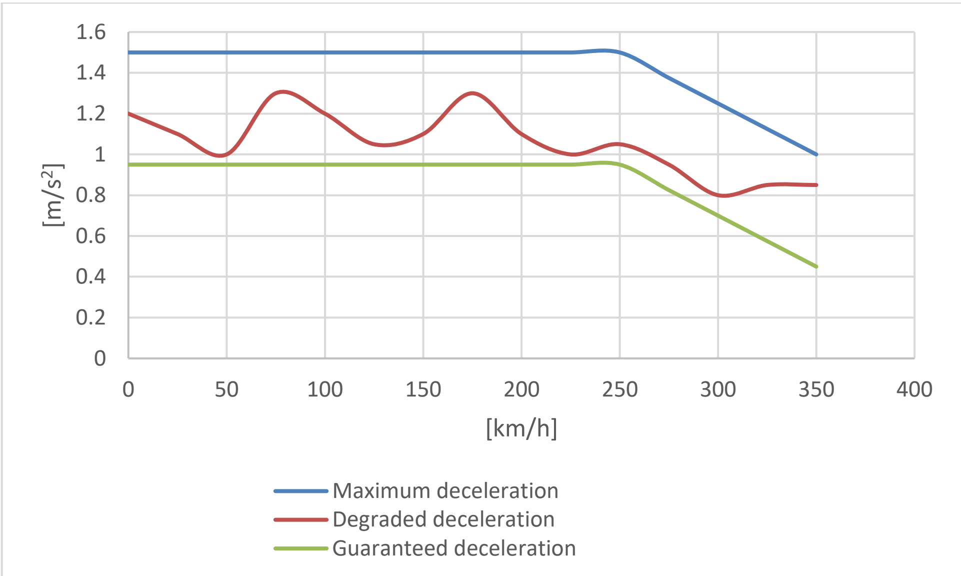


Figure 3 – Guaranteed deceleration (example)

$$Dec_{guar} = Dec_{max} * BrPower$$

The braking power permits to define the guaranteed stopping distance (emergency performances) by the formula above mentioned using the below parameters:

- Maximum equivalent time,
- Maximum emergency brake deceleration.

Braking power is mass independent: it is defined by the «nominal maximum deceleration» parameter, which is defined at maximum mass. If the brake system has an emergency braking force control managing the mass, same deceleration is obtained also with minimum mass. If the mass is not managed, the deceleration is for sure higher. In both cases the maximum stopping distances requested are achieved.

Braking power is speed independent: it doesn't change with the speed. The speed dependency of the performances is given by the «nominal maximum deceleration» parameter.

Braking power is slope independent: the slope information is considered by signalling which take care of it in its braking model.

The braking power is directly linked to the isolation status.

Braking power changes when brake force is permanently isolated.

The braking power calculation is in charge of BSM function, which has under control all type of brakes forces.

Note 1: it could be also possible to have braking power dynamic definition, based on real brake force available, but it would be a strong exported requirement to signalling technical system.

Note 2: the service brake performance concept and the braking power concept are performance concept similar to existing ones. This is a consequence of the decision taken to not follow the deceleration closed loop control technical choice for the reference brake system for the EDV.

3.8.4.4 Other constraints on performances

Other dimensioning constraints are considered as well in requirements by proper parameters:

– Maximum Slope,
– Maximum Speed,
– Minimum mass,
– Maximum mass,
– Maximum jerk,
– Maximum deceleration (force limit for the track/passenger safety).

The maximum speed is the maximum speed permitted by the brake system. The value is defined at dimensioning level, and univocally linked to braking power value:

- in nominal condition nominal maximum train speed is possible;
- with isolation active the speed is limited by energy dissipation constraints.

The speed limitation is demanded to ETCS (which can have braking power or equivalent information as input).

Failures in the signals of mass, speed and (optionally) slope would not permit to define the braking force. Further parameters are foreseen:

– Default train mass,
– Default track slope,
– Default train speed.

The values of above parameter for mass and speed shall be defined by dimensioning/safety analysis. Track slope has influence only on service brake, so the default value is 0.

3.8.4.5 Different brake types forces dimensioning constraints

The dimensioning of the different type of brake defines the maximum force that each of them can apply.

The maximum force value is a parameter which can be speed dependent (also dissipation temperature and line voltage dependent for dynamic brake).

It is economically not useful to over dimension the brake system, but it is safe to have a certain margin on the available force to guarantee the performances.
The general dimensioning principle considered is that the **maximum emergency brake force** (by which the nominal maximum deceleration described in §3.8.4.3 is obtained) is provided by:

- 100% adhesion independent brakes forces (dynamic and friction),
- 100% adhesion dependent dynamic brake force,
- < 100% of the adhesion independent friction brake.

The dimensioning principle considered for adhesion dependent friction brake minimum force is the following:

- necessary force to reach the emergency brake maximum deceleration with the contemporary application of 100% of both adhesion independent brakes and the minimum force *guaranteed* by the adhesion dependent dynamic brake.

The above assumptions are based on following assumption about safety of the different types of brakes:

- Both adhesion independent brake and adhesion dependent friction brake are considered safe, i.e. inexhaustible as defined in §3.8.5.3.
- Adhesion dependent dynamic brake is considered not safe or only a *portion* of its maximum force is safe, the so called *minimum force guaranteed*.

This is why the sub-functions "SB/EB5.4 - *Achieved adhesion dependent dynamic service/emergency brake force*" is foreseen: to provide the information necessary to manage the compensation of eventually missing adhesion dependent dynamic brake force.
If the adhesion dependent dynamic brake guaranteed force is null, the adhesion dependent friction brake shall apply the whole adhesion dependent force.

The adhesion dependent friction brake force not used in nominal condition (i.e. with 100% of adhesion dependent dynamic brake force achieved) represents the over-dimensioning.

Considering that the adhesion dependent friction brake is in charge of holding brake, the holding brake dimensioning force represent the lowest dimensioning value for the adhesion dependent friction brake force.

3.8.4.6 Energy dimensioning constraints

The energy supply (pneumatic and electric) *shall provide* the energy to *guarantee* the braking force application functions. It means that following parameters shall be defined by dimensioning and considered in requirements:

- Minimum pressure,
- Minimum air delivery,
- Minimum Voltage,
- Minimum current.

The energy supply *shall be limited* by the *maximum power* acceptable by braking force application functions. Other parameters to be considered:

- Maximum pressure,
- Maximum air delivery,
- Maximum voltage,

- Maximum current.

The friction brake dissipation capacity is part of the dimensioning of energy dissipation devices of friction brake. No functions are normally considering about energy dissipation control.

An optional function is in any case foreseen, detecting the dissipation temperature (disc and/or pads temperature), to monitor any deterioration in the capacity of the brake to dissipate the energy (for example by brake duty cycle above the one considered in dimensioning).

This function is only for service brake, to manage a better deceleration regulation. The brake dimensioning shall guarantee a safe energy dissipation in emergency.

3.8.5 Main safety requirements

The safety requirements are the outcome of the safety analysis (see Chapter 4). The following are the main safety requirements that are normally considered already during design phase, before any safety analysis. Other requirements are also considered, referring to safety requirements indication in [1] and [9].

3.8.5.1 Continuity

Standard [9] defines the brake system continuity property with the following sentence:

“The brake system shall be continuous: all brakes in the train shall be capable of being applied from a single control point, normally in the operational cab”.

At functional level the continuity is intended as continuity of transmission of the brake request from actors to the force application sub-functions.

The sub-functions involved in continuity are:

SB1/EB1 - Brake request,

SB2/EB2 - Brake request transmission.

SB3-SB4/EB3-EB4 – Train brake mass and force calculation are considered part of the force application sub-functions.

The loss of continuity causes an automatic brake application by the service and emergency force application sub-functions, to avoid that the train cannot be braked.

3.8.5.2 Automaticity

Standard [9]defines the brake system automaticity property with the following sentence:

“The brake system shall be automatic: each individual brake type or combinations of them shall operate automatically, i.e. in the event of an unintentional train separation (train integrity lost), the brakes on the two parts of the train shall apply, bring the train to a standstill and keep it in the same position until released by other intentional operations.)”.

A train integrity information is necessary to manage the train separation. This information could be assimilated to the continuity information, because a separated train is also a not continuous train. But a not continuous train could not be separated.

To guarantee an independency between the two functionalities it is preferred to consider the two information independent.

When a train is separated causes an automatic permanent brake application by the emergency brake force calculation sub-function EB4, to guarantee the stopping of both train parts and guaranteed immobilization.

3.8.5.3 Inexhaustibility

Standard [9]defines the brake system inexhaustibility property with the following sentence:

"The brake system shall be inexhaustible: the braking energy available shall be adequate to attain full brake force:

– at all times during the train journey,
– under all track conditions."

This is obtained by:

- Proper dimensioning of energy store,
- Pneumatic pressure and electric voltage monitoring,
- Pneumatic energy "leakages" limitation (electric energy "leakages are not considered because guaranteed sufficiently by passive protection, i.e. isolation).

The reaction to a loss of inexhaustibility is a brake application by emergency brake.

The brake application is automatic at adhesion dependent friction brake force application level in case of loss of electric energy (by EB5.5), it is demanded to BSM in case of loss of pneumatic energy.

The inexhaustibility is linked to the safety level of the brake forces. Only if a force is inexhaustible (the force is available "at all times during the train journey") its amount can be used in the guaranteed emergency brake performance calculation. Refer to §3.8.4.3.

They must be always guaranteed. If not the train cannot move.

Note: continuity and inexhaustibility are at the base of the hazard scenario described in §4.2.4.2.2 of TSI.

3.8.5.4 Running capability

For running capability is intended:

- the capacity of the brake system of the train to guarantee the resistance to the fire for at least 15 minutes without undue application of the brake due to the fire.
  This is obtained by passive protection, giving the proper fire resistance to brake system components. These requirements are part of the technical requirements, not scope of this document.
- the capacity of brake system to eventually release requested brake application when it is safer to not stop the train (bridge, tunnel, fire present outside the train, …).

  These requirements are part of external technical system which are providing brake requests (ERTMS/ATP, Vigilance, Passenger Alarm, etc.), and are not part of this document's scope.
- The capacity of the brake system to react to automatic brake application due to major fault (safe state) which could impact the energy dissipation or in general the safe functionality of the brake system.

  This functionality is internal to the brake system.
  Requirements are defined (see below Safe state), managed by BSM, which permits to release automatically the service brake and emergency brake when considered necessary.
- The capacity of brake system to enable, by proper voluntary action of the driver, degraded service and emergency brake request control functions permitting to apply and release the brake after failure of the main brake request generation and transmission functions (generally known as back-up brake or depannage mode).

  The sub-functions BSM2.1.2 and BSM2.2.2 are dedicated to this.

Requirements about these functionalities by BSM are not developed because not in the scope of EDV.

3.8.5.5 Major fault

A major fault is a fault which consequence can be a brake performances (as intended at §3.8.4.2 and §3.8.4.3) lower than expected or impact the safety of the train.

Any fault which has not the major fault characteristics is a minor fault.

3.8.5.6 Safe state

Every major fault can generate a different reaction by the brake system.

The reaction is managed at train level (BSM) and at force application level.

The train level has a higher priority, because shall be able to recover unsafe situation provided by force application functions major faults.

The reaction by BSM can be apply emergency brake or service brake or reduce the speed or release the brake which is applied due to major fault.

The definition is part of the safety analysis. In the requirements the reaction to major fault is generally not specified.

A **remote release function** is provided in service brake and emergency brake isolation sub-functions, allowing BSM remote release command to take the control of the brake force in failure. The BSM command effect is then enabled only by the presence of a major fault.

Emergency brake remote release is enabled only if:

- there is not emergency brake: in emergency brake has no sense not using the force eventually automatically applied due to major fault.
- for one major fault only: the guaranteed emergency performances are single fault tolerant and the remote release on more than one fault would put the train in a condition to have no more the performance guaranteed.

When any type of brake force application has lost **its control** its own safe state shall be applied, where the definition of the safe state depends from the type of force (if it is simple to apply a force without control) and the consequence of the safe state application.

The safe state of adhesion dependent friction brake control is the **brake application** because priority is given to the apply condition being present the remote release and the force application is pneumatically piloted, so it is simple to be applied automatically. The automatic application is done by SB/EB5.5.2.1.1 functions.

The concept of remote release covers the need to satisfy the train safety requirement of running capability, because it allow to release undue brake application due to major fault.

The remote release cannot remove the request of brake, but only the application of force applied consequently to a major fault.

3.8.6 System, main functions and sub-functions requirements definition

For the definition of the requirements the top down process described in Chapter 2 for the functional structure is again applied, starting from Brake system functional requirements and propagating them to the main functions and from there to the sub-functions.

Each sub-functions name synthetizes the general requirement of the sub-function.

The first requirement is then describing it in a more extensive way. The following ones propagate the consequence of:

- the first requirements;
- standards/norms requirements considered relevant;
- basic concept above described (physics, dimensioning, safety);
- other requirements at upper level which has to be propagated to the lower one;
- other sub-functions requirements which output information have an impact on the functionality.

a) Service brake main requirements:

The service brake shall apply an adjustable deceleration to the train proportional to the request received by actors or brake system internal function BSM with the following goals:

- Reduce the speed of the train;
- Maintain the speed of the train on a slope;
- Immobilize temporary the train.

Service brake is enabled by BSM, if brake configuration is successful and only one driver's desk is enabled.

In case of "undue" service brake requested the only way to remove the service brake request is to activate the degraded mode by BSM, which requirements are not developed (an example can be the activation of back-up brake controller).

b) Emergency brake main requirements:

The emergency brake is the system function used by the users and technical systems (actors) to apply predefined retarding force to the track (directly or by the wheelset) with the following goal:

- to stop the train in the guaranteed stopping distance.

Emergency brake function is always active with train power on (because it is the main safety related brake function).

Emergency brake can be released only if the request is removed (the emergency brake request has the highest priority). In case of "undue" emergency brake requested the only way to remove the emergency request is to activate the degraded mode by BSM, which requirements are not developed (an example of emergency brake degraded mode on conventional train is safety loop bypass in case of safety loop major fault).

Service and Emergency brake are managed as autonomous functions, each of them with their proper requirements and dedicated information. This guarantees the functions independency.

The only constraints fixed are:

- Service brake deceleration shall be lower of Emergency brake deceleration at any speed;
- Service brake force shall not be applied in case emergency brake force is applied.

3.8.7 Brake request functions (SB1/EB1)

The service brake demand is provided by all actors and transformed into a request.

The service brake request is the maximum request among the ones received by actors.

The service brake request to brake force application functions is a percentage of maximum deceleration request.

The reasons are:

- Clear and friendly user identification of the request level;
- One single request for the whole speed range (the differences in deceleration request with the speed are managed by the maximum deceleration request parameter).

The requirements suppose that the brake and traction request are provided by the same information, to have an interlock between traction and brake, as alternative independent signals can be considered. In this case a logic to manage contemporary traction and brake request has to be defined.

The user also provides the train direction information to brake system for roll back protection function done by holding brake.

The emergency brake demand is an on/off information by different actors.

The emergency brake request is activated in presence of any demand.

3.8.8 Brake request transmission (SB2/EB2)

This sub-function has the main goal to represent the link between brake request and brake application, being in charge of the continuity property of the brake request.

3.8.9 Train mass calculation (SB3/EB3)

This function provides to any train function the mass of the train (and equivalent mass).

The mass calculation is done elaborating information coming from the bogie about car body load and adding relevant predefined mass of bogie (and rotating mass to have equivalent mass).

The acquisition of the load is done when the doors are closed or when the speed goes above 3 km/h.

This function is in charge to fix default nominal mass in case of not valid input information of the load of the car body.

3.8.10 Brake force calculation (SB4/EB4)

This function is the link between the brake request and the brake force application.

It transforms the deceleration request into a nominal force to be applied at the train, via the mass, speed, slope (optional) information and the evaluation of the running resistance external force.

For the service brake it calculates the maximum and minimum force to be applied to define the range of acceptable forces which represent the nominal performances.

It is in charge to fix default nominal force in case of not valid input information of mass, speed and slope to have always a brake force definition.

It is in charge of guarantee the reaction to the loss of continuity of service brake.

The reaction to the loss of train integrity is an emergency brake function.

3.8.11 Blending (SB5/EB5)

Blending function shall apply the train braking force requested by SB4/EB4 by the 4 types (3 in service) of braking forces.
The different type of forces applied shall be always coherent, their sum shall fit with the train nominal force request.
This is done by the *availability* information management (SB/EB5.1) and by defining a *priority* in applying the forces (SB/EB5.2).
A non-valid availability information can generate a not defined situation, with consequent not coherent force distribution and lost control of the train braking force application. A major fault is generated in case of not valid availability information and in case of not valid information both sender and receiver shall adopt the same default availability status information, so that blending rules remain coherent.

The brake system base concepts constraints are considered, which means to consider:

- Limit of the forces to the maximum according dimensioning (including tolerances),
- Limit of the adhesion dependent forces to not overcome the maximum adhesion,
- Guarantee the minimum performance by management of the failures.

Nominal dimensioning of the system permits to have the expected performances without reaching the adhesion limits.

Blending logics can be managed by:

- a central function controlling all type of brakes;
- the functions controlling each type of brake, each of them implementing the same blending logic, to have coherent force distribution.

Second option is considered.
The reason is to have the maximum number of functionality inside EDV. This was also the driving principle in defining the sub-functions in charge of EDV.

The failure management is done considering that the failures of the not safe type of force (adhesion dependent dynamic brake) is compensated by adhesion dependent friction brake force.

The compensation of the failure of dynamic brake is done in functions SB/EB5.3.2.1, using the information of achieved adhesion dependent dynamic brake information by SB/EB5.4.

Note: In a conventional direct brake system the output of functions SB/EB5.3.2.1 is the output pressure of EP-module piloting the relay valve.

The functions SB/EB5.5 *generate* the braking force to the rail.

"SB/EB5.5.2.1 Adhesion dependent friction brake force generation" functions are split in two parts to permit the integration of the LAM sub-function; which scope is to reduce or hold the brake force to avoid sliding.

SB/EB5.5.2.1.1 generate a pilot command to "SB/EB5.5.2.1.2 Adhesion dependent friction brake force application" which effect, without LAM intervention, is the application at the train of the requested force. In case of sliding the LAM function reduce the pilot command and the applied force is reduced. The force is increased of the amount necessary to brake the rotating mass (see §3.8.2).

The feedback of achieved dynamic brake force gives the priority to dynamic brake in braking the rotating mass. Considering that dynamic brake is braking the rotating mass as well (same functionalities are supposed eve if requirement is not written), the achieved force read by SB/EB5.4 will be higher than the nominal one, so the friction brake force is reduced of the same amount, which means that the rotating mass are braked by dynamic brake.

The SB5.5.2.1.1 function has also the goal to monitor the energy supply and the force applied, in order to generate the major faults in case of situation out of the dimensioning tolerances or functionalities. Dragging brake monitoring and safe state automatic brake force application (see §3.8.5.6) is piloted by this function.

Note: In a conventional brake system the output of functions SB/EB5.5.2.1.1 is the output pressure of relay valve and the SB/EB5.5.2.1.2 function is done by the cylinder. In between there is the LAM1 function which is WSP.

3.8.11.1 Service brake

The SB5 sub-functions have following sources of service brake force request:

- Train brake nominal force received by SB4,
- Holding brake request by SB7,
- Major faults reaction by the sub-functions itself,
- service brake not enabled status: in this case a predefined brake force is applied.

The availability of each type of service brake force is defined by elaborating following information:

- the isolation status (permanent isolation),
- the remote release status,
- the dimensioning constraints parameters (maximum forces),
- the train speed received by Odometry,
- the actual dissipation capacity (optional, temperature detected by dissipation monitoring functions).

Taking in account the remote release status information, the blending logic automatically increase the request to other following force types and the deceleration request for service brake can be fully achieved, also in case of more than one failures.

The train speed is necessary to follow the speed dependency of the maximum deceleration parameter described in §3.8.4.2.

The minimum *service* brake performances shall be guaranteed by adhesion dependent brake only (dynamic and friction). They are the two type of forces always present on conventional train. It takes in account also the possibility that the adhesion independent dynamic service brake force could be inhibited in certain part of the lines to avoid overheating of the track (for example if all trains brake on the same point).

If the minimum pneumatic energy supply pressure is not achieved the availability of adhesion dependent friction service brake is set to the minimum value permitted. It is given priority to the availability of the brake (the inexhaustibility is supposed to be guaranteed by emergency brake). Even if there is the possibility that the service brake is not able to stay in the range defined by the brake request, considering that the adhesion dependent friction brake is the last type of brake to be applied, a limitation of its availability could have no effect. The fixing of the availability to the minimum force permit to continue the management of the blending by all type of forces inside the expected values, and only in the moment that the performances goes out of the expected range an impact of the train operation can happen.

The blending logics can be several (see [9] §5.9.1). In requirements following is considered:
- the priority is given to dynamic brake and then to friction brakes: LCC benefits because dynamic brake is wear-less:
    - Inside dynamic brakes, the first priority is given to adhesion dependent brake because it is a regenerative brake, transforming the kinetic energy in electric energy (LCC benefit).
    - Inside friction brakes, the adhesion dependent brake only is used, in line with conventional solution (there is not operational and economical benefit to use adhesion independent brake in service).

The function SB5.2 defines the brake nominal force for every type of brake starting from SB4 train force request.

The function “SB5.3.2.1 Adhesion dependent friction brake force request” considered in addition to the output of SB5.2 the holding brake request, manages the fading between traction and brake at train start and manage adhesion dependent dynamic brake failure.

3.8.11.2 Emergency brake

The emergency brake application sub-functions can have following sources of emergency brake force request:
- Train brake nominal force received by EB4;
- Major faults reaction by application functions: generally, not defined in requirements, except certain cases.

The availability of each type of service brake force is defined by elaborating following information:
- the isolation status (permanent isolation),
- the dimensioning constraints (maximum forces),
- the train speed.

The remote release information is NOT considered. The guaranteed emergency performances are defined by the braking power (see §3.8.4.3), which is defined by *permanent* isolation status. If remote release status information would be considered, an additional limitation to the force would be introduced respect the ones considered by braking power and a lower nominal brake force would be requested. But the guaranteed performances are obtained if the dimensioning nominal force is requested.
To avoid this incoherence between brake force availability and braking power, remote release status shall be considered and *only one major fault* is allowed to use the remote release in emergency brake (if two remote release are active the train exit from the condition of single fault tolerance).

The availability of adhesion dependent friction brake force is set to 0 if the minimum pneumatic energy supply pressure is not achieved (inexhaustibility). This situation generates also a major fault. The application of the failed force is inhibited in case of low pressure. The emergency brake single fault tolerant, the missing application of force correspondent to a single failure is already considered in guaranteed performances and it is preferred not to introduce an availability value that is not possible to guarantee.

The blending logics of EB5.2 is:

- The first priority is given to adhesion independent brake and then to adhesion dependent: in emergency the performances are more important than LCC.
- Inside both adhesion independent and dependent brake, the first priority is given to dynamic brake because it is regenerative and/or wear-less (LCC benefit).

3.8.12 Energy store (SB6/EB6)

These functions provide for a sufficient time to SB/EB the pneumatic and electric energy to permit the correct regulation of service brake force by different types of brakes.

As general approach it is supposed that all the type of brake force need both type of energy, even if in the reality not all are using pneumatic energy to control or apply the brake force.

The requirements are all dimensioning one because they are the voltage/current/pressure/air flow maximum and minimum limits and storing capacity to fulfil the dimensioning constraints of different type of force and the inexhaustibility requirements.

3.8.13 Holding brake (SB7)/Braking power calculation(EB7)

3.8.13.1 Holding brake (SB7)

The holding brake is the *temporary* immobilisation brake. It is applied automatically by adhesion dependent friction brake. For this reason, is one of the EDV sub-functions.

The holding brake function generates the holding brake request signal. The application and release of the holding brake force is in charge of the function SB5.3.2.1.

The holding brake force definition consider the maximum mass to be immobilized because the train mass can change during the immobilisation.

It is activated automatically when the train stop and released when the door is closed and locked and the traction is activated.

Considering that not always traction is inhibited when doors are not closed and locked, in alternative to the door closed and locked signal the release is possible when the speed is greater than 0 in the correct train direction.

It is possible for the driver to inhibit the holding brake function via BSM2.1.2 sub-function.

Holding brake has the optional functionality of roll back protection: in case the train roll back an automatic predefined brake force is applied (for example emergency brake force). This requires the detection of the wheel rotation direction.

3.8.13.2 Braking power calculation (EB7)

EB7 calculate the train braking power based on dimensioning and permanent isolation status of different types of brakes.

This sub-function is a central function, so is in charge of BSM main function (it could be included in BSM, like ABT, see below §3.8.22).

3.8.14 Traction cut-off (SB8/EB8)

Traction cut off is a function demanded to other system then brake system:

- TCMS.
- Traction system.

The brake system provides to this function the brake request, which is the trigger for traction cut off.

3.8.15 State and fault detection and indication (SB9/EB9)

3.8.15.1 Service brake

The service brake function has following level of states:

- Train level:
  - Applied or released.
- Brake request level (SB1 and SB2):
  - Enabled/Disabled;
  - Nominal: no major fault active on SB1 andSB2;
  - Faulty: SB1 or/and SB2 sub-functions major fault active (continuity lost);
  - Degraded: in case the driver enabled the degraded mode (see §3.8.6).
- Brake application level (SB5).
  For every type of brake:
    - Applied or Released;
    - Faulty: any major fault active;
    - Isolated: percentage of the maximum force which is not available (due to *remote OR permanent isolation*).

3.8.15.2 Emergency brake

The emergency brake function has following level of states:

- Train level:
  - Applied or released.
- Brake request level:
  - Nominal: no major fault active on EB1/EB2;
  - Faulty: EB1 or/and EB2 sub-functions major fault (continuity lost);
  - Degraded: in case the driver enabled the degraded mode (see also §3.8.6).
- Brake application level.
  For every type of brake:
    - Applied or Released,
    - Faulty: any major fault active;
    - Isolated: percentage of the maximum force which is not available (due *to permanent isolation only*).

The brake load calculation SB3/EB3 sub-function have following states:

- Enabled/Disabled: the load calculation is enabled if the service brake system is correctly initialized and no major faults are present on SB3/EB3 sub-functions;
- Faulty: any major fault on SB3/EB3.

3.8.16 Isolation (SB10, EB10)

There are two type of isolation:

- permanent isolation: voluntary action by the driver, removing the braking energy permanently;
- remote release: automatic action by BSM2.1.1 (service brake) or BSM2.2.1 (emergency brake) removing the force applied due to major fault.

SB10 and EB10 provide the actuation of both type of isolation, each one for its own function.

The command of remote release is in charge of BSM, the command of permanent release can be manual or electrical. In case of electrical a further function is required to BSM: to receive the permanent isolation demand by the driver and command the permanent isolation execution to SB10/EB10.

Only permanent isolation is considered in braking power calculation and emergency brake force availability calculation.

Both permanent isolation and remote release is considered in service brake force availability calculation.

This function provides the permanent isolation status to diagnostic and other functions using it (blending), while the remote release status is provided by BSM.

3.8.17 Energy supply (SB11/EB11)

The energy supply is intended as the portion of the train technical systems supplying electric and pneumatic energy supplying the energy to brake system. Practically these are functions of external technical system (Air supply production and distribution, Battery charger and low voltage energy distribution).

They supply of energy the energy stores described in 3.8.12.

These sub-functions have no impacts on the scope, so no requirements are defined.

3.8.18 Kinetic energy transformation (SB12/EB12)

The adhesion dependent friction brake uses the friction as physical phenomena to transform the kinetic energy into thermal energy. This transformation is a thermodynamic transformation fundamental for the generation of the brake force, but not involving EDV.

Requirements about this functionality are then limited to the minimum.

The few requirements present regards the optional function to detect the temperature generated by the dissipation (see §3.8.4.6).

3.8.19 Wheel slide protection (LAM1)

The wheel slide protection is a sub-function of both SB and EB.
It operates on the force generation process, with the characteristics that it can only hold or reduce the brake force applied by SB and EB. WSP cannot increase the nominal force applied by the EB and SB.

The effect of WSP intervention on brake system dimensioning is inside the guaranteed stopping distance concept described in §3.8.4.3 (degradation of performances due to environmental condition).

WSP is not included in S4R scope, even if CTA is including in EDV functionalities, because it is a supplementary functionality that, even if safety related, is not strictly necessary for the demonstration of applicability of IMP to brake system control. It is a sleeping function during normal operation of the train, which is activated only in case of low adhesion management. It means that WP4 scope is to demonstrate that the IMP can be used for the control of the brake system for the operation of the train with nominal condition of the rail. If IMP is capable to manage the brake safety functions for the nominal rail condition it will be able to manage also the brake functions with the rail degraded condition, implementing the related additional requirements.

3.8.20 Parking brake (PB)

Parking brake requirements are not developed because they are not included in the scope.

3.8.21 Brake system management (BSM)

3.8.21.1 Train topology and brake system integrity (BSM1)

BSM1 sub-function manages the Brake System initialization and configuration at train power up or coupling/uncoupling.

The brake system integrity is detected by the collection of the self-test results done by each main function. The function checks the consistency between the brake configuration detected by self-test results and train configuration received by TCMS. If it is coherent, it enables the service brake.

3.8.21.2 Brake operating mode management (BSM2)

The requirements of this sub-function are defined developing the requirement of the service and emergency brake ones. Every time a control/monitoring by a central train function is necessary to manage fault or degraded condition a BSM2 function has been defined.

Several functions are related to remote release.

BSM monitor the correct release, in independent way from SB5/EB5 because it releases and

re-applies the brake by its own command.

BSM2 optionally provides permanent isolation remote command (in the case SB10 and/or EB10 have the functionality of electrical permanent isolation).

3.8.22 Automatic brake test (ABT)

ABT requirements are not developed because they are not included in the scope. The only requirements are the command of WSP test start to be provided to LAM sub-function to perform the WSP test during ABT.

ABT requirements are defined by safety analysis.

ABT could be a sub-function of BSM.

Chapter 4 Safety analysis

This chapter provides the results obtained by the (Preliminary) Hazard Analysis (PHA) and the Risk Assessment (RA) developed for the Brake system. These activities are aimed at completing the preliminary hazards identification and risk assessment developed within the CONNECTA project. The following paragraphs provide:

- A summary of the main input considered (see §4.1).
- A description of the methodologies adopted (see §4.1.3 and §4.1.4).
- A summary of the main results (see §4.2 and §4.3).

4.1 Input information

4.1.1 Brake system functional model

The Hazard Analysis is based on the definitions of the functions implemented by the Brake system, as provided in the previous chapters.

Table 1 provides the list of the Brake system's functions which are singularly analysed during this PHA. They are a subset of the functions identified in the Chapter 2; specifically:

- The first level of decomposition is considered for the BSM, EB and SB main functions.
- The LAM main function is not analysed, because no requirements are specified.
- The remaining ABT and PB main functions are analysed without considering their further decomposition.

The analysis takes as reference the definitions of functions provided in §3.8.

ID	Functions singularly analysed
BSM1	Train topology and Brake system integrity
BSM2	Manage brake operating modes
ABT	Automatic Brake Test
PB	Parking Brake
EB1	Emergency brake train deceleration request
EB2	Emergency brake request transmission
EB3	Train load calculation
EB4	Train Emergency brake force calculation
EB5	Emergency brake blending
EB6	Emergency brake energy storing and distribution
EB7	Actual Emergency Braking Power Calculation
EB8	Emergency brake Traction cut off

ID	Functions singularly analysed
EB9	State and fault detection and indication
EB10	Emergency Brake isolation
EB11	Energy supply
EB12	Emergency brake kinetic energy transformation
SB1	Service brake train deceleration request
SB2	Service brake request transmission
SB3	Train load calculation
SB4	Train Service brake force calculation
SB5	Service brake blending
SB6	Service brake energy storing and distribution
SB7	Holding brake
SB8	Service brake Traction cut off
SB9	Service brake state and fault detection and indication
SB10	Service Brake isolation
SB11	Energy supply
SB12	Service brake kinetic energy transformation

Table 1: PHS, Brake system's functions analysed

4.1.2 Preliminary Hazard Identification

A preliminary identification of the hazardous scenarios related to the Brake system operation is developed within the CTA project, based on some main applicable standards ([1], [10], [9]) and on the experience of brake systems manufacturers and train builders participating in the project.

§4.2.1 describes this preliminary list of the Brake system hazards from H.1 to H. 25 provided by CTA, together with the new ones resulted from the hazards identified during the analysis developed within S4R.

4.1.3 HA methodology

The main purposes of the Hazard analysis are the following:

- to identify any (functional) deviation from the normal behaviour of the Brake system which might lead the interfaced subsystems to a condition contrary to safety;
- to complete the preliminary collection, the "high level" hazardous scenarios related to the Brake system operation;
- to specify all the measures required to assure the safe functional operation of the Brake system, and reduce risks to an acceptable level.

A Preliminary Hazard Analysis (PHA) is based on a preliminary description of the brake system. It is verified and updated iteratively to support and to be consistent with the specification of the Brake system requirements.

The Hazard Analysis of the Brake system is developed in three main steps:

- Identification of the functional deviations to be assessed (functional failure modes).
- Evaluation of the effects of each functional deviation.
- Specification of the measures required to assure the safe functional operation of the Brake system.

A HAZOP-like approach is used for the systematic identification of the functional deviations from the nominal behaviour expected by the Brake system. They are defined through the application of a set of guidewords to each function analysed. Guidewords and generic functional deviations are specified in Table 2.

Guideword	Deviation
No	The function is not performed: the output is missed in spite of the input state.
Wrong	The function is not correctly performed: the output state is not the expected one for a defined input state).
Loss of / partially	The function is interrupted, only partially performed.
Undue	The function is correctly performed but when not required (undue output when there is not input)

Table 2: PHA, Guidewords and deviations

The effect of each functional deviation is evaluated with reference to the worst possible consequences on the remaining functions (local effect) and then on the Brake system and on the whole train (final effect).

Each hazardous functional deviation is referred to one or more System hazards specified in Table 8. They could be already identified during the preliminary identification developed within the CTA project or new hazards specified during the PHA or the following iterations.

For each hazardous functional deviation, all the measures required to assure the safe functional operation of the system are specified. The whole set of measures defines the safety concept of the of the Brake system. A subset of measures – Countermeasures - shall be implemented by the Brake system, i.e. they will be “covered” by the safety requirements of the system in the following design stages. These measures are classified into different categories, which refer to different sections of the Technical Safety Report (within the Safety Case structure) specified by the EN 50129 [30]:

- Assurance of functional operation.
- Detection of faults.
- Action following detection.
- Independence of items.
- Systematic & Random faults.

A further set of set of measures - Application conditions - shall be exported to users and/or external technical systems. Their fulfilment is essential to guarantee the safe functional operation and behaviour under faults of the Brake system.

A last set of measures - Recommendations – provides indications for the implementation of the above countermeasures, i.e. for the fulfilment of the Brake system's safety requirements (e.g. compliance to standards, architectural insights …).

The form used for the PHA of the Brake system is provided in the following tables. It is composed of three parts focused on the results coming from the three steps of the analysis:

- The identification of the Functional failure modes;
- The evaluation of the effects of each Functional failure mode and the specification of the related System hazards;
- The specification of the measures required to assure the safe functional operation and the proper behaviour under fault condition of the Brake system.

Table 3 shows the first two parts of the PHA form.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS			
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description

Table 3: PHA, Form, Functional failure mode and Failure effects

Table 4 shows the third part of the PHA form.

COUNTERMEASURES SPECIFICATION													
Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description

Table 4: PHA, Form, Countermeasures specification

4.1.4 RA methodology

Criteria for risk assessment and risk acceptability comply with the indication provided by the EN 50126 technical standard [7].

The risk assessment is performed through the assignment of each Brake systems hazard (identified by the PHA) to a category for its Frequency of occurrence and to a category for its Severity of consequences, which are combined through the Risk matrix shown in Table 5.

.Frequency of Occurrence	Risk Levels			
Frequent ≥ 10^{-3} per hour	Undesirable	Intolerable	Intolerable	Intolerable
Probable 10^{-3} ≤ Frequency <10^{-4} h^{-1}	Tolerable	Undesirable	Intolerable	Intolerable
Occasional 10^{-4} ≤ Frequency <10^{-5} h^{-1}	Tolerable	Tolerable	Undesirable	Intolerable
Remote 10^{-5} ≤ Frequency < 10^{-7} h^{-1}	Negligible	Tolerable	Tolerable	Undesirable
Improbable 10^{-7} ≤ Frequency <10^{-9} h^{-1}	Negligible	Negligible	Tolerable	Tolerable
Incredible Frequency < 10^{-9} h^{-1}	Negligible	Negligible	Negligible	Negligible
	Insignificant	**Marginal**	**Critical**	**Catastrophic**
	Possible minor injury Minor system damage	Minor injury and/or significant threat to the environment Severe system(s) damage	Single fatality and/or several injury and/or significant damage to the environment. Loss of major system	Fatalities and/or multiple severe injuries and/or major damage to the environment
	Severity of Consequence			

Table 5: Risk Matrix

Table 6 states the actions to be performed for each risk level.

Risk Level	Actions to be applied against each category
Intolerable	Shall be eliminated.
Undesirable	Shall only be accepted when risk reduction is impracticable and with the agreement of the Railway Authority.
Tolerable	Acceptable with adequate control and the agreement of the Railway Authority.
Negligible	Acceptable without any agreement.

Table 6: Qualitative Risk Categories

The “Safety integrity” relates to the ability of a safety-related system to achieve its required safety functions.

Table 7 provides the Tolerable Hazard Rate (THR) required to a function according to the assigned Safety Integrity Level (SIL), as defined by the EN 50129 [30].

Safety Integrity Level	**Tolerable Hazard Rate (THR)** (h^{-1} per function)
4	$10^{-8} \div 10^{-9}$
3	$10^{-7} \div 10^{-8}$
2	$10^{-6} \div 10^{-7}$
1	$10^{-5} \div 10^{-6}$

Table 7: Tolerable Hazard Rate

In general, SIL is assigned to each function performed by the system according to the potential damage produced by its missed or incorrect execution (i.e. deviations from the nominal behaviour). Operatively, the severity of consequence is estimated for a given scenario (due to the missed or incorrect execution of a given function). The acceptability criteria defined by the Risk matrix (see Table 5) allows to evaluate the category for the frequency of occurrence of the given scenario required to achieve a negligible (at least tolerable) risk level (see Table 6) and the consequent Safety Integrity Level to be met be the function.

The Safety Integrity Level required to a given function applies to the related countermeasures, and to the functional requirements specified for the Brake System covering them (to be classified as safety requirements and propagated to the lower levels, e.g. electronic, hardware & software).

4.2 HA Results

The results coming from the PHA developed for the Brake system (see Annex 1) include:

- (Preliminary) hazard analysis.
- Hazard list.
- Countermeasures list.
- Recommendations list.
- Application conditions list.

The main results are also provided in the following paragraphs.

Moreover, the (Preliminary) Hazard Analysis table providing the results coming from the Hazard analysis developed for the Brake system (after all the iterations during S4R WP4) is provided in the Annex 1.

4.2.1 System Hazards

Table 8 provides the list of the Brake system hazards coming from different sources. They include:

- The hazards identified during the preliminary identification performed within the CTA project (from H.1 to H. 25).
- The hazards identified during this Preliminary Hazard Analysis (from H.26 to H.40).

It also specifies if the hazard is linked to at least one functional deviation assessed during HA (yes / no) and the main function(s) involved (i.e. whose deviation from the nominal behaviour can lead to the given hazardous event).

Brake System hazard		Source	Ref in PHA
ID	Description		
H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	TSI	Yes
H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	TSI	Yes
H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	TSI	Yes
H.4	After activation of Parking brake, complete and permanent loss of Parking brake force.	TSI	Yes

Brake System hazard		Source	Ref in PHA
ID	**Description**		
H.5	Impossibility for a passenger to initiate the activation of brake in order to stop the train when train departs from a platform due to failure in the passenger alarm system.	TSI	No
H.6	No information given to the driver in case of activation of a passenger alarm due to failure in the passenger alarm system.	TSI	No
H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	EN 1+D95734 / EN 16185	Yes
H.8	Automatic (emergency) brake not initiated in the case of an unintended train separation (loss of train integrity).	EN 15734 / EN 16185	No
H.9	Required Parking brake performance not achieved.	EN 15734 / EN 16185	Yes
H.10	Loss of Parking brake force over the time.	EN 15734 / EN 16185	Yes
H.11	Holding brake for brake test not achieved.	EN 15734	No
H.12	Undue local application of brake force.	EN 15734 / EN 16185	Yes
H.13	Locked axle not detected.	EN 15734 / EN 16185	No
H.14	Required Holding brake performance not achieved.	CTA WP5 brainstorming	Yes
H.15	Excessive EMI interference leading to unexpected Brake system behaviour.	FTI experience	No
H.16	Excessive sound/noise level.	FTI experience	No
H.17	Accessible hazardous voltage.	FTI experience	No
H.18	Accessible sharp edges.	FTI experience	No
H.19	Accessible hot surfaces.	FTI experience	No
H.20	Small train parts detached.	FTI experience	No
H.21	Big train parts detached.	FTI experience	No
H.22	Excessive release of stored energy (e.g. air pressure, spring load).	FTI experience	No
H.23	Accessible moving/rotating parts.	FTI experience	No
H.24	Spread of smokes or fire.	FTI experience	No
H.25	Release of toxic substances.	FTI experience	No
H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	PHA	Yes
H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling.	PHA	Yes

Brake System hazard		Source	Ref in PHA
ID	**Description**		
H.28	Emergency Brake force is applied only for a fraction of consists brake.	PHA	Yes
H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	PHA	Yes
H.30	No or incorrect information on braking power provided to the external technical (signalling) system.	PHA	Yes
H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA	Yes
H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA	Yes
H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA	Yes
H.34	Incorrect indication to driver about the permanent immobilization of the train (Parking brake status).	PHA	Yes
H.35	Undue application of brake for permanent immobilization (Parking brake) during train movement.	PHA	Yes
H.36	After activation, complete and permanent loss of Holding brake force.	PHA	Yes
H.37	Incorrect indication to driver about the temporary immobilization of the train (Holding brake status).	PHA	Yes
H.38	Undue application of brake for temporary immobilization (Holding brake) during train motion.	PHA	Yes
H.39	Loss of Holding brake force over the time.	PHA	Yes
H.40	Undue train stop, due to Brake System failure, in a hazardous area.	PHA	Yes

Table 8: (Preliminary) Hazard analysis, List of System Hazards

4.2.2 Countermeasures

The following tables provide the set of countermeasures identified during the Preliminary Hazard Analysis of the Brake system.

Each table provides the countermeasures identified for each analysed main function.

Within each table, the countermeasures are listed for each category defined in §4.1.3.

The list of countermeasures assuring a proper functional operation, detection of faults, action following detection, independence of items and defence against systematic & random faults provides the safety concept of the Brake system with reference to each main function to be implemented.

The Safety Integrity Level (SIL) is specified for each countermeasure, based on the SIL specified for the related function during the Risk Assessment (see §4.3). Table 9 provides a first set of general countermeasures (GEN), i.e. applicable to the different main functions.

GENeral countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error).	SIL4
	PHA_GEN_5	The Brake system's devices exchanging safety-data shall verify the messages integrity (transmitter identity, type, value errors), sequence and timeliness (timing, sequencing error, data received in due time) and authenticity (if an open transmission system is used, with safety related access protection functions).	SIL4
Detection of faults	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	SIL4
Action following Detection	PHA_GEN_4	The Brake system shall discharge a message acquired from the external technical systems (containing safety-data) when a communication error is identified and interrupt the communication when a predefined number of messages are discharged.	SIL4
	PHA_GEN_6	The Brake system's devices exchanging safety-data shall discharge a message when a communication error is identified (because o messages authenticity, integrity, timeliness or sequence is/are violated) and interrupt the communication when a predefined number of messages are discharged.	SIL4
Independence of Items	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of: _Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake; _Parking brake, in case of concurrent requests with Service brake or Holding brake.	SIL4
	PHA_GEN_8	The Brake system shall notify a Major fault through safety transmission function, with the highest SIL assigned to the brake functions, assuring reactions against communication errors that are functionally independent by any non-trusted transmission system.	SIL4
Operation under external influence (not in table)	PHA_GEN_7	The Brake system shall operate and fulfil all its safety requirements under the effect of external influences, including environment temperature and humidity, shock and vibration, electromagnetic compatibility and electrical stresses.	SIL4

Table 9: (Preliminary) Hazard analysis, GENeral countermeasures

Table 10 provides the set of countermeasures specified for the Brake System Management (BSM). They include the countermeasures related to the Automatic Brake Test (ATB).

Brake System Management countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_BSM_1	The Brake system shall store permanently, assure the integrity and inhibit any modification (during service, i.e. restart mandatory) of the configuration data acquired during its initialization.	SIL4
	PHA_BSM_3	The Brake system shall react to a Major fault generated at consist level (i.e. affecting brakes at more than one axle / bogie) by notifying it to the driver and external systems (i.e. transition into the safe state) and by dispatching the brake command to all the local brake units (i.e. transition into the safe state).	SIL4
	PHA_BSM_4	The Brake system shall react to a Major fault generated locally (at axle or bogie level) according to the degradation in the braking power: _ by commanding the remote release of the faulted brake, if safe condition are still guaranteed by the residual braking power (i.e. permanence into the safe state); _OR otherwise by dispatching the Emergency brake command to all the local brake units (i.e. transition into the safe state) and by notifying the Major fault to the driver and external systems.	SIL4
	PHA_BSM_6	The Brake system, at the Start up or at coupling/decoupling, shall be in its initialization state, acquire data on the train and brakes configuration, and perform the automatic brake test.	SIL4
Detection of faults	PHA_BSM_2	The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid.	SIL4
Action following Detection	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	SIL4
	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.	SIL4
Independence of Items	PHA_BSM_9	The Brake system shall implement functions for the management of and reaction to Major fault conditions guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	SIL4
Systematic & Random faults	PHA_BSM_10	The Brake system shall react to the Major fault by the transition or permanence into safe conditions, with the same SIL assigned to the implementation of the Emergency brake.	SIL4
	PHA_BSM_8	The Brake system shall be initialized and acquire all data required to operate with the actual train and brakes configurations with the same SIL assigned to the implementation of the Emergency brake.	SIL4

Table 10: PHA, Brake System Management countermeasures

Table 11 provides the set of countermeasures specified for the Parking Brake (PB).

Parking Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_PB_2	The Brake system shall apply the Parking brake when a valid request for permanent immobilization of the train is active and the train speed measure is available and less than a predefined threshold.	SIL4
	PHA_PB_3	The Brake system shall guarantee the inexhaustibility of the Parking brake: without any external source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the permanent immobilization of the train.	SIL4
	PHA_PB_5	The Brake system shall release the Parking brake only when a valid request for the release of the permanent immobilization of the train is acquired from external actors (driver or external technical system), and only by transiting to the Holding brake condition.	SIL4
	PHA_PB_8	The Brake system shall guarantee the coherence between the Parking brake indication provided to driver and the real brake status.	SIL4
	PHA_PB_9	The Brake system shall apply the Parking brake guarantying the minimum performance (i.e. brake force) required for train permanent immobilization.	SIL4
Detection of faults	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.	SIL4
Action following Detection	PHA_PB_10	The Brake system shall react to the undue application of the Parking brake (i.e. without a valid request and/or during train motion) through the notification of a Major fault to the external actors (driver and external technical system) and brake(s) release.	SIL4
	PHA_PB_7	The Brake system shall react to the missed or ineffective application of the Parking brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system).	SIL4
Systematic & Random faults	PHA_PB_1	The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level, if the request comes from the driver	SIL4 SIL2
	PHA_PB_4	The Brake system shall provide to the driver the indication of Parking brake status compatibly with the SIL assigned to the Parking brake application if the request comes from the driver.	SIL4

Table 11: PHA, Parking Brake countermeasures

Table 12 provides the set of countermeasures specified for the Emergency Brake.

Emergency Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_ EB_10	The Brake system shall react to a Major fault generated locally (at axle or bogie level) through the local application of the Emergency brake and be available to a "partial" remote release.	SIL4
	PHA_EB_11	The Brake system, after the reaction to a Major fault through the Emergency brake application, shall be available to a "global" remote release commanded by the external technical system (e.g. if the train is in a non-stopping are area) and apply again the Emergency brake when the release command is removed or a new Emergency brake request is acquired.	SIL4
	PHA_EB_16	The Brake system shall dispatch the Emergency brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	SIL4
	PHA_EB_18	The Brake system shall preserve the integrity and the timeliness of the information (signals and data) related to bogies load used for the calculation of the Emergency brake force.	SIL4
	PHA_EB_20	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Emergency brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	SIL4
	PHA_EB_23	The Brake system, in any state after its initialization, shall be able to acquire Emergency brake request coming from the external actors (driver, technical systems).	SIL4
	PHA_EB_24	The Brake system shall guarantee minimum performance (i.e. minimum deceleration and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake).	SIL4
	PHA_EB_25	The Brake system shall guarantee minimum performance of Emergency brake (i.e. minimum deceleration and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic and adhesion independent brakes due to the infrastructure and/or vehicle.	SIL4
	PHA_EB_26	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the computation and notification to external technical systems of the braking power and in the calculation of the Emergency brake force to be applied by (all types of) brakes.	SIL4
	PHA_EB_27	The Brake system, after the acquisition of an Emergency brake request, shall assure the brake force application up to train standstill or to a remote release command.	SIL4

Emergency Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
	PHA_EB_31	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Emergency brake application (to the local brake units).	SIL4
	PHA_EB_34	The Brake system shall allow the remote release of Emergency brake(s) only in case of Major fault.	SIL4
	PHA_EB_35	The Brake system shall permit the total or partial isolation of Emergency brake(s) for the removal of the force applied, with or without energy available on the train, whatever are the adjustable (i.e. service) brake actual status and request, as last operation to permit the train running and recover from immobilizing failure conditions.	SIL4
	PHA_EB_37	The Brake system, in any state after its initialization, shall guarantee the inexhaustibility of the brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the application of the minimum Emergency brake force for at least 2 times (i.e. brake cannot be released if it cannot be applied again).	SIL4
	PHA_EB_39	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Emergency brake, with predefined accuracy and timing.	SIL4
	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	SIL4
	PHA_EB_49	The Brake system shall apply the Emergency brake automatically and notify a Major fault in the event of unintentional train separation (train integrity lost).	SIL4
	PHA_EB_8	The Brake system shall compute the nominal Emergency brake based on measurements of bogies loads updated and conservative (i.e. consistent and with margin) with respect to the actual load conditions.	SIL4
	PHA_EB_9	The Brake system shall provide to the external Technical systems and to the driver the information about the Emergency brake status, operating mode and active fault conditions.	SIL4
Detection of faults	PHA_EB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Emergency brake(s); _remote release of Emergency brake(s).	SIL4
	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes;	SIL4

Emergency Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
		_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	
	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	SIL4
	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	SIL4
	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	SIL4
	PHA_EB_6	The Brake system shall verify the capability to provide the Braking power information to the external technical (signalling) systems and the consistency of the last information notified with the current availability of brakes.	SIL4
Action following Detection	PHA_EB_12	The Brake system shall react to the inability to acquire a Emergency brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the transition or permanence into safe state.	SIL4
	PHA_EB_13	The Brake system shall react to braking power (computed for the actual brakes availability) less than the value communicated to external systems: _by communicating an updated value; _OR through the notification of a Major fault and the transition or permanence into safe state.	SIL4
	PHA_EB_14	The Brake system shall react to a (partial or total) inability to transmit a valid Emergency brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the transition or permanence into safe state.	SIL4
	PHA_EB_19	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Emergency brake, through the notification of a Major fault and the application of the maximum brake force.	SIL4

Emergency Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	SIL4
	PHA_EB_28	The Brake system shall react to the missed application of the (nominal) Emergency brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.	SIL4
	PHA_EB_33	The Brake system shall react to a dragging condition of Emergency brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	SIL4
	PHA_EB_36	The Brake system shall react to a missed or undue Emergency brake(s) release or isolation through the notification of a Major fault.	SIL4
	PHA_EB_38	The Brake system shall react to the unavailability of the (pneumatic / electrical) energy required to guarantee the inexhaustibility of the Emergency brake, through the notification of a Major fault and the transition or permanence into safe conditions.	SIL4
	PHA_EB_41	The Brake system shall react to the unavailability of valid information (signal, data) related to measurements used for the calculation of the nominal Emergency brake force (i.e. speed, bogies load), through the use of predefined conservative values.	SIL4
	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.	SIL4
Independence of Items	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	SIL4
	PHA_EB_29	The Brake system shall implement functions for the monitoring of the application of the Emergency brake request within a predefined maximum time and consequent reaction, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	SIL4
	PHA_EB_30	The Brake system shall implement functions for the partial or total isolation and for the remote release of Emergency brake(s) guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	SIL4
	PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signalling) systems, guarantying a degree of functional independence respect to	SIL4

Emergency Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
		functions for the application of Emergency brake that allows the achievement of the global safety objective.	
	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	SIL4
	PHA_EB_47	The Brake system shall apply the force for Emergency brakes locally (e.g. at each axle) by actuation (pneumatic / electric) circuits guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	SIL4
Systematic & Random faults	PHA_EB_17	The Brake system shall acquire the request for the deceleration to stop the train within a maximum allowable stopping distance (Emergency brake) through transmission functions with the same SIL assigned to the calculation and application of the Emergency brake force.	SIL4
	PHA_EB_22	The Brake system shall implement a request of deceleration to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	SIL4
	PHA_EB_32	The Brake system shall implement the partial or total isolation of the Emergency brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	SIL4
	PHA_EB_42	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the nominal Emergency brake with the same SIL assigned to its implementation.	SIL4
	PHA_EB_44	The Brake system shall apply the Emergency brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	SIL4
	PHA_EB_45	The Brake system shall compute the Braking power and transmit it to the external technical (signalling) systems with the same SIL assigned to the implementation of the Emergency brake.	SIL4
	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.	SIL4

Table 12: PHA, Emergency Brake countermeasures

Table 13 provides the set of countermeasures specified for the Service Brake.

Service Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_SB_13	The Brake system shall dispatch the Service brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	SIL1-SIL2
	PHA_SB_15	The Brake system shall preserve the integrity and the timeliness of the information (signals and data) related to bogies load used for the calculation of the Service brake force.	SIL1-SIL2
	PHA_SB_17	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Service brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	SIL1-SIL2
	PHA_SB_20	The Brake system, when active, shall be able to acquire Service brake request coming from the external actors (driver, technical systems).	SIL1-SIL2
	PHA_SB_21	The Brake system shall guarantee performance to be in the minimum/maximum range for the calculation and application of the Service brake force by each (type of) brake, fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake.	SIL1-SIL2
	PHA_SB_22	The Brake system shall guarantee minimum performance of Service brake, fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic brakes due to the infrastructure and/or vehicle.	SIL1-SIL2
	PHA_SB_26	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Service brake application (to the local brake units).	SIL1-SIL2
	PHA_SB_29	The Brake system shall permit the total or partial isolation of Service brake(s) for the removal of the force applied, with or without energy available on the train, whatever are the adjustable (i.e. service) brake actual status and request, as last operation to permit the train running and recover from immobilizing failure conditions.	SIL1-SIL2
	PHA_SB_31	The Brake system, when active, shall guarantee the inexhaustibility of the brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the application of the minimum Service brake force for at least 2 times (i.e. brake cannot be released if it cannot be applied again).	SIL1-SIL2
	PHA_SB_34	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Service brake, with predefined accuracy and timing.	SIL1-SIL2
	PHA_SB_36	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the Service brake with the same SIL assigned to its implementation.	SIL1-SIL2

Service Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	SIL1-SIL2
	PHA_SB_44	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signalling) systems, guarantying a degree of functional independence respect to functions for the application of Service brake that allows the achievement of the global safety objective.	SIL1-SIL2
	PHA_SB_45	The Brake system shall allow the remote release of Service brake(s) only in case of Major fault.	SIL1-SIL2
	PHA_SB_46	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the calculation of the Service brake force to be applied by (all types of) brakes.	SIL1-SIL2
	PHA_SB_7	The Brake system shall adjust the brake force (Service brake) according to the maximum train deceleration requests coming from the different sources (driver, external technical systems).	SIL1-SIL2
	PHA_SB_8	The Brake system shall provide to the external Technical systems and to the driver the information about the Service brake status, operating mode and active fault conditions.	SIL1-SIL2
Detection of faults	PHA_SB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Service brake(s); _remote release of Service brake(s).	SIL1-SIL2
	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	SIL1-SIL2
	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	SIL1-SIL2
	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	SIL1-SIL2
	PHA_SB_41	The Brake system shall monitor the temperature achieved by Service brake(s), as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy.	SIL1-SIL2

Service Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	SIL1-SIL2
Action following Detection	PHA_SB_10	The Brake system shall react to the inability to acquire a Service brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_16	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Service brake, through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_23	The Brake system shall react to the missed application of the Service brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.	SIL1-SIL2
	PHA_SB_28	The Brake system shall react to a dragging condition of Service brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	SIL1-SIL2
	PHA_SB_30	The Brake system shall react to a missed or undue Service brake(s) release or isolation through the notification of a Major fault.	SIL1-SIL2
	PHA_SB_33	The Brake system shall react to the unavailability of the (pneumatic / electrical) energy required to guarantee the inexhaustibility of the Service brake, through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_35	The Brake system shall react to the unavailability of valid information (signal, data) related to measurements used for the calculation of the nominal Service brake force (i.e. speed, bogies load), through the use of predefined conservative values.	SIL1-SIL2
	PHA_SB_42	The Brake system shall react to the over-temperature of Service brake(s) through the notification of a Major fault, the brake(s) release, and the transition or permanence into safe state.	SIL1-SIL2
	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.	SIL1-SIL2

Service Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
	PHA_SB_9	The Brake system shall react to a Major fault generated locally (at axle or bogie level) through the local application of the Emergency brake and be available to a "partial" remote release.	SIL1-SIL2
Independence of Items	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	SIL1-SIL2
	PHA_SB_24	The Brake system shall implement functions for the monitoring of the application of the Service brake request within a predefined maximum time and consequent reaction guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	SIL1-SIL2
	PHA_SB_25	The Brake system shall implement functions for the partial or total isolation and for the remote release of Service brake(s) guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	SIL1-SIL2
	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	SIL1-SIL2
	PHA_SB_40	The Brake system shall apply the force for Service brakes locally (e.g. at each axle) by actuation (pneumatic / electric) circuits guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	SIL1-SIL2
Systematic & Random faults	PHA_SB_14	The Brake system shall acquire the request for the deceleration of the train (Service brake) through transmission functions with the same SIL assigned to the calculation and application of the Service brake force.	SIL1-SIL2
	PHA_SB_19	The Brake system shall implement the adjustable deceleration to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL1-SIL2, including the Tolerable Hazard rate at train level.	SIL1-SIL2
	PHA_SB_27	The Brake system shall implement the partial or total isolation of the Service brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	SIL1-SIL2
	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	SIL1-SIL2
	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.	SIL1-SIL2

Table 13: PHA, Service Brake countermeasures

Table 14 provides the set of countermeasures specified for the Holding Brake.

Holding Brake countermeasures			
Classification	**ID**	**Countermeasures**	**SIL**
Correct operation	PHA_SB_HB_02	The Brake system shall apply the Holding brake automatically when the train speed measure is less than a predefined threshold.	SIL1-SIL2
	PHA_SB_HB_03	The Brake system shall guarantee the inexhaustibility of the Holding brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the temporary immobilization of the train for a defined minimum duration (2 hours according to TSI).	SIL1-SIL2
	PHA_SB_HB_05	The Brake system shall release the Holding brake only if the traction effort is higher enough to avoid train reverse movement or Emergency brake is applied.	SIL1-SIL2
	PHA_SB_HB_06	The Brake system shall verify the capability; _to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Holding brake; _to release the Holding brake; _to inhibit the Holding brake application through the train movement.	SIL1-SIL2
	PHA_SB_HB_08	The Brake system shall guarantee the coherence between the Holding brake indication provided to driver and the real brake status.	SIL1-SIL2
	PHA_SB_HB_09	The Brake system shall apply the Holding brake guarantying the minimum performance (i.e. brake force) required for train temporary immobilization.	SIL1-SIL2
Action following Detection	PHA_SB_HB_07	The Brake system shall react to the missed or ineffective application or loss of the Holding brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system) and the application of the Emergency brake.	SIL1-SIL2
	PHA_SB_HB_10	The Brake system shall react to the undue application of the Holding brake (i.e. without a valid request and/or during train motion) through the notification of a Major fault to the external actors (driver and external technical system) and brake(s) release.	SIL1-SIL2
Systematic & Random faults	PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.	SIL1-SIL2
	PHA_SB_HB_04	The Brake system shall provide to the driver the indication of Holding brake disabled compatibly with the SIL assigned to the Holding brake application.	SIL1-SIL2

Table 14: PHA, Holding Brake countermeasures

4.2.3 Application conditions

Table 15 provides the list of the Application conditions specified during the Preliminary hazard Analysis, i.e. measures to be met by users and/or external technical systems, in order to guarantee the safe functional operation and behaviour under faults of the Brake system.

ID	Application condition
PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.
PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.
PHA_AC_03	The external system shall inform the Brake system about constraints coming from the infrastructure and from the vehicles in the use of regenerative dynamic brake, specifically for Emergency brake, if any.
PHA_AC_04	External technical system shall monitor the temperature achieved by the friction brake, as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy. The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ….).
PHA_AC_05	The external systems shall detect a brake application (triggered by the Brake system as reaction to a Major fault) that leads the train to stop in a hazardous area. In this condition, the external system(s) shall wait till the train speed is under a predefined limit, then command a "global" remote release until the train exits from the hazardous area, and then command the emergency brake to achieve standstill condition.
PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum deceleration and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.
PHA_AC_07	External technical systems shall assure the availability of the (pneumatic and electrical) energy for the brakes regulation, without invalidating the independence required to local brake actuations (e.g. for different bogies).
PHA_AC_08	The external technical systems shall assure the traction cut-off after receiving a valid traction cut-off command from the Brake system. Traction cut-off shall remain enable until traction cut-off command is released or the Brake system is isolated.
PHA_AC_09	The external actors (driver, technical systems) shall avoid train running if no-valid information on braking power is provided by the Brake system or the actual braking power is lower than a minimum value (pre-defined to guarantee safe condition for train running).
PHA_AC_10	External technical system shall provide a safe train speed information from odometry.

ID	Application condition
PHA_AC_11	The Dynamic brake shall guarantee a minimum brake force if available and provide safe information on its availability (otherwise, the blending logic shall be based on a safe measure of the force applied). The Adhesion independent brakes shall guarantee the application of the brake force, if available.
PHA_AC_12	Safe state conditions of the Brake system fault are: _train at a standstill condition (in a non-hazardous area), achieved through the automatic application of a continuous Emergency brake; _train running, with all brakes released and a residual braking power compatible with the train speed. The applicability and specific implications of the above Brake system's safe state definition shall be evaluated for each specific application.
PHA_AC_13	The applicability and specific implications of the use of different types of brake and different blending configurations shall be evaluated for each specific application.
PHA_AC_14	External technical system shall provide to the Brake system all data (about train and brakes configurations) required by its initialization.
PHA_AC_15	The driver shall verify the application of the Parking brake request through the related indication provided by the Brake System.

Table 15: PHA, Application conditions

4.2.4 Recommendations

Table 16 provides the Recommendations (listed in the first column) specified during the Preliminary hazard Analysis of the Brake system, which provide indications for the implementation of some countermeasures (listed in in the second column) specified in §4.2.2.

Recommendation	Countermeasures
PHA_REC_01 It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).	PHA_EB_24 The Brake system shall guarantee minimum performance (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake). PHA_EB_25 The Brake system shall guarantee minimum performance of Emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake; _restriction in the use of dynamic and adhesion independent brakes due to the infrastructure and/or vehicle.
PHA_REC_02 It is recommended that the Brake system implements a closed loop control for the setting of the brake force, in the application of the train retardation request.	PHA_EB_46 The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions

Recommendation	Countermeasures
	related to Emergency brake compatibly with the SIL assigned to its implementation.
PHA_REC_03 It is recommended that the Brake system implements distributed hardware circuits for the conditioning of local signals (e.g. axle speed) and for the implementation of local interlocks (e.g. non admissible status of controlled devices) and protections (e.g. against excessive wheel-sliding protection), providing independency against errors the brake command line.	PHA_EB_47 The Brake system shall apply the force for Emergency brakes locally (e.g. at each axle) by actuation (pneumatic / electric) circuits guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.
	PHA_SB_40 The Brake system shall apply the force for Service brakes locally (e.g. at each axle) by actuation (pneumatic / electric) circuits guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.
PHA_REC_04 It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signaling and processing systems (EN 50129).	PHA_PB_1 The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems; _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level, if the request comes from the driver.
	PHA_EB_22 The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.
	PHA_SB_19 The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL1 - SIL2, including the Tolerable Hazard rate at train level.
	PHA_SB_HB_01 The Brake system shall implement the temporary immobilization of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.
PHA_REC_05 It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).	PHA_PB_1 The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems; _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level, if the request comes from the driver.
	PHA_EB_22 The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.

Recommendation	Countermeasures
	PHA_SB_19 The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL1 - SIL2, including the Tolerable Hazard rate at train level.
	PHA_SB_HB_01 The Brake system shall implement the temporary immobilization of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.
	PHA_GEN_2 The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error).
	PHA_GEN_4 The Brake system shall discharge a message acquired from the external technical systems (containing safety-data) when a communication error is identified and interrupt the communication when a predefined number of messages are discharged.
	PHA_GEN_6 The Brake system's devices exchanging safety-data shall discharge a message when a communication error is identified (because messages authenticity, integrity, timeliness or sequence is/are violated) and interrupt the communication when a predefined number of messages are discharged.
	PHA_SB_12 The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.
PHA_REC_06 It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).	PHA_PB_1 The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems; _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level, if the request comes from the driver.
	PHA_EB_22 The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.

Recommendation	Countermeasures
	PHA_SB_19 The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL1 - SIL2, including the Tolerable Hazard rate at train level.
	PHA_SB_HB_01 The Brake system shall implement the temporary immobilization of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.
	PHA_GEN_7 The Brake system shall operate and fulfil all its safety requirements under the effect of external influences, including environment temperature and humidity, shock and vibration, electromagnetic compatibility and electrical stresses.
PHA_REC_07 It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.	PHA_BSM_1 The Brake system shall store permanently, assure the integrity and inhibit any modification (during service, i.e. restart mandatory) of the configuration data acquired during its initialization.
	PHA_BSM_2 The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid.
PHA_REC_08 It is recommended that the Brake system reacts to a Major fault by applying the Emergency brake force through the de-energization of the local I/O interfaces toward the energy regulation (pneumatic / electric) circuits.	PHA_EB_7 The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.
	PHA_EB_21 The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.
	PHA_EB_28 The Brake system shall react to the missed application of the (nominal) Emergency brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.
PHA_REC_09 It is recommended a "negative logic" in the notification of the Major fault - within the Brake system and to the external actors (i.e. driver and technical systems) - guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.	PHA_BSM_10 The Brake system shall react to the Major fault by the transition or permanence into safe conditions, with the same SIL assigned to the implementation of the Emergency brake.
PHA_REC_10 It is recommended a "negative logic" in the Emergency brake request, guarantying the train running capability (i.e. brake not applied and traction allowed) only if the	PHA_BSM_10 The Brake system shall react to the Major fault by the transition or permanence into safe conditions, with the same SIL assigned to the implementation of the Emergency brake.

Recommendation	Countermeasures
transmission system and the transmission functions are available.	
PHA_REC_11 It is recommended that friction brakes are dimensioned in order to provide the total force required for minimum Emergency brake, by complementing the minimum force assured d by the dynamic brakes.	PHA_SB_22 The Brake system shall guarantee minimum performance of Service brake, fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic brakes due to the infrastructure and/or vehicle.

Table 16: PHA, Recommendations

4.3 Risk Assessment Results

The results coming from the Risk Assessment developed for the Brake system (see Annex 1) include:

- Risk assessment;
- Hazard & SIL;
- Function & SIL.

The main results coming from the RA are also provided in the following tables.

Table 17 summarizes qualitative information characterizing each Brake system hazard (see Table 8):

- Operational Context (Normal service, Standstill, Maintenance) and Pre-condition (if applicable, e.g. PB condition, Train movement, Train in a hazardous area); they define the initial situation during which the hazardous event can occur; the pre-condition can be considered in the assignment of a given hazard to the initial category for the Frequency of occurrence, specifically when it can occur only in a limited time-window or under specific circumstances; otherwise, the Pre-condition is specified within brackets () and has not impact on the initial Frequency of occurrence.
- Protection, which defines the way to mitigate the consequences of an Hazardous event, if any, e.g. Emergency brake (e.g. in case of ineffective Service brake).

Worst Case Consequence, which defines the most severe impact of the hazard, through the qualitative description associated to the categories of Severity of Consequence. Table 18 summarizes the results coming from the RA, providing for each Brake system hazard:

- the initial level of risk, by its assignment to a category for the Severity of consequence and to a category for the Frequency of occurrence;
- the function(s) whose deviation(s) from the nominal behaviour can lead to the hazard, according to the PHA results (see §4.2);
- the Safety Integrity Level to be required to each function in order to achieve a negligible (at least tolerable) risk level (see Table 6);
- the final level of risk, assuming that all the countermeasures are implemented according to the SIL required to the given function.

Table 19 provides a different view of the results coming from the risk assessment, groping the Brake system hazards by their Initial Risk level, Severity category and Frequency category, and specifying the SIL to be required to the involved functions and the final level of risk. “Non-functional hazard” (i.e. not related to - i.e. produced or mitigated by - functions implemented by the Brake system) are not included.

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB1 - Emergency brake train retardation request EB11 - Energy supply EB2 - Emergency brake request transmission EB4 - Train Emergency brake force calculation EB5 - Emergency brake blending
H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB8 - Emergency brake Traction cut off
H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB1 - Emergency brake train retardation request EB10 - Emergency Brake isolation EB12 - Emergency brake kinetic energy transformation EB2 - Emergency brake request transmission EB3 - Train load calculation EB4 - Train Emergency brake force calculation EB5 - Emergency brake blending EB6 - Emergency brake energy storing and distribution EB9 - State and fault detection and indication
H.4	After activation of Parking brake, complete and permanent loss of Parking brake force.	Standstill	(PB condition)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	PB - Parking Brake
H.5	Impossibility for a passenger to initiate the activation of brake in order to stop the train when train departs from a platform due to failure in the passenger alarm system.	Emergency	Passenger require the activation of the EB.	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB1 - Emergency brake train retardation request EB2 - Emergency brake request transmission
H.6	No information given to the driver in case of activation of a passenger alarm due to failure in the passenger alarm system.	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	External passenger alarm system.

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	Normal service	(EB, SB, HB, PB activation)	-	Minor injury and/or significant threat to the environment.	EB3 - Train load calculation EB4 - Train Emergency brake force calculation EB5 - Emergency brake blending EB6 - Emergency brake energy storing and distribution SB3 - Train load calculation SB4 - Train Service brake force calculation SB5 - Service brake blending SB6 - Service brake energy storing and distribution
H.8	Automatic (emergency) brake not initiated in the case of an unintended train separation (loss of train integrity).	Normal service	Loss of train integrity	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB1 - Emergency brake train retardation request EB2 - Emergency brake request transmission
H.9	Required Parking brake performance not achieved.	Standstill	(PB activation)	EB if commanded by the driver	Fatalities and/or multiple severe injuries and/or major damage to the environment.	PB - Parking Brake
H.10	Loss of Parking brake force over the time.	Standstill	(PB condition)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	PB - Parking Brake
H.11	Holding brake for brake test not achieved.	Standstill	(PB, HB activation)	EB in case of no/ineffective /loss of HB	Minor injury and/or significant threat to the environment.	SB7 - Holding brake
H.12	Undue local application of brake force.	Normal service	(EB, SB, HB, PB activation)	-	Minor injury and/or significant threat to the environment.	EB10 - Emergency Brake isolation EB5 - Emergency brake blending EB6 - Emergency brake energy storing and distribution EB9 - State and fault detection and indication SB10 - Service Brake isolation SB5 - Service brake blending SB6 - Service brake energy storing and distribution SB9 - Service brake state and fault detection and indication

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.13	Locked axle not detected.	Normal service	(EB, SB, HB, PB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB9 - State and fault detection and indication EB10 - Emergency Brake isolation SB10 - Service Brake isolation
H.14	Required Holding brake performance not achieved.	Standstill	(HB condition)	EB in case of no/ineffective /loss of HB	Minor injury and/or significant threat to the environment.	SB7 - Holding brake
H.15	Excessive EMI interference leading to unexpected Brake system behaviour.	Normal service / Maintenance	-	-	Possible minor injury.	Note: Non-functional hazard
H.16	Excessive sound/noise level.	Normal service / Maintenance	-	-	Possible minor injury.	Note: Non-functional hazard
H.17	Accessible hazardous voltage.	Normal service / Maintenance	-	-	Single fatality and/or severe injury and/or significant damage to the environment.	Note: Non-functional hazard
H.18	Accessible sharp edges.	Normal service / Maintenance	-	-	Minor injury and/or significant threat to the environment.	Note: Non-functional hazard
H.19	Accessible hot surfaces.	Normal service / Maintenance	-	-	Minor injury and/or significant threat to the environment.	Note: Non-functional hazard
H.20	Small train parts detached.	Normal service / Maintenance	-	-	Single fatality and/or severe injury and/or significant damage to the environment.	Note: Non-functional hazard

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.21	Big train parts detached.	Normal service / Maintenance	-	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	Note: Non-functional hazard
H.22	Excessive release of stored energy (e.g. air pressure, spring load).	Normal service / Maintenance	-	-	Minor injury and/or significant threat to the environment.	Note: Non-functional hazard
H.23	Accessible moving/rotating parts.	Normal service / Maintenance	-	-	Minor injury and/or significant threat to the environment.	Note: Non-functional hazard
H.24	Spread of smokes or fire.	Normal service / Maintenance	-	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	Note: Non-functional hazard
H.25	Release of toxic substances.	Normal service / Maintenance	-	-	Minor injury and/or significant threat to the environment.	Note: Non-functional hazard
H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	Normal service / Maintenance	Hazardous undetected failure(s)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	ABT - Automatic Brake Test
H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	Normal service / Maintenance	(train power up or coupling / uncoupling)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	BSM1 - Train topology and Brake system integrity BSM2 - Manage brake operating modes.
H.28	Emergency Brake force is applied only for a fraction of consists brake	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB2 - Emergency brake request transmission EB5 - Emergency brake blending EB6 - Emergency brake energy storing and distribution

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	Normal service	(EB, SB, HB, PB activation)	-	Minor injury and/or significant threat to the environment.	EB12 - Emergency brake kinetic energy transformation EB5 - Emergency brake blending EB6 - Emergency brake energy storing and distribution SB12 - Service brake kinetic energy transformation SB5 - Service brake blending SB6 - Service brake energy storing and distribution
H.30	No or incorrect information on braking power provided to the external technical (signalling) system	Normal service	(EB activation)	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	EB10 - Emergency Brake isolation EB7 - Actual Emergency Braking Power Calculation
H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	Normal service	(SB activation)	EB in case of no/ineffective SB	Minor injury and/or significant threat to the environment.	SB1 - Service brake train retardation request SB11 - Energy supply SB2 - Service brake request transmission SB4 - Train Service brake force calculation SB5 - Service brake blending SB6 - Service brake energy storing and distribution
H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	Normal service	(SB activation)	EB in case of no/ineffective SB	Minor injury and/or significant threat to the environment.	SB8 - Service brake Traction cut off
H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	Normal service	(SB activation)	EB in case of no/ineffective SB	Minor injury and/or significant threat to the environment.	SB1 - Service brake train retardation request SB10 - Service Brake isolation SB12 - Service brake kinetic energy transformation SB2 - Service brake request transmission SB3 - Train load calculation SB4 - Train Service brake force calculation SB5 - Service brake blending SB6 - Service brake energy storing and distribution SB9 - Service brake state and fault detection and indication
H.34	Incorrect indication to driver about the permanent immobilization of the train (Parking brake status)	Standstill	PB not activated	-	Fatalities and/or multiple severe injuries and/or major damage to the environment.	PB - Parking Brake

Brake System Hazard		Operational Context	Pre-condition	Protection	Worst Case Consequence	Brake system functions involved
ID	Description					
H.35	Undue application of brake for permanent immobilization (Parking brake) during train movement	Service	(Train movement)	-	Single fatality and/or severe injury and/or significant damage to the environment.	PB - Parking Brake
H.36	After activation, complete and permanent loss of Holding brake force.	Standstill	(HB condition)	EB in case of no/ineffective /loss of HB	Minor injury and/or significant threat to the environment.	PB - Parking Brake
H.37	Incorrect indication to driver about the temporary immobilization of the train (Holding brake status)	Standstill	(HB activation)	EB in case of no/ineffective /loss of HB	Minor injury and/or significant threat to the environment.	PB - Parking Brake
H.38	Undue application of brake for temporary immobilization (Holding brake) during train motion	Normal service	(Train movement)	-	Minor injury and/or significant threat to the environment.	PB - Parking Brake
H.39	Loss of Holding brake force over the time.	Standstill	(HB condition)	EB in case of no/ineffective /loss of HB	Minor injury and/or significant threat to the environment.	PB - Parking Brake
H.40	Undue train stop, due to Brake System failure, in a hazardous area.	Normal service / Emergency	Train in a hazardous area	-	Single fatality and/or severe injury and/or significant damage to the environment.	EB2 - Emergency brake request transmission SB2 - Service brake request transmission

Table 17: Brake system hazards, Risk Assessment – qualitative information

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	**Description**	**Severity category**	**Frequency category**	**Risk Level**		**Severity category**	**Frequency category**	**Risk Level**	
H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	SIL4	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	
H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	Catastrophic	To be evaluated by Traction System responsible passenger alarm system, for each specific application						
H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	SIL4	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	
H.4	After activation of Parking brake, complete and permanent loss of Parking brake force.	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	SIL4	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	
H.5	Impossibility for a passenger to initiate the activation of brake in order to stop the train when train departs from a platform due to failure in the passenger alarm system.	Catastrophic	To be evaluated by Passenger alarm system responsible, for each specific application						
H.6	No information given to the driver in case of activation of a passenger alarm due to failure in the passenger alarm system.	Catastrophic	To be evaluated by Passenger alarm system responsible, for each specific application						

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	Description	Severity category	Frequency category	Risk Level		Severity category	Frequency category	Risk Level	
H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.8	Automatic (emergency) brake not initiated in the case of an unintended train separation (loss of train integrity).	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable	SIL4	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	
H.9	Required Parking brake performance not achieved.	Catastrophic (if automatic) Marginal (if commanded by the driver)	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable Undesirable if commanded by the driver	SIL4 SIL2 if commanded by the driver	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1}) IMPROBABLE ($10^{-7} \div 10^{-9}$ h^{-1})	Negligible Tolerable (SIL2 if commanded by the driver)	
H.10	Loss of Parking brake force over the time.	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable	SIL4	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	
H.11	Holding brake for brake test not achieved.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.12	Undue local application of brake force.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	**Description**	**Severity category**	**Frequency category**	**Risk Level**		**Severity category**	**Frequency category**	**Risk Level**	
H.13	Locked axle not detected.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.14	Required Holding brake performance not achieved.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.15	Excessive EMI interference leading to unexpected Brake system behaviour.	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable	N/A	To be mitigated by non-functional measures			
H.16	Excessive sound/noise level.	Insignificant	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	N/A				
H.17	Accessible hazardous voltage.	Critical	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Undesirable	N/A	To be mitigated by non-functional measures			
H.18	Accessible sharp edges.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	N/A				
H.19	Accessible hot surfaces.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	N/A				
H.20	Small train parts detached.	Critical	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Undesirable	N/A	To be mitigated by non-functional measures			

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	Description	Severity category	Frequency category	Risk Level		Severity category	Frequency category	Risk Level	
H.21	Big train parts detached.	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	N/A	To be mitigated by non-functional measures			
H.22	Excessive release of stored energy (e.g. air pressure, spring load).	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	N/A	To be mitigated by non-functional measures			
H.23	Accessible moving/rotating parts.	Marginal	REMOTE $(10^{-5} \div 10^{-7}\ h^{-1})$	Tolerable	N/A				
H.24	Spread of smokes or fire.	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	N/A	To be mitigated by non-functional measures			
H.25	Release of toxic substances.	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	N/A	To be mitigated by non-functional measures			
H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	Catastrophic	REMOTE $(10^{-5} \div 10^{-7}\ h^{-1})$	Undesirable	SIL ≥ 2	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	
H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	SIL4	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	
H.28	Emergency Brake force is applied only for a fraction of consists brake	Catastrophic	OCCASIONAL $(10^{-4} \div 10^{-5}\ h^{-1})$	Intolerable	SIL4	Catastrophic	INCREDIBLE $(<10^{-9}\ h^{-1})$	Negligible	

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	**Description**	**Severity category**	**Frequency category**	**Risk Level**		**Severity category**	**Frequency category**	**Risk Level**	
H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.30	No or incorrect information on braking power provided to the external technical (signalling) system	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable	SIL4	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	
H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.34	Incorrect indication to driver about the permanent immobilization of the train (Parking brake status)	Catastrophic	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Undesirable	SIL ≥ 2	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	

Brake system hazard		Initial Risk Assessment			SIL to functions involved	Final Risk Assessment			Remark
ID	**Description**	**Severity category**	**Frequency category**	**Risk Level**		**Severity category**	**Frequency category**	**Risk Level**	
H.35	Undue application of brake for permanent immobilization (Parking brake) during train movement	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Intolerable	SIL4	Critical	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	
H.36	After activation, complete and permanent loss of Holding brake force.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.37	Incorrect indication to driver about the temporary immobilization of the train (Holding brake status)	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.38	Undue application of brake for temporary immobilization (Holding brake) during train motion	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.39	Loss of Holding brake force over the time.	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	Tolerable	SIL1-SIL2	Marginal	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Tolerable	SIL ≥ 2 allows a negligible residual risk
H.40	Undue train stop, due to Brake System failure, in a hazardous area.	Catastrophic	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	Undesirable	SIL ≥ 2	Catastrophic	INCREDIBLE ($<10^{-9}$ h^{-1})	Negligible	SIL ≥ 2 allows a negligible residual risk

Table 18: (Initial and final) Risk Assessment and SIL specification

Initial Risk Level	Initial Severity category	Initial Frequency category	SIL required to functions	Brake system hazard		Final Risk Level
				ID	Description	
Intolerable	Catastrophic	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	SIL4	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	Negligible
				H.9	Required Parking brake performance not achieved.	Negligible
				H.10	Loss of Parking brake force over the time.	Negligible
				H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	Negligible
				H.28	Emergency Brake force is applied only for a fraction of consists brake	Negligible
				H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	Negligible
				H.30	No or incorrect information on braking power provided to the external technical (signaling) system	Negligible
				H.35	Undue application of brake for permanent immobilization (Parking brake) during train movement	Negligible
				H.4	After activation of Parking brake, complete and permanent loss of Parking brake force.	Negligible
				H.8	Automatic (emergency) brake not initiated in the case of an unintended train separation (loss of train integrity).	Negligible
Undesirable	Catastrophic	REMOTE ($10^{-5} \div 10^{-7}$ h^{-1})	SIL ≥ 2	H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	Negligible
				H.34	Incorrect indication to driver about the permanent immobilization of the train (Parking brake status)	Negligible
				H.40	Undue train stop, due to Brake System failure, in a hazardous area.	Negligible

Initial Risk Level	Initial Severity category	Initial Frequency category	SIL required to functions	Brake system hazard		Final Risk Level
				ID	Description	
Tolerable	Marginal	OCCASIONAL ($10^{-4} \div 10^{-5}$ h^{-1})	SIL1-SIL2	H.11	Holding brake for brake test not achieved.	Tolerable
				H.12	Undue local application of brake force.	Tolerable
				H.13	Locked axle not detected.	Tolerable
				H.14	Required Holding brake performance not achieved.	Tolerable
				H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	Tolerable
				H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	Tolerable
				H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	Tolerable
				H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	Tolerable
				H.36	After activation, complete and permanent loss of Holding brake force.	Tolerable
				H.37	Incorrect indication to driver about the temporary immobilization of the train (Holding brake status)	Tolerable
				H.38	Undue application of brake for temporary immobilization (Holding brake) during train motion	Tolerable
				H.39	Loss of Holding brake force over the time.	Tolerable
				H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	Tolerable

Table 19: Risk Assessment, summary of results

Table 20 summarizes the SIL required to the main Brake system functions. The SIL required to a given main function also applies to all the related lower level functions (no exception is identified).

Brake System function		(Max) SIL
ID	**Description**	
ABT	Automatic Brake Test	SIL ≥ 2
BSM	Brake system management	SIL4
EB	Emergency brake	SIL4
PB	Parking Brake	SIL4
SB	Service brake	SIL1-SIL2

Table 20: SIL specification, summary of results

Chapter 5 Summary and conclusion

This document provides:

- an overall brake system functional view by the definition of the brake system functional structure and sub-functions main requirements definition,
- the detailed functional requirements for a subset of brake system functionalities related to adhesion dependent friction brake and for service and emergency brake main functions, which are consistent with the S4R objective to demonstrate the consistency of the new TCMS embedded platform,
- the list of input/output information defining the interfaces between brake system sub-functions and between brake system and technical systems of the train,
- the overall brake system Preliminary Hazard Analysis on brake system functions,
- the overall safety brake system requirements, the safety application condition requirements and safety recommendation for the following concept design work.

The above results are a robust base from which to start with the following activities in the next phase:

- integration for the safety analysis outputs in the whole requirements list,
- brake system architecture specification,
- limitation of the scope to emergency brake functions and evaluation about any other limitation can be introduced without affecting the final result architectural related requirements definition limited to the scope,
- allocation of requirements to electronic control, based on architecture definition identification of electronic control interfaces,
- preparation of Hazard Analysis focus on electronic control requirements,
- definition of electronic control safety requirements based on Hazard Analysis,
- Electronic control architecture definition with hardware, software and platform requirements.

The first steps will be done in tight cooperation between S4R and CTA.

The above activities will permit the definition of the new brake system concept to be integrated in the S4R WP1 and WP2 platform concept design.

Chapter 6 List of Abbreviations

ABT	Automatic Brake Test
ATP	Automatic Train Protection
BCU	Brake Control Unit
BSM	Brake System Management
CTA	Connecta
EB	Emergency Brake
EC	Electronic Control
ECU	Electronic Control Unit
ED	Electro-Dynamic
EDV	Electronic Distributor Valve
ELE	Eletech
EMU	Electrical Multiple Unit
EN	European Norm
EP	Electro-Pneumatic
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FMECA	Failure Mode, Effects, and Criticality Analysis
FSM	Functional Safety Management
FTA	Fault Tree Analysis
FTA	Fault Tree Analysis
HARA	Hazard Analysis and Risk Analysis
HB	Holding Brake
IMP	Integrated Modular Platform
LAM	Low Adhesion Management

LCC	Life Cycle Cost
N/A	Not Applicable
NonF	Non-Functional
PAS	Passenger Alarm System
PB	Parking Brake
PHA	Preliminary Hazard Analysis
RAMS	Reliability, Availability, Maintainability, Safety
S4R	Safe4RAIL
SB	Service Brake
SIL	Safety Integrity Level
SV&V	Software Verification and Validation
TCMS	Train Control and Management System
TSI	Technical specifications for interoperability
WP	Work Package
WSP	Wheel Slide Protection

Table 15: List of Abbreviations

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Annex 1 Preliminary Hazard Analysis table

This annex contains the Preliminary Hazard Analysis.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
BSM1	Train topology and Brake system integrity	Manages the Brake System initialization and configuration at train power up or coupling / uncoupling	No	Missed initialization and configuration of the Brake system at train power up or coupling / uncoupling	Unavailability of the information on about the train and Brake system configurations, required for the proper implementation of the train retardation / immobilization request.	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance). Excessive brakes force applied and abrupt train deceleration and potential brake damage. Train movement (traction on) with brake partially permanently applied and possible brake damage.	H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	PHA_BSM_6	The Brake system, at the Start up or at coupling/decoupling, shall be in its initialization state, acquire data on the train and brakes configuration, and perform the automatic brake test.	PHA_BSM_2	The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid;	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-	PHA_BSM_8	The Brake system shall be initialized and acquire all data required to operate with the actual train and brakes configurations with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_14	External technical system shall provide to the Brake system all data (about train and brakes configurations) required by its initialization.	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Wrong	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling (data non-coherent with the actual situation)	Incorrect information about the train and Brake system configurations, and ineffective implementation of the train retardation / immobilization request.	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance). Excessive brakes force applied and abrupt train deceleration and potential brake damage. Train movement (traction on) with brake partially permanently applied and possible brake damage.	H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	PHA_BSM_1	The Brake system shall store permanently, assure the integrity and inhibit any modification (during service, i.e. restart mandatory) of the configuration data acquired during its initialization.	PHA_BSM_2	The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid;	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-	PHA_BSM_8	The Brake system shall be initialized and acquire all data required to operate with the actual train and brakes configurations with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_14	External technical system shall provide to the Brake system all data (about train and brakes configurations) required by its initialization.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Loss of data acquired during initialization and configuration of the Brake system at train power up or coupling / uncoupling	Incorrect or partial information about the train and Brake system configurations, and ineffective implementation of the train retardation / immobilization request.	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance). Excessive brakes force applied and abrupt train deceleration and potential brake damage. Train movement (traction on) with brake partially permanently applied and possible brake damage.	H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	PHA_BSM_1	The Brake system shall store permanently, assure the integrity and inhibit any modification (during service, i.e. restart mandatory) of the configuration data acquired during its initialization.	PHA_BSM_2	The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid;	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-	PHA_BSM_8	The Brake system shall be initialized and acquire all data required to operate with the actual train and brakes configurations with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_14	External technical system shall provide to the Brake system all data (about train and brakes configurations) required by its initialization.		
			Undue	Not applicable																		
BSM2	Manage brake operating modes.	Manage the reaction to major fault and the degraded mode selected by the driver to exit from the major fault condition	No	Missed reaction to the notification of a Major fault	After a Brake system failures leading to the notification of a major fault, missed transition into a safe state.	Missed or ineffective brake application as reaction to failure.	H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	PHA_BSM_3	The Brake system shall react to a Major fault generated at consist level (i.e. affecting brakes at more than one axle / bogie) by notifying it to the driver and external systems (i.e. transition into the safe state) and by dispatching the brake command to all the local brake units (i.e. transition into the safe state)	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_BSM_9	The Brake system shall implement functions for the management of and reaction to Major fault conditions guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_BSM_10	The Brake system shall react to the Major fault by the transition or permanence into safe conditions, with the same SIL assigned to the implementation of the Emergency brake.				
				Missed permission to the drive to by-pass the (emergency) braking condition	After a Brake system failures leading to the notification of a major fault, the driver cannot by-pass brake application.	The driver cannot exit from the safe state.	-	-														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect reaction to the notification of a Major fault, i.e. less restrictive than required	After a Brake system failures leading to the notification of a major fault, missed brake application for the transition into a safe state.	Missed or ineffective brake application as reaction to failure.	H.27	Incorrect initialization and configuration of the Brake system at train power up or coupling / uncoupling	PHA_BSM_4	The Brake system shall react to a Major fault generated locally (at axle or bogie level) according to the degradation in the braking power: _ by commanding the remote release of the faulted brake, if safe condition are still guaranteed by the residual braking power (i.e. permanence into the safe state); _OR otherwise by dispatching the Emergency brake command to all the local brake units (i.e. transition into the safe state) and by notifying the Major fault to the driver and external systems.	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_BSM_9	The Brake system shall implement functions for the management of and reaction to Major fault conditions guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_BSM_10	The Brake system shall react to the Major fault by the transition or permanence into safe conditions, with the same SIL assigned to the implementation of the Emergency brake.				
			Loss of / Partially	Non applicable																		
			Undue	Non applicable																		
ABT	Automatic Brake Test	Manage the automatic brake test checking the functionality of Brake system	No/ Loss of / Partially	Missed or partial execution of automatic brake test	No direct effect on brake application.	Missed detection of latent failures.	H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	PHA_BSM_6	The Brake system, at the Start up or at coupling/decoupling, shall be in its initialization state, acquire data on the train and brakes configuration, and perform the automatic brake test.		-	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-					PHA_REC_09	It is recommended a "negative logic" in the notification of the Major fault - within the Brake system and to the external actors (i.e. driver and technical systems) - guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	**Sub-function**	**Description**	**Guide-word**	**Deviation / Functional Failure mode.**	**Local effect**	**Final effect**	**Hazard ID**	**Hazard description**	**ID**	**Description**	**ID**	**Description**		**Description**		**Description**		**Description**	**ID**	**Description**	**ID**	**Description**
			Wrong	Incorrect, unduly positive, results from the automatic brake test	No direct effect on brake application.	Missed detection of latent failures.	H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	PHA_BSM_6	The Brake system, at the Start up or at coupling/decoupling, shall be in its initialization state, acquire data on the train and brakes configuration, and perform the automatic brake test.		-	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-					PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Undue	Undue automatic brake test (when not required, e.g. during service)	No direct effect on brake application.	Missed detection of latent failures.	H.26	Automatic brake test not or partially performed or ineffective to detect latent failure(s).	PHA_BSM_6	The Brake system, at the Start up or at coupling/decoupling, shall be in its initialization state, acquire data on the train and brakes configuration, and perform the automatic brake test.		-	PHA_BSM_7	The Brake system shall not be able to operate without a valid initialization and react to a missed or negative result from one of the automatic brake tests through the notification of a Major fault and the permanence into a safe state.		-					PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
PB	Parking Brake	The Parking brake is used by the users and technical systems to apply predefined braking force to the track (directly or by the wheelset) with the goal to immobilize permanently the train.	No	Missed actuation of the Parking brake	Brake force required to guarantee the train standstill condition is not applied.	Missed permanent immobilization of the train	H.9	Required Parking brake performance not achieved.	PHA_PB_2	The Brake system shall apply the Parking brake when a valid request for permanent immobilization of the train is active and the train speed measure is available and less than a predefined threshold.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.	PHA_PB_7	The Brake system shall react to the missed or ineffective application of the Parking brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system).	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of: _Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake; _Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_PB_1	The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level,if the request comes from the driver	PHA_AC_15	The driver shall verify the application of the Parking brake request through the related indication provided by the Brake System	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Wrong	Incorrect indication to driver of the Parking brake status (applied when it is not)	Drive considers that the Parking brake is applied when it is not.	Missed permanent immobilization of the train	H.34	Incorrect indication to driver about the permanent immobilization of the train (Parking brake status)	PHA_PB_8	The Brake system shall guarantee the coherence between the Parking brake indication provided to driver and the real brake status.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.	PHA_PB_7	The Brake system shall react to the missed or ineffective application of the Parking brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system).			PHA_PB_4	The Brake system shall provide to the driver the indication of Parking brake status compatibly with the SIL assigned to the Parking brake application if the request comes from the driver			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Insufficient brake force applied for Parking brake	Brake force applied is not effective to guarantee the train standstill condition.	Missed permanent immobilization of the train	H.9	Required Parking brake performance not achieved.	PHA_PB_9	The Brake system shall apply the Parking brake guarantying the minimum performance (i.e. brake force) required for train permanent immobilization.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.	PHA_PB_7	The Brake system shall react to the missed or ineffective application of the Parking brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system).			PHA_PB_1	The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level,if the request comes from the driver	PHA_AC_15	The driver shall verify the application of the Parking brake request through the related indication provided by the Brake System		
						Missed permanent immobilization of the train											PHA_PB_4	The Brake system shall provide to the driver the indication of Parking brake status compatibly with the SIL assigned to the Parking brake application if the request comes from the driver				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Loss of Parking brake condition (i.e. loss of train permanent immobilization).	Loss of brake force guarantying the train standstill condition.	Missed permanent immobilization of the train	H.10	Loss of Parking brake force over the time.	PHA_PB_3	The Brake system shall guarantee the inexhaustibility of the Parking brake: without any external source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the permanent immobilization of the train.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization;_to indicate to driver the status of application of Parking brake;_to release the Parking brake;_to inhibit the Parking brake application through the train movement.					PHA_PB_1	The Brake system shall implement the Parking brake request:_fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems_coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level,if the request comes from the driver				
			Undue	Undue Parking brake release (when not required).	Loss of brake force guarantying the train standstill condition.	Missed permanent immobilization of the train	H.4	After activation of Parking brake, complete and permanent loss of Parking brake force.	PHA_PB_5	The Brake system shall release the Parking brake only when a valid request for the release of the permanent immobilization of the train is acquired from external actors (driver or external technical system), and only by transiting to the Holding brake condition.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.					PHA_PB_1	The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level,if the request comes from the driver				

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									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Undue Parking brake application	Parking brake force is applied during train motion.	Missed permanent immobilization of the train	H.35	Undue application of brake for permanent immobilization (Parking brake) during train movement	PHA_PB_2	The Brake system shall apply the Parking brake when a valid request for permanent immobilization of the train is active and the train speed measure is available and less than a predefined threshold.	PHA_PB_6	The Brake system shall verify the capability: _to apply the Parking brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Parking brake; _to release the Parking brake; _to inhibit the Parking brake application through the train movement.	PHA_PB_10	The Brake system shall react to the undue application of the Parking brake (i.e. without a valid request and/or during train motion) through the notification of a Major fault to the external actors (driver and external technical system) and brake(s) release.	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of: _Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake; _Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_PB_1	The Brake system shall implement the Parking brake request: _fulfilling the requirements stated in EN50129 for a SIL SIL4, including the Tolerable Hazard rate at train level, if the request comes from the external Technical systems _coming from the driver fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level,if the request comes from the driver				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB1	Emergency brake train retardation request	Collect any Emergency brake request by actors and transmit it to EB2.	No	Missed acquisition of Emergency brake request coming from actors (driver or technical systems).	No transmission of Emergency brake request to other Brake system functions	Missed permanent immobilization of the train	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	PHA_EB_23	The Brake system, in any state after its initialization, shall be able to acquire Emergency brake request coming from the external actors (driver, technical systems)	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_EB_12	The Brake system shall react to the inability to acquire a Emergency brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_17	The Brake system shall acquire the request for the retardation to stop the train within a maximum allowable stopping distance (Emergency brake) through transmission functions with the same SIL assigned to the calculation and application of the Emergency brake force.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_10	It is recommended a "negative logic" in the Emergency brake request, guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
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ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Delay in the acquisition of a valid Emergency brake request coming from actors (driver or technical systems).	Delayed transmission of Emergency brake request to other Brake system functions	Delayed train deceleration and stop beyond the limit	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall:_ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level);_ implement safety protection in the generation of safety-data to be exchange through the transmission system;_ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system;_to transmit valid Emergency brake request to all brake functions.	PHA_GEN_4	The Brake system shall discharge a message acquired from the external technical systems (containing safety-data) when a communication error is identified and interrupt the communication when a predefined number of messages are discharged.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_17	The Brake system shall acquire the request for the retardation to stop the train within a maximum allowable stopping distance (Emergency brake) through transmission functions with the same SIL assigned to the calculation and application of the Emergency brake force.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall:_ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Not applicable																	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
			Undue	Not applicable																		
EB2	Emergency brake request transmission	Transmit Emergency brake request received by EB1 to other Brake system functions	No	No transmission of Emergency brake request to other Brake system functions.	Missed calculation and application of the train Emergency brake force.	No train deceleration and missed stop	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	PHA_GEN_5	The Brake system's devices exchanging safety-data shall verify the messages integrity (transmitter identity, type, value errors), sequence and timeliness (timing, sequencing error, data received in due time) and authenticity (if an open transmission system is used, with safety related access protection functions).	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_EB_14	The Brake system shall react to a (partial or total) inability to transmit a valid Emergency brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the transition or permanence into safe state.	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of: _Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake; _Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_10	It is recommended a "negative logic" in the Emergency brake request, guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Transmission of non-valid Emergency brake request to brake functions.	Missed or delayed calculation and application of the train Emergency brake force.	Delayed train deceleration and stop beyond the limit	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_GEN_5	The Brake system's devices exchanging safety-data shall verify the messages integrity (transmitter identity, type, value errors), sequence and timeliness (timing, sequencing error, data received in due time) and authenticity (if an open transmission system is used, with safety related access protection functions).	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_GEN_6	The Brake system's devices exchanging safety-data shall discharge a message when a communication error is identified (because o messages authenticity, integrity, timeliness or sequence is/are violated) and interrupt the communication when a predefined number of messages are discharged.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Loss of / Partially	Partial transmission of Emergency brake request to brake functions.	Partial application of Emergency brake force by the different types of brake	Non-continuous brake applied and potential train separation.	H.28	Emergency Brake force is applied only for a fraction of consist's brake	PHA_EB_16	The Brake system shall dispatch the Emergency brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_EB_2	The Brake system shall verify the application of Emergency brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Undue transmission of Emergency brake request to brake functions	Undue application of the Emergency brake force by specific type(s) of brake	Undue brake application and train stop when not required.	H.40	Undue train stop, due to Brake System failure, in a hazardous area.	PHA_EB_16	The Brake system shall dispatch the Emergency brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_EB_2	The Brake system shall verify the application of Emergency brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_05	The external systems shall detect an emergency brake application (triggered by the Brake system as reaction to a Major fault) that leads the train to stop in a hazardous area. In this condition, the external system(s) shall wait till the train speed is under a predefined limit, then command a "global" remote release until the train exits from the hazardous area, and then command the emergency brake to achieve standstill condition.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB3	Train load calculation	Calculate the Train Mass and Train equivalent mass information and transmit them to other Brake system sub-functions and systems of brake context	No	Missed calculation of the train load for Emergency brake application.	No train load is available for the train Emergency brake force calculation and blending. Potential use of non-restrictive data and under-estimation of the brake force to be applied.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_8	The Brake system shall compute the nominal Emergency brake based on measurements of bogies loads updated and conservative (i.e. consistent and with margin) with respect to the actual load conditions.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.			PHA_EB_42	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the nominal Emergency brake with the same SIL assigned to its implementation.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation of the train load for Emergency brake application.	Under-estimation of the brake force to be applied.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_8	The Brake system shall compute the nominal Emergency brake based on measurements of bogies loads updated and conservative (i.e. consistent and with margin) with respect to the actual load conditions.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.			PHA_EB_42	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the nominal Emergency brake with the same SIL assigned to its implementation.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
					Over-estimation of the brake force to be applied.	Excessive brakes force applied and abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.													PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Delay in the calculation of the train load for Emergency brake application.	Delay in the application of the train Emergency brake force.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_8	The Brake system shall compute the nominal Emergency brake based on measurements of bogies loads updated and conservative (i.e. consistent and with margin) with respect to the actual load conditions.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.			PHA_EB_42	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the nominal Emergency brake with the same SIL assigned to its implementation.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.		
			Loss of / Partially	Not applicable																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Undue calculation of train load, based on incorrect information (on bogies load), for Emergency brake application.	Incorrect (over or under) estimation of the brake force to be applied.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_18	The Brake system shall preserve the integrity and the timeliness of the information (signals and data) related to bogies load used for the calculation of the Emergency brake force.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_41	The Brake system shall react to the unavailability of valid information (signal, data) related to measurements used for the calculation of the nominal Emergency brake force (i.e. speed, bogies load), through the use of predefined conservative values.			PHA_EB_42	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the nominal Emergency brake with the same SIL assigned to its implementation.				
						Excessive brakes force applied and abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB4	Train Emergency brake force calculation	Calculate the Train nominal Emergency brake force, based on the maximum Emergency brake retardation, the train equivalent mass, the train running resistance, the train speed	No	Missed calculation of the nominal Emergency brake force.	Missed application of Emergency brake force by all types of brake.	No train deceleration and missed stop.	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	PHA_EB_24	The Brake system shall guarantee minimum performance (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake).	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_28	The Brake system shall react to the missed application of the (nominal) Emergency brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_29	The Brake system shall implement functions for the monitoring of the application of the Emergency brake request within a predefined maximum time and consequent reaction, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation of the nominal Emergency brake force or calculation based on incorrect information (e.g. requests, measurements, results from calculation, bogies load, speed).	Underestimation of the force to be applied by the different type of brake.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_24	The Brake system shall guarantee minimum performance (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake).	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
							H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.											PHA_AC_10	External technical system shall provide a safe train speed information from odometry	PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Delay in the calculation of the nominal Emergency brake force.	Delay in the application of the train Emergency brake force.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_24	The Brake system shall guarantee minimum performance (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to:_maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI),_adhesion limits (for adhesion dependent brake).	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed);_the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_7	The Brake system shall react to the impossibility to compute the nominal Emergency brake, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_29	The Brake system shall implement functions for the monitoring of the application of the Emergency brake request within a predefined maximum time and consequent reaction, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_06	The minimum performance guaranteed by the Brake system for the emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) shall be considered by the external technical (signalling) systems for train protection.		
			Loss of / Partially	Not applicable																		
			Undue	See wrong																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB5	Emergency brake blending	Calculate the force to be applied by the brakes to perform Emergency brake, provide the requests to each type of brake and generate the brake force.Measure the really applied force by adhesion dependent dynamic and adhesion independent brakes & friction brake.	No	Missed calculation or request or generation of Emergency brake force by specific type(s) of brake.	Missed application of Emergency brake force by specific types of brakes	Non-continuous brake applied and potential train separation.	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	PHA_EB_25	The Brake system shall guarantee minimum performance of Emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to:_technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic and adhesion independent brakes due to the infrastructure and/or vehicle.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed);_the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
				Missed calculation or request or generation of Emergency brake force by specific type(s) of brake.	Missed application of Emergency brake force by specific types of brakes	Non-continuous brake applied and potential train separation.	H.8	Automatic (emergency) brake not initiated in the case of an unintended train separation (loss of train integrity).	PHA_EB_49	The Brake system shall apply the Emergency brake automatically in the event of unintentional train separation (train integrity lost).												

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Missed measurement of the real brake force applied by friction brake(s) during Emergency brake.	Unavailability of the information to monitor the friction brake(s) status and to set and verify Emergency brake force applied. Missed detection of anomalies in the brake command line.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
				Missed measurement of the real brake force applied by dynamic and adhesion independent brakes during Emergency brake.	Unavailability of the information to monitor the dynamic and adhesion independent brakes status and to set Emergency brake force by the adhesion dependent Friction brake	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_11	The Dynamic brake shall guarantee a minimum brake force if available and provide safe information on its availability (otherwise, the blending logic shall be based on a safe measure of the force applied). The Adhesion independent brakes shall guarantee the application of the brake force, if available.	PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation or request or force generation by specific type(s) of brake during Emergency brake.	Total force applied by the different types of brake less than the Emergency brake request.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_25	The Brake system shall guarantee minimum performance of Emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic and adhesion independent brakes due to the infrastructure and/or vehicle.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed); _the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_03	The external system shall inform the Brake system about constraints coming from the infrastructure and from the vehicles in the use of regenerative dynamic brake, specifically for Emergency brake, if any.		
					Excessive brake force application by specific type(s) of brake, i.e. overcame of limits on energy provided, due to technical characteristics and dimensioning of brake.	Excessive brakes force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Delay in the calculation or request or force generation by specific type(s) of brake during Emergency brake.	Delay in the application of Emergency brake force by specific types of brakes	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_25	The Brake system shall guarantee minimum performance of Emergency brake (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to:_technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic and adhesion independent brakes due to the infrastructure and/or vehicle.	PHA_EB_5	The Brake system shall verify the capability to calculate and apply the Emergency brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed);_the application of the Emergency brake within a predefined maximum time from the request, under different blending conditions.	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Incorrect measurement of the brake force applied by friction brake(s) during Emergency brake.	Incorrect information to monitor the friction brake(s) status and to set and verify Emergency brake force applied	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.				
						Excessive brakes force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Incorrect measurement of the brake force applied by dynamic and adhesion independent brakes during Emergency brake.	Incorrect information to set Emergency brake force for the adhesion dependent Friction brake	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.				
						Excessive brakes force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially/ Undue	Partial request or undue local force generation for specific type(s) of Emergency brake(s).	Partial application of Emergency brake force by the different types of brake	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance). Non-continuous brake applied and potential train separation.	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_16	The Brake system shall dispatch the Emergency brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.				
							H.12	Undue local application of brake force.														
							H.28	Emergency Brake force is applied only for a fraction of consist's brake														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB6	Emergency brake energy storing and distribution	Store and distribute the energy to permit the correct generation of Emergency brake force by type of brakes using pneumatic or electrical energy	No	Missed distribution of energy for the regulation of Emergency brake force (to be applied by specific type of brake)	Missed or partial application of Emergency brake force (by specific type of brake).	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).Non-continuous brake applied and potential train separation.	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_39	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Emergency brake, with predefined accuracy and timing.	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.:_the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement._the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request;_the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_19	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Emergency brake, through the notification of a Major fault and the application of the maximum brake force.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).
							H.28	Emergency Brake force is applied only for a fraction of consist's brake							PHA_EB_47	The Brake system shall apply the force for Emergency brakes locally (e.g. at each axle) by actuation (pneumatic / electric) circuits guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.					PHA_REC_02	It is recommended that the Brake system implements a closed loop control for the setting of the brake force, in the application of the train retardation request.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	**Sub-function**	**Description**	**Guide-word**	**Deviation / Functional Failure mode.**	**Local effect**	**Final effect**	**Hazard ID**	**Hazard description**	**ID**	**Description**	**ID**	**Description**		**Description**		**Description**		**Description**	**ID**	**Description**	**ID**	**Description**
			Wrong	Excessive energy distributed for the regulation of Emergency brake force (to be applied by specific type of brake)	Excessive Emergency brake force applied (by specific type of brake)	Abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	PHA_EB_20	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Emergency brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_19	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Emergency brake, through the notification of a Major fault and the application of the maximum brake force.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_03	It is recommended that the Brake system implements distributed hardware circuits for the conditioning of local signals (e.g. axle speed) and for the implementation of local interlocks (e.g. non admissible status of controlled devices) and protections (e.g. against excessive wheel-sliding protection), providing independency against errors the brake command line.
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.													PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Delay in the distribution of energy for the regulation of Emergency brake force (to be applied by specific type of brake)	Delay in the application of Emergency brake force (by specific type of brake)	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_39	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Emergency brake, with predefined accuracy and timing.	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_19	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Emergency brake, through the notification of a Major fault and the application of the maximum brake force.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
			Loss of / Partially	Partial distribution of energy for the regulation of Emergency brake force (to be applied by specific type of brake)	Partial application of Emergency brake force (by specific type of brake).	Non-continuous Emergency brake applied and potential train separation.	H.28	Emergency Brake force is applied only for a fraction of consist's brake	PHA_EB_27	The Brake system, after the acquisition of a Emergency brake request, shall assure the brake force application up to train standstill or to a remote release command.	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_19	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Emergency brake, through the notification of a Major fault and the application of the maximum brake force.	PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.			PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)			
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description
			Undue	Undue distribution of energy for the regulation of Emergency brake force (when not required)	Undue application of Emergency brake force by specific type(s) of brake.	Non-continuous Emergency brake applied and potential train separation.	H.12	Undue local application of brake force.
EB7	Actual Emergency Braking Power Calculation	Define the emergency braking power based on dimensioning hypothesis and availability of different types of brake.	No	Missed definition of the (Emergency) braking power based on dimensioning hypothesis and availability of different types of brake.	Unavailability for the external technical system of the emergency braking power.	The Brake system manages the train retardation request based on the availability of the different type(s) of brake (no Major fault is generated).The final effect depends on the reaction to failure of the external technical system.	H.30	No or incorrect information on braking power provided to the external technical (signaling) system

COUNTERMEASURES SPECIFICATION					
Correct functional operation		Detection of faults		Action following Detection	
ID	Description	ID	Description		Description
PHA_EB_39	The Brake system, after the acquisition of a Emergency brake request, shall assure the brake force application up to train standstill or to a remote release command.	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.:_the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement._the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request;_the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_33	The Brake system shall react to a dragging condition of Emergency brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).
PHA_EB_26	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the computation and notification to external technical systems of the braking power and in the calculation of the Emergency brake force to be applied by (all types of) brakes.	PHA_EB_6	The Brake system shall verify the capability to provide the Braking power information to the external technical (signaling) systems and the consistency of the last information notified with the current availability of brakes.	PHA_EB_13	The Brake system shall react to braking power (computed for the actual brakes availability) less than the value communicated to external systems:_by communicating an updated value;_OR through the notification of a Major fault and the transition or permanence into safe state.

COUNTERMEASURES SPECIFICATION							
Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
	Description		Description	ID	Description	ID	Description
PHA_EB_43	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Emergency brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.			PHA_REC_08	It is recommended that the Brake system reacts to a Major fault by applying the Emergency brake force through the de-energization of the local I/O interfaces toward the energy regulation (pneumatic / electric) circuits..
PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_45	The Brake system shall compute the Braking power and transmit it to the external technical (signaling) systems with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_09	The external actors (driver, technical systems) shall avoid train running if no-valid information on braking power is provided by the Brake system or the actual braking power is lower than a minimum value (pre-defined to guarantee safe condition for train running).	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect definition of the (Emergency) braking power with respect to the dimensioning and availability of different types of brake.	Incorrect braking power (potentially over-estimated) available for the technical system	The Brake system manages the train retardation request based on the availability of the different type(s) of brake (no Major fault is generated). The final effect depends on the reaction to failure of the external technical system.	H.30	No or incorrect information on braking power provided to the external technical (signaling) system	PHA_EB_26	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the computation and notification to external technical systems of the braking power and in the calculation of the Emergency brake force to be applied by (all types of) brakes.	PHA_EB_6	The Brake system shall verify the capability to provide the Braking power information to the external technical (signaling) systems and the consistency of the last information notified with the current availability of brakes.	PHA_EB_13	The Brake system shall react to braking power (computed for the actual brakes availability) less than the value communicated to external systems: _by communicating an updated value; _OR through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_45	The Brake system shall compute the Braking power and transmit it to the external technical (signaling) systems with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_09	The external actors (driver, technical systems) shall avoid train running if no-valid information on braking power is provided by the Brake system or the actual braking power is lower than a minimum value (pre-defined to guarantee safe condition for train running).	PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).
				Incorrect Braking power notified to external technical (signalling) system	Incorrect braking power (potentially over-estimated) available for the technical system	The Brake system manages the train retardation request based on the availability of the different type(s) of brake (no Major fault is generated). The final effect depends on the reaction to failure of the external technical system.	H.30	No or incorrect information on braking power provided to the external technical (signaling) system	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_EB_6	The Brake system shall verify the capability to provide the Braking power information to the external technical (signaling) systems and the consistency of the last information notified with the current availability of brakes.	PHA_EB_13	The Brake system shall react to braking power (computed for the actual brakes availability) less than the value communicated to external systems: _by communicating an updated value; _OR through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_45	The Brake system shall compute the Braking power and transmit it to the external technical (signaling) systems with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_09	The external actors (driver, technical systems) shall avoid train running if no-valid information on braking power is provided by the Brake system or the actual braking power is lower than a minimum value (pre-defined to guarantee safe condition for train running).	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	(Emergency) Braking power defined but not notified or notified with delay to external technical (signalling) system	Unavailability for the external technical system of the emergency braking power.	The Brake system manages the train retardation request based on the availability of the different type(s) of brake (no Major fault is generated). The final effect depends on the reaction to failure of the external technical system.	H.30	No or incorrect information on braking power provided to the external technical (signaling) system	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_EB_6	The Brake system shall verify the capability to provide the Braking power information to the external technical (signaling) systems and the consistency of the last information notified with the current availability of brakes.	PHA_EB_13	The Brake system shall react to braking power (computed for the actual brakes availability) less than the value communicated to external systems: _by communicating an updated value; _OR through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_45	The Brake system shall compute the Braking power and transmit it to the external technical (signaling) systems with the same SIL assigned to the implementation of the Emergency brake.	PHA_AC_09	The external actors (driver, technical systems) shall avoid train running if no-valid information on braking power is provided by the Brake system or the actual braking power is lower than a minimum value (pre-defined to guarantee safe condition for train running).		
			Undue	Non applicable																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB8	Emergency brake Traction cut off	Require the traction cut off to traction system in case of Emergency brake request.	No	Missed Traction cut-off command generation to the external (traction) system during Emergency brake.	Missed Traction cut-off command notification to the external (traction) system.Missed traction cut-off during Emergency brake application.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	PHA_EB_31	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Emergency brake application (to the local brake units).	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system;_to transmit valid Emergency brake request to all brake functions.	PHA_EB_14	The Brake system shall react to a (partial or total) inability to transmit a valid Emergency brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_44	The Brake system shall apply the Emergency brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Wrong	Traction cut-off command generated with delay during Emergency brake.	Traction cut-off command notified to the external (traction) system with delay or based on an obsolete train retardation request. Delayed traction cut-off during Emergency brake application	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	PHA_EB_31	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Emergency brake application (to the local brake units).	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_EB_14	The Brake system shall react to a (partial or total) inability to transmit a valid Emergency brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_44	The Brake system shall apply the Emergency brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Interruption of the Traction Cut Off command during Emergency brake.	Missed or loss of Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Emergency brake application Traction unduly restored during Emergency brake application	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	PHA_EB_31	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Emergency brake application (to the local brake units).	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_EB_14	The Brake system shall react to a (partial or total) inability to transmit a valid Emergency brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_44	The Brake system shall apply the Emergency brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	PHA_AC_08	The external technical systems shall assure the traction cut-off after receiving a valid traction cut-off command from the Brake system. Traction cut-off shall remain enable until traction cut-off command is released or the Brake system is isolated.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Traction cut-off command generated but not notified or notified with delay to the external technical (traction) system during Emergency brake.	Missed Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Emergency brake application. Traction cut-off command notified to the external (traction) system with delay or based on an obsolete train retardation request. Delayed traction cut-off during Emergency brake application.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.2	After activation of an Emergency brake command, no deceleration of the train due to failure in the traction system (Traction force ≥ Brake force).	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_EB_3	The Brake system shall verify the capability to react to a Emergency brake request, i.e. _to acquire the Emergency brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Emergency brake request to all brake functions.	PHA_EB_12	The Brake system shall react to the inability to acquire a Emergency brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the transition or permanence into safe state.	PHA_EB_15	The Brake system shall exchange safety data for the implementation of the Emergency brake with the external technical systems (e.g. Emergency brake request, traction cut-off command, braking power, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_44	The Brake system shall apply the Emergency brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.		
			Undue	Traction cut-off command unduly notified (when no Emergency brake is not required).	Undue traction cut-off (when not required),	Undue train slows down.	-	-														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	**Sub-function**	**Description**	**Guide-word**	**Deviation / Functional Failure mode.**	**Local effect**	**Final effect**	**Hazard ID**	**Hazard description**	**ID**	**Description**	**ID**	**Description**		**Description**		**Description**		**Description**	**ID**	**Description**	**ID**	**Description**
EB9	State and fault detection and indication	Detect and notify to the driver and external technical systems the status of Emergency brake (applied / released) and of brakes (applied / released / isolated / faulted)	No	Missed detection of the brake status information during Emergency brake.	Missed notification to driver and external technical systems of the brake status information.Impossible monitoring of the brake force application/release.Ineffective setting of Emergency brake force, detection of anomalies and notification of Major fault.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Wrong	Incorrect detection of the brake status, i.e. brake unduly detected as Applied when it is Released or Isolated, during Emergency brake.	Incorrect detection of the application of Emergency brake, and missed reaction (if needed, e.g. by applying the maximum Emergency brake).	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Incorrect detection of the brake status, i.e. brake unduly detected Released or Isolated when it is Applied, during Emergency brake.	Undue detection of the brake as released.	Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.12	Undue local application of brake force.	PHA_EB_48	The Brake system shall measure the force applied by individual Emergency brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_33	The Brake system shall react to a dragging condition of Emergency brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	PHA_EB_40	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Incorrect brake status information notified to driver and/or external technical systems, during Emergency brake.	Incorrect management of the degraded condition by the driver (according to procedures). Incorrect management of restrictions (e.g. for train speed) guarantying a safe train running.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_GEN_8	The Brake system shall notify a Major fault through safety transmission function, with the highest SIL assigned to the brake functions, assuring reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_09	It is recommended a "negative logic" in the notification of the Major fault - within the Brake system and to the external actors (i.e. driver and technical systems) - guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Brake status detected but not notified or notified with delay to the external technical (traction) system, during Emergency brake.	Missed notification to driver and external technical systems of the brake status information. Impossible monitoring of the brake force application/release. Ineffective setting of Emergency brake force, detection of anomalies and notification of Major fault.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_9	The Brake system shall provide to the external Technical systems and to the driver the information about the Emergency brake status, operating mode and active fault conditions.	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_GEN_8	The Brake system shall notify a Major fault through safety transmission function, with the highest SIL assigned to the brake functions, assuring reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_EB_46	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Emergency brake compatibly with the SIL assigned to its implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.		
			Undue	See wrong																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB10	Emergency Brake isolation	Manage:_the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application;_the remote release of the adhesion dependent friction Emergency brake force.	No	Missed (total or partial) isolation of Emergency (all types of) brake(s) when required.	(for all the types of brake) Brake considered available when it should be partially or totally isolated, with incorrect brake blending and possible insufficient total Emergency brake force.Over-estimation of the braking power.Missed release (if applied) or undue application (when not required) or missed application (when requested) of the brake force.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_35	The Brake system shall permit the total or partial isolation of Emergency brake(s) for the removal of the force applied, with or without energy available on the train, whatever are the adjustable (i.e. service) brake actual status and request, as last operation to permit the train running and recover from immobilizing failure conditions.	PHA_EB_1	The Brake system shall verify the capability and effective execution of:_partial or total isolation of Emergency brake(s);_remote release of Emergency brake(s).	PHA_EB_36	The Brake system shall react to a missed or undue Emergency brake(s) release or isolation through the notification of a Major fault.	PHA_EB_30	The Brake system shall implement functions for the partial or total isolation and for the remote release of Emergency brake(s) guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_32	The Brake system shall implement the partial or total isolation of the Emergency brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			No	Missed remote release of Emergency (adhesion dependent friction) brake(s) when required.	(for adhesion dependent friction brake) Brake force unduly applied by the adhesion dependent friction Emergency brake force, when remote release is commanded.	Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.12	Undue local application of brake force.	PHA_EB_10	The Brake system shall react to a Major fault generated locally (at axle or bogie level) through the local application of the Emergency brake and be available to a "partial" remote release.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_33	The Brake system shall react to a dragging condition of Emergency brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	PHA_EB_30	The Brake system shall implement functions for the partial or total isolation and for the remote release of Emergency brake(s) guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_32	The Brake system shall implement the partial or total isolation of the Emergency brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.				
			Wrong	See undue																		
			Loss of / Partially	See no																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Undue remote release of Emergency (adhesion dependent friction) brake(s) during Emergency brake.	(for adhesion dependent friction brake) Reduction of the brake force applied during Emergency brake.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_34	The Brake system shall allow the remote release of Emergency brake(s) only in case of Major fault.	PHA_EB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Emergency brake(s); _remote release of Emergency brake(s).	PHA_EB_36	The Brake system shall react to a missed or undue Emergency brake(s) release or isolation through the notification of a Major fault.	PHA_EB_30	The Brake system shall implement functions for the partial or total isolation and for the remote release of Emergency brake(s) guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_32	The Brake system shall implement the partial or total isolation of the Emergency brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.				
				Undue partial or total brake isolation of Emergency (all types of) brake(s) (when not required).	(for all the types of brake) Reduction of the brake force applied during Emergency brake. Reduction of the brake power for the brake force calculation.	Ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance). Unavailability of brakes to provide the minimum force for the safe train running.	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_26	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the computation and notification to external technical systems of the braking power and in the calculation of the Emergency brake force to be applied by (all types of) brakes.	PHA_EB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Emergency brake(s); _remote release of Emergency brake(s).	PHA_EB_36	The Brake system shall react to a missed or undue Emergency brake(s) release or isolation through the notification of a Major fault.	PHA_EB_30	The Brake system shall implement functions for the partial or total isolation and for the remote release of Emergency brake(s) guarantying a degree of functional independence with respect to functions for the application of Emergency brake that allows the achievement of the global safety objective.	PHA_EB_32	The Brake system shall implement the partial or total isolation of the Emergency brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.		
							H.30	No or incorrect information on braking power provided to the external technical (signaling) system														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
EB11	Energy supply	Supply the (pneumatic / electric) energy for brake generation (stored and distributed by E6)	No/Loss of / Partially	Missed or partial supply of energy for Emergency brake force generation	Missed storage or distribution of energy and missed generation of the (emergency) brake force.	No train deceleration and missed stop	H.1	After activation of emergency no deceleration of the train due to Brake system failure (including WSP).	PHA_EB_37	The Brake system, in any state after its initialization, shall guarantee the inexhaustibility of the brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the application of the minimum Emergency brake force for at least 2 times (i.e. brake cannot be released if it cannot be applied again).	PHA_EB_4	The Brake system shall verify the capability to provide energy for the Emergency brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_EB_38	The Brake system shall react to the unavailability of the (pneumatic / electrical) energy required to guarantee the inexhaustibility of the Emergency brake, through the notification of a Major fault and the transition or permanence into safe conditions	-	-	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_07	External technical systems shall assure the availability of the (pneumatic and electrical) energy for the brakes regulation, without invalidating the independence required to local brake actuations (e.g. for different bogies).	PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).
			Wrong	Not applicable.																	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	See wrong																	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
EB12	Emergency brake kinetic energy transformation	Transform the kinetic energy of the train into thermal energy by the friction between two surfaces	No / wrong	Ineffective conversion of the kinetic energy lost during Emergency brake into electric and thermal energy	Reduced force applied by the adhesion dependent Friction brake	No or ineffective train deceleration and stop beyond the limit (i.e. excessive stopping distance).	H.3	After activation of emergency stopping distances are longer than nominal one due to failure in braking system.	PHA_EB_24	The Brake system shall guarantee minimum performance (i.e. minimum retardation and maximum equivalent time to reach the maximum stopping distances) and proper safe margin (i.e. failure tolerance), fulfilling all the constraints related to:_maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI),_adhesion limits (for adhesion dependent brake).	PHA_EB_2	The Brake system shall verify the application of Emergency brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_28	The Brake system shall react to the missed application of the (nominal) Emergency brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.	-	-	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_04	External technical system shall monitor the temperature achieved by brake, as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy. The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ….).	PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Ineffective dissipation of the heat generated by the conversion of the kinetic energy lost during Emergency brake	Increase of temperature of Friction brake.	Potential brake damage.	H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	PHA_EB_20	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Emergency brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	PHA_EB_2	The Brake system shall verify the application of Emergency brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_EB_21	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total nominal Emergency brake request, through the notification of a Major fault and the application of the maximum Emergency brake.	-	-	PHA_EB_22	The Brake system shall implement a request of retardation to stop the train within a maximum allowable stopping distance (Emergency brake), fulfilling the requirements stated in EN50129 for SIL4.	PHA_AC_04	External technical system shall monitor the temperature achieved by brake, as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy. The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ….).	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Loss of / Partially	See wrong																	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Not applicable	Undue application of Service brake force by specific type(s) of brake	Undue reduction of the train speed, potentially up to standstill condition.																
SB1	Service brake train retardation request	Collect the traction/Service brake request by actors and train direction and transmit it to SB2. The traction/Service brake request is intended as percentage of the maximum Service brake retardation.	No	Missed acquisition of Service brake request coming from actors (driver or technical system).	No transmission of Service brake request to other Brake system functions.	No application of brake and missed control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_SB_20	The Brake system, when active, shall be able to acquire Service brake request coming from the external actors (driver, technical systems).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_10	The Brake system shall react to the inability to acquire a Service brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_14	The Brake system shall acquire the request for the retardation of the train (Service brake) through transmission functions with the same SIL assigned to the calculation and application of the Service brake force.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_10	It is recommended a "negative logic" in the Emergency brake request, guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Delay in the acquisition of a valid Service brake request coming from actors (driver or technical system).	Delayed transmission of Service brake request to other Brake system functions.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall:_ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level);_ implement safety protection in the generation of safety-data to be exchange through the transmission system;_ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.:_to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system;_to transmit valid Service brake request to all brake functions.	PHA_GEN_4	The Brake system shall discharge a message acquired from the external technical systems (containing safety-data) when a communication error is identified and interrupt the communication when a predefined number of messages are discharged.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_14	The Brake system shall acquire the request for the retardation of the train (Service brake) through transmission functions with the same SIL assigned to the calculation and application of the Service brake force.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall:_ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Acquisition of an incorrect Service brake (incorrect percentage of the maximum Service brake retardation)	Missed or delayed calculation and application of the train Service brake force.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall:_ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level);_ implement safety protection in the generation of safety-data to be exchange through the transmission system;_ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.:_to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system;_to transmit valid Service brake request to all brake functions.	PHA_GEN_4	The Brake system shall discharge a message acquired from the external technical systems (containing safety-data) when a communication error is identified and interrupt the communication when a predefined number of messages are discharged.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_14	The Brake system shall acquire the request for the retardation of the train (Service brake) through transmission functions with the same SIL assigned to the calculation and application of the Service brake force.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall:_ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
			Loss of / Partially	Not applicable.																		
			Undue	Not applicable																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB2	Service brake request transmission	Transmit the adjustable traction/retardation request and selected direction received by SB1 to other Brake system functions and traction system.	No	No transmission of Service brake request to other Brake system functions	Missed calculation and application of the train Service brake force.	No application of brake and missed control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_GEN_5	The Brake system's devices exchanging safety-data shall verify the messages integrity (transmitter identity, type, value errors), sequence and timeliness (timing, sequencing error, data received in due time) and authenticity (if an open transmission system is used, with safety related access protection functions).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_10	It is recommended a "negative logic" in the Emergency brake request, guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.
			Wrong	Transmission of non-valid Service brake request to other Brake system functions.	Missed or delayed calculation and application of the train Service brake force.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_GEN_5	The Brake system's devices exchanging safety-data shall verify the messages integrity (transmitter identity, type, value errors), sequence and timeliness (timing, sequencing error, data received in due time) and authenticity (if an open transmission system is used, with safety related access protection functions).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_GEN_6	The Brake system's devices exchanging safety-data shall discharge a message when a communication error is identified (because o messages authenticity, integrity, timeliness or sequence is/are violated) and interrupt the communication when a predefined number of messages are discharged.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Partial transmission of Service brake request to other Brake system functions	Partial application of Service brake force by the different types of brake	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_13	The Brake system shall dispatch the Service brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).
			Undue	Undue transmission of Service brake request to brake functions	Undue calculation and application of the train Service brake force.	Undue Service brake and train slows/stops when not required.	H.40	Undue train stop, due to Brake System failure, in a hazardous area.	PHA_SB_13	The Brake system shall dispatch the Service brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_SB_2	The Brake system shall verify the application of Service brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of:_Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake;_Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.	PHA_AC_05	The external systems shall detect an emergency brake application (triggered by the Brake system as reaction to a Major fault) that leads the train to stop in a hazardous area. In this condition, the external system(s) shall wait till the train speed is under a predefined limit, then command a "global" remote release until the train exits from the hazardous area, and then command the emergency brake to achieve standstill condition.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB3	Train load calculation	Define and calculate the train mass and the train equivalent mass information and send them to other brake sub-functions and systems of brake context.	No	Missed calculation of the train load.	No train load is available for the train Service brake force calculation and blending.Potential use of non-restrictive data and underestimation of the brake force to be applied.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_7	The Brake system shall adjust the brake force (Service brake) according to the maximum train retardation requests coming from the different sources (driver, external technical systems).	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ;_the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.			PHA_SB_36	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the Service brake with the same SIL assigned to its implementation.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation of the train load.	Underestimation of the brake force to be applied.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_7	The Brake system shall adjust the brake force (Service brake) according to the maximum train retardation requests coming from the different sources (driver, external technical systems).	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.			PHA_SB_36	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the Service brake with the same SIL assigned to its implementation.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
					Overestimation of the brake force to be applied.	Excessive brake force applied and abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.													PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Delay in the calculation of the train load for Emergency brake application.	Delay in the application of the train Emergency brake force.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command , ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_7	The Brake system shall adjust the brake force (Service brake) according to the maximum train retardation requests coming from the different sources (driver, external technical systems).	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.			PHA_SB_36	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the Service brake with the same SIL assigned to its implementation.				
			Loss of / Partially	Not applicable.																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Undue calculation of train load, based on incorrect information (on bogies load), for Service brake application.	Incorrect (over or under) estimation of the brake force to be applied.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_15	The Brake system shall preserve the integrity and the timeliness of the information (signals and data) related to bogies load used for the calculation of the Service brake force.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ;_the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_35	The Brake system shall react to the unavailability of valid information (signal, data) related to measurements used for the calculation of the nominal Service brake force (i.e. speed, bogies load), through the use of predefined conservative values.			PHA_SB_36	The Brake system shall provide a conservative estimation (i.e. consistent and with margin) of the train load used for the computation of the Service brake with the same SIL assigned to its implementation.				
						Excessive brakes force applied and abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION															
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB4	Train Service brake force calculation	Calculate the Train Service brake force and the minimum train Service brake force based on the train equivalent mass, the train running resistance, the train speed and, optionally, the slope, and transmit them to SB5.	No	Missed calculation of the train Service brake force.	Missed application of Service brake force by all types of brake.	No application of brake and missed control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_SB_21	The Brake system shall guarantee performance to be in the minimum/maximum range for the calculation and application of the Service brake force by each (type of) brake, fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_23	The Brake system shall react to the missed application of the Service brake after a predefined maximum time from the request, through the notification of a Major fault and the application of the maximum Emergency brake.	PHA_SB_24	The Brake system shall implement functions for the monitoring of the application of the Service brake request within a predefined maximum time and consequent reaction guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation of the nominal train Service brake force.	Underestimation of the brake force to be applied.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command , ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_21	The Brake system shall guarantee performance to be in the minimum/maximum range for the calculation and application of the Service brake force by each (type of) brake, fulfilling all the constraints related to: _maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI), _adhesion limits (for adhesion dependent brake.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.	PHA_AC_10	External technical system shall provide a safe train speed information from odometry	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
							H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.													PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Delay in the calculation of the train Service brake force.	Delay in the application of the train Service brake force.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_21	The Brake system shall guarantee performance to be in the minimum/maximum range for the calculation and application of the Service brake force by each (type of) brake, fulfilling all the constraints related to:_maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI),_adhesion limits (for adhesion dependent brake.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ;_the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_6	The Brake system shall react to the impossibility to compute minimum/maximum Service brake performance, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_24	The Brake system shall implement functions for the monitoring of the application of the Service brake request within a predefined maximum time and consequent reaction guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.				
			Loss of / Partially	Not applicable.																		
			Undue	Not applicable																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB5	Service brake blending	Calculate the force to be applied by the brakes to perform the service brake, provide the requests to each type of brake and generate brake force. Measures the really applied force by adhesion dependent dynamic brakes.	No	Missed calculation or request or generation of Service brake by specific types of brakes.	Missed application of Service brake force by specific types of brakes.	No application of brake and missed control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_SB_22	The Brake system shall guarantee minimum performance of Service brake, fulfilling all the constraints related to:_technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic brakes due to the infrastructure and/or vehicle.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ;_the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			No	Missed measurement of the real brake force applied by friction brake(s) during Service brake.	Unavailability of the information to monitor the friction brake(s) status and to set and verify Service brake force applied	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Missed measurement of the real brake force applied by dynamic and adhesion independent brakes during Service brake.	Unavailability of the information to monitor the dynamic and adhesion independent brakes status and to set and verify Service brake force applied	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect calculation or request or force generation by specific type(s) of brake.	Total force applied by the different types of brake less than the minimum Service brake request.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_22	The Brake system shall guarantee minimum performance of Service brake, fulfilling all the constraints related to: _technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic brakes due to the infrastructure and/or vehicle.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.: _the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load) _the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ; _the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.				
					Excessive brake force application by specific type(s) of brake, i.e. overcame of limits on energy provided, due to technical characteristics and dimensioning of brake.	Excessive force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	**Sub-function**	**Description**	**Guide-word**	**Deviation / Functional Failure mode.**	**Local effect**	**Final effect**	**Hazard ID**	**Hazard description**	**ID**	**Description**	**ID**	**Description**		**Description**		**Description**		**Description**	**ID**	**Description**	**ID**	**Description**
				Delay in the calculation or request or force generation by specific type(s) of brake.	Delay in the application of Service brake force by specific types of brakes	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command , ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_22	The Brake system shall guarantee minimum performance of Service brake, fulfilling all the constraints related to:_technical characteristics, dimensioning and status of each (type of) brake, _restriction in the use of dynamic brakes due to the infrastructure and/or vehicle.	PHA_SB_5	The Brake system shall verify the capability to calculate and apply the Service brake, i.e.:_the availability of valid information (signal, data) related to measurements used for the calculation of the brake force (e.g. speed, bogies load)_the timeliness and synchronization of the communication and calculations processes and the availability and integrity of information (e.g. requests, measurements, results from calculation, bogies load, speed) ;_the application of the Service brake within a predefined maximum time from the request, under different blending conditions.	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.				
				Incorrect measurement of the brake force applied by friction brake(s)	Incorrect information to monitor the friction brake(s) status and to set and verify Service brake force applied	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command , ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
						Excessive brakes force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														
				Incorrect measurement of the brake force applied by dynamic and adhesion independent brakes	Incorrect information to monitor the dynamic and adhesion independent brakes status and to set and verify Service brake force applied	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.				
						Excessive brakes force applied, abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.														
			Loss of / Partially/ Undue	Partial request or undue local force generation for specific type(s) of Service brake(s).	Partial application of Service brake force by the different types of brake.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_13	The Brake system shall dispatch the Service brake request to all (central and local) brake functions and to all types of brake, by a single command (i.e. assuring continuity).	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.				
							H.12	Undue local application of brake force.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB6	Service brake energy storing and distribution	Store and distribute the energy to permit the correct generation of Service brake force by type of brakes using pneumatic or electrical energy	No	Missed distribution of energy for the regulation of Service brake force (to be applied by specific type of brake)	Missed application of the Service brake force by specific type of brake.	No or ineffective control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_SB_34	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Service brake, with predefined accuracy and timing.	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.:_the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement._the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request;_the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_16	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Service brake, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).
							H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.													PHA_REC_02	It is recommended that the Brake system implements a closed loop control for the setting of the brake force, in the application of the train retardation request.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Excessive energy distributed for the regulation of Service brake force (to be applied by specific type of brake)	Excessive Service brake force applied (by specific type of brake)	Abrupt train deceleration and potential brake damage.	H.7	Brake force applied is greater than the level of brake demanded, leading to excessive jerk.	PHA_SB_17	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Service brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_16	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Service brake, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_03	It is recommended that the Brake system implements distributed hardware circuits for the conditioning of local signals (e.g. axle speed) and for the implementation of local interlocks (e.g. non admissible status of controlled devices) and protections (e.g. against excessive wheel-sliding protection), providing independency against errors the brake command line.
							H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.													PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Delay in the distribution of energy for the regulation of Service brake force (to be applied by specific type of brake).	Delay in the application of Service brake force (by specific type of brake)	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_34	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Service brake, with predefined accuracy and timing.	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_16	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Service brake, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
			Loss of / Partially	Partial distribution of energy for the regulation of Service brake force (to be applied by specific type of brake)	Partial application of Service brake force by the different types of brake (by specific type of brake).	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	-	-	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_16	The Brake system shall react to the inability to regulate properly the (pneumatic / electrical) energy for local generation of force required for Service brake, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_07	It is recommended to limit the setting of (static) data for the application of the maximum Emergency brake at the Brake system start up, to verify them at the brake test and to inhibit any modification during operation.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	**Sub-function**	**Description**	**Guide-word**	**Deviation / Functional Failure mode.**	**Local effect**	**Final effect**	**Hazard ID**	**Hazard description**	**ID**	**Description**	**ID**	**Description**		**Description**		**Description**		**Description**	**ID**	**Description**	**ID**	**Description**
			Undue	Undue distribution of energy for the regulation of Service brake force (when not required)	Undue application of Service brake force by specific type(s) of brake.	Non continuous brake applied; ineffective train deceleration and potential train separation.	H.12	Undue local application of brake force.	PHA_SB_34	The Brake system shall regulate the (pneumatic / electric) energy provided (to each type of brake) for the generation of brake force required for the application of the Service brake, with predefined accuracy and timing.	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_28	The Brake system shall react to a dragging condition of Service brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	PHA_SB_37	The Brake system shall implement functions for the monitoring of the real brake force applied, the comparison with the Service brake request and the reaction in case of any inconsistency detected, guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.			PHA_REC_08	It is recommended that the Brake system reacts to a Major fault by applying the Emergency brake force through the de-energization of the local I/O interfaces toward the energy regulation (pneumatic / electric) circuits..

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB7	Holding brake	Applying a brake force when the train is at stand still. It is automatically applied at train stop and automatically released when driver apply traction power to move the train. The release of Holding brake shall be performed in controlled way to avoid train roll back due to the rail slope. Friction brake is normally used for this function thanks to its capacity to maintain for long time the brake force without energy supply available.	No	Missed request of actuation of the Holding brake	Brake force required to guarantee the train standstill temporary condition is not applied.	Missed temporary immobilization of the train	H.14	Required Holding brake performance not achieved.	PHA_SB_HB_02	The Brake system shall apply the Holding brake automatically when the train speed measure is less than a predefined threshold.	PHA_SB_HB_06	The Brake system shall verify the capability;_to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization;_to indicate to driver the status of application of Holding brake;_to release the Holding brake;_to inhibit the Holding brake application through the train movement.	PHA_SB_HB_07	The Brake system shall react to the missed or ineffective application or loss of the Holding brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system) and the application of the Emergency brake.	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of:_Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake;_Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
							H.11	Holding brake for brake test not achieved.														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect indication to driver of the Holding brake status (applied when it is not)	Drive considers that the Holding brake is applied when it is not.	Missed temporary immobilization of the train (not applied or not required by driver).	H.37	Incorrect indication to driver about the temporary immobilization of the train (Holding brake status)	PHA_SB_HB_08	The Brake system shall guarantee the coherence between the Holding brake indication provided to driver and the real brake status.	PHA_SB_HB_06	The Brake system shall verify the capability; _to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Holding brake; _to release the Holding brake; _to inhibit the Holding brake application through the train movement.	PHA_SB_HB_07	The Brake system shall react to the missed or ineffective application or loss of the Holding brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system) and the application of the Emergency brake.			PHA_SB_HB_04	The Brake system shall provide to the driver the indication of Holding brake disabled compatibly with the SIL assigned to the Holding brake application.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).
				Insufficient brake force applied for Holding brake	Brake force applied is not effective to guarantee the train standstill condition.	Ineffective temporary immobilization of the train (not guarantying train standstill condition)	H.14	Required Holding brake performance not achieved.	PHA_SB_HB_09	The Brake system shall apply the Holding brake guarantying the minimum performance (i.e. brake force) required for train temporary immobilization.	PHA_SB_HB_06	The Brake system shall verify the capability; _to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Holding brake; _to release the Holding brake; _to inhibit the Holding brake application through the train movement.	PHA_SB_HB_07	The Brake system shall react to the missed or ineffective application or loss of the Holding brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system) and the application of the Emergency brake.			PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Loss of Holding brake condition (i.e. loss of train temporary immobilization).	Loss of brake force guarantying the train standstill condition.	Undue loss of temporary immobilization of the train	H.36	After activation, complete and permanent loss of Holding brake force.	PHA_SB_HB_03	The Brake system shall guarantee the inexhaustibility of the Holding brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the temporary immobilization of the train for a defined minimum duration (2 hours according to TSI).	PHA_SB_HB_06	The Brake system shall verify the capability; _to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Holding brake; _to release the Holding brake; _to inhibit the Holding brake application through the train movement.	PHA_SB_HB_07	The Brake system shall react to the missed or ineffective application or loss of the Holding brake request (i.e. to any inconsistency between the request and the applied brake force for train immobilization), through the notification of a Major fault to the external actors (driver and external technical system) and the application of the Emergency brake.			PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.				
			Undue	Undue Holding brake release (when not required).	Loss of brake force guarantying the train standstill condition.	Undue loss of temporary immobilization of the train	H.39	Loss of Holding brake force over the time.	PHA_SB_HB_05	The Brake system shall release the Holding brake only if the traction effort is higher enough to avoid train reverse movement or Emergency brake is applied.	PHA_SB_HB_06	The Brake system shall verify the capability; _to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization; _to indicate to driver the status of application of Holding brake; _to release the Holding brake; _to inhibit the Holding brake application through the train movement.					PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.				

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Undue Holding brake application	Holding brake force is applied during train motion.	Undue application of brake force during train motion.	H.38	Undue application of brake for temporary immobilization (Holding brake) during train motion	PHA_SB_HB_02	The Brake system shall apply the Holding brake automatically when the train speed measure is less than a predefined threshold.	PHA_SB_HB_06	The Brake system shall verify the capability;_to apply the Holding brake with enough brake force to guarantee the minimum performance for train immobilization;_to indicate to driver the status of application of Holding brake;_to release the Holding brake;_to inhibit the Holding brake application through the train movement.	PHA_SB_HB_10	The Brake system shall react to the undue application of the Holding brake (i.e. without a valid request and/or during train motion) through the notification of a Major fault to the external actors (driver and external technical system) and brake(s) release.	PHA_GEN_3	The Brake system shall avoid any over-imposition of brake forces required for Emergency brake, Service (including Holding) brake and Parking brake (to avoid the overcoming of limits due to technical characteristics and dimensioning of brakes), and give priority to the application of:_Emergency brake, in case of concurrent requests with Service brake or Parking brake or Holding brake;_Paking brake, in case of concurrent requests with Service brake or Holding brake.	PHA_SB_HB_01	The Brake system shall implement the temporary immobilisation of the train (Holding brake) fulfilling the requirements stated in EN50129 for a SIL2, including the Tolerable Hazard rate at train level.				
SB8	Service brake Traction cut off	Require the traction cut off to traction system in case of Service brake request..	No	Missed Traction cut-off command generation to the external (traction) system during Service brake.	Missed Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Service brake application.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.32	After activation of a Service brake command , ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA_SB_26	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Service brake application (to the local brake units).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command and its transmission to the external technical systems with the same SIL assigned to the brake implementation.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Traction cut-off command generated with delay during Service brake.	Traction cut-off command notified to the external (traction) system with delay or based on an obsolete train retardation request. Delayed traction cut-off during Service brake application	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA_SB_26	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Service brake application (to the local brake units).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).
			Loss of / Partially	Interruption of the Traction Cut Off command during Service brake.	Missed or loss of Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Service brake application Traction unduly restored during Service brake application	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA_SB_26	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Service brake application (to the local brake units).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	PHA_AC_08	The external technical systems shall assure the traction cut-off after receiving a valid traction cut-off command from the Brake system. Traction cut-off shall remain enable until traction cut-off command is released or the Brake system is isolated.	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Traction cut-off command generated but not notified or notified with delay to the external technical (traction) system during Service brake.	Missed Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Service brake application. Traction cut-off command notified to the external (traction) system with delay or based on an obsolete train retardation request. Delayed traction cut-off during Service brake application.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA_SB_26	The Brake system shall guarantee the consistency between the commands for traction cut-off (to the external traction system) and for Service brake application (to the local brake units).	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.: _to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system; _to transmit valid Service brake request to all brake functions.	PHA_SB_11	The Brake system shall react to a (partial or total) inability to transmit a valid Service brake request (to other brake central or local functions) and traction cut-off command (to external technical systems), through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Traction cut-off command generated but not notified or notified with delay to the external technical (traction) system during Service brake.	Missed Traction cut-off command notification to the external (traction) system. Missed traction cut-off during Service brake application.Traction cut-off command notified to the external (traction) system with delay or based on an obsolete train retardation request. Delayed traction cut-off during Service brake application.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.32	After activation of a Service brake command, ineffective control of the train speed due to failure in the traction system (Traction force ≥ Brake force).	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall:_ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level);_ implement safety protection in the generation of safety-data to be exchange through the transmission system;_ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_SB_3	The Brake system shall verify the capability to react to a Service brake request, i.e.:_to acquire the Service brake request from each external actor (driver and single technical system); _to transmit the traction cut-off command to the external system;_to transmit valid Service brake request to all brake functions.	PHA_SB_10	The Brake system shall react to the inability to acquire a Service brake request (from drivers and external technical system) and to transmit (to external technical system) the traction cut-off command, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_12	The Brake system shall exchange safety data for the implementation of the Service brake with the external technical systems (e.g. Service brake request, traction cut-off command, brake status) and internally (e.g. brake force request, brake status), through safety transmission functions implementing reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_38	The Brake system shall apply the Service brake by assuring the generation of the Traction cut-off command its transmission to the external technical systems with the same SIL assigned to the brake implementation.				
			Undue	Traction cut-off command unduly notified (when no Service brake is not required).	Undue traction cut-off (when not required),	Undue train slows down.	-	-														

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB9	Service brake state and fault detection and indication	Detect and notify to the driver and external technical systems the status of Service brake (applied / released) and of brakes (applied / released / isolated / faulted)	No	Missed detection of the brake status information	Missed notification to driver and external technical systems of the brake status information.Impossible monitoring of the brake force application/release.Ineffective setting of Service brake force, detection of anomalies and notification of Major fault.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_44	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.			PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Wrong	Incorrect detection of the brake status, i.e. brake unduly detected as Applied when it is Released or Isolated.	Incorrect detection of the application of Service brake, and missed reaction (if needed, e.g. by applying the maximum Service brake).	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	PHA_SB_44	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.			PHA_REC_05	It is recommend the compliance of the communication between the Brake system and the external technical systems with standard on Safety-related communication in transmission systems (EN50159).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Incorrect detection of the brake status, i.e. brake unduly detected Applied or Released when it is Isolated.	Incorrect detection of the brake as released.	Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.13	Locked axle not detected.	PHA_SB_43	The Brake system shall measure the force applied by individual Service brakes, and consider an updated and conservative (consistent and with margin) estimation of the actual brake force.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_28	The Brake system shall react to a dragging condition of Service brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	PHA_SB_44	The Brake system shall implement functions for the monitoring of the brakes availability and the computation and notification of the Braking power to external technical (signaling) systems, guarantying a degree of functional independence respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.			PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Incorrect detection of the brake status, i.e. brake unduly detected Applied or Released when it is Isolated.	Incorrect management of the degraded condition by the driver (according to procedures). Incorrect management of restrictions (e.g. for train speed) guarantying a safe train running.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_GEN_2	The Brake system, in the exchange of safety-data with the external Technical systems shall: _ monitor the exchange of data and react to the inability to communicate as for a Major fault (at consist level); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error);	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_GEN_8	The Brake system shall notify a Major fault through safety transmission function, with the highest SIL assigned to the brake functions, assuring reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.	PHA_REC_09	It is recommended a "negative logic" in the notification of the Major fault - within the Brake system and to the external actors (i.e. driver and technical systems) - guarantying the train running capability (i.e. brake not applied and traction allowed) only if the transmission system and the transmission functions are available.

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Loss of / Partially	Brake status detected but not notified or notified with delay to the external technical (traction) system, during Service brake.	Missed notification to driver and external technical systems of the brake status information. Impossible monitoring of the brake force application/release. Ineffective setting of Service brake force, detection of anomalies and notification of Major fault.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_8	The Brake system shall provide to the external Technical systems and to the driver the information about the Service brake status, operating mode and active fault conditions.	PHA_GEN_1	The Brake system shall verify the capability to notify a Major failure to the driver and to the external technical systems, under a representative set of failure scenarios.	PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	PHA_GEN_8	The Brake system shall notify a Major fault through safety transmission function, with the highest SIL assigned to the brake functions, assuring reactions against communication errors that are functionally independent by any non-trusted transmission system.	PHA_SB_39	The Brake system shall monitor the brake status and manage the detection and notification to external actors (drive, external technical systems) of fault conditions related to Service brake compatibly with the SIL assigned to its implementation.	PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.		
			Undue	See wrong																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB10	Service Brake isolation	Manage:_the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application;_the remote release of the adhesion dependent friction Emergency brake force.	No	Missed (total or partial) isolation of brake (for all types of brake), when required.	(for all the types of brake) Brake considered available when it should be partially or totally isolated, with incorrect brake blending and possible insufficient minimum Service brake force.Over-estimation of the braking power.Missed release (if applied) or undue application (when not required) or missed application (when requested) of the brake force.	Ineffective control of the train speed and overcoming of spatial or speed limits.Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.33	After activation of a Service brake command , ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_29	The Brake system shall permit the total or partial isolation of Service brake(s) for the removal of the force applied, with or without energy available on the train, whatever are the adjustable (i.e. service) brake actual status and request, as last operation to permit the train running and recover from immobilizing failure conditions.	PHA_SB_1	The Brake system shall verify the capability and effective execution of:_partial or total isolation of Service brake(s);_remote release of Service brake(s).	PHA_SB_30	The Brake system shall react to a missed or undue Service brake(s) release or isolation through the notification of a Major fault.	PHA_SB_25	The Brake system shall implement functions for the partial or total isolation and for the remote release of Service brake(s) guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_27	The Brake system shall implement the partial or total isolation of the Service brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
				Missed remote release (for adhesion dependent friction brake), when required.	(for adhesion dependent friction brake) Brake force unduly applied by the adhesion dependent friction brake force, when remote release is commanded.	Train movement with faulted brake partially permanently applied (not required by slope), and possible brake damage.	H.12	Undue local application of brake force.	PHA_SB_9	The Brake system shall react to a Major fault generated locally (at axle or bogie level) through the local application of the Emergency brake and be available to a "partial" remote release.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_28	The Brake system shall react to a dragging condition of Service brake(s) (i.e. measurement of a non-null brake force without any brake request) through the notification of a Major fault and the automatic release of the brakes(s).	PHA_SB_25	The Brake system shall implement functions for the partial or total isolation and for the remote release of Service brake(s) guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_27	The Brake system shall implement the partial or total isolation of the Service brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.				
			Wrong	See undue																		
			Loss of / Partially	See no																		

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Undue remote release (for adhesion dependent friction brake) during Service brake.	(for adhesion dependent friction brake) Reduction of the brake force applied during Service brake.	Ineffective control of the train speed and overcoming of spatial or speed limits.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_45	The Brake system shall allow the remote release of Service brake(s) only in case of Major fault.	PHA_SB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Service brake(s); _remote release of Service brake(s).	PHA_SB_30	The Brake system shall react to a missed or undue Service brake(s) release or isolation through the notification of a Major fault.	PHA_SB_25	The Brake system shall implement functions for the partial or total isolation and for the remote release of Service brake(s) guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_27	The Brake system shall implement the partial or total isolation of the Service brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.				
				Undue (partial or total) brake isolation (for all types of brake)	(for all the types of brake) Reduction of the brake force applied during Emergency brake. Reduction of the brake power for the brake force calculation.	Ineffective control of the train speed and overcoming of spatial or speed limits. Unavailability of brakes to provide the minimum force for the safe train running.	H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_46	The Brake system shall consider only available (i.e. not isolated/ faulted) brakes in the calculation of the Service brake force to be applied by (all types of) brakes.	PHA_SB_1	The Brake system shall verify the capability and effective execution of: _partial or total isolation of Service brake(s); _remote release of Service brake(s).	PHA_SB_30	The Brake system shall react to a missed or undue Service brake(s) release or isolation through the notification of a Major fault.	PHA_SB_25	The Brake system shall implement functions for the partial or total isolation and for the remote release of Service brake(s) guarantying a degree of functional independence with respect to functions for the application of Service brake that allows the achievement of the global safety objective.	PHA_SB_27	The Brake system shall implement the partial or total isolation of the Service brake(s) (all types) and the remote release of individual Emergency friction brake compatibly with the SIL assigned to its implementation.	PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.		
SB11	Energy supply	Supply the (pneumatic / electric) energy for brake generation (stored and distributed by SB6)	No/Loss of / Partially	Missed or partial supply of energy for Service brake force generation	Missed storage or distribution of energy and missed generation of Service brake force.	No application of brake and missed control of train speed.	H.31	No application of the Service Brake to control of the train speed, due to Brake System failure.	PHA_SB_31	The Brake system, when active, shall guarantee the inexhaustibility of the brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the application of the minimum Service brake force for at least 2 times (i.e. brake cannot be released if it cannot be applied again).	PHA_SB_4	The Brake system shall verify the capability to provide energy for the Service brake application, i.e.: _the availability of (pneumatic / electric) energy source, according to the inexhaustibility requirement. _the capability to regulate the (pneumatic / electrical) energy provided according to the brake force request; _the functionality of any interlock between (pneumatic / electric) devices and protections.	PHA_SB_33	The Brake system shall react to the unavailability of the (pneumatic / electrical) energy required to guarantee the inexhaustibility of the Service brake , through the notification of a Major fault and the application of the Emergency brake.	-	-	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.	PHA_AC_07	External technical systems shall assure the availability of the (pneumatic and electrical) energy for the brakes regulation, without invalidating the independence required to local brake actuations (e.g. for different bogies).	PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Wrong	Not applicable.																	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Undue	See wrong																	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
SB12	Service brake kinetic energy transformation	Transform the kinetic energy of the train into thermal energy by the friction between two surfaces	No / wrong	Ineffective conversion of the kinetic energy lost during Service brake into electric and thermal energy	Reduced force applied by the adhesion dependent Friction brake		H.33	After activation of a Service brake command, ineffective control of the train speed through Service Brake, due to Brake System failure.	PHA_SB_21	The Brake system shall guarantee performance to be in the minimum/maximum range for the calculation and application of the Service brake force by each (type of) brake, fulfilling all the constraints related to:_maximum deceleration (2.5 m/s2 according to TSI) and jerk (4 m/s3 according to TSI),_adhesion limits (for adhesion dependent brake.	PHA_SB_2	The Brake system shall verify the application of Service brake:_by monitoring the status of each brake (Applied, Released, Isolated, Faulted),_by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system);_by measuring the real brake force applied by (all types of) brakes;_by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_23		-	-	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.	PHA_AC_04	External technical system shall monitor the temperature achieved by brake, as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy. The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ….).	PHA_REC_01	It is recommended to define criteria for the over-dimensioning of brakes and related fault(s) tolerance capability; at least, single credible failure (e.g. affecting brake on a single axis) should be tolerated without any impact on the minimum braking power required to guarantying a safe train stop (i.e. to achieve a safe state).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
				Ineffective dissipation of the heat generated by the conversion of the kinetic energy lost during Service brake			H.29	Brake force applied is greater than the maximum force supported by brake, leading to its damage.	PHA_SB_17	The Brake system shall limit the maximum (pneumatic / electrical) energy provided for the generation of the force required for Service brake to a value compatible with the technical characteristics, dimensioning and status of brakes.	PHA_SB_2	The Brake system shall verify the application of Service brake: _by monitoring the status of each brake (Applied, Released, Isolated, Faulted), _by notifying the actual brake status (Applied, Released, Isolated, Faulted) to external actors (driver and external technical system); _by measuring the real brake force applied by (all types of) brakes; _by detecting a dragging brake condition (i.e. non-null brake force without any brake request).	PHA_SB_18	The Brake system shall react to any inconsistency between the sum of the brake force applied by the different types of brake and the total minimum Emergency brake request, through the notification of a Major fault and the application of the Emergency brake.	-	-	PHA_SB_19	The Brake system shall implement the adjustable retardation to control the speed of the train (Service brake) fulfilling the requirements stated in EN50129 for SIL2, including the Tolerable Hazard rate at train level.	PHA_AC_04	External technical system shall monitor the temperature achieved by brake, as protection against an ineffective dissipation of the heat generated by the conversion of the train kinetic energy. The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ….).	PHA_REC_04	It is recommend the compliance of the architecture of the Brake system with the standard on Safety related electronic systems for communication, signalling and processing systems (EN 50129).
			Loss of / Partially	See wrong																	PHA_REC_06	It is recommend to qualify the Brake system's devices for the operation under external conditions according to the applicable standards: EN50155 on environmental condition including temperature and humidity, EN50124 on electrical Insulation, EN61373 on shock and vibration test, EN50121 on electromagnetic compatibility, EN45545 on fire protection).

FUNCTIONAL FAILURE MODE					FAILURE EFFECTS (worst case)				COUNTERMEASURES SPECIFICATION													
									Correct functional operation		Detection of faults		Action following Detection		Independence of Items		Systematic & Random faults		Application conditions		Recommendations	
ID	Sub-function	Description	Guide-word	Deviation / Functional Failure mode.	Local effect	Final effect	Hazard ID	Hazard description	ID	Description	ID	Description		Description		Description		Description	ID	Description	ID	Description
			Undue	Not applicable																		

Annex 2 Brake by Wire System Functional Requirements list

This annex contains the export from Polarion with the list of brake by wire functional requirement.

S4R-1 - The brake system shall ensure that the train's speed can be reduced or maintained on a slope, or that the train can be stopped within the maximum allowable braking distance. Braking also ensures the immobilisation of a train.

Requirement identification	BS.1
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrBrReqUs, ImmReqUs; BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys, ImmReqBrSys
Output information	TrainRetAppl TrainRetEqTimeAppl TrainImmForAppl

S4R-2 - TrBrReqUs is the request of accelerate or decelerate the train by the driver (or any other user), provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	BS.2
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Driver
Input information	
Output information	TrBrReqUs

S4R-3 - TrBrReqUs request can be provided by service brake, emergency brake and parking brake main functions

Requirement identification	BS.3

Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrSBrReqUs EBrReqUs
Output information	TrBrReqUs

S4R-4 - TrBrReqATO is the request of accelerate or decelerate the train by the ATO system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	BS.4
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	ATO
Input information	
Output information	TrBrReqATO

S4R-5 - TrBrReqTCMS is the request of accelerate or decelerate the train by the TCMS system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	BS.5
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	TCMS
Input information	

Output information	TrBrReqTCMS

S4R-6 - BrReqATP is the request to decelerate the train by the ATP provided via proper interface. It is deceleration (negative) value.

Requirement identification	BS.6
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	ATP
Input information	
Output information	BrReqATP

S4R-7 - BrReqETCS is the request to decelerate the train by the ETCS provided via proper interface. It is deceleration (negative) value.

Requirement identification	BS.7
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	ETCS
Input information	
Output information	BrReqETCS

S4R-8 - BrReqPAS is the request to decelerate the train by the PAS provided via proper interface. It is deceleration (negative) value.

Requirement identification	BS.8
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition

Rationale	
Actor	PAS
Input information	
Output information	BrReqPAS

S4R-9 - BrReqBrSys is the request to decelerate the train by the Brake system itself, provided via its functions. It is deceleration (negative) value.

Requirement identification	BS.9
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	BrReqBrSys

S4R-10 - BrReqBrSys request is provided by brake system management main function

Requirement identification	BS.10
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	SBrReqBSM EBrReqBSM
Output information	BrReqBrSys

S4R-11 - ImmReqUs is the request of immobilize   the train by the driver or any other user, provided via proper interface

Requirement identification	BS.11

Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Driver
Input information	
Output information	ImmReqUs

S4R-12 - ImmReqUs request is provided by Parking brake main function

Requirement identification	BS.12
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	PBrReqUs
Output information	ImmReqUs

S4R-13 - ImmReqTCMS is the request of immobilize the train by the TCMS provided via proper interface

Requirement identification	BS.13
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	TCMS
Input information	
Output information	ImmReqTCMS

S4R-14 - ImmReqBrSys is the request of immobilize the train by the Brake system itself, provided via its functions

Requirement identification	BS.14
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	ImmReqBrSys

S4R-15 - ImmReqBrSys request is provided by brake system management main function

Requirement identification	BS.15
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	PBrReqBSM
Output information	ImmReqBrSys

S4R-16 - TrainRetAppl is the real retardation present on the train. It is a positive value.

Requirement identification	BS.16
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainRetAppl

S4R-17 - TrainRetAppl retardation is generated by service and emergency brake

Requirement identification	BS.17
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainSBrRetAppl TrainEBrRetAppl
Output information	TrainRetAppl

S4R-18 - TrainRetEqTimeAppl is the equivalent time by which the retardation TrainRetAppl is applied

Requirement identification	BS.18
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainRetEqTimeAppl

S4R-19 - TrainRetEqTimeAppl equivalent time is derived from TrainSBrEqTimeAppl and TrainSBrEqTimeAppl

Requirement identification	BS.19
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system

Input information	TrainSBrEqTimeAppl TrainEBrEqTimeAppl
Output information	TrainRetEqTimeAppl

S4R-20 - TrainImmForAppl is the real force applied at the track by the train when immobilized

Requirement identification	BS.20
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainImmForAppl

S4R-21 - The train retardation is given by the contribution of running resistance force, gravity force and brake force: TrainRetAppl=(TrainBrForAppl+TrainRunResAppl+GravForAppl)/TrainMass

Requirement identification	BS.21
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	See EN15431-1 for brake calculation formulas
Actor	Brake system
Input information	TrainBrForAppl TrainRunRes GravForAppl
Output information	TrainRetAppl

S4R-22 - The train retardation request is the maximum value of retardation requests among the ones received by different actors

Requirement identification	BS.22
Level	Brake System
Mainfunction	Overall Brake System

Type	Functional
Rationale	
Actor	Brake system
Input information	TrBrReqUs, BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys,
Output information	TrainRetReq

S4R-23 - The TrainRetReq is the retardation that is expected to be applied at the train based on requests by different actors. It is a positive value

Requirement identification	BS.23
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainRetReq

S4R-24 - TrainBrForNom is the force piloted by the brake system to contribute to decelerate the train with the retardation TrainRetReq

Requirement identification	BS.24
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system

Input information	
Output information	TrainBrForNom

S4R-25 - TrainBrForAppl is the brake force applied to the track via the braking force generated by the brake system

Requirement identification	BS.25
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainBrForAppl

S4R-26 - TrainRunResAppl is the force applied at the train by track and air

Requirement identification	BS.26
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Environment
Input information	
Output information	TrainRunResAppl

S4R-27 - GravForAppl is the force applied at the train by the gravity

Requirement identification	BS.27
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition

Rationale	
Actor	Environment
Input information	
Output information	GravForAppl

S4R-28 - The gravity force is given by the formula TrainMass*TrackSlope*9,81

Requirement identification	BS.28
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Environment
Input information	TrainMass TrackSlope
Output information	GravForAppl

S4R-29 - TrainMass is the Mass of the train

Requirement identification	BS.29
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainMass

S4R-30 - TrackSlope is the slope of the track in thousands, positive in uphill, negative in downhill

Requirement identification	BS.30
Level	Brake System

Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Track
Input information	
Output information	TrackSlope

S4R-31 - The brake system has available 4 different type of brakes to apply TrainBrForAppl to the track to obtain a retardation :
Adhesione dependent dynamic brake
Adhesion independent dynamic brake
Adhesione dependent friction brake
Adhesion independent friction brake

Requirement identification	BS.31
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	This types of brake are the only one physically possible applyig forces to the rail (aerodynamic brake is not considered in this functional requirements): the train kinetic energy can be trasformed in heat (by friction) or in mechanical / electrical energy (dynamic brakes) only. The force can be trasmitted to the rails by wheels (adhesion dependent due to their rotation) or by something else different (adhesion independent).
Actor	Brake system
Input information	AdDepDynBrForAppl AdIndDynBrForAppl AdDepFrBrForAppl AdIndFrBrForAppl
Output information	TrainBrForAppl

S4R-32 - AdDepDynBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force

Requirement identification	BS.32
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition

Rationale	
Actor	Brake system
Input information	
Output information	AdDepDynBrForAppl

S4R-33 - AdDepDynBrForAppl is obtained by the contribution of service brake and emergency brake forces

Requirement identification	BS.33
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AdDepDynSBrForAppl AdDepDynEBrForAppl
Output information	AdDepDynBrForAppl

S4R-34 - AdIndDynBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force

Requirement identification	BS.34
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	AdIndDynBrForAppl

S4R-35 - AdIndDynBrForAppl is obtained by the contribution of service brake and emergency brake forces

Requirement identification	BS.35
Level	Brake System

Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AdIndDynSBrForAppl AdIndDynEBrForAppl
Output information	AdIndDynBrForAppl

S4R-36 - AdDepFrBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Dependent Friction Brake Force

Requirement identification	BS.36
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	AdDepFrBrForAppl

S4R-37 - AdDepFrBrForAppl is obtained by the contribution of service brake and emergency brake forces

Requirement identification	BS.37
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AdDepFrSBrForAppl AdDepFrEBrForAppl
Output information	AdDepFrBrForAppl

S4R-38 - AdIndFrBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Independent Friction Brake Force

Requirement identification	BS.38
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	AdIndFrBrForAppl

S4R-39 - AdIndFrBrForAppl is obtained by the contribution of service brake and emergency brake forces

Requirement identification	BS.39
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AdIndFrSBrForAppl AdIndFrEBrForAppl
Output information	AdIndFrBrForAppl

S4R-40 - The brake system generate a train immobilization by applying a brake immobilisation force to the track using 2 different brakes:
Adhesion dependent friction immobilisation brake
Adhesion independent friction immobilisation brake

Requirement identification	BS.40
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional

Rationale	This types of brake are the only one physically possible applyig forces to the rail: In a stationary condition only friction can generate a force (magnetic force parallel to the rail cannot be applied in stationary condition, but magnetic force can generate the perpedicular force to the rail which provide the friction force effect parallel tpo the rail) The force can be trasmitted to the rails by wheels (adhesion dependent due to their rotation) or by something else different (adhesion independent).
Actor	Brake system
Input information	AdDepFrImmBrForAppl AdIndFrImmBrForAppl
Output information	TrainImmForAppl

S4R-41 - TrainImmForAppl is the immobilisation force applied to the track via the brake system

Requirement identification	BS.41
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainImmForAppl

S4R-42 - AdDepFrImmBrForAppl is the immobilisation force applied to the track by adhesion dependent friction immobilisation brake

Requirement identification	BS.42
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	AdDepFrImmBrForAppl

S4R-43 - AdIndFrImmBrForAppl is the immobilisation force applied to the track by adhesion independent friction immobilisation brake

Requirement identification	BS.43
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	AdIndFrImmBrForAppl

S4R-44 - Each type of brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter

Requirement identification	BS.44
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	The maximum braking force shall be the outcome of the brake calculation and dimensioning according contractual requests and below general performance requirements (see also req. 1.1.13 and 1.2.13) It represent the maximum force that the type of brake can apply without being damaged or damage the context. The temparture dependency of SB force is an option oriented to manage the situation where the dissipation capacity reach the limit due to high duty cycle or high level of isolation of service brake force.
Actor	Brake system
Input information	AdDepDynBrForMax(v,temp) AdIndDynBrForMax(v, temp) AdDepFrBrForMax(v, temp) AdIndFrBrForMax(v, temp) AdDepFrImmForMax(v) AdIndFrImmForMax(v)
Output information	AdDepDynBrForAppl AdIndDynBrForAppl AdDepFrBrForAppl AdIndFrBrForAppl AdDepFrImmForAppl AdIndFrImmForAppl

S4R-45 - AdDepDynBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic brake

Requirement identification	BS.45

Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynBrForMax

S4R-46 - AdIndDynBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic brake

Requirement identification	BS.46
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynBrForMax

S4R-47 - AdDepFrBrForMax is the maximum force that can be applied at the track by adhesion dependent friction brake

Requirement identification	BS.47
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrBrForMax

S4R-48 - AdIndFrBrForMax is the maximum force that can be applied at the track by adhesion independent friction brake

Requirement identification	BS.48
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrBrForMax

S4R-49 - AdDepFrImmForMax is the maximum immobilisation force that can be applied at the track by adhesion dependent friction immobilisation brake

Requirement identification	BS.49
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrImmForMax

S4R-50 - AdIndFrImmForMax is the maximum immobilisation force that can be applied at the track by adhesion independent friction immobilisation brake

Requirement identification	BS.50
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	AdIndFrImmForMax

S4R-51 - The brake system shall be continuous: all brakes in the train shall be capable of being applied from a single control point, normally in the operational cab

Requirement identification	BS.51
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	Major safety requirement of brake system
Actor	Brake system
Input information	TrBrReqUs, ImmReqUs; BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys, ImmReqBrSys
Output information	TrainBrForAppl TrainImmForAppl

S4R-52 - The brake system shall be automatic: Each individual brake type or combinations of them shall operate automatically, i.e. in the event of an unintentional train separation (train integrity lost), the brakes on the two parts of the train shall apply, bring the train to a standstill and keep it in the same position until released by other intentional operations.

Requirement identification	BS.52
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	Major safety requirement of brake system
Actor	Brake system
Input information	TrainIntegr
Output information	TrainBrForAppl

S4R-53 - TrainIntegr is the information assessing that the train is integer

Requirement identification	BS.53
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainIntegr

S4R-54 - The brake system shall be inexhaustible: the braking power available shall be adequate to attain full brake force:
— at all times during the train journey; and
— under all track conditions.

Requirement identification	BS.54
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	Major safety requirement of brake system
Actor	Brake system
Input information	BrPneumEn, BrElectrEn BrMechEn BrMagnEn TrainBrPower
Output information	TrainBrForAppl

S4R-55 - BrPneumEn is the pneumatic energy used to generate the TrainBrForAppl and TrainImmForAppl

Requirement identification	BS.55
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition

Rationale	
Actor	Brake system
Input information	
Output information	BrPneumEn

S4R-56 - The pneumatic energy is represented by the air supply pressure and air supply delivery to brake system

Requirement identification	BS.56
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AirSupplPress BrAirSupplDel
Output information	BrPneumEn

S4R-57 - BrElectrEn is the electric energy used to generate the TrainBrForAppl and TrainImmForAppl

Requirement identification	BS.57
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	BrElectrEn

S4R-58 - The lectric energy is represented by the electric voltage and by the electric current to brake system

Requirement identification	BS.58
Level	Brake System

Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	ElVolt BrElCurr
Output information	BrElectrEn

S4R-59 - BrMechEn is the mechanical energy used to generate the TrainBrForAppl and TrainImmForAppl

Requirement identification	BS.59
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	BrMechEn

S4R-60 - BrMagnEn is the magnetic energy used to generate the TrainBrForAppl and TrainImmForAppl

Requirement identification	BS.60
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	BrMagnEn

S4R-61 - When the brake system is no more able to guarantee the minimum retardation or a maximum equivalent time or a minimum immobilisation force a major fault shall be set

Requirement identification	BS.61
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainRetMin TrainBrEqTimeMax TrainImmForMin
Output information	MajFaultBrSys

S4R-62 - MajFaultBrSys is fault indication which inform the train that the brake system is no more able to guarantee the expected performances

Requirement identification	BS.62
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	MajFaultBrSys

S4R-63 - MajFaultBrSys van be generated by any of the main functions

Requirement identification	BS.63
Level	Brake System
Mainfunction	Overall Brake System

Type	Functional
Rationale	
Actor	Brake system
Input information	MajFaultSBx MajFaultEBx MajFaultPBx MajFaultBSMx MajFaultABTx
Output information	MajFaultBrSys

S4R-64 - TrainRetMin is the minimum retardation that the TrainBrForAppl shall guarantee based on the actual braking power on a level track in the worst environmental condition and in case of worst single failure

Requirement identification	BS.64
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	This is the deceleration used by signalling for the braking model defining the maximum stopping distance.
Actor	Brake system
Input information	
Output information	TrainRetMin

S4R-65 - TrainRetMin=TrainEBrRetMax*TrainBrPower

Requirement identification	BS.65
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainEBrRetMax TrainBrPower
Output information	TrainRetMin

S4R-66 - TrainBrEqTimeMax is the maximum equivalent time that the TrainRetEqTimeAppl shall guarantee.

Requirement identification	BS.66
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	This is the equivalent time used by signalling for the braking model defining the maximum stopping distance
Actor	Brake system
Input information	
Output information	TrainBrEqTimeMax

S4R-67 - TrainImmForMin is the minimum force that the TrainImmForAppl shall guarantee based on immobilisation power

Requirement identification	BS.67
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainImmForMin

S4R-68 - When a major fault is set Brake system shal automatically reach the most proper safe state for the train depending from the major fault

Requirement identification	BS.68
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	The train safe state for every major fault shall be defined. (The safe state for EDV is the brake application. The train has the possibility to overcome the EDV brake application by BSM2 remote release function if the brake application is not considered the safest condition for the train)
Actor	Brake system

Input information	MajFaultBrSys
Output information	TrainBrForAppl

S4R-69 - The loss of the continuity of the command or inexhaustibility of the brake force generates an automatic predefined brake force application

Requirement identification	BS.69
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	The safe state of a brake system with not continuous command line or without enough energy to brake is the braking application till the stop and brake release inhibition
Actor	Brake system
Input information	Loss of brake continuity or inexhaustibility
Output information	TrainBrForAppl

S4R-70 - The brake system shall have a safe speed information by train odometry system

Requirement identification	BS.70
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	Brake force application is speed variant. Note: it is possible that odometry system is included in brake system, but for the objectives of this document it is considered coming from external technical system
Actor	Odometry
Input information	Speed
Output information	TrainSpeed

S4R-71 - Speed is the real speed of the train

Requirement identification	BS.71

Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	Speed

S4R-72 - TrainSpeed is the speed of the train measured by odometry system

Requirement identification	BS.72
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Odometry
Input information	
Output information	TrainSpeed

S4R-73 - The brake system shall be able to release the brake when needed to guarantee the running capability of the train

Requirement identification	BS.73
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	This is a functional requirement of the running capability. The condition for releasing the brake shall be defined by safety analysis
Actor	Brake system
Input information	
Output information	TrainBrRemRelComm

S4R-74 - TrainBrRemRelComm is the brake release command given by brake system in front of an automatic request by brake system or voluntary request by users

Requirement identification	BS.74
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainBrRemRelComm

S4R-75 - TrainBrRemRelComm is obtained by brake management system main function remote release commands

Requirement identification	BS.75
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom AdDepDynBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom
Output information	TrainBrRemRelComm

S4R-76 - The brake system shall guarantee:
- in worst environmental condition
- in case of worst single failure

the minimum brake retardation rate (speed dependent) and maximum equivalent time able to guarantee maximum stopping distances associated to the braking power active at the moment of the braking activation.

Requirement identification	BS.76
Level	Brake System
Mainfunction	Overall Brake System

Type	Functional
Rationale	Minimum safe performance of the train.
Actor	Brake system
Input information	TrBrReqUs BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; BrReqPAS BrReqBrSys TrainRetMin TrainBrEqTimeMax TrainBrPower
Output information	TrainRetAppl TrainRetEqTimeAppl

S4R-77 - The braking power value shall limit the maximum speed of the train.

Requirement identification	BS.77
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	ETCS or driver
Input information	TrainBrPower
Output information	SpeedLim

S4R-78 - The TrainBrPower is a percentage of the maximum nominal retadation of train (TrainEBRetMax), percentage defined based on brake isolation status TrainEBrIsolStatus

Requirement identification	BS.78
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	UIC544-1 braked mass percentage is the existing braking power definition, which is not able to manage efficiently modern brakes, using normally disk brake instead of tread brake and not applicable to high speed brake, where the deceleration is indicated

	as figure to define the braking power. The UIC concept of percentage is maintained because is a quick way to have an indication of the braking capacity. The braking power is the reference for signalling system to calculate the guaranteed stopping distance. Note: The maximum retardation is speed dependent and there are different type of forces, with different speed dependeny, partecipating to the total retardation. The reduction of forces due to isolation can lead to different retardation curves. The braking power definition (to be done at dimnensioning level) groups the closer retardation curves of different isolation status under a single curve at which is attributed the lowest retardation among all curves grouped together.
Actor	Brake system
Input information	TrainEBRetMax TrainEBrIsolStatus
Output information	TrainBrPower

S4R-79 - A stopping distance of the train shall be associated univocally at every coupled values of braking power and TrainSpeed

Requirement identification	BS.79
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	The stopping distance is the information that can derive by proper dimensioning formula usingTrainBrPower, TrainRetMin, TrainSpeed, TrainBrEqTimeMax.
Actor	Dimensioning
Input information	TrainBrPower TrainSpeed TrainRetMin TrainBrEqTimeMax
Output information	TrainStopDist

S4R-80 - TrainBrPower represent the braking capacity of the train by which is possible to define univocally the maximum stopping distance from any speed

Requirement identification	BS.80
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system

Input information	
Output information	TrainBrPower

S4R-81 - A maximum train speed of the train shall be associated univocally at every value of braking power

Requirement identification	BS.81
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	The maximum speed is defined by energy dissipation dimensioning calculation and shall be univocally identified by the braking power value.
Actor	Dimensioning
Input information	TrainBrPower TrainSpeed TrainRetMax TrainBrEqTimeMax
Output information	TrainSpeedMax

S4R-82 - TrainSpeedMax is the maximum speed that the train can reach with the active braking power

Requirement identification	BS.82
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Brake system
Input information	
Output information	TrainSpeedMax

S4R-83 - TrainStopDist(v) is the maximum stopping distance possible by applying at a certain speed the emergency brake :
- without any failure and isolation,
- without degraded environmental condition (causing sliding or reduced applied forces),
- on a flat track
- with maximum train mass

Requirement identification	BS.83
Level	Brake System

Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainStopDist

S4R-84 - Train brake retardation shall have a maximum equivalent time of application

Requirement identification	BS.84
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	Equivalent time definition in EN14531-1. The maximum equivalent time parameter is usually 3 s fr pneumatic adhesion dependent friction brakes
Actor	Brake system
Input information	TrBrReqUs BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; BrReqPAS BrReqBrSys TrainBrEqTimeMax
Output information	TrainRetEqTimeAppl

S4R-85 - Train retardation shall be limited to TrainRetLim=2,5 m/s2

Requirement identification	BS.85
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	To avoid too high forces on the track
Actor	Brake system

Input information	TrainRetLim
Output information	TrainRetAppl

S4R-86 - TrainRetLim is the maximum value that the Train retardation can reach on level track

Requirement identification	BS.86
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainRetLim

S4R-87 - The brake system generate the train retardation using 2 different function: Service Brake : adjustable retardation to control the speed of the train
Emergency Brake : predefined minimum retardation in predefind maximum response time to stop the train in predefined maximum stopping distances

Requirement identification	BS.87
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainSBrForAppl TrainEBrForAppl
Output information	TrainBrForAppl

S4R-88 - TrainSBrForAppl is the portion of the force TrainBrForAppl or of the force TrainImmForAppl applied by the main function service brake

Requirement identification	BS.88
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	TrainSBrForAppl

S4R-89 - TrainEBrForAppl is the portion of force TrainBrForAppl applied by the main function emergency brake to the track

Requirement identification	BS.89
Level	Brake System
Mainfunction	Overall Brake System
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	TrainEBrForAppl

S4R-90 - The brake system generate the train immobilisation using 2 different function: Service Brake: temporary immobilisation
Parking Brake : permanent immobilisation

Requirement identification	BS.90
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	SB PB

Input information	TrainSBrForAppl TrainPBrForAppl
Output information	TrainImmForAppl

S4R-91 - AdDepFrImmBrForAppl is obtained by the contribution of TrainSBrForAppl and/or TrainPBrForAppl

Requirement identification	BS.91
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainSBrForAppl TrainPBrForAppl
Output information	AdDepFrImmBrForAppl

S4R-92 - AdDepFrImmBrForAppl is obtained by the contribution of TrainPBrForAppl only

Requirement identification	BS.92
Level	Brake System
Mainfunction	Overall Brake System
Type	Functional
Rationale	
Actor	Brake system
Input information	TrainPBrForAppl
Output information	AdIndFrImmBrForAppl

S4R-93 - The service brake shall apply an adjustable retardation to the train proportional to the request received by actors or brake system internal function BSM with the following goals:
- Reduce the speed of the train
- Maintain the speed of the train on a slope
- Immobilize temporary the train

Requirement identification	SB.1

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB
Input information	TrSBrReqUs SBrReqATP SBrReqETCS TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM
Output information	TrainSBrRetAppl

S4R-94 - TrSBrReqUs is the request of accelerate or decelerate via service brake the train by the driver (or any other user), provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	SB.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Driver
Input information	
Output information	TrSBrReqUs

S4R-95 - TrSBrReqATO is the request of accelerate or decelerate via service brake the train by the ATO system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	SB.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	ATO
Input information	
Output information	TrSBrReqATO

S4R-96 - TrSBrReqTCMS is the request of accelerate or decelerate via service brake the train by the TCMS system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.

Requirement identification	SB.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	TCMS
Input information	
Output information	TrSBrReqTCMS

S4R-97 - SBrReqATP is the request to decelerate via service brake the train by the ATP provided via proper interface. It is a deceleration (negative) value.

Requirement identification	SB.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	ATP
Input information	
Output information	SBrReqATP

S4R-98 - SBrReqETCS is the request to decelerate the train via service brake by the ETCS provided via proper interface. It is a deceleration (negative) value.

Requirement identification	SB.6
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	ETCS
Input information	
Output information	SBrReqETCS

S4R-99 - SBrReqPAS is the request to decelerate via service brake the train by the PAS provided via proper interface. It is a deceleration (negative) value.

Requirement identification	SB.7
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	PAS
Input information	
Output information	SBrReqPAS

S4R-100 - TrainSBrRetAppl is the portion of the train retardationTrainRetAppl which is generated by the Service brake force. It is a positive value

Requirement identification	SB.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainSBrRetAppl

S4R-101 - TrainSBrEqTimeAppl is the equivalent time by which the force TrainSBrRetAppl is applied

Requirement identification	SB.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	TrainSBrEqTimeAppl

S4R-102 - The train retardation requested is given as percentage of the maximum retardation: TrainRetReq=TrainSBrRetReq/TrainSBrRetReqMax*100%

Where TrainSBrRetReq is the minimum acceleration/deceleration value between all the SBrReq received by different actors and TrainSBrRetReqMax is the retardation expected with 100% of service brake request in nominal condition

Requirement identification	SB.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The use of percentage of TrainSBrRetMax permit to have brake request non dependent from the speed. The maximum service brake retardation shall be the outcome of the brake calculation according contractual requests and below general performance requirements. Note: If ithe option of considering the slope is active, the dimensioning shall consider the additional force given by the downhill on the maxslope.
Actor	SB
Input information	TrSBrReqUs SBrReqATP SBrReqETCS TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM
Output information	TrainRetReq

S4R-103 - TrainSBrRetReq is the retardation that is expected to be applied at the train when a service brake is requested. It is a positive value

Requirement identification	SB.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	TrainSBrRetReq

S4R-104 - TrainSBrRetMax is the maximum retardation of the train on a level track (TrackSlope=0) with nominal running resistance force (TrainRunResSB) expected applying the maximum service brake request

Requirement identification	SB.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainSBrRetMax

S4R-105 - TrainRetReq is the adimensional way to define the train service brake retardation request TrainSBrRetReq (TrainSBRet/TrainSBrRetReqMax)

Requirement identification	SB.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	

Output information	TrainRetReq

S4R-106 - The Train Service brake retardation TrainSBrRetReq defines the Train service brake force TrainSBrForNom by brake force calculation formulas

Requirement identification	SB.14
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See EN15431-1 for brake calculation formulas
Actor	SB
Input information	TrainSBrRetReq
Output information	TrainSBrForNom

S4R-107 - The Service brake equivalent time of application shall be TrainSBrEqTimeAppl< TrainSBrEqTimeMax

Requirement identification	SB.15
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See above requirement about brake performances
Actor	SB
Input information	TrainSBrEqTimeMax
Output information	TrainSBrEqTimeAppl

S4R-108 - TrainSBrEqTimeMax is the maximum equivalent time by which the retardation TrainSBrRetAppl shall be applied

Requirement identification	SB.16
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	TrainSBrEqTimeMax

S4R-109 - Train retardation shall be limited to TrainRetLim=2,5 m/s2

Requirement identification	SB.17
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	To avoid too high forces on the track
Actor	SB
Input information	TrainSBrForAppl TrainRetLim
Output information	TrainRetAppl

S4R-110 - TrainSBrMaxRet is the maximum absolute value that the service brake retardation can reach

Requirement identification	SB.18
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainSBrMaxRet

S4R-111 - The service brake function shall be able to apply to the train a minimum retardation which guarantee the minimal condition to operate the train. The minimum retardation can be an invariant parameter or a speed dependent parameter

Requirement identification	SB.19
Level	Brake System
Mainfunction	Service Brake

Type	Functional
Rationale	The minimum service brake retardation shall be the outcome of contractual requests and below general performance requirements Note: it is the retardation providing the minimum allowed performances with 100% of service brake request. It can depend from the braking power parameter (which is function of the emergency brake isolation status)
Actor	SB
Input information	Dimensioning
Output information	TrainSBrRetMin

S4R-112 - TrainSBrRetMin is the minimum service brake retardation which shall be possible on the train to guarantee the operation

Requirement identification	SB.20
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainSBrRetMin

S4R-113 - Train service brake retardation shall reach its full value in max SBrRetRiseTimeMax

Requirement identification	SB.21
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Force application time
Actor	SB
Input information	SBRetRiseTimeMax
Output information	TrainSBrRetAppl

S4R-114 - SBRetRiseTimeMax is the maximum rising time of the train service brake retardation TrainSBrRetAppl

Requirement identification	SB.22
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	SBRetRiseTimeMax

S4R-115 - Releasing of train brake retardation shall be ≤SBrRetDecrTimeMax

Requirement identification	SB.23
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Force application time
Actor	SB
Input information	SBRetDecrTimeMax
Output information	TrainSBrRetAppl

S4R-116 - SBRetDecrTimeMax is the maximum decreasing time of the train service brake retardation TrainSBrRetAppl

Requirement identification	SB.24
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	SBRetDecrTimeMax

S4R-117 - The SB retardation increasing and releasing time shall be limited by the maximum jerk MaxJerk to be not overpassed at train level

Requirement identification	SB.25
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB
Input information	MaxJerk
Output information	TrainSBrRetAppl

S4R-118 - Service brake retardation shall be < of Emergency brake retardation at any speed

Requirement identification	SB.26
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Emergency brake is the brake used by the train to stop in the shortest distances.
Actor	SB
Input information	TrainEBrRetNom
Output information	TrainSBrRetReq

S4R-119 - The train service brake retardation TrainSBrRetReq is obtained by the contribution of adhesion dependent dynamic brake, adhesion independent dynamic brake, adhesion dependent friction brake: TrainSBrForAppl(v)= AdDEpDynSBrForAppl(v)+ AdIndDynSBrForAppl(v)+ AdDEpFrSBrForAppl(v)

Requirement identification	SB.27
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The adhesion independent friction brake is not used in service brake in analogyto conventional train
Actor	SB

Input information	TrainSBrForNom
Output information	AdDepDynSBrForAppl AdIndDynSBrForAppl AdDepFrSBrForAppl

S4R-120 - AdDepDynSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force

Requirement identification	SB.28
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	AdDepDynSBrForAppl

S4R-121 - AdIndDynSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force

Requirement identification	SB.29
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	AdIndDynSBrForAppl

S4R-122 - AdDepFrSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Dependent Friction Brake Force

Requirement identification	SB.30
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	AdDepFrSBrForAppl

S4R-123 - Each type of service brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter

Requirement identification	SB.31
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB
Input information	AdDepDynSBrForMax AdIndDynSBrForMax AdDepFrSBrForMax
Output information	AdDepDynSBrForAppl AdIndDynSBrForAppl AdDepFrSBrForAppl

S4R-124 - AdDepDynSBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic service brake

Requirement identification	SB.32
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning

Input information	
Output information	AdDepDynSBrForMax

S4R-125 - AdIndDynSBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic service brake

Requirement identification	SB.33
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrForMax

S4R-126 - AdDepFrSBrForMax is the maximum force that can be applied at the track by adhesion dependent service friction brake

Requirement identification	SB.34
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrForMax

S4R-127 - When SB functions is supplied by the electrical power supply shall perform a self test and trasmit the result to BSM1 function

Requirement identification	SB.35
Level	Brake System
Mainfunction	Service Brake

Type	Functional
Rationale	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of SB and compare it with the expected one (initialization of the brake)
Actor	SB
Input information	SBrElVolt
Output information	SelfTestSBrRes

S4R-128 - SelfTestSBrRes is the result of the self test performed by service brake when receive electric power supply

Requirement identification	SB.36
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB
Input information	
Output information	SelfTestSBrRes

S4R-129 - Service brake force shall not be applied in case emergency brake force is applied

Requirement identification	SB.37
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	To avoid compounding of different type of brakes
Actor	SB
Input information	TrainEBrForAppl
Output information	TrainSBrForAppl

S4R-130 - SB1 shall collect the traction/service brake request by actors and train direction and trasmit it to SB2. The traction/service brake request is intended as percentage of the maximun service brake retardation TrainSBrRetMax(v)

Requirement identification	SB1.1

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Traction and brake are connected: one exclude the other. It is then proposed to use the same information to command both. The information TrSBrReq"x" is changing from -100% to +100% (negative brake, positive traction)
Actor	SB1
Input information	TrSBrReqUs; ForwBackDir SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM
Output information	TrainTrSBrReq ActDir

S4R-131 - TrainTrSBrReq is the adimensional information (percentage) about traction and service brake retardation request. It is in the range +100%/-100%. The value -100% correspond to a retardation of TrainSBrRetMax. The value +100% correspond to TrainTractAccMax.
(Note: when TrainTrSBrReq<0 it is equal to (-TrainRetReq)

Requirement identification	SB1.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB1
Input information	
Output information	TrainTrSBrReq

S4R-132 - TrainTractAccMax is the maximum traction acceleration of the train

Requirement identification	SB1.3

Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainTractAccMax

S4R-133 - ActDir is the information about train direction selected by the driver

Requirement identification	SB1.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB1
Input information	
Output information	ActDir

S4R-134 - The brake request with higher absolute percentage value shall be trasmitted to SB2

Requirement identification	SB1.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The higher brake request has priority
Actor	SB1
Input information	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS;

	SBrReqPAS SBrReqBSM
Output information	TrainTrSBrReq

S4R-135 - Driver and any technical system shall be able to command at least 7 different level of service brake force including brake release

Requirement identification	SB1.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Moderability concept.
Actor	SB1
Input information	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM
Output information	TrainTrSBrReq

S4R-136 - TrainTrSBrReq ramping shall be limited in order to have a jerk of TrainTrSBrReq*TrainSBrRetMax limited to MaxJerk=4 m/s3

Requirement identification	SB1.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See performance req. 1.1.13.2
Actor	SB1
Input information	MaxJerk

Output information	TrainTrSBrReq

S4R-137 - MaxJerk is the maximum jerk that the retardation of the train shall reach

Requirement identification	SB1.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	MaxJerk

S4R-138 - If SB1 TrainTrSBrReq information is not valid or out of order a major fault shall be set

Requirement identification	SB1.9
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement is linked to next requirements about continuity to guarantee the automatic brake retardation by SB4-SB5 sub-function. BSM reaction to major fault in this case could not be reliable due to un-reliable SB1
Actor	SB1
Input information	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM
Output information	TrainTrSBrReq MajFaultSB1.1

S4R-139 - MajFaultSB1.1 is the fault indicating that it is lost the traction brake request information (continuity lost)

Requirement identification	SB1.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB1
Input information	
Output information	MajFaultSB1.1

S4R-140 - If SB1 ActDir informationis not valid or out of order a major fault shall be set

Requirement identification	SB1.11
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The lost direction have the major impact on traction (traction force inhibition). On brake system makes the roll back protection function out of order. For this reason there is not an automatic brake application by SB4-SB5, but the inhibition of holding brake release by SB7 (see requirement in SB7)
Actor	SB1
Input information	ForwBackDir
Output information	ActDir MajFaultSB1.2

S4R-141 - MajFaultSB1.2 is the fault indicating that it is lost the train direction information ActDir

Requirement identification	SB1.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB1
Input information	

Output information	MajFaultSB1.2

S4R-142 - SB2 shall trasmit the adjustable traction/retardation request and selected direction received by SB1 to other brake system functions and traction system

Requirement identification	SB2.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Continuity requirement. The trasmission to traction and brake of the same request guarantee the consistency of the traction/brake command to the two systems
Actor	SB2
Input information	TrainTrSBrReq ActDir
Output information	TrSBrReq TrainDir

S4R-143 - TrSBrReq is the information TrainTrSBrReq trasmitted along the train

Requirement identification	SB2.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB2
Input information	
Output information	TrSBrReq

S4R-144 - TrainDir is the information ActDir trasmitted along the train

Requirement identification	SB2.3
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB2
Input information	
Output information	TrainDir

S4R-145 - In case TrainTrSBrReq is not valid or out of order a major fault shall be set and TrSbrReq shall be not valid

Requirement identification	SB2.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement provide automatic brake application in case of lost continuity of the brake command (see propagation to SB4 and SB8) BSM reaction to major fault in this case could not be reliable
Actor	SB2
Input information	TrainTrSBrReq
Output information	TrSBrReq MajFaultSB2.1

S4R-146 - MajFaultSB2 is the fault indicating that it is lost the traction brake request information TrainTrSBrReq (continuity lost)

Requirement identification	SB2.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB2
Input information	
Output information	MajFaultSB2.1

S4R-147 - In case TrSBrReq is not valid or out of order a major fault shall be set

Requirement identification	SB2.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB2
Input information	TrainEBrReq
Output information	TrSBrReq MajFaultSB2.1

S4R-148 - MajFaultSB2.2 is the fault indicating that it is lost the traction/service brake request information TrSBrReq (continuity lost)

Requirement identification	SB2.7
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB2
Input information	
Output information	MajFaultSB2.2

S4R-149 - SB3 shall define the train mass and the train equivalent mass information and send them to all brake sub-functions and context systems which need it

Requirement identification	SB3.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	

Actor	SB3
Input information	BogLoad
Output information	TrainMassSB TrainEqMassSB

S4R-150 - BogLoad is the information of the carbody load insisting on the bogies

Requirement identification	SB3.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Bogie
Input information	
Output information	BogLoad

S4R-151 - TrainMassSB is the mass of the complete train defined by service brake

Requirement identification	SB3.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB3.2
Input information	
Output information	TrainMassSB

S4R-152 - TrainEqMassSB is the mass of the train + the rotating mass

Requirement identification	SB3.4
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB3.2
Input information	
Output information	TrainEqMassSB

S4R-153 - SB3.1 shall calculate the load insisting on the bogies by memorizing the bogie load information once that door are closed and locked (passenger in/out finished) and trasmit it to SB3.2

Requirement identification	SB3.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The best moment to measure the bogie load necessary to define the brake force is when the train is in stanstill, ready to leave and no more load variation on it
Actor	SB3.1
Input information	BogLoad
Output information	BogLoadMemSB

S4R-154 - BogLoadMemSB is the BogLoad information recorded by service brake in the moment that the train leave the station

Requirement identification	SB3.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB3.1
Input information	
Output information	BogLoadMemSB

S4R-155 - The bogie technical system shall trasmit continuously the bogie load information to SB3.1 Load acquisition sub-function

Requirement identification	SB3.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The continuous transmission permit to have a permanent diagnostic
Actor	Bogie
Input information	CarLoad
Output information	BogLoad

S4R-156 - The door technical system shall trasmit continuously the Door Closed and Locked information to SB3.1 Load acquisition sub-function

Requirement identification	SB3.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The door closed and locked data is informing the brake system of the end of the passenger transfer in the station, so that the train load cannot change anymore
Actor	Door
Input information	DoorStatus
Output information	DoorClLock

S4R-157 - DoorClLock is the passenger door status Closed and locked: active = closed and locked, not active: not closed and locked

Requirement identification	SB3.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Door
Input information	

Output information	DoorClLock

S4R-158 - SB3.1 shall measure the BogLoad information at any time

Requirement identification	SB3.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Note: the detection of the BogLoad information can be done by any detection device technically speaking (pneumatic or electric). The detection device is considered part of brake sub-system SB3
Actor	SB3.1
Input information	BogLoad
Output information	BogLoadMeasSB

S4R-159 - BogLoadMeasSB is the measured value by service brake of the BogLoad information

Requirement identification	SB3.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB3.1
Input information	
Output information	BogLoadMeasSB

S4R-160 - SB3.1 shall memorize the BogLoadMeasSB information when (Door Closed and Locked data is active OR the TrainSpeed>3 km/h)

Requirement identification	SB3.12
Level	Brake System
Mainfunction	Service Brake
Type	Functional

Rationale	The door closed and locked information is in OR to the train movement to allow to memorize the bogie load also in case of Door closed and Locked information not valid or (exceptional) train movement with door opened
Actor	SB3.1
Input information	BogLoadMeasSB DoorClLock TrainSpeed
Output information	BogLoadMemSB

S4R-161 - When the BogLoadMeasSB information is not valid or is out of tolerance SB3.1 shall set a major fault and fix the BogLoadMemSB information to the value of BogLoadDefSB when the DoorClLock data is no more active or as soon as the train move (speed > 3 km/h).

Requirement identification	SB3.13
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement permit to have always a mass of the train, even if a default one. Note: The dafault mass definition shall be linked to guaranteed perfromance calculation and adhesion constraints
Actor	SB3.1
Input information	BogLoadMeasSB BogLoadDefSB DoorClLock TrainSpeed
Output information	BogLoadMemSB MajFaultSB31

S4R-162 - BogLoadDefSB is the default load insisting on the bogie to be considered in case of not available BogLoadMeasSB information

Requirement identification	SB3.14
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	BogLoadDefSB

S4R-163 - MajFaultSB31 is the fault information indicating that it is lost the BogLoad information (mass information lost)

Requirement identification	SB3.15
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB3.1
Input information	
Output information	MajFaultSB31

S4R-164 - The BogLoad information shall have an accuracy of +x/- y% respect the real load

Requirement identification	SB3.16
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Mass of the train directly impact the train stopping distances and the used adhesion.
Actor	Bogie
Input information	CarLoad
Output information	BogLoad

S4R-165 - CarlLoad is the Load of the car insisting on the bogie

Requirement identification	SB3.17
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	Carbody
Input information	
Output information	CarLoad

S4R-166 - The BogLoadMeasSB information shall have an accuracy of +x/- y% respect the BogLoad information

Requirement identification	SB3.18
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Mass of the train directly impact the train stopping distances and the used adhesion.
Actor	SB3.1
Input information	BogLoad
Output information	BogieLoadMeasSB

S4R-167 - SB3.2 calculate the Train Mass and Train equivalent mass by BogLoadMeasSB information and trasmit them to other brake system sub-functions and systems of brake context which are interested in

Requirement identification	SB3.19
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The train mass and equivalent mass are the information transforming the retardation request into a brake force by SB4
Actor	SB3.2
Input information	BogLoadMemSB
Output information	TrainMassSB TrainEqMassSB

S4R-168 - The train mass shall be derived from Bogie Load adding the mass of the bogies

Requirement identification	SB3.20

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB3.2
Input information	BogLoadMemSB BogieMass
Output information	TrainMassSB

S4R-169 - BogieMass is the mass of the bogies

Requirement identification	SB3.21
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	BogieMass

S4R-170 - The train equivalent mass shall be derived from the train mass adding the translating mass equivalent to rotating mass of the train

Requirement identification	SB3.22
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB3.2
Input information	BogLoadMemSB RotMass BogieMass

Output information	TrainEqMassSB

S4R-171 - RotMass is the translating mass correspondent to the rotating mass of the train

Requirement identification	SB3.23
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	RotMass

S4R-172 - SB4 shall calculate the Train service brake force and the minimum train service brake force and trasmit them to SB5.2 and SB5.1

Requirement identification	SB4.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The train service brake force is the force necessary to obtain the expected retardation with the active brake request by actors and existing equivalent mass. The minimum train service brake force is the force necessary to obtain the minimum train service brake retardation
Actor	SB4
Input information	TrSBrReq TrainMassSB TrackSlopeVal TrainSpeed TrainSBrMaxRet TrainSBrRetMin a,b,c
Output information	TrainSBrForNom

S4R-173 - TrainSBrForNom is the nominal force to be applied by the brake system to the rail to obtain a retardation of the train TrainSBrRetReq

Requirement identification	SB4.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	TrainSBrForNom

S4R-174 - TrainSBrForNomMax is the service brake force that applied to the train on a level track (TrackSlope=0) with nominal runnining resistance force (TrainRunResSB) and actual TrainMassSB generate a TrainSBrRetReq=TrainSBrRetReqMax

Requirement identification	SB4.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	TrainSBrForMax

S4R-175 - The Train service brale force shall be calculated based on retardation request received by SB2, the TrainSBrRetMax, the train mass, the train running resistance, the train speed and, optionally, the slope, as follow:

If braking is not active (TrSBrReq≥0) then TrainSBrForNom=0

If braking is active (TrSBrReq<0) TrainSBrForNom=TrainMassSB*(-TrSBrReq)*TrainSBrRetMax-TrainRunResSB-TrainMassSB*TrackSlopeVal*9,81

Requirement identification	SB4.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See EN14531-1 for brake force calculation

Actor	SB4
Input information	TrSBrReq TrainMassSB TrackSlopeVal TrainSBrRetMax TrainSpeed TrainRunResSB
Output information	TrainSBrForNom

S4R-176 - TrainRunResSB is the force that service brake consider applied by track and aerodynamic forces to the train

Requirement identification	SB4.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainRunResSB

S4R-177 - TrackSlopeVal is the slope of the track indicated in thousandths, positive in uphill, negative in downhill

Requirement identification	SB4.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	ATP
Input information	
Output information	TrackSlopeVal

S4R-178 - If TrSBrReq information is not valid or out of range SB4 shall set the force request to a force correspondent to the request TrSBrReqDef and set a major fault

Requirement identification	SB4.7

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Loss of continuity or train integrity shall cause the application of a predefined brake force. At force application level the loss of SB request signal and the loss of the train integrity is managed at the same way. It is the train level which can be able to have different reactions based on the real situation. Function linked to SB2 req. 1.1.2.1 Note: BSM reaction to major fault could not be reliable in this case due to un-reliable SB1, so the loss of integrity shall be trasmitted till the force generation system EB5.
Actor	SB4
Input information	TrSBrReq TrainMassSB TrackSlopeVal TrSBrReqDef TrainSpeed TrainRunResSB
Output information	MajFaultSB4.1 TrainSBrForNom

S4R-179 - TrSBrReqDef is a default Service brake request to be considered in case of service brake request continuity lost

Requirement identification	SB4.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrSBrReqDef

S4R-180 - MajFaultSB4.1 is is the fault information indicating that it is lost the TrSBrReq information (continuity lost)

Requirement identification	SB4.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	SB4
Input information	
Output information	MajFaultSB4.1

S4R-181 - If the track slope data by ETCS, which is an optional information, is not valid the track slope value shall be set to TrackSlopeValDefPar (=0) and a major fault shall be set

Requirement identification	SB4.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The slope can be responsible of a maximum tolerance on retardation rate of +/- 9,81m/s2*0,040=0,4m/s2. Signalling already consider the slope in defining the stopping distance of the train. The slope is relevenat only in case of closed loop control of train retardation, but this is not a function developed by EDV.
Actor	SB4
Input information	TrackSlopeVal TrackSlopeValDefPar
Output information	MajFaultSB4.2 TrainSBrForNom

S4R-182 - TrackSlopeValDefPar is the dafault value of TrackSlopeVal information in case TrackSlopeVal information is not valid

Requirement identification	SB4.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrackSlopeValDefPar

S4R-183 - MajFaultSB4.2 is is the fault information indicating that it is lost the TrackSlopeVal information

Requirement identification	SB4.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	MajFaultSB4.2

S4R-184 - If the TrainMassSB information is not valid the Train MassSB shall be set to TrainMassDefSB value and a major fault shall be set

Requirement identification	SB4.13
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB4
Input information	TrainMassSB TrainMassDefSB
Output information	MajFaultSB4.3 TrainSBrForNom

S4R-185 - TrainMassDefSB is the default train mass value consistent with the BogLoadDefSB value

Requirement identification	SB4.14
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	TrainMassDefSB

S4R-186 - MajFaultSB4.3 is is the fault information indicating that it is lost the TrainMassSB information

Requirement identification	SB4.15
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	MajFaultSB4.3

S4R-187 - If the TrainSpeed information is not valid the Trainspeed shall be set to TrainSpeedDefSB value and a major fault shall be set

Requirement identification	SB4.16
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB4
Input information	TrainSpeed TrainSpeedDefSB
Output information	MajFaultSB4.4 TrainSBrForNom

S4R-188 - TrainSpeedDefSB is the default speed information to be considered by SB when the TrainSpeed is not available

Requirement identification	SB4.17
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	TrainSpeedDefSB

S4R-189 - MajFaultSB4.4 is is the fault information indicating that it is lost the TrainSpeed information

Requirement identification	SB4.18
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	MajFaultSB4.4

S4R-190 - The train runnig resistance force shall be calculated considering running resistance formula proper of the train: a*TrainMassSB+b*v+c*v2

Requirement identification	SB4.19
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	a,b,c parameter of the train
Actor	SB4
Input information	a,b,c TrainMassSB
Output information	TrainRunResSB

S4R-191 - a,b,c are the parameters of the standard running resistance force formula used to calculate the running resistance force

Requirement identification	SB4.20
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	a, b, c

S4R-192 - The Minimum train service brake force shall be calculated based on the TrainSBrRetMin, the max train mass, the train running resistance, the train speed and, optionally, the slope, as follow:

If braking is not active (TrSBrReq≥0) then TrainSBrForMin=0

If braking is active (TrSBrReq<0) TrainSBrForMin=TrainMassMax*TrainSBrRetMin-a*TrainMassMax+b*v+c*v2-TrainMassMax*TrackSlopeVal*9,81

Requirement identification	SB4.21
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See EN14531-1 for brake force calculation. The minimum force shall considered the worst condition in term of mass and track slope. This is a speed dependent parameter
Actor	SB4
Input information	TrainMassMax TrackSlopeMax TrainSBrRetMin TrainSpeed a,b,c
Output information	TrainSBrForMin

S4R-193 - TrainSBrForMin is the service brake force that applied to the train on a maximum Slope with nominal runnining resistance force (TrainRunResSB), with maximum Train mass generate a TrainSBrRetReq=TrainSBrRetReqMin

Requirement identification	SB4.22
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	TrainSBrForMin

S4R-194 - TrainMassMax is the Maximum train mass possible according dimensioning

Requirement identification	SB4.23
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainMassMax

S4R-195 - TrackSlopeMax is the maximum slope present on the line according contractual requirements

Requirement identification	SB4.24
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrackSlopeMax

S4R-196 - SB5 shall apply a service brake force at the train of the amount of the train service brake force information received by SB4 fulfilling the constraints in terms of:
- force tolerance
- maximum force applicable to different type of brake (dimensioning constraints)
- maximum adhesion

Requirement identification	SB5.1
Level	Brake System

Mainfunction	Service Brake
Type	Functional
Rationale	Note: SB5 is in charge of all type of brakes. Next requirements regards the implementation of SB5 function by adhesion dependent friction brake, and in particular the requirements in charge of EDV. The requirements about other type of brakes or function not in charge of EDV are mentioned only if relevant.
Actor	SB5
Input information	TrainSBrForNom TrainSpeed
Output information	TrainSBrForAppl

S4R-197 - If an emergency brake force request is active (EBrREq active) the train service brake force shall not be applied

Requirement identification	SB5.2
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Emergency brake requirement has priority .
Actor	SB5
Input information	EBrReq
Output information	TrainSBrForAppl

S4R-198 - SB5 shall not generate leakages which can decrease of more than MaxDeltaPressSB per minute the SBrAirSupplPress (without air supply available)

Requirement identification	SB5.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	To guarantee inexhaustibility during the 2 hours of immobilization (see perfromance requirement)
Actor	SB5
Input information	MaxDeltaPressSB SBrAirSupplPress

Output information	SB5AirSupplLeak

S4R-199 - AdDepDynSBrAirSupplPress is the air supply pressure of the Adhesion dependent dynamic service brake

Requirement identification	SB5.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	AdDepDynSBrAirSupplPress

S4R-200 - AdIndDynSBrAirSupplPress is the air supply pressure of the Adhesion independent dynamic service brake

Requirement identification	SB5.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	AdIndDynSBrAirSupplPress

S4R-201 - AdDepFrSBrAirSupplPress is the air supply pressure of the Adhesion dependent friction service brake

Requirement identification	SB5.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	SB5
Input information	
Output information	AdDepFrSBrAirSupplPress

S4R-202 - AdDepDynSBrAirCons is the air supply consumption of the Adhesion dependent dynamic service brake

Requirement identification	SB5.7
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	AdDepDynSBrAirCons

S4R-203 - AdIndDynSBrAirCons is the air supply consumption of the Adhesion independent dynamic service brake

Requirement identification	SB5.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	AdIndDynSBrAirCons

S4R-204 - AdDepFrSBrAirCons is the air supply consumption of the Adhesion dependent friction service brake

Requirement identification	SB5.9
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	AdDepFrSBrAirCons

S4R-205 - SB5AirSupplLeak are the leakages of the pneumatic system distributing pneumatic energy necessary to apply theservice brake force

Requirement identification	SB5.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5
Input information	
Output information	SB5AirSupplLeak

S4R-206 - SB5.1. 2.1 shall define the adhesion dependent friction brake force availability by elaborating the isolation status infomation, the remote release information, the dimensioning constraints (ie max force), the actual dissipation capacity (optional, depending from temperature detected by dissipation functions) and the train speed received by Odometry

AdDepFrSBrAvFor(v, temp)= AdDepFrBrForMax(v, temp)-(AdDepFrSBrIsolStatus+ AdDepFrSBrREmRelStatus);

Requirement identification	SB5.1.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The status information is obtained by the 2 function able to isolate the SB: SB10.3 (permanent isolation) and BSM2.1.1 (remote release). The dimensioning constraint is a parameter (see req. 1.0.2) , speed and/or dissipation temperature dependent . The temperature of the dissipation unit is an optional information which could help in optimizing the LCC (if the temperatura is too high the adhesion dependent friction service brake force can be limited but not the emergency and the driver can be invited to have a more smooth way of driving). The adhesion constraints are not considered atthis stage because they shall be considered once that blending with adhesion dependent dynamic brake is defined.

Actor	SB5.1.2.1
Input information	AdDepFrSBrIsolStatus AdDepFrSBrREmRelStatus AdDepFrBrForMax TrainSpeed AdDepFrSBrDissTempMeas
Output information	AdDepFrSBrAvFor

S4R-207 - AdDepFrSBrAvFor is the adhesion dependent friction service brake force that is available on the train for application to the track.

Requirement identification	SB5.1.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.2.1
Input information	
Output information	AdDepFrSBrAvFor

S4R-208 - The adhesion dependent available forces (friction+dynamic) shall guarantee the TrainSBrForMin in case of -100% of TrSBrReq

TrainSBrForMin(v)=AdDepSBrForMin(v)= AdDepFrSBrForMin(v)+AdDepDynSBrForMin(v)

Requirement identification	SB5.1.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement is derived by the fact that the adhesion dependent brake are the type of brake which are always present on the train. In principle if adhesion independent brake is available on the train it can contribute, but certain speed reduction could be necessary by different train on the same portion of the track, so it could be necessary that it shall be inhibited to avoid track heating up. In such a case the minimum force shall be guaranteed only by adhesion dependent forces.
Actor	SB5.1.2.1
Input information	TrainSBrForMin

Output information	AdDepSBrForMin

S4R-209 - AdDepSBrForMin is the minimum force that shall be available to be applied at the track by adhesion dependent brake forces (dynamic and friction brake forces applied together according blending rules)

Requirement identification	SB5.1.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.2.1
Input information	
Output information	AdDepSBrForMin

S4R-210 - The minimum adhesion dependent friction service brake force is TrainSBrForMin(v)= AdDepSBrForMin(v)-AdDepDynSBrForMin(v)

Requirement identification	SB5.1.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The minimum friction service brake force is dependent from the minimum guaranteed dynamic service brake force to be coherent with the blending rules, which use the friction brake as complementary to the dynamic one. The minimum adhesion dependent dynamic brake force is received by SB5.1.1.1 (it could be also equal to 0). It is what is always guaranteed by adhesion dependent dynamic brake
Actor	SB5.1.2.1
Input information	AdDepDynSBrForMin TrainSBrForMin
Output information	AdDepFrSBrForMin

S4R-211 - AdDepDynSBrForMin is the minimum force applied at the track that is **guaranteed** by adhesion dependent dynamic brake.It depends from dimensioning and isolation active on adhesion dependent dynamic brake. (It is different from AdDepDynSBrAvFor, which is the total available force, guaranteed + not guaranteed)

Requirement identification	SB5.1.6
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	This information depends from the design of the adhesion dependent dynamic brake: if a portion of the force is safe enough, the value can be > 0. If the force application is not safe enough the value is 0.
Actor	SB5.1.1.1
Input information	
Output information	AdDepDynSBrForMin

S4R-212 - AdDepFrSBrForMin is the minimum force at the track that shall be available by adhesion dependent friction brake (for friction brake available and guaranteed is the same).

Requirement identification	SB5.1.7
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.2.1
Input information	
Output information	AdDepFrSBrForMin

S4R-213 - If the available adhesion dependent friction service brake force is lower of the minimum friction service brake force, SB5.1.2.1 shall consider available the minimum force and set a major fault

Requirement identification	SB5.1.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The train during the operation should not reach the minimal condition to run. It is up to BSM to define the reaction to this condition, there is not any automatic emergency brake application by SB.
Actor	SB5.1.2.1
Input information	AdDepFrSBrAvFor AdDepFrSBrForMin

Output information	MajFaultSB5121

S4R-214 - MajFaultSB5121 is the fault information indicating that the service brake cannot guarantee the minimum service brake retardation necessary for the operation

Requirement identification	SB5.1.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.2.1
Input information	
Output information	MajFaultSB5121

S4R-215 - If the AdDepFrSBrAirSupplPress < AdDepFrSBrAirSupplPressMin the Availability shall be set to 0

Requirement identification	SB5.1.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Inexhaustibility requirement
Actor	SB5.1.2.1
Input information	AdDepFrSBrAirSupplPress AdDepFrSBrAirSupplPressMin
Output information	AdDepFrSBrAvFor

S4R-216 - SB5.2.shall define the nominal forces of different type of brakes as result of blending logic giving priority to regenerative dynamic brake first, not regenerative dynamic brake second and adhesion dependent friction brake (using consumable parts) last one, providing the missing brake force.

Requirement identification	SB5.2.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional

Rationale	The Adhesion independent friction brake force is not considered in analogy to the conventional solution. The proposed blending logic maximize the use of regenerative brake and the use of wearless brake types (Dynamic brakes), to reduce the LCC. It has the inconvenient of possible warmimg up of the rails due to the higher priority given to adhesion independent dynamic brake respect friction brake (for example when all trains are braking in the same part of the line, ie before the station). Note1: different blending rules can be possible. Here only one is considered, but could be a further functionality to provide the possibility for the driver to change the blending rules, as suggested by EN16185 §5.9.1 Note2:SB5.2 provide for all type of brakes the expected force to be applied taking in account already of the limitations by availability and adhesion (that's why the output has the extension Ltd). For this reason it is not sure that the total force is equal to the TrainSBrForNom Note3: Blending logics can be managed by a central function controlling all type of brakes or by functions controlling each type of brake implementing the same blending logic to have coherent force distribution. Here below the second option is considered: ED brake, Friction brake, EC Brake have independent coherent blending logic installed in their controller and exchange information to guarantee the consistency.
Actor	SB5.2
Input information	TrainSBrForNom AdDepDynSBrAvFor AdIndDynSBrAvFor AdDepFrSBrAvFor
Output information	AdDepDynSBrForNomLtd AdIndDynSBrForNomLtd AdDepFrSBrForNomLtd

S4R-217 - AdDepDynSBrAvFor is the adhesion dependent dynamic brake force available on the train, which can be applied to the track

Requirement identification	SB5.2.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.1.1
Input information	
Output information	AdDepDynSBrAvFor

S4R-218 - AdIndDynSBrAvFor is the adhesion independent dynamic brake force available on the train, which can be applied to the track

Requirement identification	SB5.2.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.1.1.2
Input information	
Output information	AdIndDynSBrAvFor

S4R-219 - AdDepDynSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent dynamic brake to apply the TrainSBrForNom .

Requirement identification	SB5.2.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.2.1.1
Input information	
Output information	AdDepDynSBrForNomLtd

S4R-220 - AdIndDynSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent dynamic brake to apply the TrainSBrForNom .

Requirement identification	SB5.2.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.2.1.2
Input information	

Output information	AdIndDynSBrForNomLtd

S4R-221 - AdDepFrSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent friction brake to apply the TrainSBrForNom .

Requirement identification	SB5.2.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.2.2.1
Input information	
Output information	AdDepFrSBrForNomLtd

S4R-222 - SB5.2.1.1 shall calculate the adhesion dependent dynamic brake nominal force as the minimum between the train service brake force requested by SB4, the constraints of force availability of adhesion dependent dynamic brake and adhesion limits.

AdDepDynSBrForNomLtd= min(AdMaxVal(v)*(TrainMassSB)*9,81; AdDepDynSBrAvFor(v); TrainSBrForNom)

Requirement identification	SB5.2.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Derived from above blending logic, availability and adhesion limitation
Actor	SB5.2.1.1
Input information	TrainSBrForNom AdDepDynSBrAvFor AdMaxVal TrainMassSB
Output information	AdDepDynSBrForNomLtd

S4R-223 - AdMaxVal is the maximum available adhesion between wheel and rail. It can be speed dependent and also train configuration dependent. It can be the value indicated in TSI or contractual or project constraint

Requirement identification	SB5.2.8

Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdMaxVal

S4R-224 - SB5.2.1.2 shall calculate the adhesion independent dynamic brake nominal force as the minimum between (TrainSBrForNom- AdDepDynSBrForNomLtd) and the constraints of force availability.

AdIndDynSBrForNomLtd= min((TrainSBrForNom- AdDepDynSBrForNomLtd); AdIndDynSBrAvFor(v))

Requirement identification	SB5.2.9
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Derived from blending logic and availability limitation
Actor	SB5.2.1.2
Input information	TrainSBrForNom AdDepDynSBrForNomLtd AdIndDynSBrAvFor
Output information	AdIndDynSBrForNomLtd

S4R-225 - SB5.2.2.1 shall calculate the adhesion dependent friction service brake nominal force by the following formula: AdDepFrSBrForNomLtd=min(TrainSBrForNom-(AdDepDynSBrForNomLtd+AdIndDynSBrForNomLtd); AdDepFrSBrAvFor; (AdMaxVal(v)*(TrainMassSB)*9,81-AdDepDynSBrForNomLtd))

Requirement identification	SB5.2.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Derived from blending logic and availability and adhesion limitation.

Actor	SB5.2.2.1
Input information	TrainSBrForNom AdDepDynSBrForNomLtd AdIndDynSBrForNomLtd AdMaxVal TrainMassSB AdDepFrSBrAvFor
Output information	AdDepFrSBrForNomLtd

S4R-226 - If the TrainSBrForNom received by SB4 is not valid the AdDepDynSBrForLtd shall be not valid

Requirement identification	SB5.2.12
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Propagation of the integrity/continuity loss information
Actor	SB5.2.1.1
Input information	TrainSBrForNom
Output information	AdDepDynSBrNomFor

S4R-227 - If the TrainSBrForNom received by SB4 is not valid the AdDepFrSBrForLtd shall be not valid

Requirement identification	SB5.2.13
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Propagation of the integrity/continuity loss information
Actor	SB5.2.1.2
Input information	TrainSBrForNom
Output information	AdIndDynSBrNomFor

S4R-228 - SB5.3.2.1 shall generate an adhesion dependent friction service brake force request to SB5.5.2.1 , the service brake enabled status, taking in account the nominal force by SB5.2.2.1, real time blending with achieved adhesion dependent dynamic brake force (received by SB5.4), holding brake request by SB7

Requirement identification	SB5.3.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	.
Actor	SB5.3.2.1
Input information	SBrEnabled SBrDisFor AdDepFrSBrForNom AdDepDynSBrForNomLtd HBReq MaxSlope TrainMassSB TrSBrReq AdDepDynSBrAchFor
Output information	AdDepFrSBrForReqLtd

S4R-229 - SBrDisFor is the force that shall be requested to be applied by the adhesion dependent friction service brake when the service brake is disabled.

Requirement identification	SB5.3.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrDisFor

S4R-230 - AdDepFrSBrForReqLtd is the force to be requested to to be applied by the adhesion dependent friction service brake force generation function SB5.5.2.1.

Requirement identification	SB5.3.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	SB5.3.2.1
Input information	
Output information	AdDepFrSBrForReqLtd

S4R-231 **-** When the Service brake system is disabled SB5.3.2.1 shall set a predefined force request: AdDepFrSBrForReqLtd=SBrDisFor

Requirement identification	SB5.3.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	There are not constraint on predefined force because the immobilisation of a train with disabled service brake is in charge of Parking brake
Actor	SB5.3.2.1
Input information	SBrEnabled SBrDisFor
Output information	AdDepFrSBrForReqLtd

S4R-232 **-** When the Service brake system is enabled, SB5.3.2.1 shall calculate the requested adhesion dependent friction SB force taking in account the nominal force by SB5.2.2.1 , real time blending with achieved dynamic brake force (received by SB5.4) and the holding brake request

Requirement identification	SB5.3.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The adhesion dependent friction brake force is the back-up brake of adhesion dependent dynamic brake to guarantee the performances also in case of adhesion dependent dynamic brake failure
Actor	SB5.3.2.1
Input information	SBrEnabled AdDepFrSBrForNomLtd AdDepDynSBrForNomLtd AdIndDynSBForNomLtd AdDepDynSBrAchFor AdDepDynTractAchFor HBReq

Output information	AdDepFrSBrForReqLtd

S4R-233 - When the Service brake system is enabled, if the holding brake request is not active, the adhesione dependent friction brake requested force shall be: AdDepFrSBrForReqLtd=min(AdDepFrSBrForNomLtd+(AdDepDynSBrForNomLtd-AdDepDynSBrAchFor));

Requirement identification	SB5.3.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	See above req. 1.1.5.3.2
Actor	SB5.3.2.1
Input information	SBrEnabled AdDepFrSBrForNomLtd AdDepDynSBrForNomLtd AdDepDynSBrAchFor AdIndDynSBrForNomLtd HBReq
Output information	AdDepFrSBrForReqLtd

S4R-234 - When the Service brake system is enabled, if the holding brake request is active, the adhesione dependent friction brake requested force shall be :
If TrSBrReq≤0: AdDepFrSBrForReqLtd=min(k*TrainMassMax*MaxSlope*9,81; AdDepFrSBrAvFor; AdMaxVal*TrainMassSB*9,81)

If TrSBrReq>0: AdDepFrSBrForReqLtd=min(k*TrainMassMax*MaxSlope*9,81; AdDepFrSBrAvFor; AdMaxVal*TrainMassSB*9,81)-AdDepDynTractAchFor

Requirement identification	SB5.3.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The holding brake force is defined by the worst situation of mass and slope. The "k" safety coefficient is considered . The removal of holding brake is done ramping it with the real traction force measured via SB5.4 function (by TORQ device). Note: The check that the expected holding brake force is achieved once that the adhesion and availability limitations are introduced is done by SB7 sub-function
Actor	SB5.3.2.1

Input information	SBrEnabled TrSBrReq MaxSlope TrainMassSB TrainMassMax HBReq AdDEpDynSBrAchFor AdDEpDynTractAchFor K
Output information	AdDepFrSBrForReqLtd

S4R-235 - "k" is the safety coefficient considered in defining the adhesion dependent frictio brake force to be applied by holding brake function to immobilize the train on the maximum slope with maximum train mass

Requirement identification	SB5.3.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	k

S4R-236 - If the Train friction SB requested force is < then the minimum expected one a major fault shall be activated

If AdDepDynSBrAchFor+AdIndDynSBrForReqLtd+AdDepFrSBrForReqLtd < TrSBrReq*TrainSBrForMin
a major fault shall be set.

Requirement identification	SB5.3.9
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement is the final check that the sum of the requested/applied forces to all type of brakes achieve the minimum target given by SB4. This check is atrributed to adhesion dependent friction brake because is the last type of brake in the blending chain.
Actor	SB5.3.2.1
Input information	AdDepFrSBrForReqLtd AdDepDynSBrAchFor AdIndDynSBrForReqLtd TrainSBrForNom

Output information	MajFaultSB5321.1

S4R-237 - MajFaultSB5321 is the fault information that the service brake is not able to apply the minimum force acceptable for operation

Requirement identification	SB5.3.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.3.2.1
Input information	
Output information	MajFaultSB5321.1

S4R-238 - AdIndDynSBrForReqLtd is the force to be requested to the adhesion independent dynamic service brake force generation function SB5.5.1.2

Requirement identification	SB5.3.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.3.1.2
Input information	
Output information	AdIndDynSBrForReqLtd

S4R-239 - If AdDepDynSBrAchFor is not valid the AdDepFrSBrForReqLtd shall be set to the value AdDepFrSBrForNom and a major fault shall be set

Requirement identification	SB5.3.12
Level	Brake System
Mainfunction	Service Brake
Type	Functional

Rationale	
Actor	SB5.3.1.1
Input information	AdDepDynSBrAchFor
Output information	AdDepFrSBrForReqLtd MajFaultSB5321.2

S4R-240 - MajFaultSB5321.2 is the fault information of AdDepDynSBrAchFor information not valid

Requirement identification	SB5.3.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.3.1.1
Input information	
Output information	MajFaultSB5321.2

S4R-241 - SB5.4 shall measure the really applied traction and braking force applied by traction and adhesion dependent dynamicbrake and trasmit it to SB5.3

Requirement identification	SB5.4.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This requirement is a consequence of the blending logic defined in SB5. This functionality is introduced becuase it is supposed that SB5.1.1.1 is not able to provide a safe information of the available ashesion dependent dynamic brake
Actor	SB5.4
Input information	WheelTorq
Output information	AdDepDynTractAchFor AdDepDynSBrAchFor

S4R-242 - The adhesion dependent dynamic brake shall provide the information of the really applied braking force and trasmit it to SB5.3.2.1

Requirement identification	SB5.4.2
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	TORQ device mentioned in D5.1
Actor	SB5.4
Input information	WheelTorq
Output information	AdDepDynSBrAchFor

S4R-243 - The adhesion dependent dynamic brake shall provide the information of the really applied traction force and trasmit it to SB5.3.2.1

Requirement identification	SB5.4.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	TORQ device mentioned in D5.1
Actor	SB5.4
Input information	WheelTorq
Output information	AdDepDynTractAchFor

S4R-244 - WheelTorq is the the torque applied to the bogieapplying the traction force or the adhesion dependent dynamic brake force to the track

Requirement identification	SB5.4.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.1.1.2
Input information	

Output information	WheelTorq

S4R-245 - AdDepDynSBrAchFor is the value of the force applied at the track by the adhesion dependent dynamic brake

Requirement identification	SB5.4.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.4
Input information	
Output information	AdDepDynSBrAchFor

S4R-246 - AdDepDynTractAchFor is the information providing the force applied at the track by the traction

Requirement identification	SB5.4.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.4
Input information	
Output information	AdDepDynTractAchFor

S4R-247 - SB5.5.2.1.1 shall generate an adhesion dependent friction brake force pilot command piloting, by SB5.5.2.1.2, a force application at the track equal to the force request by SB5.3.2.1 (rotating mass to be considered)

Requirement identification	SB5.5.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This function shall take in care to consider in the pilot also the rotating mass braking force necessary to apply at the track the requested force

Actor	SB5.5.2.1.1
Input information	AdDepFrSBrForReqLtd RotMass
Output information	AdDEpFrSBrPilCom

S4R-248 - AdDEpFrSBrPilCom is the pilot command applying an adhesion dependent friction brake force to the track equal to the requested force AdDepFrSBrForReqLtd

Requirement identification	SB5.5.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	AdDEpFrSBrPilCom

S4R-249 - SB5.5.2.1 .1 shall monitor the real adhesion dependent friction brake force applied

Requirement identification	SB5.5.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Monitoring is fundamental for control/diagnosys of the whole force generation process and precision of the force generated (closed loop control).
Actor	SB5.5.2.1.1.
Input information	AdDepFrSBrForAppl
Output information	AdDepFrSBrForApplMeas

S4R-250 - AdDepFrSBrForApplMeas is the information of the adhesion dependent friction service brake force applied at the track

Requirement identification	SB5.5.4
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1.
Input information	
Output information	AdDepFrSBrForApplMeas

S4R-251 - SB5.5.2.1.2 shall apply an adhesion dependent friction brake force to the track proportional to the pilot command trasmitted by SB5.5.2.1.1 and eventually reduced by LAM1.2.1

Requirement identification	SB5.5.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB5.5.2.1.2
Input information	AdDEpFrSBrPilComLAM
Output information	AdDepFrSBrForAppl

S4R-252 - AdDEpFrSBrPilComLAM is the pilot command,conditioned by the LAM1.2.1 function, provided to the adhesion dependent friction brake actuation function SB5.5.2.1.2

Requirement identification	SB5.5.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	LAM1.2.1
Input information	
Output information	AdDEpFrSBrPilComLAM

S4R-253 - The holding brake force applied shall guarantee the brake force application for at least 2 hours

Requirement identification	SB5.5.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB
Input information	AdDepFrSBrForReqLtd AdDepFrSBrPilCom AdDepFrSBrPilComLAM
Output information	TrainSBrForAppl

S4R-254 - SB5.5.2.1.1 shall monitor the adhesion dependent friction SB air supply pressure and trasmit the pressure value to diagnostic system

Requirement identification	SB5.5.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB5.5.2.1.1
Input information	AdDEpFrSBrAirSupplPress
Output information	AdDEpFrSBrAirSupplMeas

S4R-255 - AdDepFrSBrAirSupplMeas is the information of the pressure of the air supply to the adhesion independent friction service brake

Requirement identification	SB5.5.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	

Output information	AdDepFrSBrAirSupplMeas

S4R-256 - If the AdDepFrSBrAirSupplPress is below the dimensioning limit AdDepFrSBrAirSupplPressMin, SB5.5.2.1.1 shall set major fault

Requirement identification	SB5.5.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Inexhaustibility requirement for the friction service brake. BSM shall manage it at train level.
Actor	SB5.5.2.1.1
Input information	AdDepFrSBrAirSupplMeas AdDepFrSBrAirSupplPressMin
Output information	MajFaultSB55211.1

S4R-257 - MajFaultSB55211.1 is the fault information of adhesion dependent friction service brake supply pressure below the minimum limit AdDepFrSBrAirSupplPressMin

Requirement identification	SB5.5.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	MajFaultSB55211.1

S4R-258 - SB5.5.2.1.1 shall monitor the Electric Voltage to adhesion dependent friction service brake

Requirement identification	SB5.5.12
Level	Brake System

Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB5.5.2.1.1.
Input information	AdDepFrSBrElVolt
Output information	AdDepFrSBrElVoltMeas

S4R-259 - AdDepFrSBrElVoltMeas is the information of the voltage of the electric supply to the adhesion independent friction service brake

Requirement identification	SB5.5.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	AdDepFrSBrAirSupplMeas

S4R-260 - If the electric voltage to SB5 is below the AdDepFrSBrElVoltMin or is lost, SB5.5.2.1.1 shall apply automatically a default pilot command and a major fault shall be set

Requirement identification	SB5.5.14
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The safe state for SB5 is brake application. In such a case the adhesion could be higher than allowed . In any case major fault is generated and BSM2.1.1 is able to release the braking by remote release if considered safe
Actor	SB5.5.2.1.1.
Input information	AdDepFrSBrElVoltMeas AdDepFrSBrElVoltMin AdDepFrSBrPilCommEnOff

Output information	AdDEpFrSBrPilCom MajFaultSB55211.2

S4R-261 - AdDepFrSBrPilCommEnOff is the Default pilot command to be applied in case of electric energy off or below the minimum value

Requirement identification	SB5.5.15
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1.
Input information	
Output information	AdDepFrSBrPilCommEnOff

S4R-262 - MajFaultSB55211.2 is the fault information that the electric voltage is below the minimum AdDepFrSBrElVoltMin or is lost

Requirement identification	SB5.5.16
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1.
Input information	
Output information	MajFaultSB55211.2

S4R-263 - If the adhesion dependent friction brake force measured is out of regulation tolerance SB5.5.2.1.1 shall generate a minor fault

Requirement identification	SB5.5.17
Level	Brake System
Mainfunction	Service Brake

Type	Functional
Rationale	The regulation tolerance is the one taking care of the accuracy of the brake force. The consistency of the force application with the dimensioning constraints is guaranteed by the other requirements considering the maximum or minimum forces
Actor	SB5.5.2.1.1
Input information	AdDEpFrSBrForApplMeas AdDepFrSBrForReqLtd AdDepFrSBrForTol
Output information	MinFaultSB55211.1

S4R-264 - AdDepFrSBrForTol is the upper and lower regulation tolerance of the adhesion dependent friction service brake force

Requirement identification	SB5.5.18
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrForTol

S4R-265 - MinFaultSB55211.1 is the fault information of adhesion dependent friction service brake force out of regulation tolerance

Requirement identification	SB5.5.19
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	MinFaultSB55211.1

S4R-266 - If the adhesion dependent friction brake force measured is higher then the maximum allowed force for SB5.5.2.1.2, a major fault shall be set by SB5.5.2.1.1

Requirement identification	SB5.5.20
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Exceeded dimensioning constraints
Actor	SB5.5.2.1.1
Input information	AdDEpFrSBrForApplMeas AdDepFrSBrForMax
Output information	MajFaultSB55211.3

S4R-267 - MajFaultSB55211.3 is the fault information of adhesion dependent friction service brake force above the maximum value AdDepFrSBrForMax

Requirement identification	SB5.5.21
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	MajFaultSB55211.3

S4R-268 - If the adhesion dependent friction brake force applied measured is lower then AdDEpFrSBrForReqLtd of a value higher then AdDepFrSBrForMaxTol a major fault shall be set

Requirement identification	SB5.5.22
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	consistency check between the requested and the applied force
Actor	SB5.5.2.1.1

Input information	AdDepFrSBrForMaxTol AdDEpFrSBrForReqLtd AdDEpFrSBrForApplMeas
Output information	MajFaultSB55211.4

S4R-269 - MajFaultSB55211.4 is the fault information of adhesion dependent friction service brake force applied is lower than requested of a value higher than AdDepFrSBrForMaxTol

Requirement identification	SB5.5.23
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	MajFaultSB55211.4

S4R-270 - AdDepFrSBrForMaxTol is the maximu lower tolerance acceptable for Adhesion dependent friction service brake force

Requirement identification	SB5.5.24
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrForMaxTol

S4R-271 - If speed is > 3 km/h and the adhesion dependent friction brake force measured is >0 and the there is not a Adhesion dependent friction service brake request (taking in account a delay related to releasing time), a major fault shall be set by SB5.5.2.1.1

Requirement identification	SB5.5.25
Level	Brake System

Mainfunction	Service Brake
Type	Functional
Rationale	Dragging brake condition
Actor	SB5.5.2.1.1
Input information	TrainSpeed AdDEpFrSBrForApplMeas AdDepFrSBrForReqLtd
Output information	MajFaultSB55211.5

S4R-272 - MajFaultSB55211.5 is the fault information of adhesion dependent friction service brake force applied when not requested (dragging brake)

Requirement identification	SB5.5.26
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB5.5.2.1.1
Input information	
Output information	MajFaultSB55211.5

S4R-273 - SB6.1 shall provide to SB the pneumatic energy to permit the correct regulation of service brake force by type of brakes using pneumatic energy

Requirement identification	SB6.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB6.1
Input information	AirSupplPress BrAirSupplDel

Output information	SBrAirSupplPress SBrAirSupplDel

S4R-274 - AirSupplPress is the pressure of the air supply providing pneumatic energy to the brake system

Requirement identification	SB6.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB11.3
Input information	
Output information	AirSupplPress

S4R-275 - BrAirSupplDel is the air delivery to the brake system

Requirement identification	SB6.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB11.3
Input information	
Output information	BrAirSupplDel

S4R-276 - SBrAirSupplPress is the pressure of the air supply providing pneumatic energy to service brake

Requirement identification	SB6.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	SB6.1
Input information	
Output information	SBrAirSupplPress

S4R-277 - SBrAirSupplDel is the air delivery to the service brake functions

Requirement identification	SB6.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB6.1
Input information	
Output information	SBrAirSupplDel

S4R-278 - SB6.1 shall limit the pneumatic pressure to the maximum permitted by SB5 dimensioning limits and shall provide an air delivery congruent with the air consumption of all types of brakes (taking care of WSPintervention as well)

Requirement identification	SB6.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Dimensioning constraint on different types of brakes. Note: this function can be done by any air pressure regulator limiting the supply pressure to EDV
Actor	SB6.1
Input information	AdDepDynSBrAirSupplPressMax AdIndDynSBrAirSupplPressMax AdDepFrSBrAirSupplPressMax AdDepDynSBrAirConsMax AdIndDynSBrAirConsMax AdDepFrSBrAirConsMax
Output information	SBrAirSupplPressMax SBrAirDelMin SBrAirDelMax

S4R-279 - The SB6.1 minimum pressure and SB6.1 store volume shall guarantee the application for at least x≥ 2 time of the TrainSBrForMin without air supply function SB11.3 available.

Requirement identification	SB6.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Inexhaustibility requirement. The number of time to be defined with customer
Actor	SB6.1
Input information	AdDepDynSBrAirSupplPressMin AdIndDynSBrAirSupplPressMin AdDepFrSBrAirSupplPressMin AdDepDynSBrAirConsMax AdIndDynSBrAirConsMax AdDepFrSBrAirConsMax TrainSBrForMin SBrAirSupplPressMin SBrAirSupplStoreVol
Output information	AdDEpFrSBrAirSuppl

S4R-280 - SB6.1 leakages and store capacity shall guarantee that the supply pressure doesn't decrease of more than MaxDeltaPressSB/min due to leakages (without air supply available)

Requirement identification	SB6.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	To guarantee inexhaustibility during the 2 hour of immobilization (see perfromance requirement) Requirement connected with SB5 req. 1.1.6.1.7
Actor	SB6.1
Input information	MaxDeltaPressSB SBrAirSupplStoreVol
Output information	SB6AirSupplLeak

S4R-281 - SBrAirSupplPressMax is the max pressure of the service brake air supply

Requirement identification	SB6.9
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrAirSupplPressMax

S4R-282 - SBrAirSupplPressMin is the minimum pressure of the service brake air supply

Requirement identification	SB6.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrAirSupplPressMin

S4R-283 - SBrAirDelMax is the maximum air delivery of the service brake air supply which guarantee correct functionalities

Requirement identification	SB6.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrAirDelMax

S4R-284 - SBrAirDelMin is the minimum air delivery of the service brake air supply which guarantee correct functionalities

Requirement identification	SB6.12

Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrAirDelMin

S4R-285 - SBrAirSupplStoreVol is the volume of the service brake supply air store

Requirement identification	SB6.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrAirSupplStoreVol

S4R-286 - SB6AirSupplLeak are the air leakages produced by SB6

Requirement identification	SB6.14
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB6.1
Input information	
Output information	SB6AirSupplLeak

S4R-287 - AdDepDynSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent dynamic service brake permitted by dimensioning

Requirement identification	SB6.15
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrAirSupplPressMax

S4R-288 - AdIndDynSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion independent dynamic service brake permitted by dimensioning

Requirement identification	SB6.16
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrAirSupplPressMax

S4R-289 - AdDepFrSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent friction service brake permitted by dimensioning

Requirement identification	SB6.17
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning

Input information	
Output information	AdDepFrSBrAirSupplPressMax

S4R-290 - AdDepDynSBrAirConsMax is the maximum air supply consumption of the Adhesion dependent dynamic service brake considered by dimensioning

Requirement identification	SB6.18
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrAirConsMax

S4R-291 - AdIndDynSBrAirConsMax is the maximum air supply consumption of the Adhesion independent dynamic service brake considered by dimensioning

Requirement identification	SB6.19
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrAirConsMax

S4R-292 - AdDepFrSBrAirConsMax is the maximum air supply consumption of the Adhesion dependent friction service brake considered by dimensioning

Requirement identification	SB6.20
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrAirConsMax

S4R-293 - AdDepDynSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent dynamic service brake permitted by dimensioning

Requirement identification	SB6.21
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrAirSupplPressMin

S4R-294 - AdIndDynSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion independent dynamic service brake permitted by dimensioning

Requirement identification	SB6.22
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrAirSupplPressMin

S4R-295 - AdDepFrSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction service brake permitted by dimensioning

Requirement identification	SB6.23
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrAirSupplPressMin

S4R-296 - MaxDeltaPressSB is the maximum acceptable decrease per minute of service brake supply pressure SBrAirSupplPress

Requirement identification	SB6.24
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	MaxDeltaPressSB

S4R-297 - SB6.2 shall provide to SB the electric energy to permit the correct regulation of service brake force by type of brakes using electric energy

Requirement identification	SB6.25
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	SBrElVoltMax SBrElCurrMax
Actor	SB6.2
Input information	ElVolt BrElCurr AdDepDynSBrElVoltNom

	AdIndDynSBrElVoltNom AdDepFrSBrElVoltNom AdDepDynSBrElCurrNom AdIndDynSBrElCurrNom AdDepFrSBrElCurrNom
Output information	SBrElVolt SBrElCurr

S4R-298 - SB6.2 shall limit the electric energy voltage to the maximum permitted by SB dimensioning limits

Requirement identification	SB6.26
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Dimensioning constraint
Actor	SB6.2
Input information	AdDepDynSBrElVoltMax AdIndDynSBrElVoltMax AdDepFrSBrElVoltMax AdDepDynSBrElCurrMax AdIndDynSBrElCurrMax AdDepFrSBrElCurrMax
Output information	SBrElVoltMax SBrElCurrMax SBrElCurrMin

S4R-299 - SB6.2 shall provide the necessary el energy to SB to apply the minimum force applicable by all the type of brake using electric energy even in case of missing supply of energy by SB11.2 and guarantee the maximum brake application time

Requirement identification	SB6.27
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Dimensioning constraint
Actor	SB6.2
Input information	AdDepDynSBrElVoltMin AdIndDynSBrElVoltMin AdDepFrSBrElVoltMin

Output information	SBrElVoltMin

S4R-300 - The minimum voltage and energy storing capacity shall guarantee the supply for at least x> 2h of holding brake force without low Voltage electric energy supply function SB11.2 available

Requirement identification	SB6.28
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Inexhaustibility.
Actor	SB6.2
Input information	SBrElVoltMin ElEnStoreCap
Output information	SBrElVolt SBrElCurr

S4R-301 - ElVolt is the voltage of the electric energy supply to the brake system

Requirement identification	SB6.29
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Electric Energy Supply
Input information	
Output information	ElVolt

S4R-302 - BrElCurr is the electric current supplied to the brake system

Requirement identification	SB6.30
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	Electric Energy Supply
Input information	
Output information	BrElCurr

S4R-303 - SBrElVolt is the voltage of the electric energy supply to the service brake system

Requirement identification	SB6.31
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB11.2
Input information	
Output information	SBrElVolt

S4R-304 - SBElCurr is the electric current supplied to the service brake system

Requirement identification	SB6.32
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB11.2
Input information	
Output information	SBElCurr

S4R-305 - SBrElVoltMax is the maximum voltage by which SBr system can be supplied according dimensioning

Requirement identification	SB6.33
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrElVoltMax

S4R-306 - SBrElVoltMin is the minimum voltage by which SB system guarantee the functionalities

Requirement identification	SB6.34
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrElVoltMin

S4R-307 - SBrElCurrMax is the maximum current by which SBr system can be supplied according dimensioning

Requirement identification	SB6.35
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrElCurrMax

S4R-308 - SBrElCurrMin is the minimum current which guarantee correct functionalities of the service brake

Requirement identification	SB6.36
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	SBrElCurrMax

S4R-309 - ElEnStoreCap is the electric energy storing capacity of the electric energy store

Requirement identification	SB6.37
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	ElEnStoreCap

S4R-310 - AdDepDynSBrElVoltNom is the nominal voltage by which adhesion dependent dynamic service brake shall be supplied

Requirement identification	SB6.38
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrElVoltNom

S4R-311 - AdIndDynSBrElVoltNom is the nominal voltage by which adhesion independent dynamic service brake shall be supplied

Requirement identification	SB6.39
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrElVoltNom

S4R-312 - AdDepFrSBrElVoltNom is the nominal voltage by which adhesion dependent friction service brake shall be supplied

Requirement identification	SB6.40
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrElVoltNom

S4R-313 - AdDepDynSBrElCurrNom is the nominal current consumption of adhesion dependent dynamic service brake

Requirement identification	SB6.41
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning

Input information	
Output information	AdDepDynSBrElCurrNom

S4R-314 - AdIndDynSBrElCurrNom is the nominal current consumption of adhesion independent dynamic service brake

Requirement identification	SB6.42
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrElCurrNom

S4R-315 - AdDepFrSBrElCurrNom is the nominal current consumption of adhesion dependent friction service brake

Requirement identification	SB6.43
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrElCurrNom

S4R-316 - AdDepDynSBrElVoltMax is the maximum voltage by which adhesion dependent dynamic service brake shall be supplied

Requirement identification	SB6.44
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrElVoltMax

S4R-317 - AdIndDynSBrElVoltMax is the maximum voltage by which adhesion independent dynamic service brake shall be supplied

Requirement identification	SB6.45
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrElVoltMax

S4R-318 - AdDepFrSBrElVoltMax is the maximum voltage by which adhesion dependent friction service brake shall be supplied

Requirement identification	SB6.46
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrElVoltMax

S4R-319 - AdDepDynSBrElCurrMax is the maximum current consumption of adhesion dependent dynamic service brake

Requirement identification	SB6.47
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrElCurrMax

S4R-320 - AdIndDynSBrElCurrMax is the maximum current consumption of adhesion independent dynamic service brake

Requirement identification	SB6.48
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrElCurrMax

S4R-321 - AdDepFrSBrElCurrMax is the maximum current consumption of adhesion dependent friction service brake

Requirement identification	SB6.49
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrElCurrMax

S4R-322 - AdDepDynSBrElVoltMin is the minimum voltage by which adhesion dependent dynamic service brake shall be supplied

Requirement identification	SB6.50
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynSBrElVoltMin

S4R-323 - AdIndDynSBrElVoltMin is the minimum voltage by which adhesion independent dynamic service brake shall be supplied

Requirement identification	SB6.51
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynSBrElVoltMin

S4R-324 - AdDepFrSBrElVoltMin is the minimum voltage by which adhesion dependent friction service brake shall be supplied

Requirement identification	SB6.52
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	AdDepFrSBrElVoltMin

S4R-325 - Holding brake sub-function shall immobilize the train for at least 2 hours on the maximum line gradient

Requirement identification	SB7.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	SB7 generate the force to immobilize the train providing a command to SB5.3.2.1
Actor	SB7
Input information	TrainSpeed TrSBrReq TrainDir HBrEnabled WheelDir
Output information	HBReq

S4R-326 - HBrReq is the request to apply the holding brake

Requirement identification	SB7.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB8
Input information	
Output information	HBReq

S4R-327 - WheelDir is the information of the rotation direction of the wheel

Requirement identification	SB7.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	LAM1.1
Input information	
Output information	WheelDir

S4R-328 - Holding brake force is applied by adhesion dependent friction service brake force

Requirement identification	SB7.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The adhesion dependent friction service brake is the type of brake which is normally present in every train
Actor	SB7
Input information	TrainSpeed TrSBrReq TrainDir HBrEnabled
Output information	HBReq

S4R-329 - If Holding brake is not enabled it shall never set the Holding brake request to active

Requirement identification	SB7.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The driver has the possibility to remove the automatic application of holding brake by BSM2.1.2 sub-function. In this case the temporary immobilisation is in charge of the driver (see BSM requirements).
Actor	SB7
Input information	HBrEnabled
Output information	HBReq

S4R-330 - With holding brake enabled, if TrSBrReq≤0 and the train speed is < 3 km/h, SB7 shall activate the holding brake request to SB5.3.2.1

Requirement identification	SB7.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The Holding brake is requested automatically at zero speed. See requirements in SB5.3.2.1 for force generation
Actor	SB7
Input information	TrainSpeed TrSBrReq HBrEnabled
Output information	HBReq

S4R-331 - With holding brake enabled, the Holding brake request shall be de-activated only once that TrSBrReq>0 and the TrainSpeed is > 3 km/h in the correct direction

Requirement identification	SB7.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The brake is removed only once that the traction effort is higher then gravity force to permit the start in uphill
Actor	SB7
Input information	TrainSpeed WheelDir TrSBrReq TrainDir HBrEnabled
Output information	HBReq

S4R-332 - If, with holding brake enabled, holding brake req active and TrSBrReq>0, the train move to the opposite direction respect the selected one, SB7 shall set a major fault

TO BE AGREED IF TO EXPORT THE ROLL BACK PROTECTION TO THE TRAIN (in such a case the train direction information by SB2 and the WheelDir is no more necessary)

Requirement identification	SB7.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional

Rationale	Roll back protection, the reaction is demanded to BSM
Actor	SB7
Input information	TrainSpeed WheelDir TrSBrReq TrainDir HBrEnabled
Output information	MajFaultSB7.1

S4R-333 - If any input signal to SB7 is not valid or out of range a major fault shall be set

Requirement identification	SB7.9
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Holding brake out of order, the reaction is demanded to BSM
Actor	SB7
Input information	TrainSpeed TrSBrReq TrainDir HBrEnabled WheelDir
Output information	MajFaultSB7.2

S4R-334 - If, with holding brake enabled and holding brake request active and TrSBrReq≤0, the friction brake force applied is < k*TrainMassMax*MaxSlope-HBForTol, SB7 shall set a major fault

Requirement identification	SB7.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	If the HB force is too low the train can move with high slope. It means that the service brake is no more able to guarantee the temporary immobilization. The reaction is demanded to BSM
Actor	SB7
Input information	AdDEpFrSBrForApplMeas TrainMassMax

	MaxSlope HBForTol HBrEnabled k
Output information	MajFaultSB7.3

S4R-335 - MajFaultSB7.1 is the fault information of roll back detection

Requirement identification	SB7.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB7
Input information	
Output information	MajFaultSB7.1

S4R-336 - MajFaultSB7.2 is the fault information of holding brake out of order

Requirement identification	SB7.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB7
Input information	
Output information	MajFaultSB7.2

S4R-337 - MajFaultSB7.3 is the fault information of not sufficient holding brake force applied

Requirement identification	SB7.13
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB7
Input information	
Output information	MajFaultSB7.3

S4R-338 - SB8 shall require the traction cut off to traction system in case of brake request

Requirement identification	SB8.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The traction shall be cutted off only if brake request is active. If a brake force is applied without service brake request (during brake force fade off or with holding brake applied) traction can be requested and applied.
Actor	SB8
Input information	TrSBrReq
Output information	TractForAppl

S4R-339 - TractForAppl is the traction force applied at the track by the traction technical system

Requirement identification	SB8.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB8
Input information	
Output information	TractForAppl

S4R-340 - If TrSBrReq is < 0 the traction system shall set to 0 the traction force request

Requirement identification	SB8.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Traction request is active only if TrSBrReq>0, so this is automatically obtained by the use of the same information to trasmit the traction and brake request
Actor	SB8
Input information	TrSBrReq
Output information	TractForAppl

S4R-341 - If TrSBrReq information has lost its integrity or is out of range traction shall be cut off immediately

Requirement identification	SB8.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	If the TrSBrReq is not valid automatic brake application is piloted by SB4 and traction shall be cut off
Actor	SB8
Input information	TrSBrReq
Output information	TractForAppl

S4R-342 - The service brake function SB9 shall detect and indicate in the driver cab and/or outside the train the status of the service brake and of its sub-functions

Requirement identification	SB9.1
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB9
Input information	

Output information	SBrStatus

S4R-343 - SBrStatus is the information providing the released or applied status of service brake

Requirement identification	SB9.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9
Input information	
Output information	SBrStatus

S4R-344 - SB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the service brake (SB) which can have following status:
Applied: if any type of brake is applying a braking force
Released: if every type of brake is released

Requirement identification	SB9.3
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The SB status represent the presence of an applied force to the train, independently from enabled status or fault or type of brake applying a force. Note: the adhesion independent friction brake is not used in service brake and for this reason its status is not considered
Actor	SB9.1
Input information	AdDepDynSBrStatus AdIndDynSBrStatus AdDepFrSBrStatus
Output information	SBrStatus

S4R-345 - AdDepDynSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent dynamic service brake

Requirement identification	SB9.4
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB9.2
Input information	
Output information	AdDepDynSBrStatus

S4R-346 - AdIndDynSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent dynamic service brake

Requirement identification	SB9.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.3
Input information	
Output information	AdIndDynSBrStatus

S4R-347 - AdDepFrSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent friction service brake

Requirement identification	SB9.6
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.4
Input information	
Output information	AdDepFrSBrStatus

S4R-348 - SB9.1 function shall provide to the driver HMI, diagnostic system, diagnostic tool the status of the service brake functions SB1, SB2 which can have following status:

enabled: when BSM1 has enabled the service brake system and there is not any major fault active in SB1 or SB2 disabled: when the status is not enabled or degraded

degraded: when the service brake degraded mode is successfully activated by BSM2.1.2 after the driver selection of service brake degraded mode

faulty: if it is enabled and any major fault active in SB1 or SB2

Requirement identification	SB9.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	SB1 and SB2 are the sub-function managing the train retardation request, which is the brake central command. For this reason a single status is defined. A faulty SB1,SB2correspond to the impossibility to provide the service brake command, ie to loose the continuity of the service brake. For this reason any major fault on SB1 and SB2 functions shall lead to an automatic emergency brake.
Actor	SB9.1
Input information	SBrEnabled MajFaultAnySB1 MajFaultAnySB2 SBrDegr
Output information	SBrStatusSB1-2

S4R-349 - SBrStatusSB1-2 is the information providing the enabled/disabled/degraded/faulty status of service brake sub-functions SB1 and SB2

Requirement identification	SB9.8
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.1
Input information	
Output information	SBrStatusSB1-2

S4R-350 - MajFaultAnySB1 is the summary information of any major fault active on sub-function SB1

Requirement identification	SB9.9
Level	Brake System

Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB1
Input information	
Output information	MajFaultAnySB1

S4R-351 - MajFaultAnySB2 is the summary information of any major fault active on sub-function SB2

Requirement identification	SB9.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB2
Input information	
Output information	MajFaultAnySB2

S4R-352 - SB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the service brake function SB3 which can have following status:
enabled: when BSM1 has correctly initialized the brake system and there is not any major fault active in SB3

disabled: when it is not enabled

faulty: if it is enabled and any major fault active in SB3

Requirement identification	SB9.11
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	SB3 function is independent from other brake function and need a independent status If the brake system is not enabled also the weighting s not enabled and a predefined brake force is applied (see req. In SB5.3.2.1) Major fault of SB3 is managed by SB3 fixing a predefined mass (see req. in SB3)

Actor	SB9.1
Input information	SBrEnabled MajFaultAnySB3
Output information	SBrStatusSB3

S4R-353 - MajFaultAnySB3 is the summary information of any major fault active on sub-function SB3

Requirement identification	SB9.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.1
Input information	
Output information	MajFaultAnySB3

S4R-354 - SBrStatusSB3 is the information providing the enabled/disabled/faulty status of service brake sub-function SB3

Requirement identification	SB9.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.1
Input information	
Output information	SBrStatusSB3

S4R-355 - The adhesion dependent friction brake shall provide its own status derived from SB4-SB5-SB7-SB10-SB12 functions. The status can be:
Applied: if any braking force is applied
Released: if force is not applied
Isolated: if it is isolated
Faulty: if a major fault is active

Requirement identification	SB9.14

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB9.4
Input information	AdDepFrSBrApplMeas MajFaultAnyAdDepFrSBrSB4-5-7-10 AdDepFrSBrRemRelStatus AdDepFrSBrIsolStatus AdDepFrSBrForMax
Output information	AdDepFrSBrStatus

S4R-356 - MajFaultAnyAdDepFrSBrSB4-5-7-10 is the summary information of any major fault active on adhesion dependent friction service brale in sub-function SB4, SB5.1.2.1, SB5.2.2.1, SB5.3.2.1 SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3

Requirement identification	SB9.15
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB9.4
Input information	
Output information	MajFaultAnySB4-5-6-7-10

S4R-357 - The adhesion depedent friction brake status is applied if SB5.5.2.1.1 detect AdDepFrSBrApplMeas>0

Requirement identification	SB9.16
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The force application is detected by the closer information to the wheelset
Actor	SB9.4
Input information	AdDepFrSBrApplMeas

Output information	AdDepFrSBrStatus

S4R-358 - The adhesion depedent friction brake status is releassed if SB5.5.2.1.1 detect AdDepFrSBrApplMeas=0

Requirement identification	SB9.17
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The force application is detected by the closer information to the wheelset
Actor	SB9.4
Input information	AdDepFrSBrApplMeas
Output information	AdDepFrSBrStatus

S4R-359 - The adhesion depedent friction brake status is faulty if any major fault is detected by functions SB4, SB5.1.2.1, SB5.2.2.1, SB5.3.2.1 SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3 perfromed by adhesion dependent friction brake type

Requirement identification	SB9.18
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The mentioned SB4, SB5, SB7, SB10.3 functions are in charge of the adhesion dependent friction brake force. SB5.4 major fault does not impact the correct functionality of adhesion dependent friction brake, for this reason is not mentioned. SB6 function, which can cause a fault in adhesion dependent friction brake, is monitored by SB5.2 so its faulty status is already included in SB5 faulty status. SB12.2 function, which can cause a fault in adhesion dependent friction brake (i.e. by dissipation temperature), is optionally monitored by SB5.1.2.1 availability function, which is an EDV function, so its faulty status (not valid or out of range AdDepFrSBrDissTempMeas information) can be included in SB5 faulty status (actually this is not considered major fault because the reliability of the measurement device can be lower than the real possibility of overpass the dimensioning duty cycle) .
Actor	SB9.4
Input information	MajFaultAnySB4-5-7-10
Output information	AdDepFrSBrStatus

S4R-360 - The adhesion dependent friction service brake isolation status shall indicate the percentage of available force respect the maximum one based on SB10.3 permanent isolation AND remote release status

Requirement identification	SB9.19
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The isolation gives the information about service brake force availability to SB5.1.2.1 function. The service brake isolation status include the result of both remote release and permanent isolation because it is oriented to know the really applicable force to obtain the retardation requested. Note: The emergency brake isolation status given by EB10.3 is considering only permanent release, which is the one defining braking power. (see emergency brake requirements and BSM2.2 requirements)
Actor	SB9.4
Input information	AdDepFrSBrRemRelStatus AdDepFrSBrIsolStatus AdDepFrSBrForMax
Output information	AdDepFrSBrStatus

S4R-361 - The adhesion depedent friction service brake status (only if applied or released) shall be show optionally external the train, also in case of lack of energy (pneumatic or electric)

Requirement identification	SB9.20
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The external indication is usefull for maintenance.
Actor	SB9.4
Input information	AdDepFrSBrStatus
Output information	AdDepFrSBrStatusEXT

S4R-362 - AdDepFrSBrStatusEXT is the information of applied/released adhesion dependent friction brake visible externally of the train

Requirement identification	SB9.21
Level	Brake System
Mainfunction	Service Brake

Type	Definition
Rationale	
Actor	SB9.4
Input information	
Output information	AdDepFrSBrStatusEXT

S4R-363 - Any minor fault or major fault shall be trasmitted to diagnostic system, diagnostic tool

Requirement identification	SB9.22
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB9.4
Input information	MinFaultSBx MajFaultSBx
Output information	MinFaultSBx MajFaultSBx

S4R-364 - Any major fault shall be trasmitted to driver HMI, diagnostic system, diagnostic tool

Requirement identification	SB9.23
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB9.4
Input information	MajFaultSBx
Output information	MajFaultSBx

S4R-365 - SB10 shall manage the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application by SB5.5.2 sub-function

Requirement identification	SB10.1

Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The isolation has the scope to remove an amount of force, independently from the force generation function, to be able to react toany major fault which would stop permanentely the train
Actor	SB10
Input information	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom; AdDepDynSBrIsolCom AdIndDynSBrIsolCom AdDepFrSBrIsolCom
Output information	AdDEpDynSBrForAppl AdIndDynSBrForAppl AdDEpFrSBrForAppl

S4R-366 - AdDepDynSBrIsolCom is the command of permanent isolation of adhesion dependent dynamic service brake

Requirement identification	SB10.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepDynSBrIsolCom

S4R-367 - AdIndDynSBrIsolCom is the command of permanent isolation of adhesion independent dynamic service brake

Requirement identification	SB10.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	User

Input information	
Output information	AdIndDynSBrIsolCom

S4R-368 - AdDepFrSBrIsolCom is the command of permanent isolation of adhesion dependent friction service brake

Requirement identification	SB10.4
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepFrSBrIsolCom

S4R-369 - SB10.3 shall manage the isolation of adhesion dependent friction brake by remote release and permanent isolation command

Requirement identification	SB10.5
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB10.3
Input information	AdDepFrSBrRemRelCom AdDepFrSBrIsolCom
Output information	AdDEpFrSBrForAppl

S4R-370 - SB10.3 remote release shall permit to remove the adhesion dependent friction service brake force by remote command during running or standstill.

Requirement identification	SB10.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional

Rationale	The remote isolation permit to react to any major fault quickly permitting to manage also the running capability requirements in case of major faults. The remote release command is a function in charge of BSM2.1.1.
Actor	SB10.3
Input information	AdDepFrSBrRemRelCom
Output information	AdDEpFrSBrForAppl

S4R-371 - The remote release shall operate on SB5.5.2.1 sub-function removing the force application independently from SB5.3.2.1 command

Requirement identification	SB10.7
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Closer the release command is to the force generation fewer are the functions which can influence the release.
Actor	SB10.3
Input information	AdDepFrSBrRemRelCom
Output information	AdDEpFrSBrPilCom or AdDEpFrSBrPilComLAM

S4R-372 - The remote release shall be enabled in case of major fault only

Requirement identification	SB10.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The BSM2.1 function shall be capable to remove a braking only in presence of major fault to mitigate the possibility to have undue braking force releasing
Actor	SB10.4
Input information	MajFaultSBx
Output information	AdDepFrSBrRemRelCom

S4R-373 - SB10.3 permanent isolation sub-function shall permit to remove the adhesion dependent friction service brake force applied, totally or partially, permanentely, with or without energy available on the train, with SB in any status

Requirement identification	SB10.9
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The permanent isolation shall be an autonomous sub-function able to operate whatever are the condition of the other service brake sub-functions because it is the last operation that can be done to permit at the train to remove the braking force and be able to be moved.
Actor	SB10.3
Input information	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom
Output information	AdDEpFrSBrForAppl

S4R-374 - The permanent isolation can be commanded by driver or maintenance operator manually or, optionally, by remote command via BSM2.1.1

Requirement identification	SB10.10
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	The optional remote command permit to isolate permanentely from a central position
Actor	SB10.3
Input information	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom
Output information	AdDEpFrSBrForAppl

S4R-375 - AdDepFrSBrIsolManCom is the command of permanent isolation of adhesion dependent friction service brake provided by manual command

Requirement identification	SB10.11
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	User
Input information	
Output information	AdDepFrSBrIsolManCom

S4R-376 - The permanent isolation sub-function shall operate on SB5.5.2.1 sub-function removing the force application independently from SB5.3.2.1 command

Requirement identification	SB10.12
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Closer the permanent isolation is to the force generation fewer are the functions which can influence the result by any failure or power switch off.
Actor	SB10.3
Input information	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom
Output information	AdDEpFrSBrPilCom or AdDEpFrSBrPilComLAM

S4R-377 - Permanent isolation sub-function shall monitor the permanent isolation execution checking the applied force by AdDepFrSBrForApplMeas information received by SB5.5.2.1.1.
If permanent release is not successfull (command of permanent release active and brake force still applied) SB10.3 shall set a major fault

Requirement identification	SB10.13
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	To diagnose dragging brake
Actor	SB10.3
Input information	AdDepFrSBrForApplMeas AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom
Output information	MajFaultSB103.1

S4R-378 - MajFaultSB103.1 is the fault information about the not success permanent isolation execution

Requirement identification	SB10.14
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB10.3
Input information	
Output information	MajFaultSB103.1

S4R-379 - Permanent isolation shall define the permanent isolation status as:
Isolated force: it shall provide the percentage of maximum adhesion depedent friction service brake force released by permanent isolation.
Faulty: if permanent isolation is not succesfull in releasing completely the expected force

Requirement identification	SB10.15
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB10.3
Input information	AdDepFRSBrForApplMeas AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom MajFault103.1 AdDepFrSBrForMax
Output information	AdDepFrSBrIsolStatus

S4R-380 - AdDepFrSBrIsolStatus is the information of permanent isolated force/faulty permanent isolation of adhesion dependent friction service brake force

Requirement identification	SB10.16
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	

Actor	SB10.3
Input information	
Output information	AdDepFrSBrIsolStatus

S4R-381 - If the permanent isolated force = (Isolated force percentage)*AdDepFrSBrForMax>AdDepFrSBrForMax-AdDepFrSBrForMin a major fault shall be set

Requirement identification	SB10.17
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	MinSBrFor not available
Actor	SB10.3
Input information	AdDepFRSBrIsolStatus AdDepFrSBrForMin
Output information	MajFaultSB103.2

S4R-382 - MajFaultSB103.2 is the fault information about the too high isolation of a adhesion dependent friction service brake force, not permitting to apply the minimum service brake force by the adhesion dependent friction service brake

Requirement identification	SB10.18
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB10.3
Input information	
Output information	MajFaultSB103.2

S4R-383 - SB12.2 function shall transform the kinetic energy of the train into thermal energy by the friction between two surfaces

Requirement identification	SB12.1
Level	Brake System

Mainfunction	Service Brake
Type	Functional
Rationale	Physics
Actor	SB12.2
Input information	TrainKinEn
Output information	ThermEn

S4R-384 - TrainKinEn is the kinetic energy of the train

Requirement identification	SB12.2
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainKinEn

S4R-385 - ThermEn is the thermal energy to be dissipated by brake system

Requirement identification	SB12.3
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2
Input information	
Output information	ThermEn

S4R-386 - SB12.2.1 shall generate thermal energy (heat) from the contact between two friction surface sliding with an applied perpendicular force that generates the AdDEpFrSBrForAppl force at the track

Requirement identification	SB12.4
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB12.2.1
Input information	AdDepFrSBrForAppl
Output information	AdDepFrSBrHeat

S4R-387 - AdDepFrSBrHeat is the heat generated by dissipation process of adhesion dependent friction service brake

Requirement identification	SB12.5
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2.1
Input information	
Output information	AdDepFrSBrHeat

S4R-388 - SB12.2.2 shall dissipate the heat generated by SB12.2.1 into the air

Requirement identification	SB12.6
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	
Actor	SB12.2.2.
Input information	AdDepFrSBrHeat
Output information	AirThermEnSB

S4R-389 - AirThermEnSB is the service brake thermal energy dissipated into the air

Requirement identification	SB12.7
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2.2.
Input information	
Output information	AirThermEnSB

S4R-390 - SB12.2.2 shall measure the temperature reached during braking by dissipation function

Requirement identification	SB12.8
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	Optional function, usefull in case of unpredictable mission profile. Function not included in EDV functionalities
Actor	SB12.2.2.
Input information	AdDepFrSBrDissTemp
Output information	AdDepFrSBrDissTempMeas

S4R-391 - AdDepFrSBrDissTemp is the dissipation temperature of the adhesion dependent friction brake

Requirement identification	SB12.9
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2.2.
Input information	

Output information	AdDepFrSBrDissTemp

S4R-392 - AdDepFrSBrDissTempMeas is the information of the dissipation temperature of the adhesion dependent friction brake AdDepFrSBrDiss Temp

Requirement identification	SB12.10
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2.2.
Input information	
Output information	AdDepFrSBrDissTempMeas

S4R-393 - SB12.2.2 shall set a major fault if it will detect a too high temperature

Requirement identification	SB12.11
Level	Brake System
Mainfunction	Service Brake
Type	Functional
Rationale	This function is optional because the thermal dissipation is dimensioned by calculations and test, so it should not happen during operation to have too high temperature. This function protect the brake system against unpredictable mission profiles or combination of isolation with heavy duty cycles
Actor	SB12.2.2.
Input information	AdDepFrSBrDissTempMeas AdDepFrSBrDissTempMax
Output information	MajFaultSB122

S4R-394 - AdDepFrSBrDissTempMax is the maximum temperature that can be reached by adhesion dependent friction brake

Requirement identification	SB12.12
Level	Brake System
Mainfunction	Service Brake
Type	Definition

Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrSBrDissTempMax

S4R-395 - MajFaultSB122 is the fault information about too high temperature at the adhesion dependent friction service brake energy dissipation sub-function

Requirement identification	SB12.13
Level	Brake System
Mainfunction	Service Brake
Type	Definition
Rationale	
Actor	SB12.2.2.
Input information	
Output information	MajFaultSB122

S4R-396 - The emergency brake is the system function used by the users and technical systems (actors) to apply predefined retarding force to the track (directly or by the wheelset) with the following goals:
- to stop the train in the guaranteed stopping distance

Requirement identification	EB.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The guaranteed performances are the ones considered by ETCS/ATP to calculate the free space necessary in front of the train
Actor	EB
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM

Output information	TrainEBrRetAppl TrainEBrEqTimeAppl

S4R-397 - EBReqUs is the request to apply the emergency brake by any user

Requirement identification	EB.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	EBReqUs

S4R-398 - EBrReqATO is the request to apply the emergency brake by ATO

Requirement identification	EB.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	ATO
Input information	
Output information	EBrReqATO

S4R-399 - EBrReqTCMS is the request to apply the emergency brake by TCMS

Requirement identification	EB.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	TCMS
Input information	
Output information	EBrReqTCMS

S4R-400 - EBrReqATP is the request to apply the emergency brake by ATP

Requirement identification	EB.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	ATP
Input information	
Output information	EBrReqATP

S4R-401 - EBrReqETCS Eis the request to apply the emergency brake by ETCS

Requirement identification	EB.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	ETCS
Input information	
Output information	EBrReqETCS

S4R-402 - EBrReqPAS is the request to apply the emergency brake by PAS

Requirement identification	EB.7
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	PAS
Input information	
Output information	EBrReqPAS

S4R-403 - TrainEBrRetAppl is the portion of the train retardation TrainRetAppl which is generated by the Emergency brake force. It is a positive value

Requirement identification	EB.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Train
Input information	
Output information	TrainEBrRetAppl

S4R-404 - TrainEBrEqTimeAppl is the equivalent time by which the force TrainEBrRetAppl is applied

Requirement identification	EB.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	TrainEBrEqTimeAppl

S4R-405 - The emergency brake function shall be always active when the train is powered on

Requirement identification	EB.10

Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Depending from the status of the emergency brake request information the emergency brake force shall be applied accordingly based on EBr status.
Actor	EB
Input information	EBrElVolt
Output information	TrainEBrForAppl

S4R-406 - When an emergency brake is applied after an emergency request, it can be released only if the request is removed

Requirement identification	EB.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Note: If there is an undue emergency brake request, the function BSM2.2.2 shall allow the driver to remove the undue request to permit the train to guarantee running capability.
Actor	EB
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM
Output information	TrainEBrRetAppl TrainEBrEqTimeAppl

S4R-407 - The emergency brake retardation applied TrainRetAppl shall be ≥ maximum emergency brake retardation TrainEBrRetMax in following condition:
- without any failure and isolation,
- without degraded environmental condition (causing sliding or reduced applied forces),
- on a flat track
- any train mass

Requirement identification	EB.12
Level	Brake System

Mainfunction	Emergency Brake
Type	Functional
Rationale	The maximum emergency brake retardation is the nominal retardation provided by brake system applying forces according dimensioning. It is the reference retardation to calculate the braking power. The maximum retardation can be an invariant parameter or a speed dependent parameter In presence of slope the retardation should be updated adding the gravity force retardation, but this is not considered (normally it is taken in consideration by ATP/ETCS. It could become relevant in case of perfromances control, which is not in the scope of this document)
Actor	EB
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM TrainEBrRetMax
Output information	TrainRetAppl

S4R-408 - TrainEBrRetMax is the nominal retardation of the train obtained by the force applied by the emergency brake in following condition:
- without any failure and isolation,
- without degraded environmental condition (causing sliding or reduced applied forces),
- on a flat track
- with maximum train mass

Requirement identification	EB.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainEBrRetMax

S4R-409 - The emergency brake is the main function which shall guarantee the minimum performances of the brake system:
TrainEBrRetMin = TrainRetMin
TrainEBrEqTimeMax= TrainBrEqTimeMax

Requirement identification	EB.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	Dimensioning
Input information	TrainRetMin TrainBrEqTimeMax
Output information	TrainEBrRetMin

S4R-410 - The Emergency brake equivalent time of applied retardation shall be TrainEBrEqTimeAppl< TrainEBrEqTimeMax

Requirement identification	EB.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	See above requirement about brake performances. The TrainEBrEqTimeMax is the brake application equivalent time considered by signalling
Actor	EB
Input information	TrainEBrEqTimeMax
Output information	TrainEBrEqTimeAppl

S4R-411 - TrainEBrEqTimeMax is the the maximum equivalent time in emergency brake considered by dimensioning

Requirement identification	EB.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	TrainEBrEqTimeMax

S4R-412 - TrainEBrRetMin is the guaranteed emergency minimum retardation provided by the emergency brake application, which permit to stop the train in the maximum stopping distances TrainStopDist associated to the active braking power TrainBrPower.

Requirement identification	EB.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	The guaranteed retardation and the maximum equivalent time are the input for ATP/ETCS to define the distance of the train
Actor	Dimensioning
Input information	
Output information	TrainEBrRetMin

S4R-413 - The train emergency brake force applied to the track shall provide at least the minimum emergency brake performances associated to the braking power active at the moment of the braking in any track and environmental condition and in presence of the worst single failure during emergency application

Requirement identification	EB.18
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB
Input information	TrainEBrRetMin TrainEBrEqTimeMax TrainEBrForNomAppl TrainEBrEqTimeAppl
Output information	TrainEBrRetAppl TrainEBrEqTimeAppl

S4R-414 - Train retardation shall be limited to TrainRetLim= 2,5 m/s2

Requirement identification	EB.19
Level	Brake System

Mainfunction	Emergency Brake
Type	Functional
Rationale	To avoid too high forces on the track
Actor	EB
Input information	TrainEBrForAppl TrainRetLim
Output information	TrainRetAppl

S4R-415 - The maximum jerk shall be MaxJerk= 4 m/s3

Requirement identification	EB.20
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB
Input information	MaxJerk TrainEBrForAppl
Output information	TrainRetAppl

S4R-416 - Maximum adhesion used by adhesion dependent force AdDepEBrForAppl shall be limited to maximum value of TSI

Requirement identification	EB.21
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The maximum adhesion is speed dependent and train confguration dependent
Actor	EB
Input information	TSIAdMaxVal
Output information	AdDepEBrForAppl

S4R-417 - AdDepEBrForAppl is the force applied at the track by the adhesion dependent brake types (AdDepDynEBrForAppl+AdDepFrEBrForAppl)

Requirement identification	EB.22
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	AdDepEBrForAppl

S4R-418 - The Train Emergency brake retardation TrainEBrRetAppl is obtained by piloting a Train emergency brake force TrainEBrForNom providing a retardation of the train TrainEBrRetNom

Requirement identification	EB.23
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	See EN15431-1 for brake calculation formulas
Actor	EB
Input information	TrainEBrForNom TrainEBrRetNom
Output information	TrainEBrRetAppl

S4R-419 - TrainEBrRetNom is the retardation obtained by the application of the TrainEBrForNom

Requirement identification	EB.24
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	

Output information	TrainEBrRetNom

S4R-420 - TrainEBrForNom is the nominal force applied at the track by the emergency brake

Requirement identification	EB.25
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	TrainEBrForNom

S4R-421 - The train emergency brake force applied to the track is obtained by the contribution of adhesion dependent dynamic brake, adhesion independent dynamic brake, adhesion dependent friction brake, adhesion independent friction brake: TrainEBrForAppl(v)= AdDEpDynEBrForAppl(v)+ AdIndDynEBrForAppl(v)+ AdDEpFrEBrForAppl(v)+ AdIndFrEBrForAppl

Requirement identification	EB.26
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	All the type of brake are used. The dimensioning of the different type of brake maximum force is focused to reach the requested maximum retardation. It means that the fist level of "blending" between forces is done at dimensioning level, deciding the maximum force is attributed to each type of brake. The dimensionimg criteria considered are: adhesion independent brakes are dimensioned to be applied at 100% in EB. adhesion dependent brake are dimensioned to guarantee a minimum force, which added to the adhesion independent brakes can provide the maximum train EB retardation. The nominal force by adhesion dependent brake can be higher than the minimum one. In this way they are able to compensate failures (possible positive impact on guaranteed emergency brake performances) The total adhesion dependent force available can be higher than allowed by adhesion limits, but its use shall be limited by adhesion limit.
Actor	EB
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS;

	EBrReqPAS EBrReqBSM
Output information	AdDepDynEBrForAppl AdIndDynEBrForAppl AdDepFrEBrForAppl AdIndFrEBrForAppl

S4R-422 - AdDepDynEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force

Requirement identification	EB.27
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	AdDepDynEBrForAppl

S4R-423 - AdIndDynEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force

Requirement identification	EB.28
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	AdIndDynEBrForAppl

S4R-424 - AdDepFrEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Dependent Friction Brake Force

Requirement identification	EB.29

Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	AdDepFrEBrForAppl

S4R-425 - AdIndFrEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Independent Friction Brake Force

Requirement identification	EB.30
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	AdIndFrEBrForAppl

S4R-426 - Each type of emergency brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter

Requirement identification	EB.31
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB
Input information	AdDepDynEBrForMax AdIndDynEBrForMax AdDepFrEBrForMax AdIndFrEBrForMax

Output information	AdDepDynEBrForAppl AdIndDynEBrForAppl AdDepFrEBrForAppl AdIndFrEBrForAppl

S4R-427 - AdDepDynEBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic service brake

Requirement identification	EB.32
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrForMax

S4R-428 - AdDepDynEBrForMin is the minimum force applied at the track that is guaranteed by adhesion dependent dynamic brake.It depends from dimensioning and isolation active on adhesion dependent dynamic brake. (It is different from AdDepDynEBrAvFor, which is the total available force, guaranteed + not guaranteed)

Requirement identification	EB.33
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	This information depends from the design of the adhesion dependent dynamic brake: if a portion of the force is safe enough, the value can be > 0. If the force application is not safe enough the value is 0.
Actor	EB5.1.1.1
Input information	
Output information	AdDepDynEBrForMin

S4R-429 - AdIndDynEBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic service brake

Requirement identification	EB.34
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrForMax

S4R-430 - AdDepFrEBrForMax is the maximum force that can be applied at the track by adhesion dependent service friction brake

Requirement identification	EB.35
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrForMax

S4R-431 - AdIndFrEBrForAppl is the maximum force that can be applied at the track by Adhesion Independent Friction Brake Force

Requirement identification	EB.36
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	AdIndFrEBrForMax

S4R-432 - When EB functions receive the electrical power supply shall perform a self test and trasmit the result to BSM1 function

Requirement identification	EB.37
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of EB and compare it with the expected one (initialization of the brake)
Actor	EB
Input information	EBrElVolt
Output information	SelfTestEBrRes

S4R-433 - SelfTestEBrRes is the result of the self test performed by emrgncy brake when receive electric power supply

Requirement identification	EB.38
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	SelfTestEBrRes

S4R-434 - EB1 shall trasmit to EB2 any of the emergency request received by actors

Requirement identification	EB1.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	The emergency brake request is an on/off information
Actor	EB1
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM
Output information	TrainEBrReq

S4R-435 - TrainEBrReq is the request of an emergency brake by any actor

Requirement identification	EB1.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB1
Input information	
Output information	TrainEBrReq

S4R-436 - The emergency brake request has priority on any other brake application/release request

Requirement identification	EB1.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The emergency brake is the safe brake
Actor	EB1
Input information	EBrReqUs

	EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM
Output information	TrainEBrReq

S4R-437 - If EB1 TrainEBrReq information is not valid or out of order a major fault shall be set

Requirement identification	EB1.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirement is linked to next requirements about continuity to guarantee the automatic brake retardation by EB4-EB5 sub-function. BSM reaction to major fault in this case could not be reliable due to un-reliable EB1
Actor	EB1
Input information	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM
Output information	TrainEBrReq MajFaultEB1.1

S4R-438 - MajFaultEB1 is the fault indicating that it is faulty the emergency brake request information TrainEBrReq (continuity lost)

Requirement identification	EB1.5
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB1
Input information	
Output information	MajFaultEB1

S4R-439 - EB2 shall trasmit the emergency brake request received by EB1 to other brake system functions

Requirement identification	EB2.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Continuity requirement.
Actor	EB2
Input information	TrainEBrReq
Output information	EBrReq

S4R-440 - EBrReq is the emergency brake request information TrainEBrReq trasmitted along the train

Requirement identification	EB2.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB2
Input information	
Output information	EBrReq

S4R-441 - In case TrainEBrReq is not valid a major fault shall be set and EBreq shall be set active

Requirement identification	EB2.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirement provide automatic brake application in case of lost continuity of the brake command BSM reaction to major fault in this case could not be reliable (as TrainEBrReq information is not valid, BSM EB trasmission signal could be not reliable as well)
Actor	EB2
Input information	TrainEBrReq
Output information	EBrReq MajFaultEB2.1

S4R-442 - MajFaultEB2.1 is the fault indicating that it is lost the emergency request information TrainEBrReq (continuity lost)

Requirement identification	EB2.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB2
Input information	
Output information	MajFaultEB2.1

S4R-443 - In case EBrReq is not valid a major fault shall be set

Requirement identification	EB2.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	
Actor	EB2
Input information	TrainEBrReq
Output information	EBrReq MajFaultEB2

S4R-444 - MajFaultEB2.2 is the fault indicating that it is lost the emergency request information EBrReq (continuity lost)

Requirement identification	EB2.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB2
Input information	
Output information	MajFaultEB2.2

S4R-445 - EB3 shall define the train mass and the train equivalent mass information and send them to all emergency brake sub-functions and context systems which need it

Requirement identification	EB3.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB3
Input information	BogLoad
Output information	TrainMassEB TrainEqMassEB

S4R-446 - TrainMassEB is the mass of the complete train defined by service brake

Requirement identification	EB3.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB3.2
Input information	
Output information	TrainMassEB

S4R-447 - TrainEqMassEB is the mass of the train + the rotating mass

Requirement identification	EB3.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB3.2
Input information	
Output information	TrainEqMassEB

S4R-448 - EB3.1 shall calculate the load insisting on the bogies by memorizing the bogie load information once that door are closed and locked (passenger in/out finished) and trasmit it to EB3.2

Requirement identification	EB3.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The best moment to measure the bogie load necessary to define the brake force is when the train is in stanstill ready to leave and no more load variation on it
Actor	EB3.1
Input information	BogLoad

Output information	BogLoadMemEB

S4R-449 - BogLoadMemEB is the BogLoad information recorded by service brake in the moment that the train leave the station

Requirement identification	EB3.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB3.1
Input information	
Output information	BogLoadMemEB

S4R-450 - The bogie technical system shall trasmit continuously the bogie load information to EB3.1 Load acquisition sub-function

Requirement identification	EB3.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The continuous transmission permit to have a permanent diagnostic
Actor	Bogie
Input information	CarLoad
Output information	BogLoad

S4R-451 - The door technical system shall trasmit continuously the Door Closed and Locked information to EB3.1 Load acquisition sub-function

Requirement identification	EB3.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	The door closed and locked data is informing the brake system of the end of the passenger transfer in the station, so that the train load cannot change anymore
Actor	Door
Input information	DoorStatus
Output information	DoorClLock

S4R-452 - EB3.1 shall measure the BogLoad information at any time

Requirement identification	EB3.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Note: the detection of the BogLoad information can be done by any detection device technically speaking (pneumatic or electric). The detection device is considered part of brake sub-system EB3
Actor	EB3.1
Input information	BogLoad
Output information	BogLoadMeas

S4R-453 - BogLoadMeasEB is the measured value by service brake of the BogLoad information

Requirement identification	EB3.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB3.1
Input information	
Output information	BogLoadMeasEB

S4R-454 - EB3.1 shall memorize the BogLoadMeas information when (Door Closed and Locked data is active OR the TrainSpeed>3 km/h)

Requirement identification	EB3.10

Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The door closed and locked information is in OR to the train movement to allow to memorize the bogie load also in case of Door closed and Locked information not valid or (exceptional) train movement with door opened
Actor	EB3.1
Input information	BogLoadMeasEB DoorClLock TrainSpeed
Output information	BogLoadMemEB

S4R-455 - When the BogLoadMeasEB information is not valid or is out of tolerance EB3.1 shall set a major fault and fix the BogLoadMemEB information to the value of BogLoadDefEB when the DoorClLock data is no more active or as soon as the train move (speed > 3 km/h).

Requirement identification	EB3.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirement permit to have always a mass of the train, even if a default one. Note: The default mass definition shall be linked to guaranteed perfromance calculation and adhesion constraints
Actor	EB3.1
Input information	BogLoadMeasEB BogLoadDefEB DoorClLock TrainSpeed
Output information	BogLoadRMemEB MajFaultEB31

S4R-456 - BogLoadDefEB is the default load insisting on the bogie to be considered in case of not available BogLoadMeasEB information

Requirement identification	EB3.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition

Rationale	
Actor	Dimensioning
Input information	
Output information	BogLoadDefEB

S4R-457 - MajFaultEB31 is the fault information indicating that it is lost the BogLoad information (mass information lost)

Requirement identification	EB3.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB3.1
Input information	
Output information	MajFaultEB31

S4R-458 - The BogLoad information shall have an accuracy of +x/- y% respect the real load

Requirement identification	EB3.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Mass of the train directly impact the train stopping distances and the used adhesion.
Actor	Bogie
Input information	CarLoad
Output information	BogLoad

S4R-459 - The BogLoadMeasEB information shall have an accuracy of +x/- y% respect the BogLoad information

Requirement identification	EB3.15

Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Mass of the train directly impact the train stopping distances and the used adhesion.
Actor	EB3.1
Input information	BogLoad
Output information	BogieLoadMeasEB

S4R-460 - EB3.2 calculate the Train Mass and Train equivalent mass by BogLoadMeasEB information and trasmit them to other brake system sub-functions and systems of brake context which are interested

Requirement identification	EB3.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The train mass and equivalent mass are the information transforming the reatardation request into a brake force by EB4
Actor	EB3.2
Input information	BogLoadMemEB
Output information	TrainMassEB TrainEqMassEB

S4R-461 - The train mass shall be derived from Bogie Load adding the mass of the bogies

Requirement identification	EB3.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB3.2
Input information	BogLoadMemEB BogieMass

Output information	TrainMassEB

S4R-462 - The train equivalent mass shall be derived from the train mass adding the translating mass equivalent to rotating mass of the train

Requirement identification	EB3.18
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB3.2
Input information	BogLoadMemEB RotMass BogieMass
Output information	TrainEqMassEB

S4R-463 - EB4 shall calculate the Train nominal emergency brake force

Requirement identification	EB4.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB4
Input information	EBrReq TrainMassEB TrainSpeed TrainEBrRetMax a,b,c
Output information	TrainEBrForNom

S4R-464 - The Train emergency brake nominal force shall be calculated based on the maximum emergency brake retardation, the train mass, the train running resistance, the train speed as follow:

If EBrReq is active TrainEBrForNom=TrainMassEB*TrainEBrRetMax-TrainRunResEB

If EBrReq is not active TrainEBrForNom=0

Requirement identification	EB4.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	See EN14531-1 for brake force calculation. The force is calculated to obtain the TrainEBrRetMax on a flat track. Slope is not considered because already considered by ETCS/ATP. In case of isolation present the force cannot be achieved, but to ask for the maximum force at any time is the only way to guarantee to have always the maximum force available by any type of brake. The blending rules are in charge of defining the amount of each of them (isolation can have different impact on emergency performances depending from the mass)
Actor	EB4
Input information	EBrReq TrainMassEB TrainEBrRetMax TrainSpeed TrainRunResEB
Output information	TrainEBrForNom

S4R-465 - TrainEBrForNom ramping shall be limited in order to have a jerk of TrainRet limited to MaxJerk=4 m/s3.

Requirement identification	EB4.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB4
Input information	MaxJerk
Output information	TrainEBrForNom

S4R-466 - TrainRunResEB is the force that emergency brake consider applied by track and aerodynamic forces to the train

Requirement identification	EB4.4
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainRunResEB

S4R-467 - If EBrReq information is not valid EB4 shall set the force request to default request EBrReqDef =active and set a major fault

Requirement identification	EB4.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Loss of continuity generate emergency brake application request
Actor	EB4
Input information	EBrReq TrainMass EBrReqDef TrainSpeed TrainRunResEB
Output information	MajFaultEB4.1 TrainEBrForNom

S4R-468 - EBrReqDef is the default status of EBrREq to be considered by SB4 in case of EBrREq not valid

Requirement identification	EB4.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	EBrReqDef

S4R-469 - MajFaultEB4.1 is the fault information about the not valid information of EBrReq

Requirement identification	EB4.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	SB4
Input information	
Output information	MajFaultEB4.1

S4R-470 - In case of lost train integrity, EB4 shall set the force request to TrainEBrForDef and set a major fault

Requirement identification	EB4.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Automaticity requirement The loss of integrity doesn't requires to fulfill the performances (see TSI requirement 4.2.4.2.1 (11)
Actor	EB4
Input information	TrainIntegr TrainMass TrainEBrForDef EBrReqDef TrainSpeed TrainRunResEB
Output information	MajFaultEB4.2 TrainEBrForNom

S4R-471 - TrainEBrForDef is the default force value at which TrainEBrForNom shall be set in case of lost train integrity

Requirement identification	EB4.9
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainEBrForDef

S4R-472 - MajFaultEB4.2 is the fault information about train integrity lost

Requirement identification	EB4.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB4
Input information	
Output information	MajFaultEB4.2

S4R-473 - If the TrainMassEB information is not valid the Train Mass shall be set to TrainMassDefEB value and a major fault shall be set

Requirement identification	EB4.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB4
Input information	TrainMassEB TrainMassDefEB
Output information	MajFaultEB4.3 TrainEBrForNom

S4R-474 - TrainMassDefSB is the default train mass value consistent with the BogLoadDefSB value

Requirement identification	EB4.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainMassDefEB

S4R-475 - MajFaultSB4.3 is is the fault information indicating that it is lost the TrainMass information

Requirement identification	EB4.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB4
Input information	
Output information	MajFaultEB4.3

S4R-476 - If the TrainSpeed information is not valid the Trainspeed shall be set to TrainSpeedDefSB value and a major fault shall be set

Requirement identification	EB4.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB4
Input information	TrainSpeed TrainSpeedDefEB

Output information	MajFaultEB4.4 TrainEBrForNom

S4R-477 - TrainSpeedDefSB is the default speed information to be considered by SB when the TrainSpeed is not available

Requirement identification	EB4.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	TrainSpeedDefEB

S4R-478 - MajFaultEB4.4 is the fault information indicating that it is lost the TrainSpeed information

Requirement identification	EB4.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB4
Input information	
Output information	MajFaultEB4.4

S4R-479 - The train runnig resistance force shall be calculated considering running resistance formula proper of the train: a*TrainMassEB+b*v+c*v2

Requirement identification	EB5.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	a,b,c parameter of the train

Actor	EB4
Input information	a,b,c TrainMassEB
Output information	TrainRunResEB

S4R-480 - EB5 shall apply a emergency brake force at the train of the amount of the train emergency brake force information received by EB4 fulfilling the constraints in terms of:
- force tolerance
- maximum force applicable to different type of brake (dimensioning constraints)
- maximum adhesion

Requirement identification	EB5.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Note: EB5 is in charge of all type of brakes. Next requirements regards the implementation of EB5 function by adhesion dependent friction brake, and in particular the requirements in charge of EDV. The requirements about other type of brakes or function not in charge of EDV are mentioned only if relevant. Note: considering what written Rtionale of req.
Actor	EB5
Input information	TrainEBrForNom TrainSpeed
Output information	TrainEBrForAppl

S4R-481 - EB5 shall not generate leakages which can decrease of more than MaxDeltaPressEB/min the EBrAirSupplPress (without air supply available)

Requirement identification	EB5.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	To guarantee inexhaustibility for at least 2 hours
Actor	EB5
Input information	MaxDeltaPressEB EBrAirSupplPress
Output information	EB5AirSupplLeak

S4R-482 - AdDepDynEBr+J518:V524AirSupplPress is the air supply pressure of the Adhesion dependent dynamic emergency brake

Requirement identification	EB5.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdDepDynEBrAirSupplPress

S4R-483 - AdIndDynEBrAirSupplPress is the air supply pressure of the Adhesion independent dynamic emergency brake

Requirement identification	EB5.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdIndDynEBrAirSupplPress

S4R-484 - AdDepFrEBrAirSupplPress is the air supply pressure of the Adhesion dependent friction emergency brake

Requirement identification	EB5.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	

Output information	AdDepFrEBrAirSupplPress

S4R-485 - AdIndFrEBrAirSupplPress is the air supply pressure of the Adhesion independent friction emergency brake

Requirement identification	EB5.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdIndFrEBrAirSupplPress

S4R-486 - AdDepDynEBrAirCons is the air supply consumption of the Adhesion dependent dynamic emergency brake

Requirement identification	EB5.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdDepDynEBrAirCons

S4R-487 - AdIndDynEBrAirCons is the air supply consumption of the Adhesion independent dynamic emergency brake

Requirement identification	EB5.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	EB5
Input information	
Output information	AdIndDynEBrAirCons

S4R-488 - AdDepFrEBrAirCons is the air supply consumption of the Adhesion dependent friction emergency brake

Requirement identification	EB5.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdDepFrEBrAirCons

S4R-489 - AdIndFrEBrAirCons is the air supply consumption of the Adhesion independent friction emergency brake

Requirement identification	EB5.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	AdIndFrEBrAirCons

S4R-490 - EB5AirSupplLeak are the leakages of the pneumatic system distributing pneumatic energy necessary to apply the emergency brake force

Requirement identification	EB5.12
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	EB5
Input information	
Output information	EB5AirSupplLeak

S4R-491 - EB5.1. 2.1 shall define the adhesion dependent friction brake force availability by elaborating the isolation status infomation, the dimensioning constraints (ie max force), and the train speed received by Odometry

AdDepFrEBrAvFor(v)=
min(AdDepFrEBrForMax(v);
AdDepFrEBrForMax(v)*(AdDepFrEBrIsolStatus))

Requirement identification	EB5.1.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The status information is obtained by EB10.3 function (permanent isolation) only. Remote release of emergency brake is allowed only for single fault and not applicable if emergency brake is applied (see EN10.3 requirements) . The dimensioning constraint is a parameter (see req. 1.0.1.4) , speed dependent . The temperature of the dissipation unit is not considered because the emergency brake dimensioning shall cover the worst operative situation (see also TSI §4.2.4.5.4 for reference cases). If there is the risk that unpredictable situation can occurr leading to thermal load in emergency brake higher than considered in emergency dimensioning, the service brake (optional) req. 1.1.5.1 can protect the train from exeeding the thermal dimensioning condition for emergency brake. The adhesion constraints are not considered at this stage because they shall be considered once that blending with adhesion dependent dynamic brake is defined
Actor	EB5.1.2.1
Input information	AdDepFrEBrIsolStatus AdDepFrEBrForMax(v) TrainSpeed AdDepFrEBrDissTempMeas
Output information	AdDepFrEBrAvFor

S4R-492 - AdDepFrEBrAvFor is the adhesion dependent friction emergency brake force that is available on the train for application to the track.

Requirement identification	EB5.1.2
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	SB5.1.2.1
Input information	
Output information	AdDepFrEBrAvFor

S4R-493 - If the AdDepFrEBrAirSupplPress < AdDepFrEBrAirSupplPressMin the Availability shall be set to 0

Requirement identification	EB5.1.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Inexhaustibility requirement
Actor	EB5.1.2.1
Input information	AdDepFrEBrAirSupplPress AdDepFrEBrAirSupplPressMin
Output information	AdDepFrEBrAvFor

S4R-494 - EB5.2.shall define the nominal forces of different type of brakes as result of emergency blending logic giving priority to adhesion independent brakes first and then to adhesion dependent brakes. The adhesion dependent friction brake shall be the last one to be considered, providing the missing force to reach the maximum possible emergency brake force

Requirement identification	EB5.2.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The proposed blending logic maximize the use of adhesion independent brake to reduce the risk of longer stopping distances due to wheel sliding and the use of wearless brake types (Dynamic brakes) to reduce the LCC. Adhesion independent brake are dimensioned to be used at 100% of their capacity to reach the expected train emergency brake force. Blending is usefull between the two adhesion dependent type of brake to avoid exceeding of adhesion and failure compensation. Note 1:As consequence of blending logic, EB5.2 will provide for all type of brakes the expected force to be applied taking in account already of the limitations by availability and adhesion (that's why the output has the extension Ltd). The consistency between the expected force and the one obtained by limitation is given by dimensioning and dependance of expected performances from active braking power (braking power take in account the availability)

	Note 3: Blending logics can be managed by a central function controlling all type of brakes or functions controlling each type of brake shall implement the same blending logic to have coherent force distribution. Here below the second option is considered: ED brake, Friction brake, EC Brake have independent coherent blending logic installed in their controller and exchange information to guarantee the consistency.
Actor	EB5.2
Input information	TrainEBrForNom AdDepDynEBrAvFor AdDepFrEBrAvFor AdIndDynEBrAvFor AdIndFrEBrAvFor
Output information	AdDepDynEBrForNomLtd AdIndDynEBrForNomLtd AdDepFrEBrForNomLtd AdIndFrEBrForNomLtd

S4R-495 - AdDepDynEBrAvFor is the adhesion dependent dynamic brake force available on the train, which can be applied to the track

Requirement identification	EB5.2.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.1.1.1
Input information	
Output information	AdDepDynEBrAvFor

S4R-496 - AdIndDynEBrAvFor is the adhesion independent dynamic brake force available on the train, which can be applied to the track

Requirement identification	EB5.2.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.1.1.2

Input information	
Output information	AdIndDynEBrAvFor

S4R-497 - AdIndFrEBrAvFor is the adhesion independent friction brake force available on the train, which can be applied to the track

Requirement identification	EB5.2.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.1.2.2
Input information	
Output information	AdFrDynEBrAvFor

S4R-498 - AdDepDynEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent dynamic brake to apply the TrainEBrForNom .

Requirement identification	EB5.2.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.2.1.1
Input information	
Output information	AdDepDynEBrForNomLtd

S4R-499 - AdIndDynEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent dynamic brake to apply the TrainEBrForNom .

Requirement identification	EB5.2.6
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	EB5.2.1.2
Input information	
Output information	AdIndDynEBrForNomLtd

S4R-500 - AdDepFrEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent friction brake to apply the TrainEBrForNom .

Requirement identification	EB5.2.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.2.2.1
Input information	
Output information	AdDepFrEBrForNomLtd

S4R-501 - AdIndFrEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent friction brake to apply the TrainEBrForNom .

Requirement identification	EB5.2.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.2.2.2
Input information	
Output information	AdIndFrEBrForNomLtd

S4R-502 - EB5.2.1.2 shall calculate the adhesion independent dynamic brake nominal force as the minimum between the train emergency brake force requested by EB4 and the constraints of force availability of adhesion independent dynamic brake

AdIndDynEBrForNomLtd= min((TrainEBrForNom; AdIndDynEBrAvFor(v))

Requirement identification	EB5.2.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Derived from blending logic and availability limitation.
Actor	EB5.2.1.2
Input information	TrainEBrForNom AdIndDynEBrAvFor
Output information	AdIndDynEBrForNomLtd

S4R-503 - EB5.2.2.2 shall calculate the adhesion Independent friction emergency brake nominal force by the following formula:
AdIndFrEBrForNomLtd= min(TrainEBrForNom-AdIndDynEBrForNomLtd; AdIndFrEBrAvFor)

Requirement identification	EB5.2.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Derived from blending logic and availability limitation
Actor	EB5.2.2.2
Input information	TrainEBrForNom AdIndDynEBrForLtd AdIndFrEBrAvFor
Output information	AdIndFrEBrForNomLtd

S4R-504 - EB5.2.1.1 shall calculate the adhesion dependent dynamic brake nominal force taking in account the constraints of force availability and adhesion limits.

AdDepDynEBrForNomLtd= min(AdMaxVal*(TrainMassEB)*9,81; TrainEBrForNom-AdIndDynEBrForLtd-AdIndFrEBrForLtd; AdDepDynEBrAvFor(v))

Requirement identification	EB5.2.11
Level	Brake System

Mainfunction	Emergency Brake
Type	Functional
Rationale	Derived from above blending logic, availability and adhesion limitation Note: the AdMaxVal is a parameter speed and train composition dependent, it can be the TSI value or contractually or project defined.
Actor	EB5.2.1.1
Input information	TrainEBrForNom AdDepDynEBrAvFor AdIndDynEBrForLtd AdIndFrEBrForLtd AdMaxVal TrainMassEB
Output information	AdDepDynEBrForNomLtd

S4R-505 - If AdDepDynEBrAchFor is not valid AdDepDynEBrForNomLtd=min(AdMaxVal*(TrainMassEB)*9,81; TrainEBrForNom-AdIndDynEBrForLtd-AdIndFrEBrForLtd; AdDepDynEBrForMin)

Requirement identification	EB5.2.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Without AdDepDynEBrAchFor information compensation of failure by friction brake cannot be performed, so the guaranteed value of adhesion dependent dynamic brake force is considered
Actor	EB5.3.1.1
Input information	AdDepDynEBrAchFor AdDepDynEBrForMin
Output information	AdDepDynEBrForNomLtd

S4R-506 - EB5.2.2.1 shall calculate the adhesion dependent friction emergency brake nominal force by the following formula: AdDepFrEBrForNomLtd=min((TrainEBrForNom-(AdDepDynSBrForNomLtd+AdIndDynSBrForNomLtd+AdIndFrEBrForNomLtd)); AdDepFrEBrAvFor; (AdMaxVal*(TrainMassEB)*9,81-AdDepDynEBrForNomLtd))

Requirement identification	EB5.2.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Derived from blending logic.

Actor	EB5.2.2.1
Input information	TrainEBrForNom AdDepDynEBrForNomLtd AdIndDynEBrForNomLtd AdIndFrEBrForLtd AdMaxVal TrainMassEB AdDepFrEBrAvFor
Output information	AdDepFrEBrForNomLtd

S4R-507 - EB5.3.2.1 shall generate an adhesion dependent friction emergency brake force request to EB5.5.2.1 , taking in account the nominal force by EB5.2.2.1 and real time blending with achieved force by adhesion cdependent dynamic emergency brake (received by EB5.4)

Requirement identification	EB5.3.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This is the step of the blending logics where the adhesion dependent friction emergency brake force request is defined.
Actor	EB5.3.2.1
Input information	AdDepFrEBrForNomLtd AdDepDynEBrForNomLtd AdDepDynEBrAchFor AdMaxVal (v)
Output information	AdDepFrEBrForReqLtd

S4R-508 - AdDepFrEBrForReqLtd is the force to be requested to be applied by the adhesion dependent friction emergency brake force generation function EB5.5.2.1

Requirement identification	EB5.3.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.3.2.1
Input information	

Output information	AdDepFrEBrForReqLtd

S4R-509 - The adhesione dependent friction emergency brake requested force shall be: AdDepFrEBrForReqLtd=AdDepFrEBrForNom+(AdDepDynEBrForNomLtd-AdDepDynEBrAchFor)

Requirement identification	EB5.3.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	See above req. 1.2.5.3
Actor	EB5.3.2.1
Input information	AdDepFrEBrForNomLtd AdDepDynEBrForNomLtd AdDepDynEBrAchFor
Output information	AdDepFrEBrForReqLtd

S4R-510 - If the total EB requested force is lower then the expected one (with a certain tolerance) a major fault shall be activated

AdDepDynEBrAchFor+AdIndDynEBrForReqLtd+AdDepFrEBrForReqLtd+AdIndFrEBrForReqLtd < TrainEBrRetMax*TrainBrPower-EBrForTol

Requirement identification	EB5.3.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirement is the final check that the sum of the requested forces to different type of brakes achieve the target given by braking power . Note: If the forces are not reached, after the train stop the braking power should be updated (see EB7 requirements). It can happen if double failure occurr during braking, because the braking power takes already in account the single failure
Actor	EB5.3.2.1
Input information	AdDepFrEBrForReqLtd AdDepDynEBrAchFor AdIndDynEBrForLtd AdIndFrEBrForLtd TrainEBrForNom EBrForTol TrainBrPower
Output information	MajFaultEB5321.1

S4R-511 - AdIndDynEBrForReqLtd is the force to be requested to the adhesion independent dynamic emergency brake force generation function EB5.5.1.2

Requirement identification	EB5.3.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.3.1.2
Input information	
Output information	AdIndDynEBrForReqLtd

S4R-512 - AdIndFrEBrForReqLtd is the force to be requested to the adhesion independent friction emergency brake force generation function EB5.5.2.2.2

Requirement identification	EB5.3.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.3.2.2
Input information	
Output information	AdIndFrEBrForReqLtd

S4R-513 - EBrForTol is the permitted tolerance of emergency brake force requested and the nominal one.

Requirement identification	EB5.3.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning

Input information	
Output information	EBrForTol

S4R-514 - MajFaultEB5321.1 is the fault information of emergency brake requested force lower than expected

Requirement identification	EB5.3.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.3.2.1
Input information	
Output information	MajFaultEB5321.1

S4R-515 - If AdDepDynEBrAchFor is not valid the AdDepFrEBrForReqLtd=AdDepFrEBrForNomLtd

Requirement identification	EB5.3.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Without AdDepDynEBrAchFor compensation of adhesion dependent dynamic brake failures cannot be performed.
Actor	EB5.3.1.1
Input information	AdDepDynEBrAchFor
Output information	AdDepFrEBrForReqLtd

S4R-516 - If AdDepDynEBrAchFor is not valid a major fault shall be set

Requirement identification	EB5.3.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	
Actor	EB5.3.1.1
Input information	AdDepDynEBrAchFor
Output information	MajFaultEB5321.2

S4R-517 - MajFaultEB5321.2 is the fault information of AdDepDynEBrAchFor information not valid

Requirement identification	EB5.3.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.3.1.1
Input information	
Output information	MajFaultEB5321.2

S4R-518 - EB5.4 shall measure the really applied braking force by adhesion dependent dynamic brake and trasmit it to EB5.3

Requirement identification	EB5.4.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This requirement is a consequence of the blending logic defined in EB5
Actor	EB5.4
Input information	WheelTorq
Output information	AdDepDynEBrAchFor

S4R-519 - The adhesion dependent dynamic brake shall provide the information of the really applied traction or braking force at the Trackset and trasmit it to EB5.3.2.1

Requirement identification	EB5.4.2
Level	Brake System

Mainfunction	Emergency Brake
Type	Functional
Rationale	TORQ device mentioned in D5.1
Actor	EB5.4
Input information	WheelTorq
Output information	AdDepDynEBrAchFor

S4R-520 - AdDepDynEBrAchFor is the value of the force applied at the track by the adhesion dependent dynamic brake

Requirement identification	EB5.4.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.4
Input information	
Output information	AdDepDynEBrAchFor

S4R-521 - EB5.5.2.1.1 shall generate an adhesion dependent friction brake force pilot command piloting a force application at the Track by EB5.5.2.1.2 equal to the force requested by EB5.3.2.1 (rotating mass to be considered)

Requirement identification	EB5.5.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	This function shall take in care to consider in the pilot also the rotating mass braking force necessary to apply at the track the requested force
Actor	EB5.5.2.1.1
Input information	AdDepFrEBrForReqLtd
Output information	AdDEpFrEBrPilCom

S4R-522 - AdDEpFrEBrPilCom is the pilot command applying an adhesion dependent friction brake force to the track equal to the requested force AdDepFrEBrForReqLtd

Requirement identification	EB5.5.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	AdDEpFrEBrPilCom

S4R-523 - EB5.5.2.1 .1 shall monitor the real adhesion dependent friction brake force applied

Requirement identification	EB5.5.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Monitoring is fundamental for control/diagnosys of the whole force generation process and precision of the force generated (closed loop control).
Actor	EB5.5.2.1.1.
Input information	AdDEpFrEBrForAppl
Output information	AdDEpFrEBrForApplMeas

S4R-524 - AdDepFrEBrForApplMeas is the information of the adhesion dependent friction emergency brake force applied at the track

Requirement identification	EB5.5.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1.
Input information	

Output information	AdDepFrEBrForApplMeas

S4R-525 - EB5.5.2.1.2 shall apply an adhesion dependent friction brake force to the Trackset, proportional to the pilot command trasmitted by EB5.5.2.1.1 and eventually reduced by LAM1.2.1

Requirement identification	EB5.5.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB5.5.2.1.2
Input information	AdDEpFrEBrPilComLAM
Output information	AdDepFrEBrForAppl

S4R-526 - AdDEpFrEBrPilComLAM is the pilot command,conditioned by the LAM1.2.1 function, provided to the adhesion dependent friction brake actuation function EB5.5.2.1.2

Requirement identification	EB5.5.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	LAM1.2.1
Input information	
Output information	AdDEpFrEBrPilComLAM

S4R-527 - EB5.5.2.1.1 shall monitor the adhesion dependent friction EB air supply pressure and trasmit the pressure value to diagnostic system

Requirement identification	EB5.5.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	The EB supply pressure shall be monitore by the force generation system, because it is the responsible of the effect of the pneumatic energy (generation of the force)
Actor	EB5.5.2.1.1
Input information	AdDEpFrEBrAirSupplPress
Output information	AdDEpFrEBrAirSupplMeas

S4R-528 - AdDepFrEBrAirSupplMeas is the information of the pressure of the air supply to the adhesion independent friction Emergency brake

Requirement identification	EB5.5.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	AdDepFrEBrAirSupplMeas

S4R-529 - If the AdDepFrEBrAirSupplPress is below the dimensioning limits AdDepFrEBrAirSupplPressMin, EB5.5.2.1.1 shall set major fault

Requirement identification	EB5.5.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Inexhaustibility requirement for the friction emergency brake. BSM shall manage it at train level.
Actor	EB5.5.2.1.1
Input information	AdDepFrEBrAirSupplMeas AdDepFrEBrAirSupplPressMin
Output information	MajFaultEB55211.1

S4R-530 - MajFaultEB55211.1 is the fault information of adhesion dependent friction Emergency brake supply pressure below the minimum limit AdDepFrEBrAirSupplPressMin

Requirement identification	EB5.5.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	MajFaultEB55211.1

S4R-531 - EB5.5.2.1.1 shall monitor the Electric Voltage to adhesion dependent friction emergency brake

Requirement identification	EB5.5.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB5.5.2.1.1.
Input information	AdDepFrEBrElVolt
Output information	AdDepFrEBrElVoltMeas

S4R-532 - AdDepFrEBrElVoltMeas is the information of the voltage of the electric supply to the adhesion independent friction emergency brake

Requirement identification	EB5.5.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1

Input information	
Output information	AdDepFrEBrAirSupplMeas

S4R-533 - If the electric voltage to EB5 is below the AdDepFrEBrMinElVolt or is lost, EB5.5.2.1.1 shall generate a major fault and apply automatically the maximum adhesion dependent friction emergency brake force by pilot command

Requirement identification	EB5.5.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The safe state for EB5 is brake application. The maximum emergency brake force correspond to the force with maximum load. In such a case the adhesion can be higher than allowed . In any case major fault is generated and BSM2.2.1 is able to release the braking if considered safe
Actor	EB5.5.2.1.1
Input information	AdDepFrEBrElVoltMeas AdDepFrEBrMinElVolt AdDepFrEBrPilCommEnOff AdDepFrEBrForMax
Output information	MajFaultEB55211.2 AdDepFrEBPilComm

S4R-534 - AdDepFrEBrPilCommEnOff is the Default pilot command to be applied in case of electric energy off or below the minimum value

Requirement identification	EB5.5.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1.
Input information	
Output information	AdDepFrEBrPilCommEnOff

S4R-535 - MajFaultEB55211.2 is the fault information that the electric voltage is below the minimum AdDepFrEBrElVoltMin or is lost

Requirement identification	EB5.5.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1.
Input information	
Output information	MajFaultEB55211.2

S4R-536 - If the adhesion dependent friction brake force measured is out of regulation tolerance EB5.5.2.1.1 shall generate a minor fault

Requirement identification	EB5.5.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The regulation tolerance is the one taking care of the accuracy of the brake force. The consistency of the force application with the dimensioning constraints is guaranteed by the monitoring of the whole braking force
Actor	EB5.5.2.1.1
Input information	AdDEpFrEBrForApplMeas AdDepFrEBrForReqLtd AdDepFrEBrForTol
Output information	MinFaultEB55211.1

S4R-537 - AdDepFrEBrForTol is the the upper and lower regulation tolerance of the adhesion dependent friction emergency brake force

Requirement identification	EB5.5.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning

Input information	
Output information	AdDepFrEBrForTol

S4R-538 - MinFaultEB55211.1 is the fault information of adhesion dependent friction emergency brake force out of regulation tolerance

Requirement identification	EB5.5.18
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	MinFaultEB55211.1

S4R-539 - If the adhesion dependent friction brake force measured is higher then the maximum allowed force for EB5.5.2.1.2, a major fault shall be set by EB5.5.2.1.1

Requirement identification	EB5.5.19
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The force generation system can be damaged
Actor	EB5.5.2.1.1
Input information	AdDEpFrEBrForApplMeas AdDepFrEBrForMax
Output information	MajFaultEB55211.3

S4R-540 - MajFaultEB55211.3 is the fault information of adhesion dependent friction emergency brake force above the maximum value AdDepFrEBrForMax

Requirement identification	EB5.5.20
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	MajFaultEB55211.3

S4R-541 - If the AdDEpFrEBrForApplMeas<AdDEpFrEBrForReqLtd of a value higher then AdDepFrEBrForMaxTol a major fault shall be set

Requirement identification	EB5.5.21
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	consistency check between the requested and the applied force
Actor	EB5.5.2.1.1
Input information	AdDepFrEBrForMaxTol AdDEpFrEBrForReqLtd AdDEpFrEBrForApplMeas
Output information	MajFaultEB55211.4

S4R-542 - MajFaultEB55211.4 is the fault information of adhesion dependent friction emergency brake force applied is lower than requested of a value higher than AdDepFrEBrForMaxTol

Requirement identification	EB5.5.22
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	MajFaultEB55211.4

S4R-543 - AdDepFrEBrForMaxTol is the maximum lower tolerance acceptable for Adhesion dependent friction emergency brake force

Requirement identification	EB5.5.23
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrForMaxTol

S4R-544 - If speed is > 3 km/h and the adhesion dependent friction brake force measured is >0 and the there is not a Adhesion dependent friction emergency brake request (taking in account a delay related to releasing time), a major fault shall be set by EB5.5.2.1.1

Requirement identification	EB5.5.24
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Dragging brake condition
Actor	EB5.5.2.1.1
Input information	TrainSpeed AdDEpFrEBrForApplMeas AdDepFrEBrForReqLtd TimeFilter
Output information	MajFaultEB55211.2

S4R-545 - MajFaultEB55211.5 is the fault information of adhesion dependent friction emergency brake force applied when not requested (dragging brake)

Requirement identification	EB5.5.25
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition

Rationale	
Actor	EB5.5.2.1.1
Input information	
Output information	MajFaultEB55211.5

S4R-546 - EB6.1 shall provide to EB the pneumatic energy to permit the correct regulation of emergency brake force by type of brakes using pneumatic energy

Requirement identification	EB6.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB6.1
Input information	AirSupplPress BrAirSupplDel
Output information	EBrAirSupplPress EBrAirSupplDel

S4R-547 - EBrAirSupplPress is the pressure of the air supply providing pneumatic energy to emergency brake

Requirement identification	EB6.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB6.1
Input information	
Output information	EBrAirSupplPress

S4R-548 - EBrAirSupplDel is the air delivery to the emergency brake functions

Requirement identification	EB6.3

Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB6.1
Input information	
Output information	EBrAirSupplDel

S4R-549 - EB6.1 shall limit the pneumatic pressure to the maximum permitted by EB5 dimensioning limits and shall provide an air delivery congruent with the air consumption of all types of brakes using pneumatic energy (taking care of WSPintervention as well)

Requirement identification	EB6.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Dimensioning constraint on different types of brakes. Note: this function can be done by any air pressure regulator limiting the supply pressure to EDV
Actor	EB6.1
Input information	AdDepDynEBrAirSupplPressMax AdIndDynEBrAirSupplPressMax AdDepFrEBrAirSupplPressMax AdIndFrEBrAirSupplPressMax AdDepDynEBrAirConsMax AdIndDynEBrAirConsMax AdDepFrEBrAirConsMax AdIndFrEBrAirConsMax
Output information	EBrAirSupplPressMax EBrAirDelMin EBrAirDelMax

S4R-550 - The EB6.1 minimum pressure and EB6.1 store volume shall guarantee the application for at least $x \geq 2$ time of the TrainEBrForNom without air supply function EB11.3 available.

Requirement identification	EB6.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional

Rationale	Inexhaustibility requirement. The number of time to be defined with customer
Actor	EB6.1
Input information	AdDepDynEBrAirSupplPressMin AdIndDynEBrAirSupplPressMin AdDepFrEBrAirSupplPressMin AdDepDynEBrAirConsMax AdIndDynEBrAirConsMax AdDepFrEBrAirConsMax TrainEBrForMin EBrAirSupplPressMin EBAirSupplStoreVol
Output information	AdDEpFrEBrAirSuppl

S4R-551 - EB6.1 leakages and store capacity shall guarantee that the supply pressure doesn't decrease of more than MaxDeltaPressEB due to leakages (without air supply available)

Requirement identification	EB6.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	To guarantee the force application for enough time
Actor	EB6.1
Input information	MaxDeltaPressEB EBAirSupplStoreVol
Output information	EBrAirSupplLeak

S4R-552 - EBrAirSupplPressMax is the max pressure of the emergency brake air supply

Requirement identification	EB6.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrAirSupplPressMax

S4R-553 - EBrAirSupplPressMin is the minimum pressure of the emergency brake air supply

Requirement identification	EB6.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrAirSupplPressMin

S4R-554 - EBrAirDelMax is the maximum air delivery of the emergency brake air supply which guarantee correct functionalities

Requirement identification	EB6.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrAirDelMax

S4R-555 - EBrAirDelMin is the minimum air delivery of the emergency brake air supply which guarantee correct functionalities

Requirement identification	EB6.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	EBrAirDelMin

S4R-556 - EBAirSupplStoreVol is the volume of the emergency brake supply air store

Requirement identification	EB6.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBAirSupplStoreVol

S4R-557 - EB6AirSupplLeak are the air leakages produced by EB6

Requirement identification	EB6.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB6.1
Input information	
Output information	EB6AirSupplLeak

S4R-558 - AdDepDynEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent dynamic emergency brake permitted by dimensioning

Requirement identification	EB6.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	AdDepDynEBrAirSupplPressMax

S4R-559 - AdIndDynEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion independent dynamic emergency brake permitted by dimensioning

Requirement identification	EB6.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrAirSupplPressMax

S4R-560 - AdDepFrEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning

Requirement identification	EB6.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrAirSupplPressMax

S4R-561 - AdIndFrEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion inddependent friction emergency brake permitted by dimensioning

Requirement identification	EB6.16
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrAirSupplPressMax

S4R-562 - AdDepDynEBrAirConsMax is the maximum air supply consumption of the Adhesion dependent dynamic emergency brake considered by dimensioning

Requirement identification	EB6.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrAirConsMax

S4R-563 - AdIndDynEBrAirConsMax is the maximum air supply consumption of the Adhesion independent dynamic emergency brake considered by dimensioning

Requirement identification	EB6.18
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrAirConsMax

S4R-564 - AdDepFrEBrAirConsMax is the maximum air supply consumption of the Adhesion dependent friction emergency brake considered by dimensioning

Requirement identification	EB6.19
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrAirConsMax

S4R-565 - AdIndFrEBrAirConsMax is the maximum air supply consumption of the Adhesion Independent friction emergency brake considered by dimensioning

Requirement identification	EB6.20
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrAirConsMax

S4R-566 - AdDepDynEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent dynamic emergency brake permitted by dimensioning

Requirement identification	EB6.21
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	AdDepDynEBrAirSupplPressMin

S4R-567 - AdIndDynEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion independent dynamic emergency brake permitted by dimensioning

Requirement identification	EB6.22
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrAirSupplPressMin

S4R-568 - AdDepFrEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning

Requirement identification	EB6.23
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrAirSupplPressMin

S4R-569 - AdIndFrEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning

Requirement identification	EB6.24
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition

Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrAirSupplPressMin

S4R-570 - MaxDeltaPressEB is the maximum acceptable decrease per minute of emergency brake supply pressure EBrAirSupplPress

Requirement identification	EB6.25
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	MaxDeltaPressEB

S4R-571 - EB6.2 shall provide to EB the low voltage electric energy to permit the correct regulation of emergency brake force by type of brakes using electric energy

Requirement identification	EB6.26
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	EBrMaxElVolt EBrMaxElCurr
Actor	EB6.2
Input information	ElVolt BrElCurr AdDepDynEBrElVoltNom AdIndDynEBrElVoltNom AdDepFrEBrElVoltNom AdIndFrEBrElVoltNom AdDepDynEBrElCurrNom AdIndDynEBrElCurrNom AdDepFrEBrElCurrNom AdIndFrEBrElCurrtNom
Output information	EBrElVolt EBrElCurr

S4R-572 - EB6.2 shall limit the electric energy voltage to the maximum permitted by EB dimensioning limits

Requirement identification	EB6.27
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Dimensioning constraint
Actor	EB6.2
Input information	AdDepDynEBrElVoltMax AdIndDynEBrElVoltMax AdDepFrEBrElVoltMax AdIndFrEBrElVoltMax AdDepDynEBrElCurrMax AdIndDynEBrElCurrMax AdDepFrEBrElCurrMax AdIndFrEBrElCurrtMax
Output information	EBrMaxElVolt EBrMaxElCurr

S4R-573 - EB6.2 shall be able to provide the necessary el energy to EB to apply the emergency brake force by all the type of brake using electric energy even in case of missing supply of energy by EB11.2 low voltage energy supply and guarantee the maximum brake application time

Requirement identification	EB6.28
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Dimensioning constraint
Actor	EB6.2
Input information	AdDepDynEBrForReqLtd AdIndDynEBrForReqLtd AdDepFrEBrForReqLtd AdIndFrEBrForReqLtd EBrMaxEqTime
Output information	EBrMinElVolt EBrMinElCurr

S4R-574 - The minimum voltage and electric energy store volume shall guarantee the supply for at least x minutes without air supply function EB11.2 available.

Requirement identification	EB6.29

Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Inexhaustibility requirement. The minutes to be agreed (at least 120 hours)
Actor	EB6.2
Input information	ElEnStoreCap EBrElVoltMin
Output information	EBrElVolt EBrElCurr

S4R-575 - ElVolt is the voltage of the electric energy supply to the brake system

Requirement identification	EB6.30
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Electric Energy Supply
Input information	
Output information	ElVolt

S4R-576 - EBrElVolt is the voltage of the electric energy supply to the Emergency brake system

Requirement identification	EB6.31
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB11.2
Input information	
Output information	EBrElVolt

S4R-577 - EBrElCurr is the electric current supplied to the Emergency brake system

Requirement identification	EB6.32
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB11.2
Input information	
Output information	EBrElCurr

S4R-578 - EBrElVoltMax is the maximum voltage by which EBr system can be supplied according dimensioning

Requirement identification	EB6.33
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrElVoltMax

S4R-579 - EBrElVoltMin is the minimum voltage by which SB system guarantee the functionalities

Requirement identification	EB6.34
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	

Output information	EBrElVoltMin

S4R-580 - EBrElCurrMax is the maximum current by which EBr system can be supplied according dimensioning

Requirement identification	EB6.35
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrElCurrMax

S4R-581 - EBrElCurrMin is the minimum current which guarantee correct functionalities of the Emergency brake

Requirement identification	EB6.36
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	EBrElCurrMax

S4R-582 - AdDepDynEBrElVoltNom is the nominal voltage by which adhesion dependent dynamic Emergency brake shall be supplied

Requirement identification	EB6.37
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	AdDepDynEBrElVoltNom

S4R-583 - AdIndDynEBrElVoltNom is the nominal voltage by which adhesion independent dynamic Emergency brake shall be supplied

Requirement identification	EB6.38
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrElVoltNom

S4R-584 - AdDepFrEBrElVoltNom is the nominal voltage by which adhesion dependent friction Emergency brake shall be supplied

Requirement identification	EB6.39
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrElVoltNom

S4R-585 - AdIndFrEBrElVoltNom is the nominal voltage by which adhesion independent friction Emergency brake shall be supplied

Requirement identification	EB6.40
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrElVoltNom

S4R-586 - AdDepDynEBrElCurrNom is the nominal current consumption of adhesion dependent dynamic Emergency brake

Requirement identification	EB6.41
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrElCurrNom

S4R-587 - AdIndDynEBrElCurrNom is the nominal current consumption of adhesion independent dynamic Emergency brake

Requirement identification	EB6.42
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrElCurrNom

S4R-588 - AdDepFrEBrElCurrNom is the nominal current consumption of adhesion dependent friction Emergency brake

Requirement identification	EB6.43
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrElCurrNom

S4R-589 - AdIndFrEBrElCurrNom is the nominal current consumption of adhesion independent friction Emergency brake

Requirement identification	EB6.44
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrElCurrNom

S4R-590 - AdDepDynEBrElVoltMax is the maximum voltage by which adhesion dependent dynamic Emergency brake shall be supplied

Requirement identification	EB6.45
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrElVoltMax

S4R-591 - AdIndDynEBrElVoltMax is the maximum voltage by which adhesion independent dynamic Emergency brake shall be supplied

Requirement identification	EB6.46
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrElVoltMax

S4R-592 - AdDepFrEBrElVoltMax is the maximum voltage by which adhesion dependent friction Emergency brake shall be supplied

Requirement identification	EB6.47
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrElVoltMax

S4R-593 - AdIndFrEBrElVoltMax is the maximum voltage by which adhesion independent friction Emergency brake shall be supplied

Requirement identification	EB6.48
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	Dimensioning
Input information	
Output information	AdIndFrEBrElVoltMax

S4R-594 - AdDepDynEBrElCurrMax is the maximum current consumption of adhesion dependent dynamic Emergency brake

Requirement identification	EB6.49
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrElCurrMax

S4R-595 - AdIndDynEBrElCurrMax is the maximum current consumption of adhesion independent dynamic Emergency brake

Requirement identification	EB6.50
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrElCurrMax

S4R-596 - AdDepFrEBrElCurrMax is the maximum current consumption of adhesion dependent friction Emergency brake

Requirement identification	EB6.51
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrElCurrMax

S4R-597 - AdIndFrEBrElCurrMax is the maximum current consumption of adhesion independent friction Emergency brake

Requirement identification	EB6.52
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrElCurrMax

S4R-598 - AdDepDynEBrElVoltMin is the minimum voltage by which adhesion dependent dynamic Emergency brake shall be supplied

Requirement identification	EB6.53
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepDynEBrElVoltMin

S4R-599 - AdIndDynEBrElVoltMin is the minimum voltage by which adhesion independent dynamic Emergency brake shall be supplied

Requirement identification	EB6.54

Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndDynEBrElVoltMin

S4R-600 - AdDepFrEBrElVoltMin is the minimum voltage by which adhesion dependent friction Emergency brake shall be supplied

Requirement identification	EB6.55
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdDepFrEBrElVoltMin

S4R-601 - AdIndFrEBrElVoltMin is the minimum voltage by which adhesion independent friction Emergency brake shall be supplied

Requirement identification	EB6.56
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	Dimensioning
Input information	
Output information	AdIndFrEBrElVoltMin

S4R-602 - EB7 shall define the train braking powe based on dimensioning hypothesis and availability of different types of brake

Requirement identification	EB7.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The protection on minimum braking power is not provided by brake system, but by ETCS/ATP. For this reason no requirement of brake application in case of too low braking power is foreseen.
Actor	EB7
Input information	AdDepDynEBrAvFor AdIndDynEBrAvFor AdDepFrEBrAvFor AdIndFrEBrAvFor
Output information	TrainBrPower

S4R-603 - EB7 shall calculate the braking power at train enabling and at any permanent isolation of any type of brake

Requirement identification	EB7.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The isolation produce a change of the available force
Actor	EB7
Input information	AdDepDynEBrAvFor AdIndDynEBrAvFor AdDepFrEBrAvFor AdIndFrEBrAvFor
Output information	TrainBrPower

S4R-604 - EB8 shall require the traction cut off to traction system in case of emergency brake request

Requirement identification	EB8.1
Level	Brake System
Mainfunction	Emergency Brake

Type	Functional
Rationale	
Actor	EB8
Input information	EBrReq
Output information	TractForAppl

S4R-605 - If EBrReq information is not valid traction shall be cut off immediately

Requirement identification	EB8.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	If the EBrReq is not valid automatic brake application is piloted by EB4 and traction shall be cut off
Actor	EB8
Input information	EBrReq
Output information	TractForAppl

S4R-606 - If Train Integrity is lost traction must be cut off immediately

Requirement identification	EB8.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB8
Input information	TrainIntegr
Output information	TractForAppl

S4R-607 - The emergency brake function EB9 shall detect and indicate in the driver cab and/or outside the train the status of the emergency brake and of its sub-functions

Requirement identification	EB9.1

Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB9
Input information	
Output information	EBrStatus

S4R-608 - EBrStatus is the information providing the released or applied status of emergency brake

Requirement identification	EB9.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9
Input information	
Output information	EBrStatus

S4R-609 - EB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake (EB) which can have following status:
Applied: if any type of brake is applying a braking force
Released: if every type of brake is released

Requirement identification	EB9.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The EB status represent the presence of an applied force to the train, independently from brake request, fault active or type of brake applying a force.
Actor	EB9.1
Input information	AdDepDynEBrStatus AdIndDynEBrStatus

	AdDepFrEBrStatus AdIndFrEBrStatus
Output information	EBrStatus

S4R-610 - AdDepDynEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent dynamic emergency brake

Requirement identification	EB9.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.2
Input information	
Output information	AdDepDynEBrStatus

S4R-611 - AdIndDynEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent dynamic emergency brake

Requirement identification	EB9.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.3
Input information	
Output information	AdIndDynEBrStatus

S4R-612 - AdDepFrEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent friction emergency brake

Requirement identification	EB9.6
Level	Brake System
Mainfunction	Emergency Brake

Type	Definition
Rationale	
Actor	EB9.4
Input information	
Output information	AdDepFrEBrStatus

S4R-613 - AdIndFrEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent friction emergency brake

Requirement identification	EB9.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.4
Input information	
Output information	AdIndFrEBrStatus

S4R-614 - EB9.1 function shall provide to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake functions EB1, EB2 which can have following status:
Nominal: when BSM1 has correctly configured the brake system and there is not any major fault active in EB1 or EB2

Degraded: when the emergency brake degraded mode is successfully activated by BSM2.1.2 after the driver selection of emergency brake degraded mode

Faulty: if it is not in degraded mode and there is a major fault on EB1 or EB2

Requirement identification	EB9.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	EB1 and EB2 are the sub-function managing the emergency brake request, which is the brake central command. For this reason a single status is defined. A faulty EB1,EB2correspond to the impossibility to provide the emergency brake command, ie to loose the continuity of the emergency brake (for this reason any major fault on EB1 and EB2 functions leads to an automatic emergency brake).
Actor	EB9.1

Input information	MajFaultAnyEB1 MajFaultAnyEB2 EBrDegr
Output information	EBrStatusEB1-2

S4R-615 - EBrStatusEB1-2 is the information providing the enabled/disabled/degraded/faulty status of emergency brake sub-functions EB1 and EB2

Requirement identification	EB9.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.1
Input information	
Output information	EBrStatusEB1-2

S4R-616 - MajFaultAnyEB1 is the summary information of any major fault active on sub-function EB1

Requirement identification	EB9.10
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB1
Input information	
Output information	MajFaultAnyEB1

S4R-617 - MajFaultAnyEB2 is the summary information of any major fault active on sub-function EB2

Requirement identification	EB9.11
Level	Brake System

Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB2
Input information	
Output information	MajFaultAnyEB2

S4R-618 - EB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake function EB3 which can have following status:
enabled: when BSM1 has correctly initialized the brake system and there is not any major fault active in EB3

disabled: when it is not enabled

faulty: if it is enabled and any major fault active in EB3

Requirement identification	EB9.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	EB3 function is independent from other brake function and need a independent status Major fault of EB3 is managed by EB3 fixing a predefined mass (see req. in EB3)
Actor	EB9.1
Input information	EBrEnabled MajFaultAnyEB3
Output information	EBrStatusEB3

S4R-619 - MajFaultAnyEB3 is the summary information of any major fault active on sub-function EB3

Requirement identification	EB9.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	

Actor	EB9.1
Input information	
Output information	MajFaultAnyEB3

S4R-620 - EBrStatusEB3 is the information providing the enabled/disabled/faulty status of emergency brake sub-function EB3

Requirement identification	EB9.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.1
Input information	
Output information	EBrStatusEB3

S4R-621 - The adhesion dependent friction brake shall provide is own status derived from EB4-EB5-EB10 functions . The status can be :
Applied: if any braking force is applied
Released: if force is not applied
Isolated: if it is isolated
Faulty: if a major fault is active

Requirement identification	EB9.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	EB12 function has not influence on EB status because EB12 is dimensioned according the worst thermal dissipation condition and in any case SB12 would send a warnng in case dimensioning condition should be overpassed (see req. 1.1.12.4)
Actor	EB9.4
Input information	AdDepFrEBrApplMeas MajFaultAnyAdDepFrEBrEB4-5-10 AdDepFrEBrIsolStatus AdDepFrEBrForMax
Output information	AdDepFrEBrStatus

S4R-622 - MajFaultAnyAdDepFrEBrEB4-5-10 is the summary information of any major fault active on adhesion dependent friction emergency brake in sub-function EB4, EB5.1.2.1, EB5.2.2.1, EB5.3.2.1 EB5.5.2.1.1, EB5.5.2.1.2, EB10.3

Requirement identification	EB9.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.4
Input information	
Output information	MajFaultAnyEB4-5-10

S4R-623 - The adhesion depedent friction emergency brake status is applied if EB5.5.2.1.1 detect AdDepFrEBrApplMeas>0

Requirement identification	EB9.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The force application is detected by the closer information to the wheelset
Actor	EB9.4
Input information	AdDepFrEBrApplMeas
Output information	AdDepFrEBrStatus

S4R-624 - The adhesion depedent friction emerency brake status is released if EB5.5.2.1.1 detect AdDepFrEBrApplMeas=0

Requirement identification	EB9.18
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The force application is detected by the closer information to the wheelset
Actor	EB9.4
Input information	AdDepFrEBrApplMeas
Output information	AdDepFrEBrStatus

S4R-625 - The adhesion depedent friction emergency brake status is faulty if any major fault is detected by functions EB4, EB5.1.2.1, EB5.2.2.1, EB5.3.2.1 EB5.5.2.1.1, EB5.5.2.1.2, EB10.3 performed by adhesion dependent friction brake type

Requirement identification	EB9.19
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The mentioned EB4, EB5, EB10.3 functions are in charge of the adhesion dependent friction brake force generation. EB5.4 major fault does not impact the correct functionality of adhesion dependent friction brake, for this reason is not mentioned. EB6 function, which can cause a fault in adhesion dependent friction emergency brake, is monitored by EB5.2 so its faulty status is already included in EB5 faulty status. EB7 is a function at brake system level, it doesn't influence the adhesion dependent emergency brake force
Actor	EB9.4
Input information	MajFaultAnyEB4-5-10
Output information	AdDepFrEBrStatus

S4R-626 - The adhesion dependent friction emergency brake isolation status shall indicate the percentage of available force respect the maximum one, based on EB10.3 permanent isolation

Requirement identification	EB9.20
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The isolation gives the information about force availability to EB5.1.2.1 function. The remote release is not considered in EB because it is a degraded condition and is inhibited when EB is triggered by the actors (see BSM sub-function).
Actor	EB9.4
Input information	AdDepFrEBrIsolStatus AdDepFrEBForMax
Output information	AdDepFrEBrStatus

S4R-627 - The adhesion dependent friction emergency brake status (only applied or released information) shall be show optionally external the train, also in case of lack of energy (pneumatic or electric)

Requirement identification	EB9.21
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The external indication is usefull for maintenance.
Actor	EB5.5.2.1.2
Input information	AdDepFrEBrStatus
Output information	AdDepFrEBrStatusEXT

S4R-628 - AdDepFrEBrStatusEXT is the information of applied/released adhesion dependent friction brake visible externally of the train

Requirement identification	EB9.22
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB9.4
Input information	
Output information	AdDepFrEBrStatusEXT

S4R-629 - Any minor fault or major fault shall be trasmitted to diagnostic system, diagnostic tool

Requirement identification	EB9.23
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB9.4
Input information	MinFaultEBx MajFaultEBx

Output information	MinFaultEBx MajFaultEBx

S4R-630 - Any major fault shall be trasmitted to driver HMI, diagnostic system, diagnostic tool

Requirement identification	EB9.24
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB9.4
Input information	MajFaultEBx
Output information	MajFaultEBx

S4R-631 - EB10 shall manage the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application by EB5.5.2 function

Requirement identification	EB10.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The isolation has the scope to remove permanentely an amount of force, independently from the force generation function, to be able to react to any major fault which would stop permanentely the train or oblige the driver to run in degraded mode
Actor	EB10
Input information	AdDepDynEBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom; AdDepFrEBrRemRelCom AdDepDynEBrIsolCom AdIndDynEBrIsolCom AdDepFrEBrIsolCom AdIndFrEBrIsolCom
Output information	AdDEpDynEBrForAppl AdIndDynEBrForAppl AdDEpFrEBrForAppl AdIndFrEBrForAppl

S4R-632 - AdDepDynEBrIsolCom is the command of permanent isolation of adhesion dependent dynamic emergency brake

Requirement identification	EB10.2

Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepDynEBrIsolCom

S4R-633 - AdIndDynEBrIsolCom is the command of permanent isolation of adhesion independent dynamic emergency brake

Requirement identification	EB10.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdIndDynEBrIsolCom

S4R-634 - AdDepFrEBrIsolCom is the command of permanent isolation of adhesion dependent friction emergency brake

Requirement identification	EB10.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepFrEBrIsolCom

S4R-635 - AdIndFrEBrIsolCom is the command of permanent isolation of adhesion Independent friction emergency brake

Requirement identification	EB10.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdIndFrEBrIsolCom

S4R-636 - EB10.3 shall manage the isolation of adhesion dependent friction brake by remote release and permanent isolation subfunctions

Requirement identification	EB10.6
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB10.3
Input information	AdDepFrEBrRemRelCom AdDepFrEBrIsolCom
Output information	AdDEpFrEBrForAppl

S4R-637 - EB10.3 remote release sub-function shall permit to remove the adhesion dependent friction emergency brake force by remote command

Requirement identification	EB10.7
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The remote isolation permit to react to any major fault quickly permitting to manage the running capability requirements in case of undue emergency brake application. The remote release command is in charge of BSM2.2.1
Actor	EB10.3

Input information	AdDepFrEBrRemRelCom
Output information	AdDEpFrEBrForAppl

S4R-638 - The remote release sub-function shall operate on EB5.5.2.1 sub-function removing the force application independently from EB5.3.2.1 command

Requirement identification	EB10.8
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Closer the release command is to the force generation fewer are the functions which can influence the release.
Actor	EB10.3
Input information	AdDepFrEBrRemRelCom
Output information	AdDEpFrEBrPilCom or AdDEpFrEBrPilComLAM

S4R-639 - The emergency brake remote release shall be enabled in case of major fault only.

Requirement identification	EB10.9
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The BSM2.1 function shall be capable to remove a braking only in presence of major fault to mitigate the possibility to have undue emergency braking force releasing
Actor	EB10.3
Input information	MajFaultEBx
Output information	AdDEpFrEBrRemRelCom

S4R-640 - EB10.3 permanent isolation sub-function shall permit to remove the adhesion dependent friction emergency brake force applied, totally or partially, permanentely, with or without energy available on the train, with EB in any status

Requirement identification	EB10.10
Level	Brake System

Mainfunction	Emergency Brake
Type	Functional
Rationale	The permanent isolation shall be an autonomous sub-function able to operate whatever are the condition of the other emergency brake sub-functions because it is the last operation that can be done to permit at the train to remove the braking force and be moved.
Actor	EB10.3
Input information	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom
Output information	AdDEpFrEBrForAppl

S4R-641 - The permanent isolation can be commanded by driver or maintenance operator manually or, optionally, by remote command via BSM2.2.1

Requirement identification	EB10.11
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	The optional remote command permit to isolate permanentely from a central position
Actor	EB10.3
Input information	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom
Output information	AdDEpFrEBrForAppl

S4R-642 - AdDepFrEBrIsolManCom is the command of permanent isolation of adhesion dependent friction emergency brake provided by manual command

Requirement identification	EB10.12
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepFrEBrIsolManCom

S4R-643 - The permanent isolation sub-function shall operate on EB5.5.2.1 sub-function removing the force application independently from EB5.3.2.1 command

Requirement identification	EB10.13
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Closer the permanent isolation is to the force generation fewer are the functions which can influence the result by any failure or power switch off.
Actor	EB10.3
Input information	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom
Output information	AdDEpFrEBrPilCom or AdDEpFrEBrPilComLAM

S4R-644 - Permanent isolation sub-function shall monitor the permanent isolation execution checking the applied force by AdDepFrEBrForApplMeas information received by EB5.5.2.1.1.
If permanent release is not successful (command of permanent release active and brake force still applied) EB10.3 shall set a major fault

Requirement identification	EB10.14
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	To diagnose dragging brake
Actor	EB10.3
Input information	AdDepFrEBrForApplMeas AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom
Output information	MajFaultEB103.1

S4R-645 - MajFaultEB103.1 is the fault information about the not success permanent isolation execution

Requirement identification	EB10.15
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition

Rationale	
Actor	EB10.3
Input information	
Output information	MajFaultEB103.1

S4R-646 - Permanent isolation shall define the permanent isolation status as:
Isolated force: it shall provide the percentage of maximum adhesion depedent friction emergency brake force released by permanent isolation.
Faulty: if permanent isolation is not succesfull in releasing completely the expected force

Requirement identification	EB10.16
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB10.3
Input information	AdDepFREBrForApplMeas AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom MajFault103.1 AdDepFrEBrForMax
Output information	AdDepFrEBrIsolStatus

S4R-647 - AdDepFrEBrIsolStatus is the information of permanent isolated force/faulty permanent isolation of adhesion dependent friction emergency brake force

Requirement identification	EB10.17
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB10.3
Input information	
Output information	AdDepFrEBrIsolStatus

S4R-648 - EB12.2 function shall transform the kinetic energy of the train into thermal energy by the friction between two surfaces

Requirement identification	EB12.1
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	Physics
Actor	EB12.2
Input information	TrainKinEn
Output information	ThermEn

S4R-649 - EB12.2.1 shall generate heat from the contact between two friction surface sliding with an applied perpendicular force that generates the AdDEpFrEBrForAppl force at the Trackset.

Requirement identification	EB12.2
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB12.2.1
Input information	AdDepFrEBrForAppl
Output information	AdDepFrEBrHeat

S4R-650 - AdDepFrEBrHeat is the heat generated by dissipation process of adhesion dependent friction emergency brake

Requirement identification	EB12.3
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB12.2.1
Input information	

Output information	AdDepFrEBrHeat

S4R-651 - EB12.2.2 shall dissipate the heat generated by EB12.2.1 into the air

Requirement identification	EB12.4
Level	Brake System
Mainfunction	Emergency Brake
Type	Functional
Rationale	
Actor	EB12.2.2.
Input information	AdDepFrEBrThermEn
Output information	AirThermEnEB

S4R-652 - AirThermEnEB is the emergency brake thermal energy dissipated into the air

Requirement identification	EB12.5
Level	Brake System
Mainfunction	Emergency Brake
Type	Definition
Rationale	
Actor	EB12.2.2.
Input information	
Output information	AirThermEnEB

S4R-653 - The parking brake is the system function used by the users and technical systems (actors) to apply predefined braking force to the track (directly or by the wheelset) with the following goal:
- to immobilize permantely the train, without any available energy on board

Requirement identification	PB.1
Level	Brake System
Mainfunction	Parking Brake
Type	Functional
Rationale	

Actor	PB
Input information	PBrReqUs
Output information	TrainPBrForAppl

S4R-654 - TrainPBrForAppl is the portion of force TrainImmForAppl applied by the main function parking brake to the track

Requirement identification	PB.2
Level	Brake System
Mainfunction	Parking Brake
Type	Definition
Rationale	
Actor	PB
Input information	
Output information	TrainPBrForAppl

S4R-655 - PBrReqUs is the request to apply the parking brake by driver (or any other user)

Requirement identification	PB.3
Level	Brake System
Mainfunction	Parking Brake
Type	Definition
Rationale	
Actor	PB1
Input information	
Output information	PBrReqUs

S4R-656 - When PB functions receive the electrical power supply shall perform a self test and trasmit the result to BSM1 function

Requirement identification	PB.4
Level	Brake System
Mainfunction	Parking Brake

Type	Functional
Rationale	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of PB and compare it with the expected one (initialization of the brake)
Actor	EB
Input information	PBrElVolt
Output information	SelfTestPBrRes

S4R-657 - SelfTestPBrRes is the result of the self test performed by parking brake when receive electric power supply

Requirement identification	PB.5
Level	Brake System
Mainfunction	Parking Brake
Type	Definition
Rationale	
Actor	EB
Input information	
Output information	SelfTestPBrRes

S4R-658 - BSM1 sub-function manages the Brake System initialization and configuration at train power up or coupling/uncoupling

Requirement identification	BSM1.1
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	
Actor	BSM1
Input information	
Output information	

S4R-659 - BSM1 shall check the correct brake system configuration based on train configuration received by TCMS and result of automatic self test of Service Brake, Emergency Brake and Parking brake

Requirement identification	BSM1.2
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The train configuration by TCMS, EB, EB, PB shall be consistent and EB, EB, PB shall guarantee the minimum performances
Actor	BSM1
Input information	SBrSelfTestRes EBrSelfTestRes PBrSelfTestRes TrainConfigTCMS
Output information	SBrSystInit EBrSystInit PBrSystInit

S4R-660 - TrainConfigTCMS is the train configuration information received by TCMS

Requirement identification	BSM1.3
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	TCMS
Input information	
Output information	TrainConfigTCMS

S4R-661 - SBrSystInit is the service brake correctly inizialized information

Requirement identification	BSM1.4
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM1

Input information	
Output information	SBrSystInit

S4R-662 - EBrSystInit is the emergency brake correctly inizialized information

Requirement identification	BSM1.5
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM1
Input information	
Output information	EBrSystInit

S4R-663 - PBrSystInit is the parking brake correctly inizialized information

Requirement identification	BSM1.6
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM1
Input information	
Output information	PBrSystInit

S4R-664 - The service brake function can be enabled or disabled

Requirement identification	BSM1.7
Level	Brake System
Mainfunction	Brake System Management
Type	Functional

Rationale	
Actor	BSM1
Input information	DrDeskEn BrSystInit
Output information	SBrEnabled

S4R-665 - SBrEnabled is the information about the enabling of the service brake: if SBrEnabled is active, service brake is enabled; if SBrEnabled is not active, service brake is disabled

Requirement identification	BSM1.8
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM1
Input information	
Output information	SBrEnabled

S4R-666 - The service brake system shall be disabled when the train has not a single enabled driver desk or the brake system is not correctly initialized

Requirement identification	BSM1.9
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The service brake is the brake to be used by actors during operation of the train. If the train is not enabled no operation is allowed, so service brake is not needed
Actor	BSM1
Input information	DrDeskEn SBrSystInit
Output information	SBrEnabled

S4R-667 - DrDeskEn is the information of driver desk correctly enabled by the driver

Requirement identification	BSM1.10

Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	TCMS
Input information	
Output information	DrDeskEn

S4R-668 - The service brake system shall be enabled when the train has one and only one enabled driver desk and the brake system had a correct initialization

Requirement identification	BSM1.11
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Continuity concept (one and only one central command and all brakes are connected to the central command)
Actor	BSM1
Input information	DrDeskEn SBrSystInit
Output information	SBrEnabled

S4R-669 - If service brake system configuration is not correct, service brake shall not be enabled and parking brake release inhibited

Requirement identification	BSM1.12
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Automaticity concept: service brake system integrity lost. Considering that the service brake system status is not known, the parking brake function shall guarantee the immobilization
Actor	BSM1
Input information	SBrSystInit

Output information	PBrReqBSM

S4R-670 - PBrReqBSM is the request to apply the parking brake by main function BSM

Requirement identification	BSM1.13
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM
Input information	
Output information	PBrReqBSM

S4R-671 - BSM2 manages the operative mode of the Brake system during operation

Requirement identification	BSM2.1
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	
Actor	BSM2
Input information	
Output information	

S4R-672 - BSM2.1.1 shall manage automatically the reaction to any major fault of service brake

Requirement identification	BSM2.2
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	

Actor	BSM2.1.1
Input information	MajFaultSBx
Output information	SBrReqBSM AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom AdDepDynSBrIsolRemCom AdIndDynSBrIsolRemCom AdDepFrSBrIsolRemCom

S4R-673 - SBrReqBSM is the request to decelerate via service brake the train by the Brake system itself, provided via BSM. It is a deceleration (negative) value.

Requirement identification	BSM2.3
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2
Input information	
Output information	SBrReqBSM

S4R-674 - AdDepDynSBrRemRelCom is the command of remote realease of adhesion dependent dynamic service brake force portion which is in failure

Requirement identification	BSM2.4
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdDepDynSBrRemRelCom

S4R-675 - AdIndDynSBrRemRelCom is the command of remote realease of adhesion independent dynamic service brake force portion which is in failure

Requirement identification	BSM2.5
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdIndDynSBrRemRelCom

S4R-676 - AdDepFrSBrRemRelCom is the command of remote realease of adhesion dependent friction service brake force portion which is in failure

Requirement identification	BSM2.6
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdDepFrSBrRemRelCom

S4R-677 - AdDepDynSBrIsolRemCom is the remote command of permanent isolation of adhesion dependent dynamic service brake portion of force

Requirement identification	BSM2.7
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	

Output information	AdDepDynSBrIsolRemCom

S4R-678 - AdIndDynSBrIsolRemCom is the remote command of permanent isolation of adhesion independent dynamic service brake portion of force

Requirement identification	BSM2.8
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdIndDynSBrIsolRemCom

S4R-679 - AdDepFrSBrIsolRemCom is the remote command of permanent isolation of adhesion dependent friction service brake portion of force

Requirement identification	BSM2.9
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdDepFrSBrIsolRemCom

S4R-680 - The service brake remote release command can be activated only as reaction to a major fault, when necessary to guarantee the operation of the train.

Requirement identification	BSM2.10
Level	Brake System
Mainfunction	Brake System Management
Type	Functional

Rationale	The remote release change the braking capacity of the service brake
Actor	BSM2.1.1
Input information	MajFaultSBx
Output information	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom

S4R-681 - BSM2.1.1 shall limit the AdDepFrSBrForAppl remote release command to guarantee at least the AdDepFrSBrForMin

Requirement identification	BSM2.11
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The Adhesion dependent friction service brake force min force shall be always available
Actor	BSM2.1.1
Input information	MajFaultSBx AdDepFrSBrForMin
Output information	AdDepFrSBrRemRelCom

S4R-682 - BSM2.1.1 sub-function shall monitor the remote release execution, monitoring the adhesion dependent friction service brake applied force

Requirement identification	BSM2.12
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	A indipenden service brake force application measurement to the one done by SB5.5.2.1 permit to diagnose the correct release also in case of major fault of force application sub-function
Actor	BSM2.1.1
Input information	AdDepFrSBrRemRelCom
Output information	AdDepFRSBrForRelMeas

S4R-683 - AdDepFrSBrForRelMeas is the information of remote release correctly applied

Requirement identification	BSM2.13
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdDepFrSBrForRelMeas

S4R-684 - If remote release is not successfull (command of remote release active and brake force still applied) a major fault shall be set

Requirement identification	BSM2.14
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	To activate protection against dragging brake also with SB5.5.2.1.1 monitoring faulty
Actor	BSM2.1.1
Input information	AdDepFrSBrRemRelCom
Output information	MajFaultBSM211.1

S4R-685 - MajFaultBSM211.1 is the fault information of not correct remote release application

Requirement identification	BSM2.15
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	MajFaultBSM211.1

S4R-686 - The remote release monitoring shall be crosschecked with SB5.5.2.1.1 force appl monitoring and in case of inconsistency a major fault generated

Requirement identification	BSM2.16
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Permanent check of diagnostic consistency.
Actor	BSM2.1.1
Input information	AdDepFRSBrForRelMeas AdDepFRSBrForApplMeas
Output information	MajFaultBSM211.2

S4R-687 - MajFaultBSM211.2 is the fault information of brake release detection inconsistency between BSM2.1.1 and SB5.5.2.1.1

Requirement identification	BSM2.17
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	MajFaultBSM211.2

S4R-688 - BSM2.1.1 shall define the remote release status as
Released force: it shall provide the percentage of maximum adhesion depedent friction service brake force released by remote release.
Faulty: if remote release is not succesfull in release completely the expected force

Requirement identification	BSM2.18
Level	Brake System
Mainfunction	Brake System Management
Type	Functional

Rationale	Information that will be used by SB5.1.2.1 to calculated the available frition brake force
Actor	BSM2.1.1
Input information	AdDEpFrSBrForRelMeas AdDepFrSBrRemRelCom MajFaultBSM211.1 AdDepFrSBrForMax
Output information	AdDepFrSBrRemRelStatus

S4R-689 - AdDepFrSBrRemRelStatus is the the information of Remotly released force/faulty remote release

Requirement identification	BSM2.19
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.1
Input information	
Output information	AdDepFrSBrREmRelStatus

S4R-690 - The service brake remote release shall be possible only if the service brake system is enabled

Requirement identification	BSM2.20
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The remote release can be done only by remote commands, requiring an operating brake system
Actor	BSM2.1.1
Input information	SBrEnable
Output information	AdDepFrSBrRemRelCom

S4R-691 - The permanent isolation of the force which is remotly released shall remove the remote release command insisting on that force

Requirement identification	BSM2.21

Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	To guarantee the consistency of isolation status
Actor	BSM2.1.1
Input information	AdDepFrSBrIsolStatus
Output information	AdDepFrSBrRemRelCom

S4R-692 - The remote release shall be inhibited if the TrainSBrForMin is not available

Requirement identification	BSM2.22
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Inexhaustibility requirement
Actor	BSM2.1.2
Input information	AdDepDynSBrAvFor AdIndDynSBrAvFor AdDepFrSBrAvFor TrainSBrForMin
Output information	AdDepFrSBrRemRelCom

S4R-693 - BSM2.1.1 shall permit the driver or maintenance operator to permanentely isolate by centralized command totally or partially the Adhesion dependent Friction Service brake applied force

Requirement identification	BSM2.23
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	This is a consequence of requirement about permanent isolation of SB10.3
Actor	BSM2.1.1
Input information	AdDepFrSBrIsolCentrCom
Output information	AdDepFrSBrIsolRemCom

S4R-694 - AdDepFrSBrIsolCentrCom is the remote command by any user to permantly isolate adhesion dependent friction service brake portion of force

Requirement identification	BSM2.24
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepFrSBrIsolCentrCom

S4R-695 - The driver shall be allowed to disabled the holding brake function SB7 at train level

Requirement identification	BSM2.25
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	If the SB7 Holding brake function is in major fault emergency brake is applied on the whole train. To guarantee running capability it shall be possible to remove the emergency brake
Actor	BSM2.1.2
Input information	HBrEnDis
Output information	HBrEnabled

S4R-696 - HBrEnabled is the information of the status of the holding brake activation: if active HBrEnabled = active, if not active HBrEnabled = not active

Requirement identification	BSM2.26
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	

Actor	BSM2.1.2
Input information	
Output information	HBrEnabled

S4R-697 - If the holding brake is disabled the driver shall be continuesly awared by the driver HMI

Requirement identification	BSM2.27
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The driver shall be continuesly awared of a degraded condition of the train which remind him to change the normal habits
Actor	Driver HMI
Input information	HBrEnabled
Output information	HBrDisabled

S4R-698 - If the Holding brake is disabled the driver shall take care of the temporary immobilization of the train by applying the proper service or emergency brake command at any stop or in case of roll back

Requirement identification	BSM2.28
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Safety function exported to the driver
Actor	Driver
Input information	HBrDisabled
Output information	TrSBrReqUs, SBrReqUs

S4R-699 - The driver shall be allowed to activate a degraded mode to manage the service brake command in case of major faults of sub-functions SB1 and SB2

Requirement identification	BSM2.29
Level	Brake System
Mainfunction	Brake System Management

Type	Functional
Rationale	Note: This function is what actually is called back-up brake in case of electronic control of brake pipe is in major fault
Actor	BSM2.1.2
Input information	MajFaultAnySB1 MajFaultAnySB2 SBrDegrCommDr
Output information	SBrDegr

S4R-700 - SBrDegrCommDr is the command selecting the SB degraded mode

Requirement identification	BSM2.30
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	Driver
Input information	
Output information	SBrDegrCommDr

S4R-701 - SBrDegr is the information that driver has selected the Service Brake degraded mode

Requirement identification	BSM2.31
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.1.2
Input information	
Output information	SBrDegr

S4R-702 - BSM2.2.1 shall manage automatically the reaction to any major fault of emergency brake

Requirement identification	BSM2.32

Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	
Actor	BSM2.2.1
Input information	MajFaultEBx
Output information	EBrReqBSM AdDepDynBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom AdDepDynEBrIsolRemCom AdIndDynEBrIsolRemCom AdDepFrEBrIsolRemCom AdIndFrEBrIsolRemCom

S4R-703 - EBrReqBSM is the request to apply the emergency brake by brake system itsself via BSM sub-function

Requirement identification	BSM2.33
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	EBrReqBSM

S4R-704 - AdDepDynEBrRemRelCom is the command of remote realease of adhesion dependent dynamic Emergency brake force portion which is in failure

Requirement identification	BSM2.34
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	

Actor	BSM2.2.1
Input information	
Output information	AdDepDynEBrRemRelCom

S4R-705 - AdIndDynEBrRemRelCom is the command of remote realease of adhesion independent dynamic Emergency brake force portion which is in failure

Requirement identification	BSM2.35
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdIndDynEBrRemRelCom

S4R-706 - AdDepFrEBrRemRelCom is the command of remote realease of adhesion dependent friction Emergency brake force portion which is in failure

Requirement identification	BSM2.36
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdDepFrEBrRemRelCom

S4R-707 - AdIndFrEBrRemRelCom is the command of remote realease of adhesion independent friction Emergency brake force portion which is in failure

Requirement identification	BSM2.37
Level	Brake System

Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdIndFrEBrRemRelCom

S4R-708 - AdDepDynEBrIsolRemCom is the remote command of permanent isolation of adhesion dependent dynamic Emergency brake portion of force

Requirement identification	BSM2.38
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdDepDynEBrIsolRemCom

S4R-709 - AdIndDynEBrIsolRemCom is the remote command of permanent isolation of adhesion independent dynamic Emergency brake portion of force

Requirement identification	BSM2.39
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdIndDynEBrIsolRemCom

S4R-710 - AdDepFrEBrIsolRemCom is the remote command of permanent isolation of adhesion dependent friction Emergency brake portion of force

Requirement identification	BSM2.40
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdDepFrEBrIsolRemCom

S4R-711 - AdIndFrEBrIsolRemCom is the remote command of permanent isolation of adhesion independent friction Emergency brake portion of force

Requirement identification	BSM2.41
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdIndFrEBrIsolRemCom

S4R-712 - BSM2.2.2 shall permit the driver to bypass any undue emergency brake request coming from any actor

Requirement identification	BSM2.42
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	
Actor	BSM2.2.2
Input information	

Output information	

S4R-713 - The emergency brake remote release command can be activated only as reaction to a major fault, when necessary to guarantee the operation of the train.

Requirement identification	BSM2.43
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The remote release permit to release an undue emergency brake force applied due to a major fault to permit the run of the train
Actor	BSM2.2.1
Input information	MajFaultEBx
Output information	AdDepDynEBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom

S4R-714 - BSM2.2.1 shall monitor the remote release execution monitoring the adhesion dependent friction service brake applied force

Requirement identification	BSM2.44
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	A indipenden emergency brake force application measurement to the one done by EB5.5.2.1 permit to diagnose the correct release also in case of major fault of force application sub-function
Actor	BSM2.2.1
Input information	AdDepFrEBrForAppl
Output information	AdDepFREBrForRelMeas

S4R-715 - AdDepFrEBrForRelMeas is the information of remote release correctly applied

Requirement identification	BSM2.45
Level	Brake System

Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdDepFrEBrForRelMeas

S4R-716 - If remote release is not successfull (command of remote release active and brake force still applied) a major fault shall be set

Requirement identification	BSM2.46
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	To activate protection against dragging brake also with EB5.5.2.1.1 monitoring faulty
Actor	BSM2.2.1
Input information	AdDepFrEBrRemRelCom
Output information	MajFaultBSM221.1

S4R-717 - MajFaultBSM221.1 is the fault information of not correct remote release application

Requirement identification	BSM2.47
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	MajFaultBSM221.1

S4R-718 - The remote release monitoring shall be crosschecked with EB5.5.2.1.1 force monitoring and in case of inconsistency a major fault generated

Requirement identification	BSM2.48
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Permanent check of diagnostic consistency.
Actor	BSM2.2.1
Input information	AdDepFREBrForRelMeas AdDepFREBrForApplMeas
Output information	MajFaultBSM221.2

S4R-719 - MajFaultBSM221.2 is the fault information of brake release detection inconsistency between BSM2.2.1 and EB5.5.2.1.1

Requirement identification	BSM2.49
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	MajFaultBSM221.2

S4R-720 - BSM2.2.1 shall define the remote release status as
Stand by: remote release command not actve
Released: if remote release command is active and the adhesion dependent friction brake is fully released.
Faulty: if remote release command is active an the release is not successfull

Requirement identification	BSM2.50
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	
Actor	BSM2.2.1

Input information	AdDEpFrEBrForRelMeas AdDepFrEBrRemRelCom MajFaultBSM221.1 AdDepFrEBrForMax
Output information	AdDepFrEBrRemRelStatus

S4R-721 - AdDepFrEBrRemRelStatus is the the information of Remotly released force/faulty remote release

Requirement identification	BSM2.51
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.1
Input information	
Output information	AdDepFrEBrREmRelStatus

S4R-722 - The emergency brake remote release shall be inhibited if an emergency brake is active OR if >1 major fault is active

Requirement identification	BSM2.52
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	The emergency brake guaranteed performances are single fault tolerant.
Actor	BSM2.2.1
Input information	MajFaultEBx EBrReq
Output information	AdDepFrEBrRemRelCom

S4R-723 - BSM2.2.1 shall permit the driver or maintenance operator to permanentely isolate by centralized command totally or partially the Adhesion dependent Friction emergency brake applied force

Requirement identification	BSM2.53
Level	Brake System

Mainfunction	Brake System Management
Type	Functional
Rationale	This is a consequence of requirement about permanent isolation of EB10.3 electrically controlled
Actor	BSM2.2.1
Input information	AdDepFrEBrIsolCentrCom
Output information	AdDepFrEBrIsolRemCom

S4R-724 - AdDepFrEBrIsolCentrCom is the remote command by any user to permantly isolate adhesion dependent friction emergency brake portion of force

Requirement identification	BSM2.54
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	User
Input information	
Output information	AdDepFrEBrIsolCentrCom

S4R-725 - The driver shall be allowed to activate a degraded mode to manage the emergency brake command in case of major faults of sub-functions EB1 and EB2

Requirement identification	BSM2.55
Level	Brake System
Mainfunction	Brake System Management
Type	Functional
Rationale	Note: This function is what actually is called back-up brake in case safety loop is in major fault
Actor	BSM2.2.2
Input information	MajFaultAnyEB1 MajFaultAnyEB2 EBrDegrCommDr
Output information	EBrDegr

S4R-726 - EBrDegrCommDr is the command selecting the EB degraded mode

Requirement identification	BSM2.56
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	Driver
Input information	
Output information	EBrDegrCommDr

S4R-727 - EBrDegr is the information that driver has selected the emergency Brake degraded mode

Requirement identification	BSM2.57
Level	Brake System
Mainfunction	Brake System Management
Type	Definition
Rationale	
Actor	BSM2.2.2
Input information	
Output information	EBrDegr

S4R-728 - ABT shall manage the automatic brake test checking the functionality of brake system

Requirement identification	ABT.1
Level	Brake System
Mainfunction	Automatic Brake Test
Type	Functional
Rationale	
Actor	ABT
Input information	

Output information	

S4R-729 - ABT11 shall send a WSPtestReq to LAM1 when WSP test shall be performed

Requirement identification	ABT.2
Level	Brake System
Mainfunction	Automatic Brake Test
Type	Functional
Rationale	The goal of ABT is to check that brake system works properly, so ABT use the normal functionalities described in other requirements to perform the ABT. The only test which requires a dedicated function is the command of WSP test. This command is received by LAM1 function. Note: It can be supposed that the brake test functions are managed by BSM1, ie ABT should be sub-function of BSM
Actor	ABT11
Input information	WSPTestStart
Output information	WSPtestReq

S4R-730 - WSPtestReq is the request to start the test to LAM1 subfunction

Requirement identification	ABT.3
Level	Brake System
Mainfunction	Automatic Brake Test
Type	Definition
Rationale	
Actor	ABT11
Input information	
Output information	WSPtestReq

S4R-731 - WSPTestStart is the request of starting the WSP test by ABT test procedure

Requirement identification	ABT.4
Level	Brake System
Mainfunction	Automatic Brake Test

Type	Definition
Rationale	
Actor	ABT
Input information	
Output information	WSPTestStart

Annex 3 EDV system requirements

This annex contains the list of the EDV system requirements.

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
				BS - BRAKE SYSTEM										
BS.1	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall ensure that the train's speed can be reduced or maintained on a slope, or that the train can be stopped within the maximum allowable braking distance. Braking also ensures the immobilisation of a train.		Brake system	TrBrReqUs, ImmReqUs; BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys, ImmReqBrSys	Driver Brake test operator Maintenance staff Maintenance tool ATP on board ETCS on board ATO TCMS PAS Brake System	TrainRetAppl TrainRetEqTimeAppl TrainImmForAppl	Train Train Train		Giraudo		
BS.2	SYSTEM	BRAKE SYSTEM	Definition	TrBrReqUs is the request of accelerate or decelerate the train by the driver (or any other user), provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		Driver			TrBrReqUs			Giraudo		
BS.3	SYSTEM	BRAKE SYSTEM	Functional	TrBrReqUs request can be provided by service brake, emergency brake and parking brake main functions		Brake system	TrSBrReqUs EBrReqUs	SB EB	TrBrReqUs	Brake system		Giraudo		
BS.4	SYSTEM	BRAKE SYSTEM	Definition	TrBrReqATO is the request of accelerate or decelerate the train by the ATO system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		ATO			TrBrReqATO			Giraudo		
BS.5	SYSTEM	BRAKE SYSTEM	Definition	TrBrReqTCMS is the request of accelerate or decelerate the train by the TCMS system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		TCMS			TrBrReqTCMS			Giraudo		
BS.6	SYSTEM	BRAKE SYSTEM	Definition	BrReqATP is the request to decelerate the train by the ATP provided via proper interface. It is deceleration (negative) value.		ATP			BrReqATP			Giraudo		

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BS.7	SYSTEM	BRAKE SYSTEM	Definition	BrReqETCS is the request to decelerate the train by the ETCS provided via proper interface. It is deceleration (negative) value.		ETCS			BrReqETCS			Giraudo		
BS.8	SYSTEM	BRAKE SYSTEM	Definition	BrReqPAS is the request to decelerate the train by the PAS provided via proper interface. It is deceleration (negative) value.		PAS			BrReqPAS			Giraudo		
BS.9	SYSTEM	BRAKE SYSTEM	Definition	BrReqBrSys is the request to decelerate the train by the Brake system itself, provided via its functions. It is deceleration (negative) value.		Brake system			BrReqBrSys			Giraudo		
BS.10	SYSTEM	BRAKE SYSTEM	Functional	BrReqBrSys request is provided by brake system management main function		Brake system	SBrReqBSM EBrReqBSM	BSM2.1 BSM2.2	BrReqBrSys	Brake system		Giraudo		
BS.11	SYSTEM	BRAKE SYSTEM	Definition	ImmReqUs is the request of immobilize the train by the driver or any other user, provided via proper interface		Driver			ImmReqUs			Giraudo		
BS.12	SYSTEM	BRAKE SYSTEM	Functional	ImmReqUs request is provided by Parking brake main function		Brake system	PBrReqUs	PB1	ImmReqUs	Brake system		Giraudo		
BS.13	SYSTEM	BRAKE SYSTEM	Definition	ImmReqTCMS is the request of immobilize the train by the TCMS provided via proper interface		TCMS			ImmReqTCMS			Giraudo		
BS.14	SYSTEM	BRAKE SYSTEM	Definition	ImmReqBrSys is the request of immobilize the train by the Brake system itself, provided via its functions		Brake system			ImmReqBrSys			Giraudo		
BS.15	SYSTEM	BRAKE SYSTEM	Functional	ImmReqBrSys request is provided by brake system management main function		Brake system	PBrReqBSM	BSM	ImmReqBrSys	Brake system		Giraudo		
BS.16	SYSTEM	BRAKE SYSTEM	Definition	TrainRetAppl is the real retardation present on the train. It is a positive value.		Train			TrainRetAppl			Giraudo		
BS.17	SYSTEM	BRAKE SYSTEM	Functional	TrainRetAppl retardation is generated by service and emergency brake		Brake system	TrainSBrRetAppl TrainEBrRetAppl	SB EB	TrainRetAppl	Brake system		Giraudo		
BS.18	SYSTEM	BRAKE SYSTEM	Definition	TrainRetEqTimeAppl is the equivalent time by which the retardation TrainRetAppl is applied		Brake system			TrainRetEqTimeAppl			Giraudo		
BS.19	SYSTEM	BRAKE SYSTEM	Functional	TrainRetEqTimeAppl equivalent time is derived from TrainSBrEqTimeAppl and TrainSBrEqTimeAppl		Brake system	TrainSBrEqTimeAppl TrainEBrEqTimeAppl	SB EB	TrainRetEqTimeAppl	Brake system		Giraudo		

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BS.20	SYSTEM	BRAKE SYSTEM	Definition	TrainImmForAppl is the real force applied at the track by the train when immobilized		Train			TrainImmForAppl			Giraudo		
BS.21	SYSTEM	BRAKE SYSTEM	Functional	The train retardation is given by the contribution of running resistance force, gravity force and brake force: TrainRetAppl=(TrainBrForAppl+TrainRunResAppl+GravForAppl)/TrainMass	See EN15431-1 for brake calculation formulas	Brake system	TrainBrForAppl TrainRunRes GravForAppl	Brake system Environment Environment	TrainRetAppl	Train		Giraudo		
BS.22	SYSTEM	BRAKE SYSTEM	Functional	The train retardation request is the maximum value of retardation requests among the ones received by different actors		Brake system	TrBrReqUs, BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys,	Driver Brake test operator Maintenance staff Maintenance tool ATP on board ETCS on board ATO TCMS PAS Brake System	TrainRetReq	Brake system		Giraudo		
BS.23	SYSTEM	BRAKE SYSTEM	Definition	The TrainRetReq is the retardation that is expected to be applied at the train based on requests by different actors. It is a positive value		Brake system			TrainRetReq			Giraudo		
BS.24	SYSTEM	BRAKE SYSTEM	Definition	TrainBrForNom is the force piloted by the brake system to contribute to decelerate the train with the retardation TrainRetReq		Brake system			TrainBrForNom			Giraudo		
BS.25	SYSTEM	BRAKE SYSTEM	Definition	TrainBrForAppl is the brake force applied to the track via the braking force generated by the brake system		Brake system			TrainBrForAppl			Giraudo		
BS.26	SYSTEM	BRAKE SYSTEM	Definition	TrainRunResAppl is the force applied at the train by track and air		Environment			TrainRunResAppl			Giraudo		
BS.27	SYSTEM	BRAKE SYSTEM	Definition	GravForAppl is the force applied at the train by the gravity		Environment			GravForAppl			Giraudo		
BS.28	SYSTEM	BRAKE SYSTEM	Functional	The gravity force is given by the formula TrainMass*TrackSlope*9,81		Environment	TrainMass TrackSlope	Train Track	GravForAppl	Brake system		Giraudo		
BS.29	SYSTEM	BRAKE SYSTEM	Definition	TrainMass is the Mass of the train		Train			TrainMass			Giraudo		
BS.30	SYSTEM	BRAKE SYSTEM	Definition	TrackSlope is the slope of the track in thousands, positive in uphill, negative in downhill		Track			TrackSlope			Giraudo		

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BS.31	SYSTEM	BRAKE SYSTEM	Functional	The brake system has available 4 different type of brakes to apply TrainBrForAppl to the track to obtain a retardation : Adhesione dependent dynamic brake Adhesion independent dynamic brake Adhesione dependent friction brake Adhesion independent friction brake	This types of brake are the only one physically possible applyig forces to the rail (aerodynamic brake is not considered in this functional requirements): the train kinetic energy can be trasformed in heat (by friction) or in mechanical / electrical energy (dynamic brakes) only. The force can be trasmitted to the rails by wheels (adhesion dependent due to their rotation) or by something else different (adhesion independent).	Brake system	AdDepDynBrForAppl AdIndDynBrForAppl AdDepFrBrForAppl AdIndFrBrForAppl	Brake system	TrainBrForAppl	Train		Giraudo		
BS.32	SYSTEM	BRAKE SYSTEM	Definition	AdDepDynBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force		Brake system			AdDepDynBrForAppl			Giraudo		
BS.33	SYSTEM	BRAKE SYSTEM	Functional	AdDepDynBrForAppl is obtained by the contribution of service brake and emergency brake forces		Brake system	AdDepDynSBrForAppl AdDepDynEBrForAppl	SB EB	AdDepDynBrForAppl	Track		Giraudo		
BS.34	SYSTEM	BRAKE SYSTEM	Definition	AdIndDynBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force		Brake system			AdIndDynBrForAppl			Giraudo		
BS.35	SYSTEM	BRAKE SYSTEM	Functional	AdIndDynBrForAppl is obtained by the contribution of service brake and emergency brake forces		Brake system	AdIndDynSBrForAppl AdIndDynEBrForAppl	SB EB	AdIndDynBrForAppl	Track		Giraudo		
BS.36	SYSTEM	BRAKE SYSTEM	Definition	AdDepFrBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Dependent Friction Brake Force		Brake system			AdDepFrBrForAppl			Giraudo		

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BS.37	SYSTEM	BRAKE SYSTEM	Functional	AdDepFrBrForAppl is obtained by the contribution of service brake and emergency brake forces		Brake system	AdDepFrSBrForAppl AdDepFrEBrForAppl	SB EB	AdDepFrBrForAppl	Track		Giraudo		
BS.38	SYSTEM	BRAKE SYSTEM	Definition	AdIndFrBrForAppl is the portion of TrainBrForAppl applied at the track by Adhesion Independent Friction Brake Force		Brake system			AdIndFrBrForAppl			Giraudo		
BS.39	SYSTEM	BRAKE SYSTEM	Functional	AdIndFrBrForAppl is obtained by the contribution of service brake and emergency brake forces		Brake system	AdIndFrSBrForAppl AdIndFrEBrForAppl	SB EB	AdIndFrBrForAppl	Track		Giraudo		
BS.40	SYSTEM	BRAKE SYSTEM	Functional	The brake system generate a train immobilization by applying a brake immobilisation force to the track using 2 different brakes: Adhesion dependent friction immobilisation brake Adhesion independent friction immobilisation brake	This types of brake are the only one physically possible applyig forces to the rail: In a stationary condition only friction can generate a force (magnetic force parallel to the rail cannot be applied in stationary condition, but magnetic force can generate the perpedicular force to the rail which provide the friction force effect parallel tpo the rail) The force can be trasmitted to the rails by wheels (adhesion dependent due to their rotation) or by something else different (adhesion independent).	Brake system	AdDepFrImmBrForAppl AdIndFrImmBrForAppl	Brake system	TrainImmForAppl	Train		Giraudo		
BS.41	SYSTEM	BRAKE SYSTEM	Definition	TrainImmForAppl is the immobilisation force applied to the track via the brake system		Brake system			TrainImmForAppl			Giraudo		
BS.42	SYSTEM	BRAKE SYSTEM	Definition	AdDepFrImmBrForAppl is the immobilisation force applied to the track by adhesion dependent friction immobilisation brake		Brake system			AdDepFrImmBrForAppl			Giraudo		

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BS.43	SYSTEM	BRAKE SYSTEM	Definition	AdIndFrImmBrForAppl is the immobilisation force applied to the track by adhesion independent friction immobilisation brake		Brake system			AdIndFrImmBrForAppl			Giraudo		
BS.44	SYSTEM	BRAKE SYSTEM	Functional	Each type of brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter	The maximum braking force shall be the outcome of the brake calculation and dimensioning according contractual requests and below general performance requirements (see also req. 1.1.13 and 1.2.13) It represent the maximum force that the type of brake can apply without being damaged or damage the context. The temparture dependency of SB force is an option oriented to manage the situation where the dissipation capacity reach the limit due to high duty cycle or high level of isolation of service brake force.	Brake system	AdDepDynBrForMax(v,temp) AdIndDynBrForMax(v, temp) AdDepFrBrForMax(v, temp) AdIndFrBrForMax(v, temp) AdDepFrImmForMax(v) AdIndFrImmForMax(v)	Dimensioning	AdDepDynBrForAppl AdIndDynBrForAppl AdDepFrBrForAppl AdIndFrBrForAppl AdDepFrImmForAppl AdIndFrImmForAppl	Track Track Track Track Track Track		Giraudo		
BS.45	SYSTEM	BRAKE SYSTEM	Definition	AdDepDynBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic brake		Dimensioning			AdDepDynBrForMax			Giraudo		
BS.46	SYSTEM	BRAKE SYSTEM	Definition	AdIndDynBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic brake		Dimensioning			AdIndDynBrForMax			Giraudo		
BS.47	SYSTEM	BRAKE SYSTEM	Definition	AdDepFrBrForMax is the maximum force that can be applied at the track by adhesion dependent friction brake		Dimensioning			AdDepFrBrForMax			Giraudo		
BS.48	SYSTEM	BRAKE SYSTEM	Definition	AdIndFrBrForMax is the maximum force that can be applied at the track by adhesion independent friction brake		Dimensioning			AdIndFrBrForMax			Giraudo		

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BS.49	SYSTEM	BRAKE SYSTEM	Definition	AdDepFrImmForMax is the maximum immobilisation force that can be applied at the track by adhesion dependent friction immobilisation brake		Dimensioning			AdDepFrImmForMax			Giraudo		
BS.50	SYSTEM	BRAKE SYSTEM	Definition	AdIndFrImmForMax is the maximum immobilisation force that can be applied at the track by adhesion independent friction immobilisation brake		Dimensioning			AdIndFrImmForMax			Giraudo		
BS.51	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall be continuous: all brakes in the train shall be capable of being applied from a single control point, normally in the operational cab	Major safety requirement of brake system	Brake system	TrBrReqUs, ImmReqUs; BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys, ImmReqBrSys	Driver Brake test operator Maintenance staff Maintenance tool ATP on board ETCS on board ATO TCMS PAS Brake System	TrainBrForAppl TrainImmForAppl	Train		Giraudo		
BS.52	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall be automatic: Each individual brake type or combinations of them shall operate automatically, i.e. in the event of an unintentional train separation (train integrity lost), the brakes on the two parts of the train shall apply, bring the train to a standstill and keep it in the same position until released by other intentional operations.	Major safety requirement of brake system	Brake system	TrainIntegr	Train	TrainBrForAppl	Train		Giraudo		
BS.53	SYSTEM	BRAKE SYSTEM	Definition	TrainIntegr is the information assessing that the train is integer		Train			TrainIntegr			Giraudo		
BS.54	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall be inexhaustible: the braking power available shall be adequate to attain full brake force: — at all times during the train journey; and — under all track conditions.	Major safety requirement of brake system	Brake system	BrPneumEn, BrElectrEn BrMechEn BrMagnEn TrainBrPower	Brake system Brake system Brake system Brake system Brake system	TrainBrForAppl	Train		Giraudo		
BS.55	SYSTEM	BRAKE SYSTEM	Definition	BrPneumEn is the pneumatic energy used to generate the TrainBrForAppl and TrainImmForAppl		Brake system			BrPneumEn			Giraudo		

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BS.56	SYSTEM	BRAKE SYSTEM	Functional	The pneumatic energy is represented by the air supply pressure and air supply delivery to brake system		Brake system	AirSupplPress BrAirSupplDel	EB11,SB11	BrPneumEn			Giraudo		
BS.57	SYSTEM	BRAKE SYSTEM	Definition	BrElectrEn is the electric energy used to generate the TrainBrForAppl and TrainImmForAppl		Brake system			BrElectrEn			Giraudo		
BS.58	SYSTEM	BRAKE SYSTEM	Functional	The lectric energy is represented by the electric voltage and by the electric current to brake system		Brake system	ElVolt BrElCurr	EB11,SB11	BrElectrEn			Giraudo		
BS.59	SYSTEM	BRAKE SYSTEM	Definition	BrMechEn is the mechanical energy used to generate the TrainBrForAppl and TrainImmForAppl		Brake system			BrMechEn			Giraudo		
BS.60	SYSTEM	BRAKE SYSTEM	Definition	BrMagnEn is the magnetic energy used to generate the TrainBrForAppl and TrainImmForAppl		Brake system			BrMagnEn			Giraudo		
BS.61	SYSTEM	BRAKE SYSTEM	Functional	When the brake system is no more able to guarantee the minimum retardation or a maximum equivalent time or a minimum immobilisation force a major fault shall be set		Brake system	TrainRetMin TrainBrEqTimeMax TrainImmForMin	Parameter Parameter Parameter	MajFaultBrSys	Diagnosrtic, DriverHMI		Giraudo		
BS.62	SYSTEM	BRAKE SYSTEM	Definition	MajFaultBrSys is fault indication which inform the train that the brake system is no more able to guarantee the expected performances		Brake system			MajFaultBrSys			Giraudo		
BS.63	SYSTEM	BRAKE SYSTEM	Functional	MajFaultBrSys van be generated by any of the main functions		Brake system	MajFaultSBx MajFaultEBx MajFaultPBx MajFaultBSMx MajFaultABTx	SB EB PB BSM ABT	MajFaultBrSys	Brake system		Giraudo		
BS.64	SYSTEM	BRAKE SYSTEM	Definition	TrainRetMin is the minimum retardation that the TrainBrForAppl shall guarantee based on the actual braking power on a level track in the worst environmental condition and in case of worst single failure	This is the deceleration used by signalling for the braking model defining the maximum stopping distance.	Brake system			TrainRetMin			Giraudo		
BS.65	SYSTEM	BRAKE SYSTEM	Functional	TrainRetMin=TrainEBrRetMax*TrainBrPower		Brake system	TrainEBrRetMax TrainBrPower	Parameter EB7	TrainRetMin	Train		Giraudo		

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BS.66	SYSTEM	BRAKE SYSTEM	Definition	TrainBrEqTimeMax is the maximum equivalent time that the TrainRetEqTimeAppl shall guarantee.	This is the equivalent time used by signalling for the braking model defining the maximum stopping distance	Brake system			TrainBrEqTimeMax			Giraudo		
BS.67	SYSTEM	BRAKE SYSTEM	Definition	TrainImmForMin is the minimum force that the TrainImmForAppl shall guarantee based on immobilisation power		Brake system			TrainImmForMin			Giraudo		
BS.68	SYSTEM	BRAKE SYSTEM	Functional	When a major fault is set Brake system shal automatically reach the most proper safe state for the train depending from the major fault	The train safe state for every major fault shall be defined. (The safe state for EDV is the brake application. The train has the possibility to overcome the EDV brake application by BSM2 remote release function if the brake application is not considered the safest condition for the train)	Brake system	MajFaultBrSys	SB EB PB	TrainBrForAppl	Train		Giraudo		
BS.69	SYSTEM	BRAKE SYSTEM	Functional	The loss of the continuity of the command or inexhaustibility of the brake force generates an automatic predefined brake force application	The safe state of a brake system with not continuous command line or without enough energy to brake is the braking application till the stop and brake release inhibition	Brake system	Loss of brake continuity or inexhaustibility	Brake system	TrainBrForAppl	Train		Giraudo		
BS.70	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall have a safe speed information by train odometry system	Brake force application is speed variant. Note: it is possible that odometry system is included in brake system, but for the objectives of this document it is considered coming from external technical system	Odometry	Speed	Train	TrainSpeed	Brake System	x	Giraudo		
BS.71	SYSTEM	BRAKE SYSTEM	Definition	Speed is the real speed of the train		Train			Speed			Giraudo		

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BS.72	SYSTEM	BRAKE SYSTEM	Definition	TrainSpeed is the speed of the train measured by odometry system		Odometry			TrainSpeed			Giraudo		
BS.73	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall be able to release the brake when needed to guarantee the running capability of the train	This is a functional requirement of the running capability. The condition for releasing the brake shall be defined by safety analysis	Brake system			TrainBrRemRelComm	Brake system		Giraudo		
BS.74	SYSTEM	BRAKE SYSTEM	Definition	TrainBrRemRelComm is the brake release command given by brake system in front of an automatic request by brake system or voluntary request by users		Brake system			TrainBrRemRelComm			Giraudo		
BS.75	SYSTEM	BRAKE SYSTEM	Functional	TrainBrRemRelComm is obtained by brake management system main function remote release commands		Brake system	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom AdDepDynBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom	BSM	TrainBrRemRelComm	Brake system		Giraudo		
BS.76	SYSTEM	BRAKE SYSTEM	Functional	The brake system shall guarantee: - in worst environmental condition - in case of worst single failure the minimum brake retardation rate (speed dependent) and maximum equivalent time able to guarantee maximum stopping distances associated to the braking power active at the moment of the braking activation.	Minimum safe performance of the train.	Brake system	TrBrReqUs BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; BrReqPAS BrReqBrSys TrainRetMin TrainBrEqTimeMax TrainBrPower	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS Brake System Parameter Parameter Brake system	TrainRetAppl TrainRetEqTimeAppl	Train		Giraudo		

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BS.77	SYSTEM	BRAKE SYSTEM	Functional	The braking power value shall limit the maximum speed of the train.		ETCS or driver	TrainBrPower	Brake System	SpeedLim	ETCS or train		Giraudo		

BS.78	SYSTEM	BRAKE SYSTEM	Functional	The TrainBrPower is a percentage of the maximum nominal retadation of train (TrainEBRetMax), percentage defined based on brake isolation status TrainEBrIsolStatus	UIC544-1 braked mass percentage is the existing braking power definition, which is not able to manage efficiently modern brakes, using normally disk brake instead of tread brake and not applicable to high speed brake, where the deceleration is indicated as figure to define the braking power. The UIC concept of percentage is maintained because is a quick way to have an indication of the braking capacity. The braking power is the reference for signalling system to calculate the guaranteed stopping distance. Note: The maximum retardation is speed dependent and there are different type of forces, with different speed dependeny, partecipating to the total retardation. The reduction of forces due to isolation can lead to different retardation curves. The braking power definition (to be done at dimnensioning level) groups the closer retardation curves of different isolation status under a single curve at which is attributed the lowest retardation among all curves grouped together.	Brake system	TrainEBRetMax TrainEBrIsolStatus	Parameter Brake system	TrainBrPower	Train	x	Giraudo			

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BS.79	SYSTEM	BRAKE SYSTEM	Functional	A stopping distance of the train shall be associated univocally at every coupled values of braking power and TrainSpeed	The stopping distance is the information that can derive by proper dimensioning formula usingTrainBrPower, TrainRetMin, TrainSpeed, TrainBrEqTimeMax.	Dimensioning	TrainBrPower TrainSpeed TrainRetMin TrainBrEqTimeMax	Brake system Odometry Parameter Parameter	TrainStopDist	Parameter Parameter		Giraudo		
BS.80	SYSTEM	BRAKE SYSTEM	Definition	TrainBrPower represent the braking capacity of the train by which is possible to define univocally the maximum stopping distance from any speed		Brake system			TrainBrPower			Giraudo		
BS.81	SYSTEM	BRAKE SYSTEM	Functional	A maximum train speed of the train shall be associated univocally at every value of braking power	The maximum speed is defined by energy dissipation dimensioning calculation and shall be univocally identified by the braking power value.	Dimensioning	TrainBrPower TrainSpeed TrainRetMax TrainBrEqTimeMax	Brake system Odometry Parameter Parameter	TrainSpeedMax	Parameter Parameter		Giraudo		
BS.82	SYSTEM	BRAKE SYSTEM	Definition	TrainSpeedMax is the maximum speed that the train can reach with the active braking power		Brake system			TrainSpeedMax			Giraudo		
BS.83	SYSTEM	BRAKE SYSTEM	Definition	TrainStopDist(v) is the maximum stopping distance possible by applying at a certain speed the emergency brake : - without any failure and isolation, - without degraded environmental condition (causing sliding or reduced applied forces), - on a flat track - with maximum train mass		Dimensioning			TrainStopDist			Giraudo		
BS.84	SYSTEM	BRAKE SYSTEM	Functional	Train brake retardation shall have a maximum equivalent time of application	Equivalent time definition in EN14531-1. The maximum equivalent time parameter is usually 3 s fr pneumatic adhesion dependent friction brakes	Brake system	TrBrReqUs BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; BrReqPAS BrReqBrSys TrainBrEqTimeMax	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO PAS Brake System Parameter	TrainRetEqTimeAppl	Train		Giraudo		

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BS.85	SYSTEM	BRAKE SYSTEM	Functional	Train retardation shall be limited to TrainRetLim=2,5 m/s2	To avoid too high forces on the track	Brake system	TrainRetLim	Parameter	TrainRetAppl	Train		Giraudo		
BS.86	SYSTEM	BRAKE SYSTEM	Definition	TrainRetLim is the maximum value that the Train retardation can reach on level track		Dimensioning			TrainRetLim			Giraudo		
BS.87	SYSTEM	BRAKE SYSTEM	Functional	The brake system generate the train retardation using 2 different function: Service Brake : adjustable retardation to control the speed of the train Emergency Brake : predefined minimum retardation in predefind maximum response time to stop the train in predefined maximum stopping distances		Brake system	TrainSBrForAppl TrainEBrForAppl	SB EB	TrainBrForAppl	Train		Giraudo		
BS.88	SYSTEM	BRAKE SYSTEM	Definition	TrainSBrForAppl is the portion of the force TrainBrForAppl or of the force TrainImmForAppl applied by the main function service brake		SB			TrainSBrForAppl			Giraudo		
BS.89	SYSTEM	BRAKE SYSTEM	Definition	TrainEBrForAppl is the portion of force TrainBrForAppl applied by the main function emergency brake to the track		EB			TrainEBrForAppl			Giraudo		
BS.90	SYSTEM	BRAKE SYSTEM	Functional	The brake system generate the train immobilisation using 2 different function: Service Brake: temporary immobilisation Parking Brake : permanent immobilisation		SB PB	TrainSBrForAppl TrainPBrForAppl	SB PB	TrainImmForAppl	Train		Giraudo		
BS.91	SYSTEM	BRAKE SYSTEM	Functional	AdDepFrImmBrForAppl is obtained by the contribution of TrainSBrForAppl and/or TrainPBrForAppl		Brake system	TrainSBrForAppl TrainPBrForAppl	SB PB	AdDepFrImmBrForAppl	Train		Giraudo		
BS.92	SYSTEM	BRAKE SYSTEM	Functional	AdDepFrImmBrForAppl is obtained by the contribution of TrainPBrForAppl only		Brake system	TrainPBrForAppl	PB	AdIndFrImmBrForAppl	Train		Giraudo		
				SB - SERVICE BRAKE								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.1	SYSTEM	Service Brake	Functional	The service brake shall apply an adjustable retardation to the train proportional to the request received by actors or brake system internal function BSM with the following goals: - Reduce the speed of the train - Maintain the speed of the train on a slope - Immobilize temporary the train		SB	TrSBrReqUs SBrReqATP SBrReqETCS TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainSBrRetAppl	Train		Giraudo		DR
SB.2	SYSTEM	Service Brake	Definition	TrSBrReqUs is the request of accelerate or decelerate via service brake the train by the driver (or any other user), provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		Driver			TrSBrReqUs			Giraudo		
SB.3	SYSTEM	Service Brake	Definition	TrSBrReqATO is the request of accelerate or decelerate via service brake the train by the ATO system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		ATO			TrSBrReqATO			Giraudo		
SB.4	SYSTEM	Service Brake	Definition	TrSBrReqTCMS is the request of accelerate or decelerate via service brake the train by the TCMS system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.		TCMS			TrSBrReqTCMS			Giraudo		
SB.5	SYSTEM	Service Brake	Definition	SBrReqATP is the request to decelerate via service brake the train by the ATP provided via proper interface. It is a deceleration (negative) value.		ATP			SBrReqATP			Giraudo		
SB.6	SYSTEM	Service Brake	Definition	SBrReqETCS is the request to decelerate the train via service brake by the ETCS provided via proper interface. It is a deceleration (negative) value.		ETCS			SBrReqETCS			Giraudo		
SB.7	SYSTEM	Service Brake	Definition	SBrReqPAS is the request to decelerate via service brake the train by the PAS provided via proper interface. It is a deceleration (negative) value.		PAS			SBrReqPAS			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.8	SYSTEM	Service Brake	Definition	TrainSBrRetAppl is the portion of the train retardationTrainRetAppl which is generated by the Service brake force. It is a positive value		Train			TrainSBrRetAppl			Giraudo		
SB.9	SYSTEM	Service Brake	Definition	TrainSBrEqTimeAppl is the equivalent time by which the force TrainSBrRetAppl is applied		SB			TrainSBrEqTimeAppl			Giraudo		
SB.10	SYSTEM	Service Brake	Functional	The train retardation requested is given as percentage of the maximum retardation: TrainRetReq=TrainSBrRetReq/TrainSBrRetReqMax*100% Where TrainSBrRetReq is the minimum acceleration/deceleration value between all the SBrReq received by different actors and TrainSBrRetReqMax is the retardation expected with 100% of service brake request in nominal condition	The use of percentage of TrainSBrRetMax permit to have brake request non dependent from the speed. The maximum service brake retardation shall be the outcome of the brake calculation according contractual requests and below general performance requirements. Note: If ithe option of considering the slope is active, the dimensioning shall consider the additional force given by the downhill on the maxslope.	SB	TrSBrReqUs SBrReqATP SBrReqETCS TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainRetReq	SB1		Giraudo		
SB.11	SYSTEM	Service Brake	Definition	TrainSBrRetReq is the retardation that is expected to be applied at the train when a service brake is requested. It is a positive value		SB			TrainSBrRetReq			Giraudo		
SB.12	SYSTEM	Service Brake	Definition	TrainSBrRetMax is the maximum retardation of the train on a level track (TrackSlope=0) with nominal runnining resistance force (TrainRunResSB) expected applying the maximum service brake request		Dimensioning			TrainSBrRetMax			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.13	SYSTEM	Service Brake	Definition	TrainRetReq is the adimensional way to define the train service brake retardation request TrainSBrRetReq (TrainSBRet/TrainSBrRetReqMax)		SB			TrainRetReq			Giraudo		
SB.14	SYSTEM	Service Brake	Functional	The Train Service brake retardation TrainSBrRetReq defines the Train service brake force TrainSBrForNom by brake force calculation formulas	See EN15431-1 for brake calculation formulas	SB	TrainSBrRetReq	Driver Brake test operator Maintenance staff Maintenance tool ATP on board ETCS on board ATO TCMS PAS Brake System	TrainSBrForNom	Track		Giraudo		
SB.15	SYSTEM	Service Brake	Functional	The Service brake equivalent time of application shall be TrainSBrEqTimeAppl< TrainSBrEqTimeMax	See above requirement about brake performances	SB	TrainSBrEqTimeMax	Parameter	TrainSBrEqTimeAppl	Train		Giraudo		
SB.16	SYSTEM	Service Brake	Definition	TrainSBrEqTimeMax is the maximum equivalent time by which the retardation TrainSBrRetAppl shall be applied		Dimensioning			TrainSBrEqTimeMax			Giraudo		
SB.17	SYSTEM	Service Brake	Functional	Train retardation shall be limited to TrainRetLim=2,5 m/s2	To avoid too high forces on the track	SB	TrainSBrForAppl TrainRetLim	SB Parameter	TrainRetAppl	Train		Giraudo		
SB.18	SYSTEM	Service Brake	Definition	TrainSBrMaxRet is the maximum absolute value that the service brake retardation can reach		Dimensioning			TrainSBrMaxRet			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.19	SYSTEM	Service Brake	Functional	The service brake function shall be able to apply to the train a minimum retardation which guarantee the minimal condition to operate the train. The minimum retardation can be an invariant parameter or a speed dependent parameter	The minimum service brake retardation shall be the outcome of contractual requests and below general performance requirements Note: it is the retardation providing the minimum allowed performances with 100% of service brake request. It can depend from the braking power parameter (which is function of the emergency brake isolation status)	SB	Dimensioning	Performances requirements	TrainSBrRetMin	Train		Giraudo		
SB.20	SYSTEM	Service Brake	Definition	TrainSBrRetMin is the minimum service brake retardation which shall be possible on the train to guarantee the operation		Dimensioning			TrainSBrRetMin			Giraudo		
SB.21	SYSTEM	Service Brake	Functional	Train service brake retardation shall reach its full value in max SBrRetRiseTimeMax	Force application time	SB	SBRetRiseTimeMax	Parameter	TrainSBrRetAppl	Train		Giraudo		
SB.22	SYSTEM	Service Brake	Definition	SBRetRiseTimeMax is the maximum rising time of the train service brake retardation TrainSBrRetAppl		SB			SBRetRiseTimeMax			Giraudo		
SB.23	SYSTEM	Service Brake	Functional	Releasing of train brake retardation shall be ≤SBrRetDecrTimeMax	Force application time	SB	SBRetDecrTimeMax	Parameter	TrainSBrRetAppl	Train		Giraudo		
SB.24	SYSTEM	Service Brake	Definition	SBRetDecrTimeMax is the maximum decreasing time of the train service brake retardation TrainSBrRetAppl		SB			SBRetDecrTimeMax			Giraudo		
SB.25	SYSTEM	Service Brake	Functional	The SB retardation increasing and releasing time shall be limited by the maximum jerk MaxJerk to be not overpassed at train level		SB	MaxJerk	Parameter	TrainSBrRetAppl	Train		Giraudo		
SB.26	SYSTEM	Service Brake	Functional	Service brake retardation shall be < of Emergency brake retardation at any speed	Emergency brake is the brake used by the train to stop in the shortest distances.	SB	TrainEBrRetNom	EB	TrainSBrRetReq	Train		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.27	SYSTEM	Service Brake	Functional	The train service brake retardation TrainSBrRetReq is obtained by the contribution of adhesion dependent dynamic brake, adhesion independent dynamic brake, adhesion dependent friction brake: TrainSBrForAppl(v)= AdDEpDynSBrForAppl(v)+ AdIndDynSBrForAppl(v)+ AdDEpFrSBrForAppl(v)	The adhesion independent friction brake is not used in service brake in analogyto conventional train	SB	TrainSBrForNom	SB	AdDepDynSBrForAppl AdIndDynSBrForAppl AdDepFrSBrForAppl	Track Track Track		Giraudo		
SB.28	SYSTEM	Service Brake	Definition	AdDepDynSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force		SB			AdDepDynSBrForAppl			Giraudo		
SB.29	SYSTEM	Service Brake	Definition	AdIndDynSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force		SB			AdIndDynSBrForAppl			Giraudo		
SB.30	SYSTEM	Service Brake	Definition	AdDepFrSBrForAppl is the portion of TrainSBrForAppl applied at the track by Adhesion Dependent Friction Brake Force		SB			AdDepFrSBrForAppl			Giraudo		
SB.31	SYSTEM	Service Brake	Functional	Each type of service brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter		SB	AdDepDynSBrForMax AdIndDynSBrForMax AdDepFrSBrForMax	Dimensioning	AdDepDynSBrForAppl AdIndDynSBrForAppl AdDepFrSBrForAppl	Track Track Track		Giraudo		
SB.32	SYSTEM	Service Brake	Definition	AdDepDynSBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic service brake		Dimensioning			AdDepDynSBrForMax			Giraudo		
SB.33	SYSTEM	Service Brake	Definition	AdIndDynSBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic service brake		Dimensioning			AdIndDynSBrForMax			Giraudo		
SB.34	SYSTEM	Service Brake	Definition	AdDepFrSBrForMax is the maximum force that can be applied at the track by adhesion dependent service friction brake		Dimensioning			AdDepFrSBrForMax			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB.35	SYSTEM	Service Brake	Functional	When SB functions is supplied by the electrical power supply shall perform a self test and trasmit the result to BSM1 function	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of SB and compare it with the expected one (initialization of the brake)	SB	SBrElVolt	SB11.2	SelfTestSBrRes	BSM1		Giraudo		
SB.36	SYSTEM	Service Brake	Definition	SelfTestSBrRes is the result of the self test performed by service brake when receive electric power supply		SB			SelfTestSBrRes			Giraudo		
SB.37	SYSTEM	Service Brake	Functional	Service brake force shall not be applied in case emergency brake force is applied	To avoid compounding of different type of brakes	SB	TrainEBrForAppl	EB	TrainSBrForAppl	SB		Giraudo		
				SB1 - SERVICE BRAKE TRAIN RETARDATION REQUEST								Giraudo		
SB1.1	SYSTEM	Service Brake	Functional	SB1 shall collect the traction/service brake request by actors and train direction and trasmit it to SB2. ~~The traction/service brake request is intended as percentage of the maximun service brake retardation TrainSBrRetMax(v)~~	Traction and brake are connected: one exclude the other. It is then proposed to use the same information to command both. The information TrSBrReq"x" is changing from -100% to +100% (negative brake, positive traction)	SB1	TrSBrReqUs; ForwBackDir SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainTrSBrReq ActDir	SB2 SB2	x	Giraudo		
SB1.2	SYSTEM	Service Brake	Definition	TrainTrSBrReq is the adimensional information (percentage) about traction and service brake retardation request. It is in the range +100%/-100%. The value -100% correspond to a retardation of TrainSBrRetMax. The value +100% correspond to TrainTractAccMax. (Note: when TrainTrSBrReq<0 it is equal to (-TrainRetReq)		SB1			TrainTrSBrReq			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB1.3	SYSTEM	Service Brake	Definition	TrainTractAccMax is the maximum traction acceleration of the train		Dimensioning			TrainTractAccMax			Giraudo		
SB1.4	SYSTEM	Service Brake	Definition	ActDir is the information about train direction selected by the driver		SB1			ActDir			Giraudo		
SB1.5	SYSTEM	Service Brake	Functional	The brake request with higher absolute percentage value shall be trasmitted to SB2	The higher brake request has priority	SB1	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainTrSBrReq	SB2	x	Giraudo		
SB1.6	SYSTEM	Service Brake	Functional	Driver and any technical system shall be able to command at least 7 different level of service brake force including brake release	Moderability concept.	SB1	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainTrSBrReq	SB2	x	Giraudo		
SB1.7	SYSTEM	Service Brake	Functional	TrainTrSBrReq ramping shall be limited in order to have a jerk of TrainTrSBrReq*TrainSBrRetMax limited to MaxJerk=4 m/s3	See performance req. 1.1.13.2	SB1	MaxJerk	Parameter	TrainTrSBrReq	SB2	x	Giraudo		
SB1.8	SYSTEM	Service Brake	Definition	MaxJerk is the maximum jerk that the retardation of the train shall reach		Dimensioning			MaxJerk			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB1.9	SYSTEM	Service Brake	Functional	If SB1 TrainTrSBrReq information is not valid or out of order a major fault shall be set	This requirement is linked to next requirements about continuity to guarantee the automatic brake retardation by SB4-SB5 sub-function. BSM reaction to major fault in this case could not be reliable due to un-reliable SB1	SB1	TrSBrReqUs; SBrReqATP; SBrReqETCS; TrSBrReqATO TrSBrReqTCMS; SBrReqPAS SBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainTrSBrReq MajFaultSB1.1	SB2 SB9.1, BSM2.1.1	x	Giraudo		
SB1.10	SYSTEM	Service Brake	Definition	MajFaultSB1.1 is the fault indicating that it is lost the traction brake request information (continuity lost)		SB1			MajFaultSB1.1			Giraudo		
SB1.11	SYSTEM	Service Brake	Functional	If SB1 ActDir informationis not valid or out of order a major fault shall be set	The lost direction have the major impact on traction (traction force inhibition). On brake system makes the roll back protection function out of order. For this reason there is not an automatic brake application by SB4-SB5, but the inhibition of holding brake release by SB7 (see requirement in SB7)	SB1	ForwBackDir	Driver	ActDir MajFaultSB1.2	SB2 SB9.1, BSM2.1.1	x	Giraudo		
SB1.12	SYSTEM	Service Brake	Definition	MajFaultSB1.2 is the fault indicating that it is lost the train direction information ActDir		SB1			MajFaultSB1.2			Giraudo		
				SB2 - SERVICE BRAKE REQUEST TRASMISSION								Giraudo		
SB2.1	SYSTEM	Service Brake	Functional	SB2 shall trasmit the adjustable traction/retardation request and selected direction received by SB1 to other brake system functions and traction system	Continuity requirement. The trasmission to traction and brake of the same request guarantee the consistency of the traction/brake command to the two systems	SB2	TrainTrSBrReq ActDir	SB1 SB1	TrSBrReq TrainDir	SB, Traction SB, Traction	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB2.2	SYSTEM	Service Brake	Definition	TrSBrReq is the information TrainTrSBrReq trasmitted along the train		SB2			TrSBrReq			Giraudo		
SB2.3	SYSTEM	Service Brake	Definition	TrainDir is the information ActDir trasmitted along the train		SB2			TrainDir			Giraudo		
SB2.4	SYSTEM	Service Brake	Functional	In case TrainTrSBrReq is not valid or out of order a major fault shall be set and TrSbrReq shall be not valid	This requirement provide automatic brake application in case of lost continuity of the brake command (see propagation to SB4 and SB8) BSM reaction to major fault in this case could not be reliable	SB2	TrainTrSBrReq	SB1	TrSBrReq MajFaultSB2.1	SB, Traction SB9.1, BSM2.1.1	x	Giraudo		
SB2.5	SYSTEM	Service Brake	Definition	MajFaultSB2 is the fault indicating that it is lost the traction brake request information TrainTrSBrReq (continuity lost)		SB2			MajFaultSB2.1			Giraudo		
SB2.6	SYSTEM	Service Brake	Functional	In case TrSBrReq is not valid or out of order a major fault shall be set		SB2	TrainEBrReq	SB1	TrSBrReq MajFaultSB2.1	EB4, EB8 EB9.1, BSM2.2.1	x	Giraudo		
SB2.7	SYSTEM	Service Brake	Definition	MajFaultSB2.2 is the fault indicating that it is lost the traction/service brake request information TrSBrReq (continuity lost)		SB2			MajFaultSB2.2			Giraudo		
				SB3 - TRAIN LOAD CALCULATION								Giraudo		
				SB3.1 LOAD ACQUISITION								Giraudo		
SB3.1	SYSTEM	Service Brake	Functional	SB3 shall define the train mass and the train equivalent mass information and send them to all brake sub-functions and context systems which need it		SB3	BogLoad	Bogie	TrainMassSB TrainEqMassSB	All	X	Giraudo		
SB3.2	SYSTEM	Service Brake	Definition	BogLoad is the information of the carbody load insisting on the bogies		Bogie			BogLoad			Giraudo		
SB3.3	SYSTEM	Service Brake	Definition	TrainMassSB is the mass of the complete train defined by service brake		SB3.2			TrainMassSB			Giraudo		
SB3.4	SYSTEM	Service Brake	Definition	TrainEqMassSB is the mass of the train + the rotating mass		SB3.2			TrainEqMassSB			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB3.5	SYSTEM	Service Brake	Functional	SB3.1 shall calculate the load insisting on the bogies by memorizing the bogie load information once that door are closed and locked (passenger in/out finished) and trasmit it to SB3.2	The best moment to measure the bogie load necessary to define the brake force is when the train is in stanstill, ready to leave and no more load variation on it	SB3.1	BogLoad	Bogie	BogLoadMemSB	SB3.2	X	Giraudo		
SB3.6	SYSTEM	Service Brake	Definition	BogLoadMemSB is the BogLoad information recorded by service brake in the moment that the train leave the station		SB3.1			BogLoadMemSB			Giraudo		
SB3.7	SYSTEM	Service Brake	Functional	The bogie technical system shall trasmit continuously the bogie load information to SB3.1 Load acquisition sub-function	The continuous transmission permit to have a permanent diagnostic	Bogie	CarLoad	Carbody	BogLoad	SB3.1	x	Giraudo		
SB3.8	SYSTEM	Service Brake	Functional	The door technical system shall trasmit continuously the Door Closed and Locked information to SB3.1 Load acquisition sub-function	The door closed and locked data is informing the brake system of the end of the passenger transfer in the station, so that the train load cannot change anymore	Door	DoorStatus	Door	DoorClLock	SB3.1	x	Giraudo		
SB3.9	SYSTEM	Service Brake	Definition	DoorClLock is the passenger door status Closed and locked: active = closed and locked, not active: not closed and locked		Door			DoorClLock			Giraudo		
SB3.10	SYSTEM	Service Brake	Functional	SB3.1 shall measure the BogLoad information at any time	Note: the detection of the BogLoad information can be done by any detection device technically speaking (pneumatic or electric). The detection device is considered part of brake sub-system SB3	SB3.1	BogLoad	Bogie	BogLoadMeasSB	SB3.2	X	Giraudo		
SB3.11	SYSTEM	Service Brake	Definition	BogLoadMeasSB is the measured value by service brake of the BogLoad information		SB3.1			BogLoadMeasSB			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB3.12	SYSTEM	Service Brake	Functional	SB3.1 shall memorize the BogLoadMeasSB information when (Door Closed and Locked data is active OR the TrainSpeed>3 km/h)	The door closed and locked information is in OR to the train movement to allow to memorize the bogie load also in case of Door closed and Locked information not valid or (exceptional) train movement with door opened	SB3.1	BogLoadMeasSB DoorClLock TrainSpeed	SB3.1 Door Odometry	BogLoadMemSB	SB3.2	X	Giraudo		
SB3.13	SYSTEM	Service Brake	Functional	When the BogLoadMeasSB information is not valid or is out of tolerance SB3.1 shall set a major fault and fix the BogLoadMemSB information to the value of BogLoadDefSB when the DoorClLock data is no more active or as soon as the train move (speed > 3 km/h).	This requirement permit to have always a mass of the train, even if a default one. Note: The dafault mass definition shall be linked to guaranteed perfromance calculation and adhesion constraints	SB3.1	BogLoadMeasSB BogLoadDefSB DoorClLock TrainSpeed	SB3.1 Parameter Door Odometry	BogLoadMemSB MajFaultSB31	SB3.2 SB9.1, BSM2.1.1	X	Giraudo		
SB3.14	SYSTEM	Service Brake	Definition	BogLoadDefSB is the default load insisting on the bogie to be considered in case of not available BogLoadMeasSB information		Dimensioning			BogLoadDefSB			Giraudo		
SB3.15	SYSTEM	Service Brake	Definition	MajFaultSB31 is the fault information indicating that it is lost the BogLoad information (mass information lost)		SB3.1			MajFaultSB31			Giraudo		
SB3.16	SYSTEM	Service Brake	Functional	The BogLoad information shall have an accuracy of +x/- y% respect the real load	Mass of the train directly impact the train stopping distances and the used adhesion.	Bogie	CarLoad	Carbody	BogLoad	SB3.1		Giraudo		
SB3.17	SYSTEM	Service Brake	Definition	CarlLoad is the Load of the car insisting on the bogie		Carbody			CarLoad			Giraudo		
SB3.18	SYSTEM	Service Brake	Functional	The BogLoadMeasSB information shall have an accuracy of +x/- y% respect the BogLoad information	Mass of the train directly impact the train stopping distances and the used adhesion.	SB3.1	BogLoad	Bogie	BogieLoadMeasSB	SB3.2	X	Giraudo		
				SB3.2 - TRAIN LOAD CALCULATION								Giraudo		

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SB3.19	SYSTEM	Service Brake	Functional	SB3.2 calculate the Train Mass and Train equivalent mass by BogLoadMeasSB information and trasmit them to other brake system sub-functions and systems of brake context which are interested in	The train mass and equivalent mass are the information transforming the retardation request into a brake force by SB4	SB3.2	BogLoadMemSB	SB3.1	TrainMassSB TrainEqMassSB	All	X	Giraudo		
SB3.20	SYSTEM	Service Brake	Functional	The train mass shall be derived from Bogie Load adding the mass of the bogies		SB3.2	BogLoadMemSB BogieMass	SB3.1 Parameter	TrainMassSB	All	X	Giraudo		
SB3.21	SYSTEM	Service Brake	Definition	BogieMass is the mass of the bogies		Dimensioning			BogieMass			Giraudo		
SB3.22	SYSTEM	Service Brake	Functional	The train equivalent mass shall be derived from the train mass adding the translating mass equivalent to rotating mass of the train		SB3.2	BogLoadMemSB RotMass BogieMass	SB3.1 Parameter Parameter	TrainEqMassSB	All	X	Giraudo		
SB3.23	SYSTEM	Service Brake	Definition	RotMass is the translating mass correspondent to the rotating mass of the train		Dimensioning			RotMass			Giraudo		
				SB4 - TRAIN SERVICE BRAKING FORCE CALCULATION								Giraudo		
SB4.1	SYSTEM	Service Brake	Functional	SB4 shall calculate the Train service brake force and the minimum train service brake force and trasmit them to SB5.2 and SB5.1	The train service brake force is the force necessary to obtain the expected retardation with the active brake request by actors and existing equivalent mass. The minimum train service brake force is the force necessary to obtain the minimum train service brake retardation	SB4	TrSBrReq TrainMassSB TrackSlopeVal TrainSpeed TrainSBrMaxRet TrainSBrRetMin a,b,c	SB2 SB3.2 ETCS Odometry Parameter Parameter	TrainSBrForNom	SB5.2	X	Giraudo		
SB4.2	SYSTEM	Service Brake	Definition	TrainSBrForNom is the nominal force to be applied by the brake system to the rail to obtain a retardation of the train TrainSBrRetReq		SB4			TrainSBrForNom			Giraudo		

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SB4.3	SYSTEM	Service Brake	Definition	TrainSBrForNomMax is the service brake force that applied to the train on a level track (TrackSlope=0) with nominal runnining resistance force (TrainRunResSB) and actual TrainMassSB generate a TrainSBrRetReq=TrainSBrRetReqMax		SB4			TrainSBrForMax			Giraudo		
SB4.4	SYSTEM	Service Brake	Functional	The Train service brale force shall be calculated based on retardation request received by SB2, the TrainSBrRetMax, the train mass, the train running resistance, the train speed and, optionally, the slope, as follow: If braking is not active (TrSBrReq≥0) then TrainSBrForNom=0 If braking is active (TrSBrReq<0) TrainSBrForNom=TrainMassSB*(-TrSBrReq)*TrainSBrRetMax-TrainRunResSB-TrainMassSB*TrackSlopeVal*9,81	See EN14531-1 for brake force calculation	SB4	TrSBrReq TrainMassSB TrackSlopeVal TrainSBrRetMax TrainSpeed TrainRunResSB	SB2 SB3.2 ATP Parameter Odometry SB4	TrainSBrForNom	SB5.2	X	Giraudo		
SB4.5	SYSTEM	Service Brake	Definition	TrainRunResSB is the force that service brake consider applied by track and aerodynamic forces to the train		Dimensioning			TrainRunResSB			Giraudo		
SB4.6	SYSTEM	Service Brake	Definition	TrackSlopeVal is the slope of the track indicated in thousandths, positive in uphill, negative in downhill		ATP			TrackSlopeVal			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB4.7	SYSTEM	Service Brake	Functional	If TrSBrReq information is not valid or out of range SB4 shall set the force request to a force correspondent to the request TrSBrReqDef and set a major fault	Loss of continuity or train integrity shall cause the application of a predefined brake force. At force application level the loss of SB request signal and the loss of the train integrity is managed at the same way. It is the train level which can be able to have different reactions based on the real situation. Function linked to SB2 req. 1.1.2.1 Note: BSM reaction to major fault could not be reliable in this case due to un-reliable SB1, so the loss of integrity shall be trasmitted till the force generation system EB5.	SB4	TrSBrReq TrainMassSB TrackSlopeVal TrSBrReqDef TrainSpeed TrainRunResSB	SB2 SB3.2 ETCS Parameter Odometry SB4	MajFaultSB4.1 TrainSBrForNom	SB9.4, BSM2.1.1 SB5.2	X	Giraudo		
SB4.8	SYSTEM	Service Brake	Definition	TrSBrReqDef is a default Service brake request to be considered in case of service brake request continuity lost		Dimensioning			TrSBrReqDef			Giraudo		
SB4.9	SYSTEM	Service Brake	Definition	MajFaultSB4.1 is is the fault information indicating that it is lost the TrSBrReq information (continuity lost)		SB4			MajFaultSB4.1			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB4.10	SYSTEM	Service Brake	Functional	If the track slope data by ETCS, which is an optional information, is not valid the track slope value shall be set to TrackSlopeValDefPar (=0) and a major fault shall be set	The slope can be responsible of a maximum tolerance on retardation rate of +/- 9,81m/s2*0,040=0,4m/s2 . Signalling already consider the slope in defining the stopping distance of the train. The slope is relevenat only in case of closed loop control of train retardation, but this is not a function developed by EDV.	SB4	TrackSlopeVal TrackSlopeValDefPar	ETCS Parameter	MajFaultSB4.2 TrainSBrForNom	SB9.4, BSM2.1.1 SB5.2	X	Giraudo		
SB4.11	SYSTEM	Service Brake	Definition	TrackSlopeValDefPar is the dafault value of TrackSlopeVal information in case TrackSlopeVal information is not valid		Dimensioning			TrackSlopeValDefPar			Giraudo		
SB4.12	SYSTEM	Service Brake	Definition	MajFaultSB4.2 is is the fault information indicating that it is lost the TrackSlopeVal information		SB4			MajFaultSB4.2			Giraudo		
SB4.13	SYSTEM	Service Brake	Functional	If the TrainMassSB information is not valid the Train MassSB shall be set to TrainMassDefSB value and a major fault shall be set		SB4	TrainMassSB TrainMassDefSB	SB3.2 Parameter	MajFaultSB4.3 TrainSBrForNom	SB9.4, BSM2.1.1 SB5.2	X	Giraudo		
SB4.14	SYSTEM	Service Brake	Definition	TrainMassDefSB is the default train mass value consistent with the BogLoadDefSB value		Dimensioning			TrainMassDefSB			Giraudo		
SB4.15	SYSTEM	Service Brake	Definition	MajFaultSB4.3 is is the fault information indicating that it is lost the TrainMassSB information		SB4			MajFaultSB4.3			Giraudo		
SB4.16	SYSTEM	Service Brake	Functional	If the TrainSpeed information is not valid the Trainspeed shall be set to TrainSpeedDefSB value and a major fault shall be set		SB4	TrainSpeed TrainSpeedDefSB	Odometry Parameter	MajFaultSB4.4 TrainSBrForNom	SB9.4, BSM2.1.1 SB5.2	X	Giraudo		
SB4.17	SYSTEM	Service Brake	Definition	TrainSpeedDefSB is the default speed information to be considered by SB when the TrainSpeed is not available		Dimensioning			TrainSpeedDefSB			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB4.18	SYSTEM	Service Brake	Definition	MajFaultSB4.4 is is the fault information indicating that it is lost the TrainSpeed information		SB4			MajFaultSB4.4			Giraudo		
SB4.19	SYSTEM	Service Brake	Functional	The train runnig resistance force shall be calculated considering running resistance formula proper of the train: a*TrainMassSB+b*v+c*v^2	a,b,c parameter of the train	SB4	a,b,c TrainMassSB	Parameters SB3.2	TrainRunResSB	SB4	X	Giraudo		
SB4.20	SYSTEM	Service Brake	Definition	a,b,c are the parameters of the standard running resistance force formula used to calculate the running resistance force		Dimensioning			a, b, c			Giraudo		
SB4.21	SYSTEM	Service Brake	Functional	The Minimum train service brake force shall be calculated based on the TrainSBrRetMin, the max train mass, the train running resistance, the train speed and, optionally, the slope, as follow: If braking is not active (TrSBrReq≥0) then TrainSBrForMin=0 If braking is active (TrSBrReq<0) TrainSBrForMin=TrainMassMax*TrainSBrRetMin-a*TrainMassMax+b*v+c*v2-TrainMassMax*TrackSlopeVal*9,81	See EN14531-1 for brake force calculation. The minimum force shall considered the worst condition in term of mass and track slope. This is a speed dependent parameter	SB4	TrainMassMax TrackSlopeMax TrainSBrRetMin TrainSpeed a,b,c	Parameter Parameter Parameter Odometry Parameter	TrainSBrForMin	SB5.1	X	Giraudo		
SB4.22	SYSTEM	Service Brake	Definition	TrainSBrForMin is the service brake force that applied to the train on a maximum Slope with nominal runnining resistance force (TrainRunResSB), with maximum Train mass generate a TrainSBrRetReq=TrainSBrRetReqMin		Dimensioning			TrainSBrForMin			Giraudo		
SB4.23	SYSTEM	Service Brake	Definition	TrainMassMax is the Maximum train mass possible according dimensioning		Dimensioning			TrainMassMax			Giraudo		
SB4.24	SYSTEM	Service Brake	Definition	TrackSlopeMax is the maximum slope present on the line according contractual requirements		Dimensioning			TrackSlopeMax			Giraudo		
				SB5 - SERVICE BRAKE BLENDING								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.1	SYSTEM	Service Brake	Functional	SB5 shall apply a service brake force at the train of the amount of the train service brake force information received by SB4 fulfilling the constraints in terms of: - force tolerance - maximum force applicable to different type of brake (dimensioning constraints) - maximum adhesion	Note: SB5 is in charge of all type of brakes. Next requirements regards the implementation of SB5 function by adhesion dependent friction brake, and in particular the requirements in charge of EDV. The requirements about other type of brakes or function not in charge of EDV are mentioned only if relevant.	SB5	TrainSBrForNom TrainSpeed	SB4 Odometry	TrainSBrForAppl	Train	X	Giraudo		
SB5.2	SYSTEM	Service Brake	Functional	If an emergency brake force request is active (EBrREq active) the train service brake force shall not be applied	Emergency brake requirement has priority .	SB5	EBrReq	EB2	TrainSBrForAppl	SB5	X	Giraudo		
SB5.3	SYSTEM	Service Brake	Functional	SB5 shall not generate leakages which can decrease of more than MaxDeltaPressSB per minute the SBrAirSupplPress (without air supply available)	To guarantee inexhaustibility during the 2 hours of immobilization (see perfromance requirement)	SB5	MaxDeltaPressSB SBrAirSupplPress	Parameter SB6.1	SB5AirSupplLeak	SB6.1	X	Giraudo		
SB5.4	SYSTEM	Service Brake	Definition	AdDepDynSBrAirSupplPress is the air supply pressure of the Adhesion dependent dynamic service brake		SB5			AdDepDynSBrAirSupplPress			Giraudo		
SB5.5	SYSTEM	Service Brake	Definition	AdIndDynSBrAirSupplPress is the air supply pressure of the Adhesion independent dynamic service brake		SB5			AdIndDynSBrAirSupplPress			Giraudo		
SB5.6	SYSTEM	Service Brake	Definition	AdDepFrSBrAirSupplPress is the air supply pressure of the Adhesion dependent friction service brake		SB5			AdDepFrSBrAirSupplPress			Giraudo		
SB5.7	SYSTEM	Service Brake	Definition	AdDepDynSBrAirCons is the air supply consumption of the Adhesion dependent dynamic service brake		SB5			AdDepDynSBrAirCons			Giraudo		
SB5.8	SYSTEM	Service Brake	Definition	AdIndDynSBrAirCons is the air supply consumption of the Adhesion independent dynamic service brake		SB5			AdIndDynSBrAirCons			Giraudo		
SB5.9	SYSTEM	Service Brake	Definition	AdDepFrSBrAirCons is the air supply consumption of the Adhesion dependent friction service brake		SB5			AdDepFrSBrAirCons			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.10	SYSTEM	Service Brake	Definition	SB5AirSupplLeak are the leakages of the pneumatic system distributing pneumatic energy necessary to apply theservice brake force		SB5			SB5AirSupplLeak			Giraudo		
				SB5.1.2.1 DETECTION OF THE ADHESION DEPENDENT SERVICE BRAKE FORCE AVAILABILITY								Giraudo		
SB5.1.1	SYSTEM	Service Brake	Functional	SB5.1. 2.1 shall define the adhesion dependent friction brake force availability by elaborating the isolation status infomation, the remote release information, the dimensioning constraints (ie max force), the actual dissipation capacity (optional, depending from temperature detected by dissipation functions) and the train speed received by Odometry AdDepFrSBrAvFor(v, temp)= AdDepFrBrForMax(v, temp)-(AdDepFrSBrIsolStatus+ AdDepFrSBrREmRelStatus);	The status information is obtained by the 2 function able to isolate the SB: SB10.3 (permanent isolation) and BSM2.1.1 (remote release). The dimensioning constraint is a parameter (see req. 1.0.2) , speed and/or dissipation temperature dependent . The temperature of the dissipation unit is an optional information which could help in optimizing the LCC (if the temperatura is too high the adhesion dependent friction service brake force can be limited but not the emergency and the driver can be invited to have a more smooth way of driving). The adhesion constraints are not considered atthis stage because they shall be considered once that blending with adhesion dependent dynamic brake is defined.	SB5.1.2.1	AdDepFrSBrIsolStatus AdDepFrSBrREmRelStatus AdDepFrBrForMax TrainSpeed AdDepFrSBrDissTempMeas	SB10.3 BSM2.1.1 Parameter Odometry SB12.2.2	AdDepFrSBrAvFor	All	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.1.2	SYSTEM	Service Brake	Definition	AdDepFrSBrAvFor is the adhesion dependent friction service brake force that is available on the train for application to the track.		SB5.1.2.1			AdDepFrSBrAvFor			Giraudo		
SB5.1.3	SYSTEM	Service Brake	Functional	The adhesion dependent available forces (friction+dynamic) shall guarantee the TrainSBrForMin in case of -100% of TrSBrReq TrainSBrForMin(v)=AdDepSBrForMin(v)= AdDepFrSBrForMin(v)+AdDepDynSBrForMin(v)	This requirement is derived by the fact that the adhesion dependent brake are the type of brake which are always present on the train. In principle if adhesion independent brake is available on the train it can contribute, but certain speed reduction could be necessary by different train on the same portion of the track, so it could be necessary that it shall be inhibited to avoid track heating up. In such a case the minimum force shall be guaranteed only by adhesion dependent forces.	SB5.1.2.1	TrainSBrForMin	SB4	AdDepSBrForMin	SB5.1.2.1	X	Giraudo		
SB5.1.4	SYSTEM	Service Brake	Definition	AdDepSBrForMin is the minimum force that shall be available to be applied at the track by adhesion dependent brake forces (dynamic and friction brake forces applied together according blending rules)		SB5.1.2.1			AdDepSBrForMin			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.1.5	SYSTEM	Service Brake	Functional	The minimum adhesion dependent friction service brake force is TrainSBrForMin(v)= AdDepSBrForMin(v)-AdDepDynSBrForMin(v)	The minimum friction service brake force is dependent from the minimum guaranteed dynamic service brake force to be coherent with the blending rules, which use the friction brake as complementary to the dynamic one. The minimum adhesion dependent dynamic brake force is received by SB5.1.1.1 (it could be also equal to 0). It is what is always guaranteed by adhesion dependent dynamic brake	SB5.1.2.1	AdDepDynSBrForMin TrainSBrForMin	SB5.1.1.1 Parameter	AdDepFrSBrForMin	SB5.1.2.1	X	Giraudo		
SB5.1.6	SYSTEM	Service Brake	Definition	AdDepDynSBrForMin is the minimum force applied at the track that is **guaranteed** by adhesion dependent dynamic brake.It depends from dimensioning and isolation active on adhesion dependent dynamic brake. (It is different from AdDepDynSBrAvFor, which is the total available force, guaranteed + not guaranteed)	This information depends from the design of the adhesion dependent dynamic brake: if a portion of the force is safe enough, the value can be > 0. If the force application is not safe enough the value is 0.	SB5.1.1.1			AdDepDynSBrForMin			Giraudo		
SB5.1.7	SYSTEM	Service Brake	Definition	AdDepFrSBrForMin is the minimum force at the track that shall be available by adhesion dependent friction brake (for friction brake available and guaranteed is the same).		SB5.1.2.1			AdDepFrSBrForMin			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.1.8	SYSTEM	Service Brake	Functional	If the available adhesion dependent friction service brake force is lower of the minimum friction service brake force, SB5.1.2.1 shall consider available the minimum force and set a major fault	The train during the operation should not reach the minimal condition to run. It is up to BSM to define the reaction to this condition, there is not any automatic emergency brake application by SB.	SB5.1.2.1	AdDepFrSBrAvFor AdDepFrSBrForMin	SB5.1.2.1 Parameter	MajFaultSB5121	SB9.4, BSM2.1.1	X	Giraudo		
SB5.1.9	SYSTEM	Service Brake	Definition	MajFaultSB5121 is the fault information indicating that the service brake cannot guarantee the minimum service brake retardation necessary for the operation		SB5.1.2.1			MajFaultSB5121			Giraudo		
SB5.1.10	SYSTEM	Service Brake	Functional	If the AdDepFrSBrAirSupplPress < AdDepFrSBrAirSupplPressMin the Availability shall be set to 0	Inexhaustibility requirement	SB5.1.2.1	AdDepFrSBrAirSupplPress AdDepFrSBrAirSupplPressMin	SB5 Parameter	AdDepFrSBrAvFor	SB5.2.2.1	X	Giraudo		
				SB5.2 - ADHESION DEPENDENT FRICTION SERVICE BRAKE FORCE CALCULATION								Giraudo		

SB5.2.1	SYSTEM	Service Brake	Functional	SB5.2.shall define the nominal forces of different type of brakes as result of blending logic giving priority to regenerative dynamic brake first, not regenerative dynamic brake second and adhesion dependent friction brake (using consumable parts) last one, providing the missing brake force.	The Adhesion independent friction brake force is not considered in analogy to the conventional solution. The proposed blending logic maximize the use of regenerative brake and the use of wearless brake types (Dynamic brakes), to reduce the LCC. It has the inconvenient of possible warmimg up of the rails due to the higher priority given to adhesion independent dynamic brake respect friction brake (for example when all trains are braking in the same part of the line, ie before the station). Note1: different blending rules can be possible. Here only one is considered, but could be a further functionality to provide the possibility for the driver to change the blending rules, as suggested by EN16185 §5.9.1 Note2:SB5.2 provide for all type of brakes the expected force to be applied taking in account already of the limitations by availability and adhesion (that's why the output has the extension Ltd). For this reason it is not sure that the total force is equal to the	SB5.2	TrainSBrForNom AdDepDynSBrAvFor AdIndDynSBrAvFor AdDepFrSBrAvFor	SB4 SB5.1.1.1 SB5.1..1.2 SB5.1.2.1	AdDepDynSBrForNomLtd AdIndDynSBrForNomLtd AdDepFrSBrForNomLtd	SB5.3.1.1. SB5.3.1.2 SB5.3.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
					TrainSBrForNom Note3: Blending logics can be managed by a central function controlling all type of brakes or by functions controlling each type of brake implementing the same blending logic to have coherent force distribution. Here below the second option is considered: ED brake, Friction brake, EC Brake have independent coherent blending logic installed in their controller and exchange information to guarantee the consistency.									
SB5.2.2	SYSTEM	Service Brake	Definition	AdDepDynSBrAvFor is the adhesion dependent dynamic brake force available on the train, which can be applied to the track		SB5.1.1.1			AdDepDynSBrAvFor			Giraudo		
SB5.2.3	SYSTEM	Service Brake	Definition	AdIndDynSBrAvFor is the adhesion independent dynamic brake force available on the train, which can be applied to the track		SB5.1.1.2			AdIndDynSBrAvFor			Giraudo		
SB5.2.4	SYSTEM	Service Brake	Definition	AdDepDynSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent dynamic brake to apply the TrainSBrForNom .		SB5.2.1.1			AdDepDynSBrForNomLtd			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.2.5	SYSTEM	Service Brake	Definition	AdIndDynSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent dynamic brake to apply the TrainSBrForNom .		SB5.2.1.2			AdIndDynSBrForNomLtd			Giraudo		
SB5.2.6	SYSTEM	Service Brake	Definition	AdDepFrSBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent friction brake to apply the TrainSBrForNom .		SB5.2.2.1			AdDepFrSBrForNomLtd			Giraudo		
SB5.2.7	SYSTEM	Service Brake	Functional	SB5.2.1.1 shall calculate the adhesion dependent dynamic brake nominal force as the minimum between the train service brake force requested by SB4, the constraints of force availability of adhesion dependent dynamic brake and adhesion limits. AdDepDynSBrForNomLtd= min(AdMaxVal(v)*(TrainMassSB)*9,81; AdDepDynSBrAvFor(v); TrainSBrForNom)	Derived from above blending logic, availability and adhesion limitation	SB5.2.1.1	TrainSBrForNom AdDepDynSBrAvFor AdMaxVal TrainMassSB	SB4 SB5.1.1.1 parameter SB3	AdDepDynSBrForNomLtd	SB5.2.2.1	X	Giraudo		
SB5.2.8	SYSTEM	Service Brake	Definition	AdMaxVal is the maximum available adhesion between wheel and rail. It can be speed dependent and also train configuration dependent. It can be the value indicated in TSI or contractual or project constraint		Dimensioning			AdMaxVal			Giraudo		
SB5.2.9	SYSTEM	Service Brake	Functional	SB5.2.1.2 shall calculate the adhesion independent dynamic brake nominal force as the minimum between (TrainSBrForNom-AdDepDynSBrForNomLtd) and the constraints of force availability. AdIndDynSBrForNomLtd= min((TrainSBrForNom-AdDepDynSBrForNomLtd); AdIndDynSBrAvFor(v))	Derived from blending logic and availability limitation	SB5.2.1.2	TrainSBrForNom AdDepDynSBrForNomLtd AdIndDynSBrAvFor	SB4 SB5.2.1.1 SB5.1.1.2	AdIndDynSBrForNomLtd	SB5.2.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.2.10	SYSTEM	Service Brake	Functional	SB5.2.2.1 shall calculate the adhesion dependent friction service brake nominal force by the following formula: AdDepFrSBrForNomLtd=min(TrainSBrForNom-(AdDepDynSBrForNomLtd+AdIndDynSBrForNomLtd); AdDepFrSBrAvFor; (AdMaxVal(v)*(TrainMassSB)*9,81-AdDepDynSBrForNomLtd))	Derived from blending logic and availability and adhesion limitation.	SB5.2.2.1	TrainSBrForNom AdDepDynSBrForNomLtd AdIndDynSBrForNomLtd AdMaxVal TrainMassSB AdDepFrSBrAvFor	SB4 SB5.2.1.1. SB5.2.1.2 Parameter SB3.2 SB5.1.2.1	AdDepFrSBrForNomLtd	SB5.3.2.1	X	Giraudo		
SB5.2.12	SYSTEM	Service Brake	~~Functional~~	~~If the TrainSBrForNom received by SB4 is not valid the AdDepDynSBrForLtd shall be not valid~~	~~Propagation of the integrity/continuity loss information~~	~~SB5.2.1.1~~	~~TrainSBrForNom~~	~~SB4~~	~~AdDepDynSBrNomFor~~	~~SB5.3.1.1~~	~~x~~	Giraudo	-	-
SB5.2.13	SYSTEM	Service Brake	~~Functional~~	~~If the TrainSBrForNom received by SB4 is not valid the AdDepFrSBrForLtd shall be not valid~~	~~Propagation of the integrity/continuity loss information~~	~~SB5.2.1.2~~	~~TrainSBrForNom~~	~~SB4~~	~~AdIndDynSBrNomFor~~	~~SB5.3.1.2~~	~~x~~	Giraudo	-	-
				SB5.3.2.1 ADHESION DEPENDENT FRICTION SERVICE BRAKE REQUESTED FORCE								Giraudo		
SB5.3.1	SYSTEM	Service Brake	Functional	SB5.3.2.1 shall generate an adhesion dependent friction service brake force request to SB5.5.2.1 , the service brake enabled status, taking in account the nominal force by SB5.2.2.1, real time blending with achieved adhesion dependent dynamic brake force (received by SB5.4), holding brake request by SB7	.	SB5.3.2.1	SBrEnabled SBrDisFor AdDepFrSBrForNom AdDepDynSBrForNomLtd HBReq MaxSlope TrainMassSB TrSBrReq AdDepDynSBrAchFor	BSM2.1.1 Parameter SB5.2.2.1 SB5.2.2.1 SB7 parameter SB3 SB2 SB5.4	AdDepFrSBrForReqLtd	SB5.5.2.1.1	X	Giraudo		
SB5.3.2	SYSTEM	Service Brake	Definition	SBrDisFor is the force that shall be requested to be applied by the adhesion dependent friction service brake when the service brake is disabled.		Dimensioning			SBrDisFor			Giraudo		
SB5.3.3	SYSTEM	Service Brake	Definition	AdDepFrSBrForReqLtd is the force to be requested to to be applied by the adhesion dependent friction service brake force generation function SB5.5.2.1.		SB5.3.2.1			AdDepFrSBrForReqLtd			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.3.4	SYSTEM	Service Brake	Functional	When the Service brake system is disabled SB5.3.2.1 shall set a predefined force request: AdDepFrSBrForReqLtd=SBrDisFor	There are not constraint on predefined force because the immobilisation of a train with disabled service brake is in charge of Parking brake	SB5.3.2.1	SBrEnabled SBrDisFor	BSM2.1.1 Parameter	AdDepFrSBrForReqLtd	SB5.5.2.1.1	X	Giraudo		
SB5.3.5	SYSTEM	Service Brake	Functional	When the Service brake system is enabled, SB5.3.2.1 shall calculate the requested adhesion dependent friction SB force taking in account the nominal force by SB5.2.2.1 , real time blending with achieved dynamic brake force (received by SB5.4) and the holding brake request	The adhesion dependent friction brake force is the back-up brake of adhesion dependent dynamic brake to guarantee the performances also in case of adhesion dependent dynamic brake failure	SB5.3.2.1	SBrEnabled AdDepFrSBrForNomLtd AdDepDynSBrForNomLtd AdIndDynSBForNomLtd AdDepDynSBrAchFor AdDepDynTractAchFor HBReq	BSM2.1.1 SB5.2.2.1 SB5.2.1.1 SB5.2.1.2 SB5.4 SB5.4 SB7	AdDepFrSBrForReqLtd	SB5.3.2.1	X	Giraudo		
SB5.3.6	SYSTEM	Service Brake	Functional	When the Service brake system is enabled, if the holding brake request is not active, the adhesione dependent friction brake requested force shall be: AdDepFrSBrForReqLtd=min(AdDepFrSBrForNomLtd+(AdDepDynSBrForNomLtd-AdDepDynSBrAchFor));	See above req. 1.1.5.3.2	SB5.3.2.1	SBrEnabled AdDepFrSBrForNomLtd AdDepDynSBrForNomLtd AdDepDynSBrAchFor AdIndDynSBrForNomLtd HBReq	BSM2.1.1 SB5.2.2.1 SB5.2.1.1 SB5.4 SB5.2.1.2 SB7	AdDepFrSBrForReqLtd	SB5.3.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.3.7	SYSTEM	Service Brake	Functional	When the Service brake system is enabled, if the holding brake request is active, the adhesione dependent friction brake requested force shall be : If TrSBrReq≤0: AdDepFrSBrForReqLtd=min(k*TrainMassMax*MaxSlope*9,81; AdDepFrSBrAvFor; AdMaxVal*TrainMassSB*9,81) If TrSBrReq>0: AdDepFrSBrForReqLtd=min(k*TrainMassMax*MaxSlope*9,81; AdDepFrSBrAvFor; AdMaxVal*TrainMassSB*9,81)-AdDepDynTractAchFor	The holding brake force is defined by the worst situation of mass and slope. The "k" safety coefficient is considered . The removal of holding brake is done ramping it with the real traction force measured via SB5.4 function (by TORQ device). Note: The check that the expected holding brake force is achieved once that the adhesion and availability limitations are introduced is done by SB7 sub-function	SB5.3.2.1	SBrEnabled TrSBrReq MaxSlope TrainMassSB TrainMassMax HBReq AdDEpDynSBrAchFor AdDEpDynTractAchFor K	BSM2.1.1 SB2 parameter SB3 parameter SB7 SB5.4 SB5.4 Parameter	AdDepFrSBrForReqLtd	SB5.3.2.1	X	Giraudo		
SB5.3.8	SYSTEM	Service Brake	Definition	"k" is the safety coefficient considered in defining the adhesion dependent frictio brake force to be applied by holding brake function to immobilize the train on the maximum slope with maximum train mass		Dimensioning			k			Giraudo		
SB5.3.9	SYSTEM	Service Brake	Functional	If the Train friction SB requested force is < then the minimum expected one a major fault shall be activated If AdDepDynSBrAchFor+AdIndDynSBrForReqLtd+AdDepFrSBrForReqLtd < TrSBrReq*TrainSBrForMin a major fault shall be set.	This requirement is the final check that the sum of the requested/applied forces to all type of brakes achieve the minimum target given by SB4. This check is atrributed to adhesion dependent friction brake because is the last type of brake in the blending chain.	SB5.3.2.1	AdDepFrSBrForReqLtd AdDepDynSBrAchFor AdIndDynSBrForReqLtd TrainSBrForNom	SB5.3.2.1 SB5.4 SB5.3.1.2 SB4	MajFaultSB5321.1	SB9.4, BSM2.1.1	X	Giraudo		
SB5.3.10	SYSTEM	Service Brake	Definition	MajFaultSB5321 is the fault information that the service brake is not able to apply the minimum force acceptable for operation		SB5.3.2.1			MajFaultSB5321.1			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.3.11	SYSTEM	Service Brake	Definition	AdIndDynSBrForReqLtd is the force to be requested to the adhesion independent dynamic service brake force generation function SB5.5.1.2		SB5.3.1.2			AdIndDynSBrForReqLtd			Giraudo		
SB5.3.12	SYSTEM	Service Brake	Functional	If AdDepDynSBrAchFor is not valid the AdDepFrSBrForReqLtd shall be set to the value AdDepFrSBrForNom and a major fault shall be set		SB5.3.1.1	AdDepDynSBrAchFor	SB5.4	AdDepFrSBrForReqLtd MajFaultSB5321.2	SB5.5.1.1.1 SB9.4	X	Giraudo		
SB5.3.13	SYSTEM	Service Brake	Definition	MajFaultSB5321.2 is the fault information of AdDepDynSBrAchFor information not valid		SB5.3.1.1			MajFaultSB5321.2			Giraudo		
				SB5.4 ACHIEVED ADHESION DEPENDENT DYNAMIC SERVICE BRAKE FORCE								Giraudo		
SB5.4.1	SYSTEM	Service Brake	Functional	SB5.4 shall measure the really applied traction and braking force applied by traction and adhesion dependent dynamicbrake and trasmit it to SB5.3	This requirement is a consequence of the blending logic defined in SB5. This functionality is introduced becuase it is supposed that SB5.1.1.1 is not able to provide a safe information of the available ashesion dependent dynamic brake	SB5.4	WheelTorq	SB5.5.1.1.2	AdDepDynTractAchFor AdDepDynSBrAchFor	SB5.3.2.1	x	Giraudo		
SB5.4.2	SYSTEM	Service Brake	Functional	The adhesion dependent dynamic brake shall provide the information of the really applied braking force and trasmit it to SB5.3.2.1	TORQ device mentioned in D5.1	SB5.4	WheelTorq	SB5.5.1.1.2	AdDepDynSBrAchFor	SB5.3.2.1	x	Giraudo		
SB5.4.3	SYSTEM	Service Brake	Functional	The adhesion dependent dynamic brake shall provide the information of the really applied traction force and trasmit it to SB5.3.2.1	TORQ device mentioned in D5.1	SB5.4	WheelTorq	SB5.5.1.1.2	AdDepDynTractAchFor	SB5.3.2.1		Giraudo		
SB5.4.4	SYSTEM	Service Brake	Definition	WheelTorq is the the torque applied to the bogieapplying the traction force or the adhesion dependent dynamic brake force to the track		SB5.5.1.1.2			WheelTorq			Giraudo		
SB5.4.5	SYSTEM	Service Brake	Definition	AdDepDynSBrAchFor is the value of the force applied at the track by the adhesion dependent dynamic brake		SB5.4			AdDepDynSBrAchFor			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.4.6	SYSTEM	Service Brake	Definition	AdDepDynTractAchFor is the information providing the force applied at the track by the traction		SB5.4			AdDepDynTractAchFor			Giraudo		
				SB5.5.2 .1 ADHESION DEPENDENT FRICTION SERVICE BRAKE FORCE GENERATION								Giraudo		
SB5.5.1	SYSTEM	Service Brake	Functional	SB5.5.2.1.1 shall generate an adhesion dependent friction brake force pilot command piloting, by SB5.5.2.1.2, a force application at the track equal to the force request by SB5.3.2.1 (rotating mass to be considered)	This function shall take in care to consider in the pilot also the rotating mass braking force necessary to apply at the track the requested force	SB5.5.2.1.1	AdDepFrSBrForReqLtd RotMass	SB5.3.2.1 Parameter	AdDEpFrSBrPilCom	LAM1.2.1	X	Giraudo		
SB5.5.2	SYSTEM	Service Brake	Definition	AdDEpFrSBrPilCom is the pilot command applying an adhesion dependent friction brake force to the track equal to the requested force AdDepFrSBrForReqLtd		SB5.5.2.1.1			AdDEpFrSBrPilCom			Giraudo		
SB5.5.3	SYSTEM	Service Brake	Functional	SB5.5.2.1 .1 shall monitor the real adhesion dependent friction brake force applied	Monitoring is fundamental for control/diagnosys of the whole force generation process and precision of the force generated (closed loop control).	SB5.5.2.1.1.	AdDepFrSBrForAppl	SB5.5.2.1.2	AdDepFrSBrForApplMeas	SB5.5.2.1.1	X	Giraudo		
SB5.5.4	SYSTEM	Service Brake	Definition	AdDepFrSBrForApplMeas is the information of the adhesion dependent friction service brake force applied at the track		SB5.5.2.1.1.			AdDepFrSBrForApplMeas			Giraudo		
SB5.5.5	SYSTEM	Service Brake	Functional	SB5.5.2.1.2 shall apply an adhesion dependent friction brake force to the track proportional to the pilot command trasmitted by SB5.5.2.1.1 and eventually reduced by LAM1.2.1		SB5.5.2.1.2	AdDEpFrSBrPilComLAM	LAM1.2.1	AdDepFrSBrForAppl	Track		Giraudo		
SB5.5.6	SYSTEM	Service Brake	Definition	AdDEpFrSBrPilComLAM is the pilot command,conditioned by the LAM1.2.1 function, provided to the adhesion dependent friction brake actuation function SB5.5.2.1.2		LAM1.2.1			AdDEpFrSBrPilComLAM			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.5.7	SYSTEM	Service Brake	Functional	The holding brake force applied shall guarantee the brake force application for at least 2 hours		SB	AdDepFrSBrForReqLtd AdDepFrSBrPilCom AdDepFrSBrPilComLAM	SB3.1.2.1 SB5.5.2.11 SB5.5.2.1.2	TrainSBrForAppl	Track		Giraudo		
SB5.5.8	SYSTEM	Service Brake	Functional	SB5.5.2.1.1 shall monitor the adhesion dependent friction SB air supply pressure and trasmit the pressure value to diagnostic system		SB5.5.2.1.1	AdDEpFrSBrAirSupplPress	SB6.1	AdDEpFrSBrAirSupplMeas	SB9.4	X	Giraudo		
SB5.5.9	SYSTEM	Service Brake	Definition	AdDepFrSBrAirSupplMeas is the information of the pressure of the air supply to the adhesion independent friction service brake		SB5.5.2.1.1			AdDepFrSBrAirSupplMeas			Giraudo		
SB5.5.10	SYSTEM	Service Brake	Functional	If the AdDepFrSBrAirSupplPress is below the dimensioning limit AdDepFrSBrAirSupplPressMin, SB5.5.2.1.1 shall set major fault	Inexhaustibility requirement for the friction service brake. BSM shall manage it at train level.	SB5.5.2.1.1	AdDepFrSBrAirSupplMeas AdDepFrSBrAirSupplPressMin	SB5.5.2.1.1 parameter	MajFaultSB55211.1	SB9.4, BSM2.1.1	X	Giraudo		
SB5.5.11	SYSTEM	Service Brake	Definition	MajFaultSB55211.1 is the fault information of adhesion dependent friction service brake supply pressure below the minimum limit AdDepFrSBrAirSupplPressMin		SB5.5.2.1.1			MajFaultSB55211.1			Giraudo		
SB5.5.12	SYSTEM	Service Brake	Functional	SB5.5.2.1.1 shall monitor the Electric Voltage to adhesion dependent friction service brake		SB5.5.2.1.1.	AdDepFrSBrElVolt	SB6.2	AdDepFrSBrElVoltMeas	SB9.4	X	Giraudo		
SB5.5.13	SYSTEM	Service Brake	Definition	AdDepFrSBrElVoltMeas is the information of the voltage of the electric supply to the adhesion independent friction service brake		SB5.5.2.1.1			AdDepFrSBrAirSupplMeas			Giraudo		
SB5.5.14	SYSTEM	Service Brake	Functional	If the electric voltage to SB5 is below the AdDepFrSBrElVoltMin or is lost, SB5.5.2.1.1 shall apply automatically a default pilot command and a major fault shall be set	The safe state for SB5 is brake application. In such a case the adhesion could be higher than allowed . In any case major fault is generated and BSM2.1.1 is able to release the braking by remote release if considered safe	SB5.5.2.1.1.	AdDepFrSBrElVoltMeas AdDepFrSBrElVoltMin AdDepFrSBrPilCommEnOff	SB5.5.2.1.1 parameter parameter	AdDEpFrSBrPilCom MajFaultSB55211.2	SB5.5.2.1.2 SB9.4, BSM2.1.1	X	Giraudo		

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SB5.5.15	SYSTEM	Service Brake	Definition	AdDepFrSBrPilCommEnOff is the Default pilot command to be applied in case of electric energy off or below the minimum value		SB5.5.2.1.1.			AdDepFrSBrPilCommEnOff			Giraudo		
SB5.5.16	SYSTEM	Service Brake	Definition	MajFaultSB55211.2 is the fault information that the electric voltage is below the minimum AdDepFrSBrElVoltMin or is lost		SB5.5.2.1.1.			MajFaultSB55211.2			Giraudo		
SB5.5.17	SYSTEM	Service Brake	Functional	If the adhesion dependent friction brake force measured is out of regulation tolerance SB5.5.2.1.1 shall generate a minor fault	The regulation tolerance is the one taking care of the accuracy of the brake force. The consistency of the force application with the dimensioning constraints is guaranteed by the other requirements considering the maximum or minimum forces	SB5.5.2.1.1	AdDEpFrSBrForAplMeas AdDepFrSBrForReqLtd AdDepFrSBrForTol	SB5.5.2.1.2 SB5.3.2.1 Parameter	MinFaultSB55211.1	SB9.4	X	Giraudo		
SB5.5.18	SYSTEM	Service Brake	Definition	AdDepFrSBrForTol is the upper and lower regulation tolerance of the adhesion dependent friction service brake force		Dimensioning			AdDepFrSBrForTol			Giraudo		
SB5.5.19	SYSTEM	Service Brake	Definition	MinFaultSB55211.1 is the fault information of adhesion dependent friction service brake force out of regulation tolerance		SB5.5.2.1.1			MinFaultSB55211.1			Giraudo		
SB5.5.20	SYSTEM	Service Brake	Functional	If the adhesion dependent friction brake force measured is higher then the maximum allowed force for SB5.5.2.1.2, a major fault shall be set by SB5.5.2.1.1	Exceeded dimensioning constraints	SB5.5.2.1.1	AdDEpFrSBrForAplMeas AdDepFrSBrForMax	SB5.5.2.1.2 Parameter	MajFaultSB55211.3	SB9.4, BSM2.1.1	X	Giraudo		
SB5.5.21	SYSTEM	Service Brake	Definition	MajFaultSB55211.3 is the fault information of adhesion dependent friction service brake force above the maximum value AdDepFrSBrForMax		SB5.5.2.1.1			MajFaultSB55211.3			Giraudo		
SB5.5.22	SYSTEM	Service Brake	Functional	If the adhesion dependent friction brake force applied measured is lower then AdDEpFrSBrForReqLtd of a value higher then AdDepFrSBrForMaxTol a major fault shall be set	consistency check between the requested and the applied force	SB5.5.2.1.1	AdDepFrSBrForMaxTol AdDEpFrSBrForReqLtd AdDEpFrSBrForAplMeas	parameter SB5.3.2.1 SB5.5.2.1.1	MajFaultSB55211.4	SB9.4	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB5.5.23	SYSTEM	Service Brake	Definition	MajFaultSB55211.4 is the fault information of adhesion dependent friction service brake force applied is lower than requested of a value higher than AdDepFrSBrForMaxTol		SB5.5.2.1.1			MajFaultSB55211.4			Giraudo		
SB5.5.24	SYSTEM	Service Brake	Definition	AdDepFrSBrForMaxTol is the maximu lower tolerance acceptable for Adhesion dependent friction service brake force		Dimensioning			AdDepFrSBrForMaxTol			Giraudo		
SB5.5.25	SYSTEM	Service Brake	Functional	If speed is > 3 km/h and the adhesion dependent friction brake force measured is >0 and the there is not a Adhesion dependent friction service brake request (taking in account a delay related to releasing time), a major fault shall be set by SB5.5.2.1.1	Dragging brake condition	SB5.5.2.1.1	TrainSpeed AdDEpFrSBrForAplMeas AdDepFrSBrForReqLtd	Odometry SB5.5.2.1.2 SB5.3.2.1	MajFaultSB55211.5	SB9.4, BSM2.1.1	X	Giraudo		
SB5.5.26	SYSTEM	Service Brake	Definition	MajFaultSB55211.5 is the fault information of adhesion dependent friction service brake force applied when not requested (dragging brake)		SB5.5.2.1.1			MajFaultSB55211.5			Giraudo		
				SB6 - SERVICE BRAKE ENERGY STORING AND DISTRIBUTION								Giraudo		
				SB6.1 PNEUMATIC ENERGY STORING AND DISTRIBUTION								Giraudo		
SB6.1	SYSTEM	Service Brake	Functional	SB6.1 shall provide to SB the pneumatic energy to permit the correct regulation of service brake force by type of brakes using pneumatic energy		SB6.1	AirSupplPress BrAirSupplDel	SB11.3 SB11.3	SBrAirSupplPress SBrAirSupplDel	SB	x	Giraudo		
SB6.2	SYSTEM	Service Brake	Definition	AirSupplPress is the pressure of the air supply providing pneumatic energy to the brake system		SB11.3			AirSupplPress			Giraudo		
SB6.3	SYSTEM	Service Brake	Definition	BrAirSupplDel is the air delivery to the brake system		SB11.3			BrAirSupplDel			Giraudo		
SB6.4	SYSTEM	Service Brake	Definition	SBrAirSupplPress is the pressure of the air supply providing pneumatic energy to service brake		SB6.1			SBrAirSupplPress			Giraudo		
SB6.5	SYSTEM	Service Brake	Definition	SBrAirSupplDel is the air delivery to the service brake functions		SB6.1			SBrAirSupplDel			Giraudo		

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SB6.6	SYSTEM	Service Brake	Functional	SB6.1 shall limit the pneumatic pressure to the maximum permitted by SB5 dimensioning limits and shall provide an air delivery congruent with the air consumption of all types of brakes (taking care of WSPintervention as well)	Dimensioning constraint on different types of brakes. Note: this function can be done by any air pressure regulator limiting the supply pressure to EDV	SB6.1	AdDepDynSBrAirSupplPressMax AdIndDynSBrAirSupplPressMax AdDepFrSBrAirSupplPressMax AdDepDynSBrAirConsMax AdIndDynSBrAirConsMax AdDepFrSBrAirConsMax	Parameter Parameter Parameter Parameter Parameter Parameter	SBrAirSupplPressMax SBrAirDelMin SBrAirDelMax	SB5 SB5 SB5	x	Giraudo		
SB6.7	SYSTEM	Service Brake	Functional	The SB6.1 minimum pressure and SB6.1 store volume shall guarantee the application for at least x≥ 2 time of the TrainSBrForMin without air supply function SB11.3 available.	Inexhaustibility requirement. The number of time to be defined with customer	SB6.1	AdDepDynSBrAirSupplPressMin AdIndDynSBrAirSupplPressMin AdDepFrSBrAirSupplPressMin AdDepDynSBrAirConsMax AdIndDynSBrAirConsMax AdDepFrSBrAirConsMax TrainSBrForMin SBrAirSupplPressMin SBrAirSupplStoreVol	Parameter Parameter Parameter Parameter Parameter Parameter Parameter	AdDEpFrSBrAirSuppl	SB5	x	Giraudo		
SB6.8	SYSTEM	Service Brake	Functional	SB6.1 leakages and store capacity shall guarantee that the supply pressure doesn't decrease of more than MaxDeltaPressSB/min due to leakages (without air supply available)	To guarantee inexhaustibility during the 2 hour of immobilization (see perfromance requirement) Requirement connected with SB5 req. 1.1.6.1.7	SB6.1	MaxDeltaPressSB SBrAirSupplStoreVol	Parameter Parameter	SB6AirSupplLeak	SB6.1	x	Giraudo		
SB6.9	SYSTEM	Service Brake	Definition	SBrAirSupplPressMax is the max pressure of the service brake air supply		Dimensioning			SBrAirSupplPressMax			Giraudo		
SB6.10	SYSTEM	Service Brake	Definition	SBrAirSupplPressMin is the minimum pressure of the service brake air supply		Dimensioning			SBrAirSupplPressMin			Giraudo		

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SB6.11	SYSTEM	Service Brake	Definition	SBrAirDelMax is the maximum air delivery of the service brake air supply which guarantee correct functionalities		Dimensioning			SBrAirDelMax			Giraudo		
SB6.12	SYSTEM	Service Brake	Definition	SBrAirDelMin is the minimum air delivery of the service brake air supply which guarantee correct functionalities		Dimensioning			SBrAirDelMin			Giraudo		
SB6.13	SYSTEM	Service Brake	Definition	SBrAirSupplStoreVol is the volume of the service brake supply air store		Dimensioning			SBrAirSupplStoreVol			Giraudo		
SB6.14	SYSTEM	Service Brake	Definition	SB6AirSupplLeak are the air leakages produced by SB6		SB6.1			SB6AirSupplLeak			Giraudo		
SB6.15	SYSTEM	Service Brake	Definition	AdDepDynSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent dynamic service brake permitted by dimensioning		Dimensioning			AdDepDynSBrAirSupplPressMax			Giraudo		
SB6.16	SYSTEM	Service Brake	Definition	AdIndDynSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion independent dynamic service brake permitted by dimensioning		Dimensioning			AdIndDynSBrAirSupplPressMax			Giraudo		
SB6.17	SYSTEM	Service Brake	Definition	AdDepFrSBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent friction service brake permitted by dimensioning		Dimensioning			AdDepFrSBrAirSupplPressMax			Giraudo		
SB6.18	SYSTEM	Service Brake	Definition	AdDepDynSBrAirConsMax is the maximum air supply consumption of the Adhesion dependent dynamic service brake considered by dimensioning		Dimensioning			AdDepDynSBrAirConsMax			Giraudo		
SB6.19	SYSTEM	Service Brake	Definition	AdIndDynSBrAirConsMax is the maximum air supply consumption of the Adhesion independent dynamic service brake considered by dimensioning		Dimensioning			AdIndDynSBrAirConsMax			Giraudo		
SB6.20	SYSTEM	Service Brake	Definition	AdDepFrSBrAirConsMax is the maximum air supply consumption of the Adhesion dependent friction service brake considered by dimensioning		Dimensioning			AdDepFrSBrAirConsMax			Giraudo		
SB6.21	SYSTEM	Service Brake	Definition	AdDepDynSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent dynamic service brake permitted by dimensioning		Dimensioning			AdDepDynSBrAirSupplPressMin			Giraudo		

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SB6.22	SYSTEM	Service Brake	Definition	AdIndDynSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion independent dynamic service brake permitted by dimensioning		Dimensioning			AdIndDynSBrAirSupplPressMin			Giraudo		
SB6.23	SYSTEM	Service Brake	Definition	AdDepFrSBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction service brake permitted by dimensioning		Dimensioning			AdDepFrSBrAirSupplPressMin			Giraudo		
SB6.24	SYSTEM	Service Brake	Definition	MaxDeltaPressSB is the maximum acceptable decrease per minute of service brake supply pressure SBrAirSupplPress		Dimensioning			MaxDeltaPressSB			Giraudo		
				SB6.2 ELECTRIC ENERGY STORING AND DISTRIBUTION								Giraudo		
SB6.25	SYSTEM	Service Brake	Functional	SB6.2 shall provide to SB the electric energy to permit the correct regulation of service brake force by type of brakes using electric energy	SBrElVoltMax SBrElCurrMax	SB6.2	ElVolt BrElCurr AdDepDynSBrElVoltNom AdIndDynSBrElVoltNom AdDepFrSBrElVoltNom AdDepDynSBrElCurrNom AdIndDynSBrElCurrNom AdDepFrSBrElCurrNom	Electric Energy Supply Electric Energy Supply Parameter Parameter Parameter Parameter Parameter Parameter	SBrElVolt SBrElCurr	SB SB	x	Giraudo		
SB6.26	SYSTEM	Service Brake	Functional	SB6.2 shall limit the electric energy voltage to the maximum permitted by SB dimensioning limits	Dimensioning constraint	SB6.2	AdDepDynSBrElVoltMax AdIndDynSBrElVoltMax AdDepFrSBrElVoltMax AdDepDynSBrElCurrMax AdIndDynSBrElCurrMax AdDepFrSBrElCurrMax	Parameter Parameter Parameter Parameter Parameter Parameter Parameter Parameter	SBrElVoltMax SBrElCurrMax SBrElCurrMin	SB SB SB	x	Giraudo		

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SB6.27	SYSTEM	Service Brake	Functional	SB6.2 shall provide the necessary el energy to SB to apply the minimum force applicable by all the type of brake using electric energy even in case of missing supply of energy by SB11.2 and guarantee the maximum brake application time	Dimensioning constraint	SB6.2	AdDepDynSBrElVoltMin AdIndDynSBrElVoltMin AdDepFrSBrElVoltMin	Parameter Parameter Parameter Parameter Parameter Parameter	SBrElVoltMin	SB SB	x	Giraudo		
SB6.28	SYSTEM	Service Brake	Functional	The minimum voltage and energy storing capacity shall guarantee the supply for at least x> 2h of holding brake force without low Voltage electric energy supply function SB11.2 available	Inexhaustibility.	SB6.2	SBrElVoltMin ElEnStoreCap	Parameter Parameter	SBrElVolt SBrElCurr	SB SB	x	Giraudo		
SB6.29	SYSTEM	Service Brake	Definition	ElVolt is the voltage of the electric energy supply to the brake system		Electric Energy Supply			ElVolt			Giraudo		
SB6.30	SYSTEM	Service Brake	Definition	BrElCurr is the electric current supplied to the brake system		Electric Energy Supply			BrElCurr			Giraudo		
SB6.31	SYSTEM	Service Brake	Definition	SBrElVolt is the voltage of the electric energy supply to the service brake system		SB11.2			SBrElVolt			Giraudo		
SB6.32	SYSTEM	Service Brake	Definition	SBElCurr is the electric current supplied to the service brake system		SB11.2			SBElCurr			Giraudo		
SB6.33	SYSTEM	Service Brake	Definition	SBrElVoltMax is the maximum voltage by which SBr system can be supplied according dimensioning		Dimensioning			SBrElVoltMax			Giraudo		
SB6.34	SYSTEM	Service Brake	Definition	SBrElVoltMin is the minimum voltage by which SB system guarantee the functionalities		Dimensioning			SBrElVoltMin			Giraudo		
SB6.35	SYSTEM	Service Brake	Definition	SBrElCurrMax is the maximum current by which SBr system can be supplied according dimensioning		Dimensioning			SBrElCurrMax			Giraudo		
SB6.36	SYSTEM	Service Brake	Definition	SBrElCurrMin is the minimum current which guarantee correct functionalities of the service brake		Dimensioning			SBrElCurrMax			Giraudo		
SB6.37	SYSTEM	Service Brake	Definition	ElEnStoreCap is the electric energy storing capacity of the electric energy store		Dimensioning			ElEnStoreCap			Giraudo		
SB6.38	SYSTEM	Service Brake	Definition	AdDepDynSBrElVoltNom is the nominal voltage by which adhesion dependent dynamic service brake shall be supplied		Dimensioning			AdDepDynSBrElVoltNom			Giraudo		

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SB6.39	SYSTEM	Service Brake	Definition	AdIndDynSBrElVoltNom is the nominal voltage by which adhesion independent dynamic service brake shall be supplied		Dimensioning			AdIndDynSBrElVoltNom			Giraudo		
SB6.40	SYSTEM	Service Brake	Definition	AdDepFrSBrElVoltNom is the nominal voltage by which adhesion dependent friction service brake shall be supplied		Dimensioning			AdDepFrSBrElVoltNom			Giraudo		
SB6.41	SYSTEM	Service Brake	Definition	AdDepDynSBrElCurrNom is the nominal current consumption of adhesion dependent dynamic service brake		Dimensioning			AdDepDynSBrElCurrNom			Giraudo		
SB6.42	SYSTEM	Service Brake	Definition	AdIndDynSBrElCurrNom is the nominal current consumption of adhesion independent dynamic service brake		Dimensioning			AdIndDynSBrElCurrNom			Giraudo		
SB6.43	SYSTEM	Service Brake	Definition	AdDepFrSBrElCurrNom is the nominal current consumption of adhesion dependent friction service brake		Dimensioning			AdDepFrSBrElCurrNom			Giraudo		
SB6.44	SYSTEM	Service Brake	Definition	AdDepDynSBrElVoltMax is the maximum voltage by which adhesion dependent dynamic service brake shall be supplied		Dimensioning			AdDepDynSBrElVoltMax			Giraudo		
SB6.45	SYSTEM	Service Brake	Definition	AdIndDynSBrElVoltMax is the maximum voltage by which adhesion independent dynamic service brake shall be supplied		Dimensioning			AdIndDynSBrElVoltMax			Giraudo		
SB6.46	SYSTEM	Service Brake	Definition	AdDepFrSBrElVoltMax is the maximum voltage by which adhesion dependent friction service brake shall be supplied		Dimensioning			AdDepFrSBrElVoltMax			Giraudo		
SB6.47	SYSTEM	Service Brake	Definition	AdDepDynSBrElCurrMax is the maximum current consumption of adhesion dependent dynamic service brake		Dimensioning			AdDepDynSBrElCurrMax			Giraudo		
SB6.48	SYSTEM	Service Brake	Definition	AdIndDynSBrElCurrMax is the maximum current consumption of adhesion independent dynamic service brake		Dimensioning			AdIndDynSBrElCurrMax			Giraudo		
SB6.49	SYSTEM	Service Brake	Definition	AdDepFrSBrElCurrMax is the maximum current consumption of adhesion dependent friction service brake		Dimensioning			AdDepFrSBrElCurrMax			Giraudo		
SB6.50	SYSTEM	Service Brake	Definition	AdDepDynSBrElVoltMin is the minimum voltage by which adhesion dependent dynamic service brake shall be supplied		Dimensioning			AdDepDynSBrElVoltMin			Giraudo		
SB6.51	SYSTEM	Service Brake	Definition	AdIndDynSBrElVoltMin is the minimum voltage by which adhesion independent dynamic service brake shall be supplied		Dimensioning			AdIndDynSBrElVoltMin			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB6.52	SYSTEM	Service Brake	Definition	AdDepFrSBrElVoltMin is the minimum voltage by which adhesion dependent friction service brake shall be supplied		Dimensioning			AdDepFrSBrElVoltMin			Giraudo		
				SB7 - HOLDING BRAKE								Giraudo		
SB7.1	SYSTEM	Service Brake	Functional	Holding brake sub-function shall immobilize the train for at least 2 hours on the maximum line gradient	SB7 generate the force to immobilize the train providing a command to SB5.3.2.1	SB7	TrainSpeed TrSBrReq TrainDir HBrEnabled WheelDir	Odometry SB2 SB2 BSM2.1.2 LAM1.1	HBReq	SB5.3.2.1	X	Giraudo		
SB7.2	SYSTEM	Service Brake	Definition	HBrReq is the request to apply the holding brake		SB8			HBReq			Giraudo		
SB7.3	SYSTEM	Service Brake	Definition	WheelDir is the information of the rotation direction of the wheel		LAM1.1			WheelDir			Giraudo		
SB7.4	SYSTEM	Service Brake	Functional	Holding brake force is applied by adhesion dependent friction service brake force	The adhesion dependent friction service brake is the type of brake which is normally present in every train	SB7	TrainSpeed TrSBrReq TrainDir HBrEnabled	Odometry SB2 SB2 BSM2.1.2	HBReq	SB5.3.2.1	X	Giraudo		
SB7.5	SYSTEM	Service Brake	Functional	If Holding brake is not enabled it shall never set the Holding brake request to active	The driver has the possibility to remove the automatic application of holding brake by BSM2.1.2 sub-function. In this case the temporary immobilisation is in charge of the driver (see BSM requirements).	SB7	HBrEnabled	BSM2.1.2	HBReq	SB5.3.2.1	X	Giraudo		
SB7.6	SYSTEM	Service Brake	Functional	With holding brake enabled, if TrSBrReq≤0 and the train speed is < 3 km/h, SB7 shall activate the holding brake request to SB5.3.2.1	The Holding brake is requested automatically at zero speed. See requirements in SB5.3.2.1 for force generation	SB7	TrainSpeed TrSBrReq HBrEnabled	Odometry SB2 BSM2.1.2	HBReq	SB5.3.2.1	X	Giraudo		
SB7.7	SYSTEM	Service Brake	Functional	With holding brake enabled, the Holding brake request shall be de-activated only once that TrSBrReq>0 and the TrainSpeed is > 3 km/h in the correct direction	The brake is removed only once that the traction effort is higher then gravity force to permit the start in uphill	SB7	TrainSpeed WheelDir TrSBrReq TrainDir HBrEnabled	Odometry LAM1.1 SB2 SB2 BSM2.1.2	HBReq	SB5.3.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB7.8	SYSTEM	Service Brake	Functional	If, with holding brake enabled, holding brake req active and TrSBrReq>0, the train move to the opposite direction respect the selected one, SB7 shall set a major fault TO BE AGREED IF TO EXPORT THE ROLL BACK PROTECTION TO THE TRAIN (in such a case the train direction information by SB2 and the WheelDir is no more necessary)	Roll back protection, the reaction is demanded to BSM	SB7	TrainSpeed WheelDir TrSBrReq TrainDir HBrEnabled	Odometry LAM1.1 SB2 SB2 BSM2.1.2	MajFaultSB7.1	SB9.4, BSM2.1.1	X	Giraudo		
SB7.9	SYSTEM	Service Brake	Functional	If any input signal to SB7 is not valid or out of range a major fault shall be set	Holding brake out of order, the reaction is demanded to BSM	SB7	TrainSpeed TrSBrReq TrainDir HBrEnabled WheelDir	Odometry SB2 SB2 BSM2.1.2 LAM1.1	MajFaultSB7.2	SB9.4, BSM2.1.1	X	Giraudo		
SB7.10	SYSTEM	Service Brake	Functional	If, with holding brake enabled and holding brake request active and TrSBrReq≤0, the friction brake force applied is < k*TrainMassMax*MaxSlope-HBForTol, SB7 shall set a major fault	If the HB force is too low the train can move with high slope. It means that the service brake is no more able to guarantee the temporary immobilization. The reaction is demanded to BSM	SB7	AdDEpFrSBrForApplMeas TrainMassMax MaxSlope HBForTol HBrEnabled k	SB5.5.2.1.2 SB3.2 parameter parameter BSM2.1.2 parameter	MajFaultSB7.3	SB9.4, BSM2.1.1	X	Giraudo		
SB7.11	SYSTEM	Service Brake	Definition	MajFaultSB7.1 is the fault information of roll back detection		SB7			MajFaultSB7.1			Giraudo		
SB7.12	SYSTEM	Service Brake	Definition	MajFaultSB7.2 is the fault information of holding brake out of order		SB7			MajFaultSB7.2			Giraudo		
SB7.13	SYSTEM	Service Brake	Definition	MajFaultSB7.3 is the fault information of not sufficient holding brake force applied		SB7			MajFaultSB7.3			Giraudo		
				SB8 - SERVICE BRAKE TRACTION CUTOFF								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB8.1	SYSTEM	Service Brake	Functional	SB8 shall require the traction cut off to traction system in case of brake request	The traction shall be cutted off only if brake request is active. If a brake force is applied without service brake request (during brake force fade off or with holding brake applied) traction can be requested and applied.	SB8	TrSBrReq	SB2	TractForAppl	track	x	Giraudo		
SB8.2	SYSTEM	Service Brake	Definition	TractForAppl is the traction force applied at the track by the traction technical system		SB8			TractForAppl			Giraudo		
SB8.3	SYSTEM	Service Brake	Functional	If TrSBrReq is < 0 the traction system shall set to 0 the traction force request	Traction request is active only if TrSBrReq>0, so this is automatically obtained by the use of the same information to trasmit the traction and brake request	SB8	TrSBrReq	SB2	TractForAppl	track	x	Giraudo		
SB8.4	SYSTEM	Service Brake	Functional	If TrSBrReq information has lost its integrity or is out of range traction shall be cut off immediately	If the TrSBrReq is not valid automatic brake application is piloted by SB4 and traction shall be cut off	SB8	TrSBrReq	SB2	TractForAppl	track	x	Giraudo		
				SB9 - STATE AND FAULT DETECTION AND INDICATION								Giraudo		
SB9.1	SYSTEM	Service Brake	Functional	The service brake function SB9 shall detect and indicate in the driver cab and/or outside the train the status of the service brake and of its sub-functions		SB9			SBrStatus	Diagnostic DriverHMI MaintTool		Giraudo		
SB9.2	SYSTEM	Service Brake	Definition	SBrStatus is the information providing the released or applied status of service brake		SB9			SBrStatus			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.3	SYSTEM	Service Brake	Functional	SB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the service brake (SB) which can have following status: Applied: if any type of brake is applying a braking force Released: if every type of brake is released	The SB status represent the presence of an applied force to the train, independently from enabled status or fault or type of brake applying a force. Note: the adhesion independent friction brake is not used in service brake and for this reason its status is not considered	SB9.1	AdDepDynSBrStatus AdIndDynSBrStatus AdDepFrSBrStatus	SB9.2 SB9.3 SB9.4	SBrStatus	Diagnostic DriverHMI MaintTool	x	Giraudo		
SB9.4	SYSTEM	Service Brake	Definition	AdDepDynSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent dynamic service brake		SB9.2			AdDepDynSBrStatus			Giraudo		
SB9.5	SYSTEM	Service Brake	Definition	AdIndDynSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent dynamic service brake		SB9.3			AdIndDynSBrStatus			Giraudo		
SB9.6	SYSTEM	Service Brake	Definition	AdDepFrSBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent friction service brake		SB9.4			AdDepFrSBrStatus			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.7	SYSTEM	Service Brake	Functional	SB9.1 function shall provide to the driver HMI, diagnostic system, diagnostic tool the status of the service brake functions SB1, SB2 which can have following status: enabled: when BSM1 has enabled the service brake system and there is not any major fault active in SB1 or SB2 disabled: when the status is not enabled or degraded degraded: when the service brake degraded mode is successfully activated by BSM2.1.2 after the driver selection of service brake degraded mode faulty: if it is enabled and any major fault active in SB1 or SB2	SB1 and SB2 are the sub-function managing the train retardation request, which is the brake central command. For this reason a single status is defined. A faulty SB1,SB2correspond to the impossibility to provide the service brake command, ie to loose the continuity of the service brake. For this reason any major fault on SB1 and SB2 functions shall lead to an automatic emergency brake.	SB9.1	SBrEnabled MajFaultAnySB1 MajFaultAnySB2 SBrDegr	BSM1 SB1 SB2 BSM2.1.2	SBrStatusSB1-2	Diagnostic DriverHMI MaintTool	x	Giraudo		
SB9.8	SYSTEM	Service Brake	Definition	SBrStatusSB1-2 is the information providing the enabled/disabled/degraded/faulty status of service brake sub-functions SB1 and SB2		SB9.1			SBrStatusSB1-2			Giraudo		
SB9.9	SYSTEM	Service Brake	Definition	MajFaultAnySB1 is the summary information of any major fault active on sub-function SB1		SB1			MajFaultAnySB1			Giraudo		
SB9.10	SYSTEM	Service Brake	Definition	MajFaultAnySB2 is the summary information of any major fault active on sub-function SB2		SB2			MajFaultAnySB2			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.11	SYSTEM	Service Brake	Functional	SB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the service brake function SB3 which can have following status: enabled: when BSM1 has correctly initialized the brake system and there is not any major fault active in SB3 disabled: when it is not enabled faulty: if it is enabled and any major fault active in SB3	SB3 function is independent from other brake function and need a independent status If the brake system is not enabled also the weighting s not enabled and a predefined brake force is applied (see req. In SB5.3.2.1) Major fault of SB3 is managed by SB3 fixing a predefined mass (see req. in SB3)	SB9.1	SBrEnabled MajFaultAnySB3	BSM1 SB3	SBrStatusSB3	Diagnostic DriverHMI MaintTool	x	Giraudo		
SB9.12	SYSTEM	Service Brake	Definition	MajFaultAnySB3 is the summary information of any major fault active on sub-function SB3		SB9.1			MajFaultAnySB3			Giraudo		
SB9.13	SYSTEM	Service Brake	Definition	SBrStatusSB3 is the information providing the enabled/disabled/faulty status of service brake sub-function SB3		SB9.1			SBrStatusSB3			Giraudo		
SB9.14	SYSTEM	Service Brake	Functional	The adhesion dependent friction brake shall provide its own status derived from SB4-SB5-SB7-SB10-SB12 functions . The status can be : Applied: if any braking force is applied Released: if force is not applied Isolated: if it is isolated Faulty: if a major fault is active		SB9.4	AdDepFrSBrApplMeas MajFaultAnyAdDepFrSBrSB4-5-7-10 AdDepFrSBrRemRelStatus AdDepFrSBrIsolStatus AdDepFrSBrForMax	SB5.5.2.1.1 SB9.4 BSM2.1.1 SB10.3 Parameter	AdDepFrSBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
SB9.15	SYSTEM	Service Brake	Definition	MajFaultAnyAdDepFrSBrSB4-5-7-10 is the summary information of any major fault active on adhesion dependent friction service brale in sub-function SB4, SB5.1.2.1, SB5.2.2.1, SB5.3.2.1 SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3		SB9.4			MajFaultAnySB4-5-6-7-10			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.16	SYSTEM	Service Brake	Functional	The adhesion depedent friction brake status is applied if SB5.5.2.1.1 detect AdDepFrSBrApplMeas>0	The force application is detected by the closer information to the wheelset	SB9.4	AdDepFrSBrApplMeas	SB5.5.2.1.1	AdDepFrSBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
SB9.17	SYSTEM	Service Brake	Functional	The adhesion depedent friction brake status is releassed if SB5.5.2.1.1 detect AdDepFrSBrApplMeas=0	The force application is detected by the closer information to the wheelset	SB9.4	AdDepFrSBrApplMeas	SB5.5.2.1.1	AdDepFrSBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.18	SYSTEM	Service Brake	Functional	The adhesion depedent friction brake status is faulty if any major fault is detected by functions SB4, SB5.1.2.1, SB5.2.2.1, SB5.3.2.1 SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3 perfromed by adhesion dependent friction brake type	The mentioned SB4, SB5, SB7, SB10.3 functions are in charge of the adhesion dependent friction brake force. SB5.4 major fault does not impact the correct functionality of adhesion dependent friction brake, for this reason is not mentioned. SB6 function, which can cause a fault in adhesion dependent friction brake, is monitored by SB5.2 so its faulty status is already included in SB5 faulty status. SB12.2 function, which can cause a fault in adhesion dependent friction brake (i.e. by dissipation temperature), is optionally monitored by SB5.1.2.1 availability function, which is an EDV function, so its faulty status (not valid or out of range AdDepFrSBrDissTempMeas information) can be included in SB5 faulty status (actually this is not considered major fault because the reliability of the measurement device can be lower than the real possibility of overpass the dimensioning duty cycle) .	SB9.4	MajFaultAnySB4-5-7-10	SB9.4	AdDepFrSBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.19	SYSTEM	Service Brake	Functional	The adhesion depedent friction service brake isolation status shall indicate the percentage of available force respect the maximum one based on SB10.3 permanent isolation AND remote release status	The isolation gives the information about service brake force availability to SB5.1.2.1 function. The service brake isolation status include the result of both remote release and permanent isolation because it is oriented to know the really applicable force to obtain the retardation requested. Note: The emergency brake isolation status given by EB10.3 is considering only permanent release, which is the one defining braking power. (see emergency brake requirements and BSM2.2 requirements)	SB9.4	AdDepFrSBrRemRelStatus AdDepFrSBrIsolStatus AdDepFrSBrForMax	BSM2.1.1 SB10.3 Parameter	AdDepFrSBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
SB9.20	SYSTEM	Service Brake	Functional	The adhesion dependent friction service brake status (only if applied or released) shall be show optionally external the train, also in case of lack of energy (pneumatic or electric)	The external indication is usefull for maintenance.	SB9.4	AdDepFrSBrStatus	SB9.4	AdDepFrSBrStatusEXT	Diagnostic DriverHMI MaintTool	X	Giraudo		
SB9.21	SYSTEM	Service Brake	Definition	AdDepFrSBrStatusEXT is the information of applied/released adhesion dependent friction brake visible externally of the train		SB9.4			AdDepFrSBrStatusEXT			Giraudo		
SB9.22	SYSTEM	Service Brake	Functional	Any minor fault or major fault shall be trasmitted to diagnostic system, diagnostic tool		SB9.4	MinFaultSBx MajFaultSBx	SB3, SB4, SB5.1.2.1, SB5.2, SB5.3.2.1, SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3	MinFaultSBx MajFaultSBx	Diagnostic DriverHMI MaintTool	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB9.23	SYSTEM	Service Brake	Functional	Any major fault shall be trasmitted to driver HMI, diagnostic system, diagnostic tool		SB9.4	MajFaultSBx	SB3, SB4, SB5.1.2.1, SB5.2, SB5.3.2.1, SB5.5.2.1.1, SB5.5.2.1.2, SB7, SB10.3	MajFaultSBx	Diagnostic DriverHMI MaintTool	X	Giraudo		
				SB10 - SERVICE BRAKE ISOLATION								Giraudo		
SB10.1	SYSTEM	Service Brake	Functional	SB10 shall manage the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application by SB5.5.2 sub-function	The isolation has the scope to remove an amount of force, independently from the force generation function, to be able to react toany major fault which would stop permanentely the train	SB10	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom; AdDepDynSBrIsolCom AdIndDynSBrIsolCom AdDepFrSBrIsolCom	BSM2.1.1 Driver, Maintenance operator	AdDEpDynSBrForAppl AdIndDynSBrForAppl AdDEpFrSBrForAppl	Track		Giraudo		
SB10.2	SYSTEM	Service Brake	Definition	AdDepDynSBrIsolCom is the command of permanent isolation of adhesion dependent dynamic service brake		User			AdDepDynSBrIsolCom			Giraudo		
SB10.3	SYSTEM	Service Brake	Definition	AdIndDynSBrIsolCom is the command of permanent isolation of adhesion independent dynamic service brake		User			AdIndDynSBrIsolCom			Giraudo		
SB10.4	SYSTEM	Service Brake	Definition	AdDepFrSBrIsolCom is the command of permanent isolation of adhesion dependent friction service brake		User			AdDepFrSBrIsolCom			Giraudo		
SB10.5	SYSTEM	Service Brake	Functional	SB10.3 shall manage the isolation of adhesion dependent friction brake by remote release and permanent isolation command		SB10.3	AdDepFrSBrRemRelCom AdDepFrSBrIsolCom	BSM2.1.1 Driver Maintenance operator	AdDEpFrSBrForAppl	Track	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB10.6	SYSTEM	Service Brake	Functional	SB10.3 remote release shall permit to remove the adhesion dependent friction service brake force by remote command during running or standstill.	The remote isolation permit to react to any major fault quickly permitting to manage also the running capability requirements in case of major faults. The remote release command is a function in charge of BSM2.1.1.	SB10.3	AdDepFrSBrRemRelCom	BSM2.1.1	AdDEpFrSBrForAppl	Track	X	Giraudo		
SB10.7	SYSTEM	Service Brake	Functional	The remote release shall operate on SB5.5.2.1 sub-function removing the force application independently from SB5.3.2.1 command	Closer the release command is to the force generation fewer are the functions which can influence the release.	SB10.3	AdDepFrSBrRemRelCom	BSM2.1.1	AdDEpFrSBrPilCom or AdDEpFrSBrPilComLAM	LAM1.2.1 SB5.5.2.1.2	X	Giraudo		
SB10.8	SYSTEM	Service Brake	Functional	The remote release shall be enabled in case of major fault only	The BSM2.1 function shall be capable to remove a braking only in presence of major fault to mitigate the possibility to have undue braking force releasing	SB10.4	MajFaultSBx	SB	AdDepFrSBrRemRelCom	BSM2.1	X	Giraudo		
SB10.9	SYSTEM	Service Brake	Functional	SB10.3 permanent isolation sub-function shall permit to remove the adhesion dependent friction service brake force applied, totally or partially, permanentely, with or without energy available on the train, with SB in any status	The permanent isolation shall be an autonomous sub-function able to operate whatever are the condition of the other service brake sub-functions because it is the last operation that can be done to permit at the train to remove the braking force and be able to be moved.	SB10.3	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom	BSM2.1.1 Driver, Maintenance operator	AdDEpFrSBrForAppl	Track		Giraudo		
SB10.10	SYSTEM	Service Brake	Functional	The permanent isolation can be commanded by driver or maintenance operator manually or, optionally, by remote command via BSM2.1.1	The optional remote command permit to isolate permanentely from a central position	SB10.3	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom	BSM2.1.1 Driver, Maintenance operator	AdDEpFrSBrForAppl	Track		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB10.11	SYSTEM	Service Brake	Definition	AdDepFrSBrIsolManCom is the command of permanent isolation of adhesion dependent friction service brake provided by manual command		User			AdDepFrSBrIsolManCom			Giraudo		
SB10.12	SYSTEM	Service Brake	Functional	The permanent isolation sub-function shall operate on SB5.5.2.1 sub-function removing the force application independently from SB5.3.2.1 command	Closer the permanent isolation is to the force generation fewer are the functions which can influence the result by any failure or power switch off.	SB10.3	AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom	BSM2.1.1 Driver	AdDEpFrSBrPilCom or AdDEpFrSBrPilComLAM	LAM1.2.1 SB5.5.2.1.2		Giraudo		
SB10.13	SYSTEM	Service Brake	Functional	Permanent isolation sub-function shall monitor the permanent isolation execution checking the applied force by AdDepFrSBrForApplMeas information received by SB5.5.2.1.1. If permanent release is not successfull (command of permanent release active and brake force still applied) SB10.3 shall set a major fault	To diagnose dragging brake	SB10.3	AdDepFrSBrForApplMeas AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom	SB5.5.2.1.1 BSM2.1.1 Driver, Maintenance operator	MajFaultSB103.1	SB9.4, BSM2.1.1		Giraudo		
SB10.14	SYSTEM	Service Brake	Definition	MajFaultSB103.1 is the fault information about the not success permanent isolation execution		SB10.3			MajFaultSB103.1			Giraudo		
SB10.15	SYSTEM	Service Brake	Functional	Permanent isolation shall define the permanent isolation status as: Isolated force: it shall provide the percentage of maximum adhesion depedent friction service brake force released by permanent isolation. Faulty: if permanent isolation is not succesfull in releasing completely the expected force		SB10.3	AdDepFRSBrForApplMeas AdDepFrSBrIsolRemCom AdDepFrSBrIsolManCom MajFault103.1 AdDepFrSBrForMax	SB5.5.2.1.1. BSM2.1.1 Driver SB10.3 Parameter	AdDepFrSBrIsolStatus	SB9.1		Giraudo		
SB10.16	SYSTEM	Service Brake	Definition	AdDepFrSBrIsolStatus is the information of permanent isolated force/faulty permanent isolation of adhesion dependent friction service brake force		SB10.3			AdDepFrSBrIsolStatus			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB10.17	SYSTEM	Service Brake	Functional	If the permanent isolated force = (Isolated force percentage)*AdDepFrSBrForMax>AdDepFrSBrForMax-AdDepFrSBrForMin a major fault shall be set	MinSBrFor not available	SB10.3	AdDepFRSBrIsolStatus AdDepFrSBrForMin	SB10.3 SB5.1.2.1	MajFaultSB103.2	SB9.4, BSM2.1.1		Giraudo		
SB10.18	SYSTEM	Service Brake	Definition	MajFaultSB103.2 is the fault information about the too high isolation of a adhesion dependent friction service brake force, not permitting to apply the minimum service brake force by the adhesion dependent friction service brake		SB10.3			MajFaultSB103.2			Giraudo		
				SB12 - SERVICE BRAKE KINETIC ENERGY TRANSFORMATION								Giraudo		
SB12.1	SYSTEM	Service Brake	Functional	SB12.2 function shall transform the kinetic energy of the train into thermal energy by the friction between two surfaces	Physics	SB12.2	TrainKinEn	Train	ThermEn	Environment	x	Giraudo		
SB12.2	SYSTEM	Service Brake	Definition	TrainKinEn is the kinetic energy of the train		Train			TrainKinEn			Giraudo		
SB12.3	SYSTEM	Service Brake	Definition	ThermEn is the thermal energy to be dissipated by brake system		SB12.2			ThermEn			Giraudo		
SB12.4	SYSTEM	Service Brake	Functional	SB12.2.1 shall generate thermal energy (heat) from the contact between two friction surface sliding with an applied perpendicular force that generates the AdDEpFrSBrForAppl force at the track		SB12.2.1	AdDepFrSBrForAppl	SB5.5.2.1.2	AdDepFrSBrHeat	SB12.2.2.	x	Giraudo		
SB12.5	SYSTEM	Service Brake	Definition	AdDepFrSBrHeat is the heat generated by dissipation process of adhesion dependent friction service brake		SB12.2.1			AdDepFrSBrHeat			Giraudo		
SB12.6	SYSTEM	Service Brake	Functional	SB12.2.2 shall dissipate the heat generated by SB12.2.1 into the air		SB12.2.2.	AdDepFrSBrHeat	SB12.2.1	AirThermEnSB	Environment	x	Giraudo		
SB12.7	SYSTEM	Service Brake	Definition	AirThermEnSB is the service brake thermal energy dissipated into the air		SB12.2.2.			AirThermEnSB			Giraudo		
SB12.8	SYSTEM	Service Brake	Functional	SB12.2.2 shall measure the temperature reached during braking by dissipation function	Optional function, usefull in case of unpredictable mission profile. Function not included in EDV functionalities	SB12.2.2.	AdDepFrSBrDissTemp	SB12.2.1	AdDepFrSBrDissTempMeas	SB9.4, SB5.1.2.1	x	Giraudo		
SB12.9	SYSTEM	Service Brake	Definition	AdDepFrSBrDissTemp is the dissipation temperature of the adhesion dependent friction brake		SB12.2.2.			AdDepFrSBrDissTemp			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
SB12.10	SYSTEM	Service Brake	Definition	AdDepFrSBrDissTempMeas is the information of the dissipation temperature of the adhesion dependent friction brake AdDepFrSBrDiss Temp		SB12.2.2.			AdDepFrSBrDissTempMeas			Girasudo		
SB12.11	SYSTEM	Service Brake	Functional	SB12.2.2 shall set a major fault if it will detect a too high temperature	This function is optional because the thermal dissipation is dimensioned by calculations and test, so it should not happen during operation to have too high temperature. This function protect the brake system against unpredictable mission profiles or combination of isolation with heavy duty cycles	SB12.2.2.	AdDepFrSBrDissTempMeas AdDepFrSBrDissTempMax	SB12 Parameter	MajFaultSB122	SB9.4	x	Giraudo		
SB12.12	SYSTEM	Service Brake	Definition	AdDepFrSBrDissTempMax is the maximum temperature that can be reached by adhesion dependent friction brake		Dimensioning			AdDepFrSBrDissTempMax			Giraudo		
SB12.13	SYSTEM	Service Brake	Definition	MajFaultSB122 is the fault information about too high temperature at the adhesion dependent friction service brake energy dissipation sub-function		SB12.2.2.			MajFaultSB122			Giraudo		
-		-	-	EB - EMERGENCY BRAKE	-	-	-	-	-	-	-	Giraudo	-	-
EB.1	SYSTEM	Emergency Brake	Functional	The emergency brake is the system function used by the users and technical systems (actors) to apply predefined retarding force to the track (directly or by the wheelset) with the following goals: - to stop the train in the guaranteed stopping distance	The guaranteed performances are the ones considered by ETCS/ATP to calculate the free space necessary in front of the train	EB	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	TrainEBrRetAppl TrainEBrEqTimeAppl	Train		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.2	SYSTEM	Emergency Brake	Definition	EBReqUs is the request to apply the emergency brake by any user		User			EBReqUs			Giraudo		
EB.3	SYSTEM	Emergency Brake	Definition	EBrReqATO is the request to apply the emergency brake by ATO		ATO			EBrReqATO			Giraudo		
EB.4	SYSTEM	Emergency Brake	Definition	EBrReqTCMS is the request to apply the emergency brake by TCMS		TCMS			EBrReqTCMS			Giraudo		
EB.5	SYSTEM	Emergency Brake	Definition	EBrReqATP is the request to apply the emergency brake by ATP		ATP			EBrReqATP			Giraudo		
EB.6	SYSTEM	Emergency Brake	Definition	EBrReqETCS Eis the request to apply the emergency brake by ETCS		ETCS			EBrReqETCS			Giraudo		
EB.7	SYSTEM	Emergency Brake	Definition	EBrReqPAS is the request to apply the emergency brake by PAS		PAS			EBrReqPAS			Giraudo		
EB.8	SYSTEM	Emergency Brake	Definition	TrainEBrRetAppl is the portion of the train retardation TrainRetAppl which is generated by the Emergency brake force. It is a positive value		Train			TrainEBrRetAppl			Giraudo		
EB.9	SYSTEM	Emergency Brake	Definition	TrainEBrEqTimeAppl is the equivalent time by which the force TrainEBrRetAppl is applied		EB			TrainEBrEqTimeAppl			Giraudo		
EB.10	SYSTEM	Emergency Brake	Functional	The emergency brake function shall be always active when the train is powered on	Depending from the status of the emergency brake request information the emergency brake force shall be applied accordingly based on EBr status.	EB	EBrElVolt	EB6.2	TrainEBrForAppl	Train		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.11	SYSTEM	Emergency Brake	Functional	When an emergency brake is applied after an emergency request, it can be released only if the request is removed	Note: If there is an undue emergency brake request, the function BSM2.2.2 shall allow the driver to remove the undue request to permit the train to guarantee running capability.	EB	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO PAS BSM2	TrainEBrRetAppl TrainEBrEqTimeAppl	Train		Giraudo		
EB.12	SYSTEM	Emergency Brake	Functional	The emergency brake retardation applied TrainRetAppl shall be ≥ maximum emergency brake retardation TrainEBrRetMax in following condition: - without any failure and isolation, - without degraded environmental condition (causing sliding or reduced applied forces), - on a flat track - any train mass	The maximum emergency brake retardation is the nominal retardation provided by brake system applying forces according dimensioning. It is the reference retardation to calculate the braking power. The maximum retardation can be an invariant parameter or a speed dependent parameter In presence of slope the retardation should be updated adding the gravity force retardation, but this is not considered (normally it is taken in consideration by ATP/ETCS. It could become relevant in case of perfromances control, which is not in the scope of this document)	EB	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM TrainEBrRetMax	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO PAS BSM2 Parameter	TrainRetAppl	Train		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.13	SYSTEM	Emergency Brake	Definition	TrainEBrRetMax is the nominal retardation of the train obtained by the force applied by the emergency brake in following condition: - without any failure and isolation, - without degraded environmental condition (causing sliding or reduced applied forces), - on a flat track - with maximum train mass		Dimensioning			TrainEBrRetMax			Giraudo		
EB.14	SYSTEM	Emergency Brake	Functional	The emergency brake is the main function which shall guarantee the minimum performances of the brake system: TrainEBrRetMin = TrainRetMin TrainEBrEqTimeMax= TrainBrEqTimeMax		Dimensioning	TrainRetMin TrainBrEqTimeMax	Dimensioning	TrainEBrRetMin	Parameter		Giraudo		
EB.15	SYSTEM	Emergency Brake	Functional	The Emergency brake equivalent time of applied retardation shall be TrainEBrEqTimeAppl< TrainEBrEqTimeMax	See above requirement about brake performances. The TrainEBrEqTimeMax is the brake application equivalent time considered by signalling	EB	TrainEBrEqTimeMax	Dimensioning	TrainEBrEqTimeAppl	Train		Giraudo		
EB.16	SYSTEM	Emergency Brake	Definition	TrainEBrEqTimeMax is the the maximum equivalent time in emergency brake considered by dimensioning		Dimensioning			TrainEBrEqTimeMax			Giraudo		
EB.17	SYSTEM	Emergency Brake	Definition	TrainEBrRetMin is the guaranteed emergency minimum retardation provided by the emergency brake application, which permit to stop the train in the maximum stopping distances TrainStopDist associated to the active braking power TrainBrPower.	The guaranteed retardation and the maximum equivalent time are the input for ATP/ETCS to define the distance of the train	Dimensioning			TrainEBrRetMin			Giraudo		
EB.18	SYSTEM	Emergency Brake	Functional	The train emergency brake force applied to the track shall provide at least the minimum emergency brake performances associated to the braking power active at the moment of the braking in any track and environmental condition and in presence of the worst single failure during emergency application		EB	TrainEBrRetMin TrainEBrEqTimeMax TrainEBrForNomAppl TrainEBrEqTimeAppl	Parameter Parameter EB EB	TrainEBrRetAppl TrainEBrEqTimeAppl	Train		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.19	SYSTEM	Emergency Brake	Functional	Train retardation shall be limited to TrainRetLim= 2,5 m/s2	To avoid too high forces on the track	EB	TrainEBrForAppl TrainRetLim	EB Parameter	TrainRetAppl	Train		Giraudo		
EB.20	SYSTEM	Emergency Brake	Functional	The maximum jerk shall be MaxJerk= 4 m/s3		EB	MaxJerk TrainEBrForAppl	Parameter EB	TrainRetAppl	Train		Giraudo		
EB.21	SYSTEM	Emergency Brake	Functional	Maximum adhesion used by adhesion dependent force AdDepEBrForAppl shall be limited to maximum value of TSI	The maximum adhesion is speed dependent and train confguration dependent	EB	TSIAdMaxVal	Parameter	AdDepEBrForAppl	Train		Giraudo		
EB.22	SYSTEM	Emergency Brake	Definition	AdDepEBrForAppl is the force applied at the track by the adhesion dependent brake types (AdDepDynEBrForAppl+AdDepFrEBrForAppl)		EB			AdDepEBrForAppl			Giraudo		
EB.23	SYSTEM	Emergency Brake	Functional	The Train Emergency brake retardation TrainEBrRetAppl is obtained by piloting a Train emergency brake force TrainEBrForNom providing a retardation of the train TrainEBrRetNom	See EN15431-1 for brake calculation formulas	EB	TrainEBrForNom TrainEBrRetNom	EB EB	TrainEBrRetAppl	Track		Giraudo		
EB.24	SYSTEM	Emergency Brake	Definition	TrainEBrRetNom is the retardation obtained by the application of the TrainEBrForNom		EB			TrainEBrRetNom			Giraudo		
EB.25	SYSTEM	Emergency Brake	Definition	TrainEBrForNom is the nominal force applied at the track by the emergency brake		EB			TrainEBrForNom			Giraudo		

EB.26	SYSTEM	Emergency Brake	Functional	The train emergency brake force applied to the track is obtained by the contribution of adhesion dependent dynamic brake, adhesion independent dynamic brake, adhesion dependent friction brake, adhesion independent friction brake: TrainEBrForAppl(v)= AdDEpDynEBrForAppl(v)+ AdIndDynEBrForAppl(v)+ AdDEpFrEBrForAppl(v)+ AdIndFrEBrForAppl	All the type of brake are used. The dimensioning of the different type of brake maximum force is focused to reach the requested maximum retardation. It means that the fist level of "blending" between forces is done at dimensioning level, deciding the maximum force is attributed to each type of brake. The dimensionimg criteria considered are: adhesion independent brakes are dimensioned to be applied at 100% in EB. adhesion dependent brake are dimensioned to guarantee a minimum force, which added to the adhesion independent brakes can provide the maximum train EB retardation. The nominal force by adhesion dependent brake can be higher than the minimum one. In this way they are able to compensate failures (possible positive impact on guaranteed emergency brake performances) The total adhesion dependent force available can be higher than allowed by adhesion limits, but its use shall be limited by adhesion limit.	EB	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2	AdDepDynEBrForAppl AdIndDynEBrForAppl AdDepFrEBrForAppl AdIndFrEBrForAppl	Track		Giraudo			

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.27	SYSTEM	Emergency Brake	Definition	AdDepDynEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Dependent Dynamic Brake Force		EB			AdDepDynEBrForAppl			Giraudo		
EB.28	SYSTEM	Emergency Brake	Definition	AdIndDynEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Independent Dynamic Brake Force		EB			AdIndDynEBrForAppl			Giraudo		
EB.29	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Dependent Friction Brake Force		EB			AdDepFrEBrForAppl			Giraudo		
EB.30	SYSTEM	Emergency Brake	Definition	AdIndFrEBrForAppl is the portion of TrainEBrForAppl applied at the track by Adhesion Independent Friction Brake Force		EB			AdIndFrEBrForAppl			Giraudo		
EB.31	SYSTEM	Emergency Brake	Functional	Each type of emergency brake shall be able to apply to the track a maximum braking force based on dimensioning calculation. The maximum forces can be an invariant parameter or a speed or/and dissipation temperature dependent parameter		EB	AdDepDynEBrForMax AdIndDynEBrForMax AdDepFrEBrForMax AdIndFrEBrForMax	Dimensioning	AdDepDynEBrForAppl AdIndDynEBrForAppl AdDepFrEBrForAppl AdIndFrEBrForAppl	Track Track Track Track		Giraudo		
EB.32	SYSTEM	Emergency Brake	Definition	AdDepDynEBrForMax is the maximum force that can be applied at the track by adhesion dependent dynamic service brake		Dimensioning			AdDepDynEBrForMax			Giraudo		
EB.33	SYSTEM	Emergency Brake	Definition	AdDepDynEBrForMin is the minimum force applied at the track that is guaranteed by adhesion dependent dynamic brake.It depends from dimensioning and isolation active on adhesion dependent dynamic brake. (It is different from AdDepDynEBrAvFor, which is the total available force, guaranteed + not guaranteed)	This information depends from the design of the adhesion dependent dynamic brake: if a portion of the force is safe enough, the value can be > 0. If the force application is not safe enough the value is 0.	EB5.1.1.1			AdDepDynEBrForMin			Giraudo		
EB.34	SYSTEM	Emergency Brake	Definition	AdIndDynEBrForMax is the maximum force that can be applied at the track by adhesion independent dynamic service brake		Dimensioning			AdIndDynEBrForMax			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB.35	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForMax is the maximum force that can be applied at the track by adhesion dependent service friction brake		Dimensioning			AdDepFrEBrForMax			Giraudo		
EB.36	SYSTEM	Emergency Brake	Definition	AdIndFrEBrForAppl is the maximum force that can be applied at the track by Adhesion Independent Friction Brake Force		Dimensioning			AdIndFrEBrForMax			Giraudo		
EB.37	SYSTEM	Emergency Brake	Functional	When EB functions receive the electrical power supply shall perform a self test and trasmit the result to BSM1 function	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of EB and compare it with the expected one (initialization of the brake)	EB	EBrElVolt	EB11.2	SelfTestEBrRes	BSM1		Giraudo		
EB.38	SYSTEM	Emergency Brake	Definition	SelfTestEBrRes is the result of the self test performed by emrgncy brake when receive electric power supply		EB			SelfTestEBrRes			Giraudo		
				EB1 - EMERGENCY BRAKE REQUEST								Giraudo		
EB1.1	SYSTEM	Emergency Brake	Functional	EB1 shall trasmit to EB2 any of the emergency request received by actors	The emergency brake request is an on/off information	EB1	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2.1.1, BSM2.2.1	TrainEBrReq	EB2	x	Giraudo		
EB1.2	SYSTEM	Emergency Brake	Definition	TrainEBrReq is the request of an emergency brake by any actor		EB1			TrainEBrReq			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB1.3	SYSTEM	Emergency Brake	Functional	The emergency brake request has priority on any other brake application/release request	The emergency brake is the safe brake	EB1	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2.1.1, BSM2.2.1	TrainEBrReq	EB2		Giraudo		
EB1.4	SYSTEM	Emergency Brake	Functional	If EB1 TrainEBrReq information is not valid or out of order a major fault shall be set	This requirement is linked to next requirements about continuity to guarantee the automatic brake retardation by EB4-EB5 sub-function. BSM reaction to major fault in this case could not be reliable due to un-reliable EB1	EB1	EBrReqUs EBrReqATP EBrReqETCS EBrReqATO EBrReqTCMS; EBrReqPAS EBrReqBSM	Driver Brake test operator Maintenance staff ATP on board ETCS on board ATO TCMS PAS BSM2.1.1, BSM2.2.1	TrainEBrReq MajFaultEB1.1	EB2 EB9.1, BSM2.2.1	x	Giraudo		
EB1.5	SYSTEM	Emergency Brake	Definition	MajFaultEB1 is the fault indicating that it is faulty the emergency brake request information TrainEBrReq (continuity lost)		EB1			MajFaultEB1			Giraudo		
				EB2 - EMERGENCY BRAKE REQUEST TRASMISSION								Giraudo		
EB2.1	SYSTEM	Emergency Brake	Functional	EB2 shall trasmit the emergency brake request received by EB1 to other brake system functions	Continuity requirement.	EB2	TrainEBrReq	EB1	EBrReq	EB	x	Giraudo		
EB2.2	SYSTEM	Emergency Brake	Definition	EBrReq is the emergency brake request information TrainEBrReq trasmitted along the train		EB2			EBrReq			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB2.3	SYSTEM	Emergency Brake	Functional	In case TrainEBrReq is not valid a major fault shall be set and EBreq shall be set active	This requirement provide automatic brake application in case of lost continuity of the brake command BSM reaction to major fault in this case could not be reliable (as TrainEBrReq information is not valid, BSM EB trasmission signal could be not reliable as well)	EB2	TrainEBrReq	EB1	EBrReq MajFaultEB2.1	EB4, EB8 EB9.1, BSM2.2.1	x	Giraudo		
EB2.4	SYSTEM	Emergency Brake	Definition	MajFaultEB2.1 is the fault indicating that it is lost the emergency request information TrainEBrReq (continuity lost)		EB2			MajFaultEB2.1			Giraudo		
EB2.5	SYSTEM	Emergency Brake	Functional	In case EBrReq is not valid a major fault shall be set		EB2	TrainEBrReq	EB1	EBrReq MajFaultEB2	EB4, EB8 EB9.1, BSM2.2.1	x	Giraudo		
EB2.6	SYSTEM	Emergency Brake	Definition	MajFaultEB2.2 is the fault indicating that it is lost the emergency request information EBrReq (continuity lost)		EB2			MajFaultEB2.2			Giraudo		
				EB3 - TRAIN LOAD CALCULATION								Giraudo		
				EB3.1 LOAD ACQUISITION								Giraudo		
EB3.1	SYSTEM	Emergency Brake	Functional	EB3 shall define the train mass and the train equivalent mass information and send them to all emergency brake sub-functions and context systems which need it		EB3	BogLoad	Bogie	TrainMassEB TrainEqMassEB	All	X	Giraudo		
EB3.2	SYSTEM	Emergency Brake	Definition	TrainMassEB is the mass of the complete train defined by service brake		EB3.2			TrainMassEB			Giraudo		
EB3.3	SYSTEM	Emergency Brake	Definition	TrainEqMassEB is the mass of the train + the rotating mass		EB3.2			TrainEqMassEB			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB3.4	SYSTEM	Emergency Brake	Functional	EB3.1 shall calculate the load insisting on the bogies by memorizing the bogie load information once that door are closed and locked (passenger in/out finished) and trasmit it to EB3.2	The best moment to measure the bogie load necessary to define the brake force is when the train is in stanstill ready to leave and no more load variation on it	EB3.1	BogLoad	Bogie	BogLoadMemEB	EB3.2	X	Giraudo		
EB3.5	SYSTEM	Emergency Brake	Definition	BogLoadMemEB is the BogLoad information recorded by service brake in the moment that the train leave the station		EB3.1			BogLoadMemEB			Giraudo		
EB3.6	SYSTEM	Emergency Brake	Functional	The bogie technical system shall trasmit continuously the bogie load information to EB3.1 Load acquisition sub-function	The continuous transmission permit to have a permanent diagnostic	Bogie	CarLoad	Carbody	BogLoad	EB3.1	x	Giraudo		
EB3.7	SYSTEM	Emergency Brake	Functional	The door technical system shall trasmit continuously the Door Closed and Locked information to EB3.1 Load acquisition sub-function	The door closed and locked data is informing the brake system of the end of the passenger transfer in the station, so that the train load cannot change anymore	Door	DoorStatus	Door	DoorClLock	EB3.1	x	Giraudo		
EB3.8	SYSTEM	Emergency Brake	Functional	EB3.1 shall measure the BogLoad information at any time	Note: the detection of the BogLoad information can be done by any detection device technically speaking (pneumatic or electric). The detection device is considered part of brake sub-system EB3	EB3.1	BogLoad	Bogie	BogLoadMeas	EB3.2	X	Giraudo		
EB3.9	SYSTEM	Emergency Brake	Definition	BogLoadMeasEB is the measured value by service brake of the BogLoad information		EB3.1			BogLoadMeasEB			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB3.10	SYSTEM	Emergency Brake	Functional	EB3.1 shall memorize the BogLoadMeas information when (Door Closed and Locked data is active OR the TrainSpeed>3 km/h)	The door closed and locked information is in OR to the train movement to allow to memorize the bogie load also in case of Door closed and Locked information not valid or (exceptional) train movement with door opened	EB3.1	BogLoadMeasEB DoorClLock TrainSpeed	EB3.1 Door Odometry	BogLoadMemEB	EB3.2	X	Giraudo		
EB3.11	SYSTEM	Emergency Brake	Functional	When the BogLoadMeasEB information is not valid or is out of tolerance EB3.1 shall set a major fault and fix the BogLoadMemEB information to the value of BogLoadDefEB when the DoorClLock data is no more active or as soon as the train move (speed > 3 km/h).	This requirement permit to have always a mass of the train, even if a default one. Note: The default mass definition shall be linked to guaranteed perfromance calculation and adhesion constraints	EB3.1	BogLoadMeasEB BogLoadDefEB DoorClLock TrainSpeed	EB3.1 Parameter Door Odometry	BogLoadRMemEB MajFaultEB31	EB3.2 EB9.1, BSM2.2.1	X	Giraudo		
EB3.12	SYSTEM	Emergency Brake	Definition	BogLoadDefEB is the default load insisting on the bogie to be considered in case of not available BogLoadMeasEB information		Dimensioning			BogLoadDefEB			Giraudo		
EB3.13	SYSTEM	Emergency Brake	Definition	MajFaultEB31 is the fault information indicating that it is lost the BogLoad information (mass information lost)		EB3.1			MajFaultEB31			Giraudo		
EB3.14	SYSTEM	Emergency Brake	Functional	The BogLoad information shall have an accuracy of +x/- y% respect the real load	Mass of the train directly impact the train stopping distances and the used adhesion.	Bogie	CarLoad	Carbody	BogLoad	EB3.1		Giraudo		
EB3.15	SYSTEM	Emergency Brake	Functional	The BogLoadMeasEB information shall have an accuracy of +x/- y% respect the BogLoad information	Mass of the train directly impact the train stopping distances and the used adhesion.	EB3.1	BogLoad	Bogie	BogieLoadMeasEB	EB3.2	X	Giraudo		
				EB3.2 - TRAIN LOAD CALCULATION								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB3.16	SYSTEM	Emergency Brake	Functional	EB3.2 calculate the Train Mass and Train equivalent mass by BogLoadMeasEB information and trasmit them to other brake system sub-functions and systems of brake context which are interested	The train mass and equivalent mass are the information transforming the reatardation request into a brake force by EB4	EB3.2	BogLoadMemEB	EB3.1	TrainMassEB TrainEqMassEB	All	X	Giraudo		
EB3.17	SYSTEM	Emergency Brake	Functional	The train mass shall be derived from Bogie Load adding the mass of the bogies		EB3.2	BogLoadMemEB BogieMass	EB3.1 Parameter	TrainMassEB	All	X	Giraudo		
EB3.18	SYSTEM	Emergency Brake	Functional	The train equivalent mass shall be derived from the train mass adding the translating mass equivalent to rotating mass of the train		EB3.2	BogLoadMemEB RotMass BogieMass	EB3.1 Parameter Parameter	TrainEqMassEB	All	X	Giraudo		
				EB4 - TRAIN EMERGENCY BRAKING FORCE CALCULATION								Giraudo		
EB4.1	SYSTEM	Emergency Brake	Functional	EB4 shall calculate the Train nominal emergency brake force		EB4	EBrReq TrainMassEB TrainSpeed TrainEBrRetMax a,b,c	EB2 EB3.2 Odometry Parameter Parameters	TrainEBrForNom	EB5.2	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB4.2	SYSTEM	Emergency Brake	Functional	The Train emergency brake nominal force shall be calculated based on the maximum emergency brake retardation, the train mass, the train running resistance, the train speed as follow: If EBrReq is active TrainEBrForNom=TrainMassEB*TrainEBrRetMax-TrainRunResEB If EBrReq is not active TrainEBrForNom=0	See EN14531-1 for brake force calculation. The force is calculated to obtain the TrainEBrRetMax on a flat track. Slope is not considered because already considered by ETCS/ATP. In case of isolation present the force cannot be achieved, but to ask for the maximum force at any time is the only way to guarantee to have always the maximum force available by any type of brake. The blending rules are in charge of defining the amount of each of them (isolation can have different impact on emergency performances depending from the mass)	EB4	EBrReq TrainMassEB TrainEBrRetMax TrainSpeed TrainRunResEB	EB2 EB3.2 Parameter Odometry EB4	TrainEBrForNom	EB5.2	X	Giraudo		
EB4.3	SYSTEM	Emergency Brake	Functional	TrainEBrForNom ramping shall be limited in order to have a jerk of TrainRet limited to MaxJerk=4 m/s3.		EB4	MaxJerk	Parameter	TrainEBrForNom	EB2	X	Giraudo		
EB4.4	SYSTEM	Emergency Brake	Definition	TrainRunResEB is the force that emergency brake consider applied by track and aerodynamic forces to the train		Dimensioning			TrainRunResEB			Giraudo		
EB4.5	SYSTEM	Emergency Brake	Functional	If EBrReq information is not valid EB4 shall set the force request to default request EBrReqDef =active and set a major fault	Loss of continuity generate emergency brake application request	EB4	EBrReq TrainMass EBrReqDef TrainSpeed TrainRunResEB	EB2 EB3.2 Parameter Odometry EB4	MajFaultEB4.1 TrainEBrForNom	EB9.4, BSM2.2.1 EB5.2	X	Giraudo		
EB4.6	SYSTEM	Emergency Brake	Definition	EBrReqDef is the default status of EBrEq to be considered by SB4 in case of EBrREq not valid		Dimensioning			EBrReqDef			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB4.7	SYSTEM	Emergency Brake	Definition	MajFaultEB4.1 is the fault information about the not valid information of EBrReq		SB4			MajFaultEB4.1			Giraudo		
EB4.8	SYSTEM	Emergency Brake	Functional	In case of lost train integrity, EB4 shall set the force request to TrainEBrForDef and set a major fault	Automaticity requirement The loss of integrity doesn't requires to fulfill the performances (see TSI requirement 4.2.4.2.1 (11)	EB4	TrainIntegr TrainMass TrainEBrForDef EBrReqDef TrainSpeed TrainRunResEB	Train EB3.2 Parameter Parameter Odometry EB4	MajFaultEB4.2 TrainEBrForNom	EB9.4, BSM2.2.1 EB5.2	X	Giraudo		
EB4.9	SYSTEM	Emergency Brake	Definition	TrainEBrForDef is the default force value at which TrainEBrForNom shall be set in case of lost train integrity		Dimensioning			TrainEBrForDef			Giraudo		
EB4.10	SYSTEM	Emergency Brake	Definition	MajFaultEB4.2 is the fault information about train integrity lost		EB4			MajFaultEB4.2			Giraudo		
EB4.11	SYSTEM	Emergency Brake	Functional	If the TrainMassEB information is not valid the Train Mass shall be set to TrainMassDefEB value and a major fault shall be set		EB4	TrainMassEB TrainMassDefEB	EB3.2 Parameter	MajFaultEB4.3 TrainEBrForNom	EB9.4, BSM2.1.1 EB5.2	X	Giraudo		
EB4.12	SYSTEM	Emergency Brake	Definition	TrainMassDefSB is the default train mass value consistent with the BogLoadDefSB value		Dimensioning			TrainMassDefEB			Giraudo		
EB4.13	SYSTEM	Emergency Brake	Definition	MajFaultSB4.3 is is the fault information indicating that it is lost the TrainMass information		EB4			MajFaultEB4.3			Giraudo		
EB4.14	SYSTEM	Emergency Brake	Functional	If the TrainSpeed information is not valid the Trainspeed shall be set to TrainSpeedDefSB value and a major fault shall be set		EB4	TrainSpeed TrainSpeedDefEB	Odometry Parameter	MajFaultEB4.4 TrainEBrForNom	EB9.4, BSM2.1.1 EB5.2	X	Giraudo		
EB4.15	SYSTEM	Emergency Brake	Definition	TrainSpeedDefSB is the default speed information to be considered by SB when the TrainSpeed is not available		Dimensioning			TrainSpeedDefEB			Giraudo		
EB4.16	SYSTEM	Emergency Brake	Definition	MajFaultEB4.4 is the fault information indicating that it is lost the TrainSpeed information		EB4			MajFaultEB4.4			Giraudo		
				EB5 - EMERGENCY BRAKE BLENDING								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.1	SYSTEM	Emergency Brake	Functional	The train runnig resistance force shall be calculated considering running resistance formula proper of the train: a*TrainMassEB+b*v+c*v^2	a,b,c parameter of the train	EB4	a,b,c TrainMassEB	Parameters EB3.2	TrainRunResEB	EB4	X	Giraudo		
EB5.2	SYSTEM	Emergency Brake	Functional	EB5 shall apply a emergency brake force at the train of the amount of the train emergency brake force information received by EB4 fulfilling the constraints in terms of: - force tolerance - maximum force applicable to different type of brake (dimensioning constraints) - maximum adhesion	Note: EB5 is in charge of all type of brakes. Next requirements regards the implementation of EB5 function by adhesion dependent friction brake, and in particular the requirements in charge of EDV. The requirements about other type of brakes or function not in charge of EDV are mentioned only if relevant. Note: considering what written Rtionale of req.	EB5	TrainEBrForNom TrainSpeed	EB4 Odometry	TrainEBrForAppl	Train	X	Giraudo		
EB5.3	SYSTEM	Emergency Brake	Functional	EB5 shall not generate leakages which can decrease of more than MaxDeltaPressEB/min the EBrAirSupplPress (without air supply available)	To guarantee inexhaustibility for at least 2 hours	EB5	MaxDeltaPressEB EBrAirSupplPress	Parameter EB6.1	EB5AirSupplLeak	EB6.1	X	Giraudo		
EB5.4	SYSTEM	Emergency Brake	Definition	AdDepDynEBr+J518:V524AirSupplPress is the air supply pressure of the Adhesion dependent dynamic emergency brake		EB5			AdDepDynEBrAirSupplPress			Giraudo		
EB5.5	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAirSupplPress is the air supply pressure of the Adhesion independent dynamic emergency brake		EB5			AdIndDynEBrAirSupplPress			Giraudo		
EB5.6	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirSupplPress is the air supply pressure of the Adhesion dependent friction emergency brake		EB5			AdDepFrEBrAirSupplPress			Giraudo		
EB5.7	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAirSupplPress is the air supply pressure of the Adhesion independent friction emergency brake		EB5			AdIndFrEBrAirSupplPress			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.8	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAirCons is the air supply consumption of the Adhesion dependent dynamic emergency brake		EB5			AdDepDynEBrAirCons			Giraudo		
EB5.9	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAirCons is the air supply consumption of the Adhesion independent dynamic emergency brake		EB5			AdIndDynEBrAirCons			Giraudo		
EB5.10	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirCons is the air supply consumption of the Adhesion dependent friction emergency brake		EB5			AdDepFrEBrAirCons			Giraudo		
EB5.11	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAirCons is the air supply consumption of the Adhesion independent friction emergency brake		EB5			AdIndFrEBrAirCons			Giraudo		
EB5.12	SYSTEM	Emergency Brake	Definition	EB5AirSupplLeak are the leakages of the pneumatic system distributing pneumatic energy necessary to apply the emergency brake force		EB5			EB5AirSupplLeak			Giraudo		
				EB5.1.2.1 DETECTION OF THE ADHESION DEPENDENT EMERGENCY BRAKE FORCE AVAILABILITY								Giraudo		

EB5.1 .1	SYST EM	Emerge ncy Brake	Functio nal	EB5.1. 2.1 shall define the adhesion dependent friction brake force availability by elaborating the isolation status infomation, the dimensioning constraints (ie max force), and the train speed received by Odometry AdDepFrEBrAvFor(v)= min(AdDepFrEBrForMax(v); AdDepFrEBrForMax(v)*(AdDepFrEBrIsolStatus))	The status information is obtained by EB10.3 function (permanent isolation) only. Remote release of emergency brake is allowed only for single fault and not applicable if emergency brake is applied (see EN10.3 requirements) . The dimensioning constraint is a parameter (see req. 1.0.1.4) , speed dependent . The temperature of the dissipation unit is not considered because the emergency brake dimensioning shall cover the worst operative situation (see also TSI §4.2.4.5.4 for reference cases). If there is the risk that unpredictable situation can occurr leading to thermal load in emergency brake higher than considered in emergency dimensioning, the service brake (optional) req. 1.1.5.1 can protect the train from exeeding the thermal dimensioning condition for emergency brake. The adhesion constraints are not considered at this stage because they shall be considered once that blending with adhesion dependent dynamic brake is defined	EB5.1.2.1	AdDepFrEBrIsolStatus AdDepFrEBrForMax(v) TrainSpeed AdDepFrEBrDissTempMeas	EB10.3 Parameter Odometry EB12.2.2	AdDepFrEBrAvFor	All	X	Gira udo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.1.2	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAvFor is the adhesion dependent friction emergency brake force that is available on the train for application to the track.		SB5.1.2.1			AdDepFrEBrAvFor			Giraudo		
EB5.1.3	SYSTEM	Emergency Brake	Functional	If the AdDepFrEBrAirSupplPress < AdDepFrEBrAirSupplPressMin the Availability shall be set to 0	Inexhaustibility requirement	EB5.1.2.1	AdDepFrEBrAirSupplPress AdDepFrEBrAirSupplPressMin	EB5.5.2.1.1	AdDepFrEBrAvFor	EB5.2.2.1	X	Giraudo		
				SB5.2 - ADHESION DEPENDENT FRICTION EMERGENCY BRAKE FORCE CALCULATION								Giraudo		

EB5.2.1	SYSTEM	Emergency Brake	Functional	EB5.2.shall define the nominal forces of different type of brakes as result of emergency blending logic giving priority to adhesion independent brakes first and then to adhesion dependent brakes. The adhesion dependent friction brake shall be the last one to be considered, providing the missing force to reach the maximum possible emergency brake force	The proposed blending logic maximize the use of adhesion independent brake to reduce the risk of longer stopping distances due to wheel sliding and the use of wearless brake types (Dynamic brakes) to reduce the LCC. Adhesion independent brake are dimensioned to be used at 100% of their capacity to reach the expected train emergency brake force. Blending is usefull between the two adhesion dependent type of brake to avoid exceeding of adhesion and failure compensation. Note 1:As consequence of blending logic, EB5.2 will provide for all type of brakes the expected force to be applied taking in account already of the limitations by availability and adhesion (that's why the output has the extension Ltd). The consistency between the expected force and the one obtained by limitation is given by dimensioning and dependance of expected performances from active braking power (braking power take in account the availability) Note 3: Blending logics	EB5.2	TrainEBrForNom AdDepDynEBrAvFor AdDepFrEBrAvFor AdIndDynEBrAvFor AdIndFrEBrAvFor	EB4 EB5.1.1.1 EB5.1.2.1 EB5.1.1.2 EB5.1.2.2	AdDepDynEBrForNomLtd AdIndDynEBrForNomLtd AdDepFrEBrForNomLtd AdIndFrEBrForNomLtd	EB5.3.1.1. EB5.3.1.2 EB5.3.2.1 EB5.3.2.2	X		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
					can be managed by a central function controlling all type of brakes or functions controlling each type of brake shall implement the same blending logic to have coherent force distribution. Here below the second option is considered: ED brake, Friction brake, EC Brake have independent coherent blending logic installed in their controller and exchange information to guarantee the consistency.									
EB5.2.2	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAvFor is the adhesion dependent dynamic brake force available on the train, which can be applied to the track		EB5.1.1.1			AdDepDynEBrAvFor			Giraudo		
EB5.2.3	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAvFor is the adhesion independent dynamic brake force available on the train, which can be applied to the track		EB5.1.1.2			AdIndDynEBrAvFor			Giraudo		
EB5.2.4	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAvFor is the adhesion independent friction brake force available on the train, which can be applied to the track		EB5.1.2.2			AdFrDynEBrAvFor			Giraudo		
EB5.2.5	SYSTEM	Emergency Brake	Definition	AdDepDynEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent dynamic brake to apply the TrainEBrForNom .		EB5.2.1.1			AdDepDynEBrForNomLtd			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.2.6	SYSTEM	Emergency Brake	Definition	AdIndDynEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent dynamic brake to apply the TrainEBrForNom .		EB5.2.1.2			AdIndDynEBrForNomLtd			Giraudo		
EB5.2.7	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion dependent friction brake to apply the TrainEBrForNom .		EB5.2.2.1			AdDepFrEBrForNomLtd			Giraudo		
EB5.2.8	SYSTEM	Emergency Brake	Definition	AdIndFrEBrForNomLtd is the nominal force that shall be requested to be applied by adhesion independent friction brake to apply the TrainEBrForNom .		EB5.2.2.2			AdIndFrEBrForNomLtd			Giraudo		
EB5.2.9	SYSTEM	Emergency Brake	Functional	EB5.2.1.2 shall calculate the adhesion independent dynamic brake nominal force as the minimum between the train emergency brake force requested by EB4 and the constraints of force availability of adhesion independent dynamic brake AdIndDynEBrForNomLtd= min((TrainEBrForNom; AdIndDynEBrAvFor(v))	Derived from blending logic and availability limitation.	EB5.2.1.2	TrainEBrForNom AdIndDynEBrAvFor	EB4 EB5.1.1.2	AdIndDynEBrForNomLtd	EB5.2.2.1	X	Giraudo		
EB5.2.10	SYSTEM	Emergency Brake	Functional	EB5.2.2.2 shall calculate the adhesion Independent friction emergency brake nominal force by the following formula: AdIndFrEBrForNomLtd= min(TrainEBrForNom-AdIndDynEBrForNomLtd; AdIndFrEBrAvFor)	Derived from blending logic and availability limitation	EB5.2.2.2	TrainEBrForNom AdIndDynEBrForLtd AdIndFrEBrAvFor	EB4 EB5.1.1.2 EB5.1.2.2	AdIndFrEBrForNomLtd	EB5.2.2.1	X	Giraudo		
EB5.2.11	SYSTEM	Emergency Brake	Functional	EB5.2.1.1 shall calculate the adhesion dependent dynamic brake nominal force taking in account the constraints of force availability and adhesion limits. AdDepDynEBrForNomLtd= min(AdMaxVal*(TrainMassEB)*9,81; TrainEBrForNom-AdIndDynEBrForLtd-AdIndFrEBrForLtd; AdDepDynEBrAvFor(v))	Derived from above blending logic, availability and adhesion limitation Note: the AdMaxVal is a parameter speed and train composition dependent, it can be the TSI value or contractually or project defined.	EB5.2.1.1	TrainEBrForNom AdDepDynEBrAvFor AdIndDynEBrForLtd AdIndFrEBrForLtd AdMaxVal TrainMassEB	EB4 EB5.1.1.1 EB5.1.1.2 EB5.1.2.2 parameter EB3	AdDepDynEBrForNomLtd	EB5.2.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.2.12	SYSTEM	Emergency Brake	Functional	If AdDepDynEBrAchFor is not valid AdDepDynEBrForNomLtd=min(AdMaxVal*(TrainMassEB)*9,81; TrainEBrForNom-AdIndDynEBrForLtd-AdIndFrEBrForLtd; AdDepDynEBrForMin)	Without AdDepDynEBrAchFor information compensation of failure by friction brake cannot be performed, so the guaranteed value of adhesion dependent dynamic brake force is considered	EB5.3.1.1	AdDepDynEBrAchFor or AdDepDynEBrForMin	EB5.4 EB5.1.1.1	AdDepDynEBrForNomLtd	EB5.5.1.1.1	X	Giraudo		
EB5.2.13	SYSTEM	Emergency Brake	Functional	EB5.2.2.1 shall calculate the adhesion dependent friction emergency brake nominal force by the following formula: AdDepFrEBrForNomLtd=min((TrainEBrForNom-(AdDepDynSBrForNomLtd+AdIndDynSBrForNomLtd+AdIndFrEBrForNomLtd)); AdDepFrEBrAvFor; (AdMaxVal*(TrainMassEB)*9,81-AdDepDynEBrForNomLtd))	Derived from blending logic.	EB5.2.2.1	TrainEBrForNom AdDepDynEBrForNomLtd AdIndDynEBrForNomLtd AdIndFrEBrForLtd AdMaxVal TrainMassEB AdDepFrEBrAvFor	EB4 EB5.2.1.1 EB5.2.1.2 EB5.2.2.2 Parameter EB3.2 EB5.1.2.1	AdDepFrEBrForNomLtd	EB5.3.2.1	X	Giraudo		
				SB5.3.2.1 ADHESION DEPENDENT FRICTION EMERGENCY BRAKE REQUESTED FORCE								Giraudo		
EB5.3.1	SYSTEM	Emergency Brake	Functional	EB5.3.2.1 shall generate an adhesion dependent friction emergency brake force request to EB5.5.2.1 , taking in account the nominal force by EB5.2.2.1 and real time blending with achieved force by adhesion cdependent dynamic emergency brake (received by EB5.4)	This is the step of the blending logics where the adhesion dependent friction emergency brake force request is defined.	EB5.3.2.1	AdDepFrEBrForNomLtd AdDepDynEBrForNomLtd AdDepDynEBrAchFor or AdMaxVal (v)	EB5.2.2.1 EB5.2.2.1 EB5.4 parameter	AdDepFrEBrForReqLtd	EB5.5.2.1.1	X	Giraudo		
EB5.3.2	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForReqLtd is the force to be requested to be applied by the adhesion dependent friction emergency brake force generation function EB5.5.2.1		EB5.3.2.1			AdDepFrEBrForReqLtd			Giraudo		
EB5.3.3	SYSTEM	Emergency Brake	Functional	The adhesione dependent friction emergency brake requested force shall be: AdDepFrEBrForReqLtd=AdDepFrEBrForNom+(AdDepDynEBrForNomLtd-AdDepDynEBrAchFor)	See above req. 1.2.5.3	EB5.3.2.1	AdDepFrEBrForNomLtd AdDepDynEBrForNomLtd AdDepDynEBrAchFor	EB5.2.2.1 EB5.2.1.1 EB5.4	AdDepFrEBrForReqLtd	EB5.3.2.1	X	Giraudo		

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EB5.3.4	SYSTEM	Emergency Brake	Functional	If the total EB requested force is lower then the expected one (with a certain tolerance) a major fault shall be activated AdDepDynEBrAchFor+AdIndDynEBrForReqLtd+AdDepFrEBrForReqLtd+AdIndFrEBrForReqLtd < TrainEBrRetMax*TrainBrPower-EBrForTol	This requirement is the final check that the sum of the requested forces to different type of brakes achieve the target given by braking power . Note: If the forces are not reached, after the train stop the braking power should be updated (see EB7 requirements). It can happen if double failure occurr during braking, because the braking power takes already in account the single failure	EB5.3.2.1	AdDepFrEBrForReqLtd AdDepDynEBrAchFor AdIndDynEBrForLtd AdIndFrEBrForLtd TrainEBrForNom EBrForTol TrainBrPower	EB5.3.2.1 EB5.4 EB5.3.1.2 EB5.3.2.2 EB4 Parameter EB7	MajFaultEB5321.1	EB9.4, BSM2.2.1	X	Giraudo		
EB5.3.5	SYSTEM	Emergency Brake	Definition	AdIndDynEBrForReqLtd is the force to be requested to the adhesion independent dynamic emergency brake force generation function EB5.5.1.2		EB5.3.1.2			AdIndDynEBrForReqLtd			Giraudo		
EB5.3.6	SYSTEM	Emergency Brake	Definition	AdIndFrEBrForReqLtd is the force to be requested to the adhesion independent friction emergency brake force generation function EB5.5.2.2.2		EB5.3.2.2			AdIndFrEBrForReqLtd			Giraudo		
EB5.3.7	SYSTEM	Emergency Brake	Definition	EBrForTol is the permitted tolerance of emergency brake force requested and the nominal one.		Dimensioning			EBrForTol			Giraudo		
EB5.3.8	SYSTEM	Emergency Brake	Definition	MajFaultEB5321.1 is the fault information of emergency brake requested force lower than expected		EB5.3.2.1			MajFaultEB5321.1			Giraudo		
EB5.3.9	SYSTEM	Emergency Brake	Functional	If AdDepDynEBrAchFor is not valid the AdDepFrEBrForReqLtd=AdDepFrEBrForNomLtd	Without AdDepDynEBrAchFor compensation of adhesion dependent dynamic brake failures cannot be performed.	EB5.3.1.1	AdDepDynEBrAchFor	EB5.4	AdDepFrEBrForReqLtd	EB5.5.1.1.1	X	Giraudo		
EB5.3.10	SYSTEM	Emergency Brake	Functional	If AdDepDynEBrAchFor is not valid a major fault shall be set		EB5.3.1.1	AdDepDynEBrAchFor	EB5.4	MajFaultEB5321.2	SB9.4	X	Giraudo		

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EB5.3.11	SYSTEM	Emergency Brake	Definition	MajFaultEB5321.2 is the fault information of AdDepDynEBrAchFor information not valid		EB5.3.1.1			MajFaultEB5321.2			Giraudo		
-			-	EB5.4 ACHIEVED ADHESION DEPENDENT DYNAMIC EMERGENCY BRAKE FORCE	-	-	-	-	-	-	-	Giraudo	-	-
EB5.4.1	SYSTEM	Emergency Brake	Functional	EB5.4 shall measure the really applied braking force by adhesion dependent dynamic brake and trasmit it to EB5.3	This requirement is a consequence of the blending logic defined in EB5	EB5.4	WheelTorq	EB5.5.1.1.2	AdDepDynEBrAchFor	EB5.3.1.2	x	Giraudo		
EB5.4.2	SYSTEM	Emergency Brake	Functional	The adhesion dependent dynamic brake shall provide the information of the really applied traction or braking force at the Trackset and trasmit it to EB5.3.2.1	TORQ device mentioned in D5.1	EB5.4	WheelTorq	EB5.5.1.1.2	AdDepDynEBrAchFor	EB5.3.2.1 EB5.3.1.2	x	Giraudo		
EB5.4.3	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAchFor is the value of the force applied at the track by the adhesion dependent dynamic brake		EB5.4			AdDepDynEBrAchFor			Giraudo		
				EB5.5.2 .1 ADHESION DEPENDENT FRICTION EMERGENCY BRAKE FORCE GENERATION								Giraudo		
EB5.5.1	SYSTEM	Emergency Brake	Functional	EB5.5.2.1.1 shall generate an adhesion dependent friction brake force pilot command piloting a force application at the Track by EB5.5.2.1.2 equal to the force requested by EB5.3.2.1 (rotating mass to be considered)	This function shall take in care to consider in the pilot also the rotating mass braking force necessary to apply at the track the requested force	EB5.5.2.1.1	AdDepFrEBrForReqLtd	EB5.3.2.1	AdDEpFrEBrPilCom	LAM1.2.1	X	Giraudo		
EB5.5.2	SYSTEM	Emergency Brake	Definition	AdDEpFrEBrPilCom is the pilot command applying an adhesion dependent friction brake force to the track equal to the requested force AdDepFrEBrForReqLtd		EB5.5.2.1.1			AdDEpFrEBrPilCom			Giraudo		
EB5.5.3	SYSTEM	Emergency Brake	Functional	EB5.5.2.1 .1 shall monitor the real adhesion dependent friction brake force applied	Monitoring is fundamental for control/diagnosys of the whole force generation process and precision of the force generated (closed loop control).	EB5.5.2.1.1.	AdDEpFrEBrForAppl	EB5.5.2.1.2	AdDEpFrEBrForAppIMeas	EB5.5.2.1.1	X	Giraudo		
EB5.5.4	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForApplMeas is the information of the adhesion dependent friction emergency brake force applied at the track		EB5.5.2.1.1.			AdDepFrEBrForAppIMeas			Giraudo		

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EB5.5.5	SYSTEM	Emergency Brake	Functional	EB5.5.2.1.2 shall apply an adhesion dependent friction brake force to the Trackset, proportional to the pilot command trasmitted by EB5.5.2.1.1 and eventually reduced by LAM1.2.1		EB5.5.2.1.2	AdDEpFrEBrPilComLAM	LAM1.2.1	AdDepFrEBrForAppl	Track	X	Giraudo		
EB5.5.6	SYSTEM	Emergency Brake	Definition	AdDEpFrEBrPilComLAM is the pilot command,conditioned by the LAM1.2.1 function, provided to the adhesion dependent friction brake actuation function EB5.5.2.1.2		LAM1.2.1			AdDEpFrEBrPilComLAM			Giraudo		
EB5.5.7	SYSTEM	Emergency Brake	Functional	EB5.5.2.1.1 shall monitor the adhesion dependent friction EB air supply pressure and trasmit the pressure value to diagnostic system	The EB supply pressure shall be monitore by the force generation system, because it is the responsible of the effect of the pneumatic energy (generation of the force)	EB5.5.2.1.1	AdDEpFrEBrAirSupplPress	EB6.1	AdDepFrEBrAirSupplMeas	EB9.4	X	Giraudo		
EB5.5.8	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirSupplMeas is the information of the pressure of the air supply to the adhesion independent friction Emergency brake		EB5.5.2.1.1			AdDepFrEBrAirSupplMeas			Giraudo		
EB5.5.9	SYSTEM	Emergency Brake	Functional	If the AdDepFrEBrAirSupplPress is below the dimensioning limits AdDepFrEBrAirSupplPressMin, EB5.5.2.1.1 shall set major fault	Inexhaustibility requirement for the friction emergency brake. BSM shall manage it at train level.	EB5.5.2.1.1	AdDepFrEBrAirSupplMeas AdDepFrEBrAirSupplPressMin	EB5.5.2.1.1 parameter	MajFaultEB55211.1	EB9.4, BSM2.2.1 EB5.5.2.1.2	X	Giraudo		
EB5.5.10	SYSTEM	Emergency Brake	Definition	MajFaultEB55211.1 is the fault information of adhesion dependent friction Emergency brake supply pressure below the minimum limit AdDepFrEBrAirSupplPressMin		EB5.5.2.1.1			MajFaultEB55211.1			Giraudo		
EB5.5.11	SYSTEM	Emergency Brake	Functional	EB5.5.2.1.1 shall monitor the Electric Voltage to adhesion dependent friction emergency brake		EB5.5.2.1.1.	AdDepFrEBrElVolt	EB6.2	AdDepFrEBrElVoltMeas	EB9.4	X	Giraudo		
EB5.5.12	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElVoltMeas is the information of the voltage of the electric supply to the adhesion independent friction emergency brake		EB5.5.2.1.1			AdDepFrEBrAirSupplMeas			Giraudo		

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EB5.5.13	SYSTEM	Emergency Brake	Functional	If the electric voltage to EB5 is below the AdDepFrEBrMinElVolt or is lost, EB5.5.2.1.1 shall generate a major fault and apply automatically the maximum adhesion dependent friction emergency brake force by pilot command	The safe state for EB5 is brake application. The maximum emergency brake force correspond to the force with maximum load. In such a case the adhesion can be higher than allowed . In any case major fault is generated and BSM2.2.1 is able to release the braking if considered safe	EB5.5.2.1.1	AdDepFrEBrElVoltMeas AdDepFrEBrMinElVolt AdDepFrEBrPilCommEnOff AdDepFrEBrForMax	EB5.5.2.1.1 parameter parameter parameter	MajFaultEB55211.2 AdDepFrEBPilComm	EB9.4, BSM2.2.1 EB5.5.2.1.2	X	Giraudo		
EB5.5.14	SYSTEM	Emergency Brake	Definition	AdDepFrEBrPilCommEnOff is the Default pilot command to be applied in case of electric energy off or below the minimum value		EB5.5.2.1.1.			AdDepFrEBrPilCommEnOff			Giraudo		
EB5.5.15	SYSTEM	Emergency Brake	Definition	MajFaultEB55211.2 is the fault information that the electric voltage is below the minimum AdDepFrEBrElVoltMin or is lost		EB5.5.2.1.1.			MajFaultEB55211.2			Giraudo		
EB5.5.16	SYSTEM	Emergency Brake	Functional	If the adhesion dependent friction brake force measured is out of regulation tolerance EB5.5.2.1.1 shall generate a minor fault	The regulation tolerance is the one taking care of the accuracy of the brake force. The consistency of the force application with the dimensioning constraints is guaranteed by the monitoring of the whole braking force	EB5.5.2.1.1	AdDEpFrEBrForAppl Meas AdDepFrEBrForReqLtd AdDepFrEBrForTol	EB5.5.2.1.2 EB5.3.2.1 Parameter	MinFaultEB55211.1	EB9.4	X	Giraudo		
EB5.5.17	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForTol is the the upper and lower regulation tolerance of the adhesion dependent friction emergency brake force		Dimensioning			AdDepFrEBrForTol			Giraudo		
EB5.5.18	SYSTEM	Emergency Brake	Definition	MinFaultEB55211.1 is the fault information of adhesion dependent friction emergency brake force out of regulation tolerance		EB5.5.2.1.1			MinFaultEB55211.1			Giraudo		
EB5.5.19	SYSTEM	Emergency Brake	Functional	If the adhesion dependent friction brake force measured is higher then the maximum allowed force for EB5.5.2.1.2, a major fault shall be set by EB5.5.2.1.1	The force generation system can be damaged	EB5.5.2.1.1	AdDEpFrEBrForAppl Meas AdDepFrEBrForMax	EB5.5.2.1.2 Parameter	MajFaultEB55211.3	EB9.4, BSM2.2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB5.5.20	SYSTEM	Emergency Brake	Definition	MajFaultEB55211.3 is the fault information of adhesion dependent friction emergency brake force above the maximum value AdDepFrEBrForMax		EB5.5.2.1.1			MajFaultEB55211.3			Giraudo		
EB5.5.21	SYSTEM	Emergency Brake	Functional	If the AdDEpFrEBrForApplMeas<AdDEpFrEBrForReqLtd of a value higher then AdDepFrEBrForMaxTol a major fault shall be set	consistency check between the requested and the applied force	EB5.5.2.1.1	AdDepFrEBrForMaxTol AdDEpFrEBrForReqLtd AdDEpFrEBrForAplMeas	parameter EB5.3.2.1 EB5.5.2.1.1	MajFaultEB55211.4	EB9.4	X	Giraudo		
EB5.5.22	SYSTEM	Emergency Brake	Definition	MajFaultEB55211.4 is the fault information of adhesion dependent friction emergency brake force applied is lower than requested of a value higher than AdDepFrEBrForMaxTol		EB5.5.2.1.1			MajFaultEB55211.4			Giraudo		
EB5.5.23	SYSTEM	Emergency Brake	Definition	AdDepFrEBrForMaxTol is the maximum lower tolerance acceptable for Adhesion dependent friction emergency brake force		Dimensioning			AdDepFrEBrForMaxTol			Giraudo		
EB5.5.24	SYSTEM	Emergency Brake	Functional	If speed is > 3 km/h and the adhesion dependent friction brake force measured is >0 and the there is not a Adhesion dependent friction emergency brake request (taking in account a delay related to releasing time), a major fault shall be set by EB5.5.2.1.1	Dragging brake condition	EB5.5.2.1.1	TrainSpeed AdDEpFrEBrForAplMeas AdDepFrEBrForReqLtd TimeFilter	Odometry EB5.5.2.1.2 EB5.3.2.1 Parameter	MajFaultEB55211.2	EB9.4, BSM2.2.1	X	Giraudo		
EB5.5.25	SYSTEM	Emergency Brake	Definition	MajFaultEB55211.5 is the fault information of adhesion dependent friction emergency brake force applied when not requested (dragging brake)		EB5.5.2.1.1			MajFaultEB55211.5			Giraudo		
				EB6 - EMERGENCY BRAKE ENERGY STORING AND DISTRIBUTION								Giraudo		
				EB6.1 PNEUMATIC ENERGY STORING AND DISTRIBUTION								Giraudo		
EB6.1	SYSTEM	Emergency Brake	Functional	EB6.1 shall provide to EB the pneumatic energy to permit the correct regulation of emergency brake force by type of brakes using pneumatic energy		EB6.1	AirSupplPress BrAirSupplDel	EB11.3 EB11.3	EBrAirSupplPress EBrAirSupplDel	EB	x	Giraudo		
EB6.2	SYSTEM	Emergency Brake	Definition	EBrAirSupplPress is the pressure of the air supply providing pneumatic energy to emergency brake		EB6.1			EBrAirSupplPress			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.3	SYSTEM	Emergency Brake	Definition	EBrAirSupplDel is the air delivery to the emergency brake functions		EB6.1			EBrAirSupplDel			Giraudo		
EB6.4	SYSTEM	Emergency Brake	Functional	EB6.1 shall limit the pneumatic pressure to the maximum permitted by EB5 dimensioning limits and shall provide an air delivery congruent with the air consumption of all types of brakes using pneumatic energy (taking care of WSPintervention as well)	Dimensioning constraint on different types of brakes. Note: this function can be done by any air pressure regulator limiting the supply pressure to EDV	EB6.1	AdDepDynEBrAirSupplPressMax AdIndDynEBrAirSupplPressMax AdDepFrEBrAirSupplPressMax AdIndFrEBrAirSupplPressMax AdDepDynEBrAirConsMax AdIndDynEBrAirConsMax AdDepFrEBrAirConsMax AdIndFrEBrAirConsMax	Parameter Parameter Parameter Parameter Parameter Parameter Parameter Parameter	EBrAirSupplPressMax EBrAirDelMin EBrAirDelMax	EB5 EB5 EB5	x	Giraudo		
EB6.5	SYSTEM	Emergency Brake	Functional	The EB6.1 minimum pressure and EB6.1 store volume shall guarantee the application for at least x≥ 2 time of the TrainEBrForNom without air supply function EB11.3 available.	Inexhaustibility requirement. The number of time to be defined with customer	EB6.1	AdDepDynEBrAirSupplPressMin AdIndDynEBrAirSupplPressMin AdDepFrEBrAirSupplPressMin AdDepDynEBrAirConsMax AdIndDynEBrAirConsMax AdDepFrEBrAirConsMax TrainEBrForMin EBrAirSupplPressMin EBAirSupplStoreVol	Parameter Parameter Parameter Parameter Parameter Parameter Parameter Parameter Parameter	AdDEpFrEBrAirSuppl	EB5	x	Giraudo		

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EB6.6	SYSTEM	Emergency Brake	Functional	EB6.1 leakages and store capacity shall guarantee that the supply pressure doesn't decrease of more than MaxDeltaPressEB due to leakages (without air supply available)	To guarantee the force application for enough time	EB6.1	MaxDeltaPressEB EBAirSupplStoreVol	Parameter Parameter	EBrAirSupplLeak	EB6.1	x	Giraudo		
EB6.7	SYSTEM	Emergency Brake	Definition	EBrAirSupplPressMax is the max pressure of the emergency brake air supply		Dimensioning			EBrAirSupplPressMax			Giraudo		
EB6.8	SYSTEM	Emergency Brake	Definition	EBrAirSupplPressMin is the minimum pressure of the emergency brake air supply		Dimensioning			EBrAirSupplPressMin			Giraudo		
EB6.9	SYSTEM	Emergency Brake	Definition	EBrAirDelMax is the maximum air delivery of the emergency brake air supply which guarantee correct functionalities		Dimensioning			EBrAirDelMax			Giraudo		
EB6.10	SYSTEM	Emergency Brake	Definition	EBrAirDelMin is the minimum air delivery of the emergency brake air supply which guarantee correct functionalities		Dimensioning			EBrAirDelMin			Giraudo		
EB6.11	SYSTEM	Emergency Brake	Definition	EBAirSupplStoreVol is the volume of the emergency brake supply air store		Dimensioning			EBAirSupplStoreVol			Giraudo		
EB6.12	SYSTEM	Emergency Brake	Definition	EB6AirSupplLeak are the air leakages produced by EB6		EB6.1			EB6AirSupplLeak			Giraudo		
EB6.13	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent dynamic emergency brake permitted by dimensioning		Dimensioning			AdDepDynEBrAirSupplPressMax			Giraudo		
EB6.14	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion independent dynamic emergency brake permitted by dimensioning		Dimensioning			AdIndDynEBrAirSupplPressMax			Giraudo		
EB6.15	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning		Dimensioning			AdDepFrEBrAirSupplPressMax			Giraudo		
EB6.16	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAirSupplPressMax is the maximum air supply pressure of the Adhesion inddependent friction emergency brake permitted by dimensioning		Dimensioning			AdIndFrEBrAirSupplPressMax			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.17	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAirConsMax is the maximum air supply consumption of the Adhesion dependent dynamic emergency brake considered by dimensioning		Dimensioning			AdDepDynEBrAirConsMax			Giraudo		
EB6.18	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAirConsMax is the maximum air supply consumption of the Adhesion independent dynamic emergency brake considered by dimensioning		Dimensioning			AdIndDynEBrAirConsMax			Giraudo		
EB6.19	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirConsMax is the maximum air supply consumption of the Adhesion dependent friction emergency brake considered by dimensioning		Dimensioning			AdDepFrEBrAirConsMax			Giraudo		
EB6.20	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAirConsMax is the maximum air supply consumption of the Adhesion Independent friction emergency brake considered by dimensioning		Dimensioning			AdIndFrEBrAirConsMax			Giraudo		
EB6.21	SYSTEM	Emergency Brake	Definition	AdDepDynEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent dynamic emergency brake permitted by dimensioning		Dimensioning			AdDepDynEBrAirSupplPressMin			Giraudo		
EB6.22	SYSTEM	Emergency Brake	Definition	AdIndDynEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion independent dynamic emergency brake permitted by dimensioning		Dimensioning			AdIndDynEBrAirSupplPressMin			Giraudo		
EB6.23	SYSTEM	Emergency Brake	Definition	AdDepFrEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning		Dimensioning			AdDepFrEBrAirSupplPressMin			Giraudo		
EB6.24	SYSTEM	Emergency Brake	Definition	AdIndFrEBrAirSupplPressMin is the minimum air supply pressure of the Adhesion dependent friction emergency brake permitted by dimensioning		Dimensioning			AdIndFrEBrAirSupplPressMin			Giraudo		
EB6.25	SYSTEM	Emergency Brake	Definition	MaxDeltaPressEB is the maximum acceptable decrease per minute of emergency brake supply pressure EBrAirSupplPress		Dimensioning			MaxDeltaPressEB			Giraudo		
				EB6.2 ELECTRIC ENERGY STORING AND DISTRIBUTION								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.26	SYSTEM	Emergency Brake	Functional	EB6.2 shall provide to EB the low voltage electric energy to permit the correct regulation of emergency brake force by type of brakes using electric energy	EBrMaxElVolt EBrMaxElCurr	EB6.2	ElVolt BrElCurr AdDepDynEBrElVoltNom AdIndDynEBrElVoltNom AdDepFrEBrElVoltNom AdIndFrEBrElVoltNom AdDepDynEBrElCurrNom AdIndDynEBrElCurrNom AdDepFrEBrElCurrNom AdIndFrEBrElCurrtNom	Electric Energy Supply Electric Energy Supply Parameter Parameter Parameter Parameter Parameter Parameter	EBrElVolt EBrElCurr	EB EB	x	Giraudo		
EB6.27	SYSTEM	Emergency Brake	Functional	EB6.2 shall limit the electric energy voltage to the maximum permitted by EB dimensioning limits	Dimensioning constraint	EB6.2	AdDepDynEBrElVoltMax AdIndDynEBrElVoltMax AdDepFrEBrElVoltMax AdIndFrEBrElVoltMax AdDepDynEBrElCurrMax AdIndDynEBrElCurrMax AdDepFrEBrElCurrMax AdIndFrEBrElCurrtMax	Parameter Parameter Parameter Parameter Parameter Parameter Parameter Parameter	EBrMaxElVolt EBrMaxElCurr	EB EB	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.28	SYSTEM	Emergency Brake	Functional	EB6.2 shall be able to provide the necessary el energy to EB to apply the emergency brake force by all the type of brake using electric energy even in case of missing supply of energy by EB11.2 low voltage energy supply and guarantee the maximum brake application time	Dimensioning constraint	EB6.2	AdDepDynEBrForReqLtd AdIndDynEBrForReqLtd AdDepFrEBrForReqLtd AdIndFrEBrForReqLtd EBrMaxEqTime	Parameter Parameter Parameter Parameter Parameter Parameter	EBrMinElVolt EBrMinElCurr	EB EB	x	Giraudo		
EB6.29	SYSTEM	Emergency Brake	Functional	The minimum voltage and electric energy store volume shall guarantee the supply for at least x minutes without air supply function EB11.2 available.	Inexhaustibility requirement. The minutes to be agreed (at least 120 hours)	EB6.2	ElEnStoreCap EBrElVoltMin	Parameter Parameter	EBrElVolt EBrElCurr	EB EB	x	Giraudo		
EB6.30	SYSTEM	Emergency Brake	Definition	ElVolt is the voltage of the electric energy supply to the brake system		Electric Energy Supply			ElVolt			Giraudo		
EB6.31	SYSTEM	Emergency Brake	Definition	EBrElVolt is the voltage of the electric energy supply to the Emergency brake system		EB11.2			EBrElVolt			Giraudo		
EB6.32	SYSTEM	Emergency Brake	Definition	EBrElCurr is the electric current supplied to the Emergency brake system		EB11.2			EBrElCurr			Giraudo		
EB6.33	SYSTEM	Emergency Brake	Definition	EBrElVoltMax is the maximum voltage by which EBr system can be supplied according dimensioning		Dimensioning			EBrElVoltMax			Giraudo		
EB6.34	SYSTEM	Emergency Brake	Definition	EBrElVoltMin is the minimum voltage by which SB system guarantee the functionalities		Dimensioning			EBrElVoltMin			Giraudo		
EB6.35	SYSTEM	Emergency Brake	Definition	EBrElCurrMax is the maximum current by which EBr system can be supplied according dimensioning		Dimensioning			EBrElCurrMax			Giraudo		
EB6.36	SYSTEM	Emergency Brake	Definition	EBrElCurrMin is the minimum current which guarantee correct functionalities of the Emergency brake		Dimensioning			EBrElCurrMax			Giraudo		
EB6.37	SYSTEM	Emergency Brake	Definition	AdDepDynEBrElVoltNom is the nominal voltage by which adhesion dependent dynamic Emergency brake shall be supplied		Dimensioning			AdDepDynEBrElVoltNom			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.38	SYSTEM	Emergency Brake	Definition	AdIndDynEBrElVoltNom is the nominal voltage by which adhesion independent dynamic Emergency brake shall be supplied		Dimensioning			AdIndDynEBrElVoltNom			Giraudo		
EB6.39	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElVoltNom is the nominal voltage by which adhesion dependent friction Emergency brake shall be supplied		Dimensioning			AdDepFrEBrElVoltNom			Giraudo		
EB6.40	SYSTEM	Emergency Brake	Definition	AdIndFrEBrElVoltNom is the nominal voltage by which adhesion independent friction Emergency brake shall be supplied		Dimensioning			AdIndFrEBrElVoltNom			Giraudo		
EB6.41	SYSTEM	Emergency Brake	Definition	AdDepDynEBrElCurrNom is the nominal current consumption of adhesion dependent dynamic Emergency brake		Dimensioning			AdDepDynEBrElCurrNom			Giraudo		
EB6.42	SYSTEM	Emergency Brake	Definition	AdIndDynEBrElCurrNom is the nominal current consumption of adhesion independent dynamic Emergency brake		Dimensioning			AdIndDynEBrElCurrNom			Giraudo		
EB6.43	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElCurrNom is the nominal current consumption of adhesion dependent friction Emergency brake		Dimensioning			AdDepFrEBrElCurrNom			Giraudo		
EB6.44	SYSTEM	Emergency Brake	Definition	AdIndFrEBrElCurrNom is the nominal current consumption of adhesion independent friction Emergency brake		Dimensioning			AdIndFrEBrElCurrNom			Giraudo		
EB6.45	SYSTEM	Emergency Brake	Definition	AdDepDynEBrElVoltMax is the maximum voltage by which adhesion dependent dynamic Emergency brake shall be supplied		Dimensioning			AdDepDynEBrElVoltMax			Giraudo		
EB6.46	SYSTEM	Emergency Brake	Definition	AdIndDynEBrElVoltMax is the maximum voltage by which adhesion independent dynamic Emergency brake shall be supplied		Dimensioning			AdIndDynEBrElVoltMax			Giraudo		
EB6.47	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElVoltMax is the maximum voltage by which adhesion dependent friction Emergency brake shall be supplied		Dimensioning			AdDepFrEBrElVoltMax			Giraudo		
EB6.48	SYSTEM	Emergency Brake	Definition	AdIndFrEBrElVoltMax is the maximum voltage by which adhesion independent friction Emergency brake shall be supplied		Dimensioning			AdIndFrEBrElVoltMax			Giraudo		
EB6.49	SYSTEM	Emergency Brake	Definition	AdDepDynEBrElCurrMax is the maximum current consumption of adhesion dependent dynamic Emergency brake		Dimensioning			AdDepDynEBrElCurrMax			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB6.50	SYSTEM	Emergency Brake	Definition	AdIndDynEBrElCurrMax is the maximum current consumption of adhesion independent dynamic Emergency brake		Dimensioning			AdIndDynEBrElCurrMax			Giraudo		
EB6.51	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElCurrMax is the maximum current consumption of adhesion dependent friction Emergency brake		Dimensioning			AdDepFrEBrElCurrMax			Giraudo		
EB6.52	SYSTEM	Emergency Brake	Definition	AdIndFrEBrElCurrMax is the maximum current consumption of adhesion independent friction Emergency brake		Dimensioning			AdIndFrEBrElCurrMax			Giraudo		
EB6.53	SYSTEM	Emergency Brake	Definition	AdDepDynEBrElVoltMin is the minimum voltage by which adhesion dependent dynamic Emergency brake shall be supplied		Dimensioning			AdDepDynEBrElVoltMin			Giraudo		
EB6.54	SYSTEM	Emergency Brake	Definition	AdIndDynEBrElVoltMin is the minimum voltage by which adhesion independent dynamic Emergency brake shall be supplied		Dimensioning			AdIndDynEBrElVoltMin			Giraudo		
EB6.55	SYSTEM	Emergency Brake	Definition	AdDepFrEBrElVoltMin is the minimum voltage by which adhesion dependent friction Emergency brake shall be supplied		Dimensioning			AdDepFrEBrElVoltMin			Giraudo		
EB6.56	SYSTEM	Emergency Brake	Definition	AdIndFrEBrElVoltMin is the minimum voltage by which adhesion independent friction Emergency brake shall be supplied		Dimensioning			AdIndFrEBrElVoltMin			Giraudo		
				EB7 - BRAKING POWER CALCULATION								Giraudo		
EB7.1	SYSTEM	Emergency Brake	Functional	EB7 shall define the train braking powe based on dimensioning hypothesis and availability of different types of brake	The protection on minimum braking power is not provided by brake system, but by ETCS/ATP. For this reason no requirement of brake application in case of too low braking power is foreseen.	EB7	AdDepDynEBrAvFor AdIndDynEBrAvFor AdDepFrEBrAvFor AdIndFrEBrAvFor	EB5.2.1.1.1 EB5.2.1.1.2 EB5.2.1.2.1 EB5.2.1.1.2	TrainBrPower	ETCS EB	x	Giraudo		
EB7.2	SYSTEM	Emergency Brake	Functional	EB7 shall calculate the braking power at train enabling and at any permanent isolation of any type of brake	The isolation produce a change of the available force	EB7	AdDepDynEBrAvFor AdIndDynEBrAvFor AdDepFrEBrAvFor AdIndFrEBrAvFor	EB5.2.1.1.1 EB5.2.1.1.2 EB5.2.1.2.1 EB5.2.1.1.2	TrainBrPower	ETCS EB	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
				EB8 - EMERGENCY BRAKE TRACTION CUTOFF								Giraudo		
EB8.1	SYSTEM	Emergency Brake	Functional	EB8 shall require the traction cut off to traction system in case of emergency brake request		EB8	EBrReq	EB2	TractForAppl	Track	x	Giraudo		
EB8.2	SYSTEM	Emergency Brake	Functional	If EBrReq information is not valid traction shall be cut off immediately	If the EBrReq is not valid automatic brake application is piloted by EB4 and traction shall be cut off	EB8	EBrReq	SB2	TractForAppl	track		Giraudo		
EB8.3	SYSTEM	Emergency Brake	Functional	If Train Integrity is lost traction must be cut off immediately		EB8	TrainIntegr	Train	TractForAppl	Track		Giraudo		
				EB9 - STATE AND FAULT DETECTION AND INDICATION								Giraudo		
EB9.1	SYSTEM	Emergency Brake	Functional	The emergency brake function EB9 shall detect and indicate in the driver cab and/or outside the train the status of the emergency brake and of its sub-functions		EB9			EBrStatus	Diagnostic DriverHMI MaintTool		Giraudo		
EB9.2	SYSTEM	Emergency Brake	Definition	EBrStatus is the information providing the released or applied status of emergency brake		EB9			EBrStatus			Giraudo		
EB9.3	SYSTEM	Emergency Brake	Functional	EB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake (EB) which can have following status: Applied: if any type of brake is applying a braking force Released: if every type of brake is released	The EB status represent the presence of an applied force to the train, independently from brake request, fault active or type of brake applying a force.	EB9.1	AdDepDynEBrStatus AdIndDynEBrStatus AdDepFrEBrStatus AdIndFrEBrStatus	EB9.2 EB9.3 EB9.4 EB9.5	EBrStatus	Diagnostic DriverHMI MaintTool	x	Giraudo		
EB9.4	SYSTEM	Emergency Brake	Definition	AdDepDynEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent dynamic emergency brake		EB9.2			AdDepDynEBrStatus			Giraudo		

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EB9.5	SYSTEM	Emergency Brake	Definition	AdIndDynEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent dynamic emergency brake		EB9.3			AdIndDynEBrStatus			Giraudo		
EB9.6	SYSTEM	Emergency Brake	Definition	AdDepFrEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion dependent friction emergency brake		EB9.4			AdDepFrEBrStatus			Giraudo		
EB9.7	SYSTEM	Emergency Brake	Definition	AdIndFrEBrStatus is the information providing the applied/released/isolated/faulty status of the adhesion independent friction emergency brake		EB9.4			AdIndFrEBrStatus			Giraudo		
EB9.8	SYSTEM	Emergency Brake	Functional	EB9.1 function shall provide to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake functions EB1, EB2 which can have following status: Nominal: when BSM1 has correctly configured the brake system and there is not any major fault active in EB1 or EB2 Degraded: when the emergency brake degraded mode is successfully activated by BSM2.1.2 after the driver selection of emergency brake degraded mode Faulty: if it is not in degraded mode and there is a major fault on EB1 or EB2	EB1 and EB2 are the sub-function managing the emergency brake request, which is the brake central command. For this reason a single status is defined. A faulty EB1,EB2correspond to the impossibility to provide the emergency brake command, ie to loose the continuity of the emergency brake (for this reason any major fault on EB1 and EB2 functions leads to an automatic emergency brake).	EB9.1	MajFaultAnyEB1 MajFaultAnyEB2 EBrDegr	EB1 EB2 BSM2.2.2	EBrStatusEB1-2	Diagnostic DriverHMI MaintTool	x	Giraudo		
EB9.9	SYSTEM	Emergency Brake	Definition	EBrStatusEB1-2 is the information providing the enabled/disabled/degraded/faulty status of emergency brake sub-functions EB1 and EB2		EB9.1			EBrStatusEB1-2			Giraudo		

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EB9.10	SYSTEM	Emergency Brake	Definition	MajFaultAnyEB1 is the summary information of any major fault active on sub-function EB1		EB1			MajFaultAnyEB1			Giraudo		
EB9.11	SYSTEM	Emergency Brake	Definition	MajFaultAnyEB2 is the summary information of any major fault active on sub-function EB2		EB2			MajFaultAnyEB2			Giraudo		
EB9.12	SYSTEM	Emergency Brake	Functional	EB9.1 function shall provide at least to the driver HMI, diagnostic system, diagnostic tool the status of the emergency brake function EB3 which can have following status: enabled: when BSM1 has correctly initialized the brake system and there is not any major fault active in EB3 disabled: when it is not enabled faulty: if it is enabled and any major fault active in EB3	EB3 function is independent from other brake function and need a independent status Major fault of EB3 is managed by EB3 fixing a predefined mass (see req. in EB3)	EB9.1	EBrEnabled MajFaultAnyEB3	BSM1 EB3	EBrStatusEB3	Diagnostic DriverHMI MaintTool	x	Giraudo		
EB9.13	SYSTEM	Emergency Brake	Definition	MajFaultAnyEB3 is the summary information of any major fault active on sub-function EB3		EB9.1			MajFaultAnyEB3			Giraudo		
EB9.14	SYSTEM	Emergency Brake	Definition	EBrStatusEB3 is the information providing the enabled/disabled/faulty status of emergency brake sub-function EB3		EB9.1			EBrStatusEB3			Giraudo		
EB9.15	SYSTEM	Emergency Brake	Functional	The adhesion dependent friction brake shall provide is own status derived from EB4-EB5-EB10 functions . The status can be : Applied: if any braking force is applied Released: if force is not applied Isolated: if it is isolated Faulty: if a major fault is active	EB12 function has not influence on EB status because EB12 is dimensioned according the worst thermal dissipation condition and in any case SB12 would send a warnng in case dimensioning condition should be overpassed (see req. 1.1.12.4)	EB9.4	AdDepFrEBrApplMeas MajFaultAnyAdDepFrEBrEB4-5-10 AdDepFrEBrIsolStatus AdDepFrEBrForMax	EB5.5.2.1.1 EB9.4 EB10.3 Parameter	AdDepFrEBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB9.16	SYSTEM	Emergency Brake	Definition	MajFaultAnyAdDepFrEBrEB4-5-10 is the summary information of any major fault active on adhesion dependent friction emergency brake in sub-function EB4, EB5.1.2.1, EB5.2.2.1, EB5.3.2.1 EB5.5.2.1.1, EB5.5.2.1.2, EB10.3		EB9.4			MajFaultAnyEB4-5-10			Giraudo		
EB9.17	SYSTEM	Emergency Brake	Functional	The adhesion depedent friction emergency brake status is applied if EB5.5.2.1.1 detect AdDepFrEBrApplMeas>0	The force application is detected by the closer information to the wheelset	EB9.4	AdDepFrEBrApplMeas	EB5.5.2.1.1	AdDepFrEBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
EB9.18	SYSTEM	Emergency Brake	Functional	The adhesion depedent friction emerency brake status is released if EB5.5.2.1.1 detect AdDepFrEBrApplMeas=0	The force application is detected by the closer information to the wheelset	EB9.4	AdDepFrEBrApplMeas	EB5.5.2.1.1	AdDepFrEBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB9.19	SYSTEM	Emergency Brake	Functional	The adhesion depedent friction emergency brake status is faulty if any major fault is detected by functions EB4, EB5.1.2.1, EB5.2.2.1, EB5.3.2.1 EB5.5.2.1.1, EB5.5.2.1.2, EB10.3 performed by adhesion dependent friction brake type	The mentioned EB4, EB5, EB10.3 functions are in charge of the adhesion dependent friction brake force generation. EB5.4 major fault does not impact the correct functionality of adhesion dependent friction brake, for this reason is not mentioned. EB6 function, which can cause a fault in adhesion dependent friction emergency brake, is monitored by EB5.2 so its faulty status is already included in EB5 faulty status. EB7 is a function at brake system level, it doesn't influence the adhesion dependent emergency brake force	EB9.4	MajFaultAnyEB4-5-10	EB9.4	AdDepFrEBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
EB9.20	SYSTEM	Emergency Brake	Functional	The adhesion dependent friction emergency brake isolation status shall indicate the percentage of available force respect the maximum one, based on EB10.3 permanent isolation	The isolation gives the information about force availability to EB5.1.2.1 function. The remote release is not considered in EB because it is a degraded condition and is inhibited when EB is triggered by the actors (see BSM sub-function).	EB9.4	AdDepFrEBrIsolStatus AdDepFrEBForMax	EB6 Parameter	AdDepFrEBrStatus	Diagnostic DriverHMI MaintTool	X	Giraudo		
EB9.21	SYSTEM	Emergency Brake	Functional	The adhesion dependent friction emergency brake status (only applied or released information) shall be show optionally external the train, also in case of lack of energy (pneumatic or electric)	The external indication is usefull for maintenance.	EB5.5.2.1.2	AdDepFrEBrStatus	EB9.4	AdDepFrEBrStatus EXT	driver HMI Diagnostic tool		Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB9.2 2	SYSTEM	Emergency Brake	Definition	AdDepFrEBrStatusEXT is the information of applied/released adhesion dependent friction brake visible externally of the train		EB9.4			AdDepFrEBrStatus EXT			Giraudo		
EB9.2 3	SYSTEM	Emergency Brake	Functional	Any minor fault or major fault shall be trasmitted to diagnostic system, diagnostic tool		EB9.4	MinFaultEBx MajFaultEBx	EB3, EB4, EB5.1.2.1, EB5.2, EB5.3.2.1, EB5.5.2.1.1, EB5.5.2.1.2, EB10.3	MinFaultEBx MajFaultEBx	Diagnostic Diagnostic tool	X	Giraudo		
EB9.2 4	SYSTEM	Emergency Brake	Functional	Any major fault shall be trasmitted to driver HMI, diagnostic system, diagnostic tool		EB9.4	MajFaultEBx	EB3, EB4, EB5.1.2.1, EB5.2, EB5.3.2.1, EB5.5.2.1.1, EB5.5.2.1.2, EB10.3	MajFaultEBx	driver HMI Diagnostic Diagnostic tool	X	Giraudo		
				EB10 - EMERGENCY BRAKE ISOLATION								Giraudo		
EB10. 1	SYSTEM	Emergency Brake	Functional	EB10 shall manage the isolation of the different type of brake releasing the eventually applied braking force and inhibiting the force application by EB5.5.2 function	The isolation has the scope to remove permanentely an amount of force, independently from the force generation function, to be able to react to any major fault which would stop permanentely the train or oblige the driver to run in degraded mode	EB10	AdDepDynEBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom; AdDepFrEBrRemRelCom AdDepDynEBrIsolCom AdIndDynEBrIsolCom AdDepFrEBrIsolCom AdIndFrEBrIsolCom	BSM2.2.2 Driver, Maintenance operator	AdDEpDynEBrForAppl AdIndDynEBrForAppl AdDEpFrEBrForAppl AdIndFrEBrForAppl	Track		Giraudo		
EB10. 2	SYSTEM	Emergency Brake	Definition	AdDepDynEBrIsolCom is the command of permanent isolation of adhesion dependent dynamic emergency brake		User			AdDepDynEBrIsolCom			Giraudo		
EB10. 3	SYSTEM	Emergency Brake	Definition	AdIndDynEBrIsolCom is the command of permanent isolation of adhesion independent dynamic emergency brake		User			AdIndDynEBrIsolCom			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB10.4	SYSTEM	Emergency Brake	Definition	AdDepFrEBrIsolCom is the command of permanent isolation of adhesion dependent friction emergency brake		User			AdDepFrEBrIsolCom			Giraudo		
EB10.5	SYSTEM	Emergency Brake	Definition	AdIndFrEBrIsolCom is the command of permanent isolation of adhesion Independent friction emergency brake		User			AdIndFrEBrIsolCom			Giraudo		
EB10.6	SYSTEM	Emergency Brake	Functional	EB10.3 shall manage the isolation of adhesion dependent friction brake by remote release and permanent isolation subfunctions		EB10.3	AdDepFrEBrRemRelCom AdDepFrEBrIsolCom	BSM2.2.1 Driver Maintenance operator	AdDEpFrEBrForAppl	Track	X	Giraudo		
EB10.7	SYSTEM	Emergency Brake	Functional	EB10.3 remote release sub-function shall permit to remove the adhesion dependent friction emergency brake force by remote command	The remote isolation permit to react to any major fault quickly permitting to manage the running capability requirements in case of undue emergency brake application. The remote release command is in charge of BSM2.2.1	EB10.3	AdDepFrEBrRemRelCom	BSM2.2.1	AdDEpFrEBrForAppl	Track	X	Giraudo		
EB10.8	SYSTEM	Emergency Brake	Functional	The remote release sub-function shall operate on EB5.5.2.1 sub-function removing the force application independently from EB5.3.2.1 command	Closer the release command is to the force generation fewer are the functions which can influence the release.	EB10.3	AdDepFrEBrRemRelCom	BSM2.2.1	AdDEpFrEBrPilCom or AdDEpFrEBrPilComLAM	LAM1.2.1 EB5.5.2.1.2	X	Giraudo		
EB10.9	SYSTEM	Emergency Brake	Functional	The emergency brake remote release shall be enabled in case of major fault only.	The BSM2.1 function shall be capable to remove a braking only in presence of major fault to mitigate the possibility to have undue emergency braking force releasing	EB10.3	MajFaultEBx	EB	AdDepFrEBrRemRelCom	BSM2.1	X	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
EB10.10	SYSTEM	Emergency Brake	Functional	EB10.3 permanent isolation sub-function shall permit to remove the adhesion dependent friction emergency brake force applied, totally or partially, permanently, with or without energy available on the train, with EB in any status	The permanent isolation shall be an autonomous sub-function able to operate whatever are the condition of the other emergency brake sub-functions because it is the last operation that can be done to permit at the train to remove the braking force and be moved.	EB10.3	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom	BSM2.2.1 Driver, Maintenance operator	AdDEpFrEBrForAppl	Track		Giraudo		
EB10.11	SYSTEM	Emergency Brake	Functional	The permanent isolation can be commanded by driver or maintenance operator manually or, optionally, by remote command via BSM2.2.1	The optional remote command permit to isolate permanentely from a central position	EB10.3	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom	BSM2.2.1 Driver, Maintenance operator	AdDEpFrEBrForAppl	Track		Giraudo		
EB10.12	SYSTEM	Emergency Brake	Definition	AdDepFrEBrIsolManCom is the command of permanent isolation of adhesion dependent friction emergency brake provided by manual command		User			AdDEpFrEBrIsolManCom			Giraudo		
EB10.13	SYSTEM	Emergency Brake	Functional	The permanent isolation sub-function shall operate on EB5.5.2.1 sub-function removing the force application independently from EB5.3.2.1 command	Closer the permanent isolation is to the force generation fewer are the functions which can influence the result by any failure or power switch off.	EB10.3	AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom	BSM2.2.1 Driver	AdDEpFrEBrPilCom or AdDEpFrEBrPilComLAM	LAM1.2.1 EB5.5.2.1.2		Giraudo		
EB10.14	SYSTEM	Emergency Brake	Functional	Permanent isolation sub-function shall monitor the permanent isolation execution checking the applied force by AdDepFrEBrForApplMeas information received by EB5.5.2.1.1. If permanent release is not successfull (command of permanent release active and brake force still applied) EB10.3 shall set a major fault	To diagnose dragging brake	EB10.3	AdDepFrEBrForApplMeas AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom	EB5.5.2.1.1 BSM2.2.1 Driver, Maintenance operator	MajFaultEB103.1	EB9.4, BSM2.2.1		Giraudo		
EB10.15	SYSTEM	Emergency Brake	Definition	MajFaultEB103.1 is the fault information about the not success permanent isolation execution		EB10.3			MajFaultEB103.1			Giraudo		

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EB10.16	SYSTEM	Emergency Brake	Functional	Permanent isolation shall define the permanent isolation status as: Isolated force: it shall provide the percentage of maximum adhesion depedent friction emergency brake force released by permanent isolation. Faulty: if permanent isolation is not succesfull in releasing completely the expected force		EB10.3	AdDepFREBrForAplMeas AdDepFrEBrIsolRemCom AdDepFrEBrIsolManCom MajFault103.1 AdDepFrEBrForMax	EB5.5.2.1.1. BSM2.2.2 Driver EB10.3 Parameter	AdDepFrEBrIsolStatus	EB9.1		Giraudo		
EB10.17	SYSTEM	Emergency Brake	Definition	AdDepFrEBrIsolStatus is the information of permanent isolated force/faulty permanent isolation of adhesion dependent friction emergency brake force		EB10.3			AdDepFrEBrIsolStatus			Giraudo		
				EB12 - EMERGENCY BRAKE KINETIC ENERGY TRANSFORMATION								Giraudo		
EB12.1	SYSTEM	Emergency Brake	Functional	EB12.2 function shall transform the kinetic energy of the train into thermal energy by the friction between two surfaces	Physics	EB12.2	TrainKinEn	Train	ThermEn	Environment	x	Giraudo		
EB12.2	SYSTEM	Emergency Brake	Functional	EB12.2.1 shall generate heat from the contact between two friction surface sliding with an applied perpendicular force that generates the AdDEpFrEBrForAppl force at the Trackset.		EB12.2.1	AdDepFrEBrForAppl	EB5.5.2.1.2	AdDepFrEBrHeat	EB12.2.2.	x	Giraudo		
EB12.3	SYSTEM	Emergency Brake	Definition	AdDepFrEBrHeat is the heat generated by dissipation process of adhesion dependent friction emergency brake		EB12.2.1			AdDepFrEBrHeat			Giraudo		
EB12.4	SYSTEM	Emergency Brake	Functional	EB12.2.2 shall dissipate the heat generated by EB12.2.1 into the air		EB12.2.2.	AdDepFrEBrThermEn	EB12.2.1	AirThermEnEB	Environment	x	Giraudo		
EB12.5	SYSTEM	Emergency Brake	Definition	AirThermEnEB is the emergency brake thermal energy dissipated into the air		EB12.2.2.			AirThermEnEB			Giraudo		
				PB - PARKING BRAKE								Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
PB.1	SYSTEM	Parking Brake	Functional	The parking brake is the system function used by the users and technical systems (actors) to apply predefined braking force to the track (directly or by the wheelset) with the following goal: - to immobilize permantely the train, without any available energy on board		PB	PBrReqUs	PB1	TrainPBrForAppl		x	Giraudo		
PB.2	SYSTEM	Parking Brake	Definition	TrainPBrForAppl is the portion of force TrainImmForAppl applied by the main function parking brake to the track		PB			TrainPBrForAppl			Giraudo		
PB.3	SYSTEM	Parking Brake	Definition	PBrReqUs is the request to apply the parking brake by driver (or any other user)		PB1			PBrReqUs			Giraudo		
PB.4	SYSTEM	Parking Brake	Functional	When PB functions receive the electrical power supply shall perform a self test and trasmit the result to BSM1 function	This requirements permit the brake system via BSM functions to recognize the configuration of the train and the status of PB and compare it with the expected one (initialization of the brake)	EB	PBrElVolt	PB11.2	SelfTestPBrRes	BSM1		Giraudo		
PB.5	SYSTEM	Parking Brake	Definition	SelfTestPBrRes is the result of the self test performed by parking brake when receive electric power supply		EB			SelfTestPBrRes			Giraudo		
				BSM - BRAKE SYSTEM MANAGEMENT								Giraudo		
				BSM1 - TRAIN TOPOLOGY AND BRAKE SYSTEM INTEGRITY								Giraudo		
BSM1.1	SYSTEM	Brake System Management	Functional	BSM1 sub-function manages the Brake System initialization and configuration at train power up or coupling/uncoupling		BSM1					x	Giraudo		
BSM1.2	SYSTEM	Brake System Management	Functional	BSM1 shall check the correct brake system configuration based on train configuration received by TCMS and result of automatic self test of Service Brake, Emergency Brake and Parking brake	The train configuration by TCMS, EB, EB, PB shall be consistent and EB, EB, PB shall guarantee the minimum performances	BSM1	SBrSelfTestRes EBrSelfTestRes PBrSelfTestRes TrainConfigTCMS	SB EB PB TCMS	SBrSystInit EBrSystInit PBrSystInit	All	x	Giraudo		

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BSM1.3	SYSTEM	Brake System Management	Definition	TrainConfigTCMS is the train configuration information received by TCMS		TCMS			TrainConfigTCMS			Giraudo		
BSM1.4	SYSTEM	Brake System Management	Definition	SBrSystInit is the service brake correctly inizialized information		BSM1			SBrSystInit			Giraudo		
BSM1.5	SYSTEM	Brake System Management	Definition	EBrSystInit is the emergency brake correctly inizialized information		BSM1			EBrSystInit			Giraudo		
BSM1.6	SYSTEM	Brake System Management	Definition	PBrSystInit is the parking brake correctly inizialized information		BSM1			PBrSystInit			Giraudo		
BSM1.7	SYSTEM	Brake System Management	Functional	The service brake function can be enabled or disabled		BSM1	DrDeskEn BrSystInit	TCMS BSM1	SBrEnabled	All	x	Giraudo		
BSM1.8	SYSTEM	Brake System Management	Definition	SBrEnabled is the information about the enabling of the service brake: if SBrEnabled is active, service brake is enabled; if SBrEnabled is not active, service brake is disabled		BSM1			SBrEnabled			Giraudo		
BSM1.9	SYSTEM	Brake System Management	Functional	The service brake system shall be disabled when the train has not a single enabled driver desk or the brake system is not correctly initialized	The service brake is the brake to be used by actors during operation of the train. If the train is not enabled no operation is allowed, so service brake is not needed	BSM1	DrDeskEn SBrSystInit	TCMS BSM1	SBrEnabled	All	x	Giraudo		
BSM1.10	SYSTEM	Brake System Management	Definition	DrDeskEn is the information of driver desk correctly enabled by the driver		TCMS			DrDeskEn			Giraudo		

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BSM1.11	SYSTEM	Brake System Management	Functional	The service brake system shall be enabled when the train has one and only one enabled driver desk and the brake system had a correct initialization	Continuity concept (one and only one central command and all brakes are connected to the central command)	BSM1	DrDeskEn SBrSystInit	TCMS BSM1	SBrEnabled	All	x	Giraudo		
BSM1.12	SYSTEM	Brake System Management	Functional	If service brake system configuration is not correct, service brake shall not be enabled and parking brake release inhibited	Automaticity concept: service brake system integrity lost. Considering that the service brake system status is not known, the parking brake function shall guarantee the immobilization	BSM1	SBrSystInit	BSM1	PBrReqBSM	PB1	x	Giraudo		
BSM1.13	SYSTEM	Brake System Management	Definition	PBrReqBSM is the request to apply the parking brake by main function BSM		BSM			PBrReqBSM			Giraudo		
				BSM2 - BRAKE OPERATING MODES MANAGEMENT								Giraudo		
BSM2.1	SYSTEM	Brake System Management	Functional	BSM2 manages the operative mode of the Brake system during operation		BSM2					x	Giraudo		
				BSM2.1 - SERVICE BRAKE MANAGEMENT								Giraudo		
BSM2.2	SYSTEM	Brake System Management	Functional	BSM2.1.1 shall manage automatically the reaction to any major fault of service brake		BSM2.1.1	MajFaultSBx	SB	SBrReqBSM AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom AdDepDynSBrIsolRemCom AdIndDynSBrIsolRemCom AdDepFrSBrIsolRemCom	SB1 SB10.1 SB10.2 SB10.3 SB10.1 SB10.2 SB10.3	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.3	SYSTEM	Brake System Management	Definition	SBrReqBSM is the request to decelerate via service brake the train by the Brake system itself, provided via BSM. It is a deceleration (negative) value.		BSM2			SBrReqBSM			Giraudo		
BSM2.4	SYSTEM	Brake System Management	Definition	AdDepDynSBrRemRelCom is the command of remote realease of adhesion dependent dynamic service brake force portion which is in failure		BSM2.1.1			AdDepDynSBrRemRelCom			Giraudo		
BSM2.5	SYSTEM	Brake System Management	Definition	AdIndDynSBrRemRelCom is the command of remote realease of adhesion independent dynamic service brake force portion which is in failure		BSM2.1.1			AdIndDynSBrRemRelCom			Giraudo		
BSM2.6	SYSTEM	Brake System Management	Definition	AdDepFrSBrRemRelCom is the command of remote realease of adhesion dependent friction service brake force portion which is in failure		BSM2.1.1			AdDepFrSBrRemRelCom			Giraudo		
BSM2.7	SYSTEM	Brake System Management	Definition	AdDepDynSBrIsolRemCom is the remote command of permanent isolation of adhesion dependent dynamic service brake portion of force		BSM2.1.1			AdDepDynSBrIsolRemCom			Giraudo		
BSM2.8	SYSTEM	Brake System Management	Definition	AdIndDynSBrIsolRemCom is the remote command of permanent isolation of adhesion independent dynamic service brake portion of force		BSM2.1.1			AdIndDynSBrIsolRemCom			Giraudo		
BSM2.9	SYSTEM	Brake System Management	Definition	AdDepFrSBrIsolRemCom is the remote command of permanent isolation of adhesion dependent friction service brake portion of force		BSM2.1.1			AdDepFrSBrIsolRemCom			Giraudo		
BSM2.10	SYSTEM	Brake System Management	Functional	The service brake remote release command can be activated only as reaction to a major fault, when necessary to guarantee the operation of the train.	The remote release change the braking capacity of the service brake	BSM2.1.1	MajFaultSBx	SB	AdDepDynSBrRemRelCom AdIndDynSBrRemRelCom AdDepFrSBrRemRelCom	SB10.1 SB10.2 SB10.3	x	Giraudo		
BSM2.11	SYSTEM	Brake System Management	Functional	BSM2.1.1 shall limit the AdDepFrSBrForAppl remote release command to guarantee at least the AdDepFrSBrForMin	The Adhesion dependent friction service brake force min force shall be always available	BSM2.1.1	MajFaultSBx AdDepFrSBrForMin	SB Parameter	AdDepFrSBrRemRelCom	SB10.3	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.12	SYSTEM	Brake System Management	Functional	BSM2.1.1 sub-function shall monitor the remote release execution, monitoring the adhesion dependent friction service brake applied force	A indipenden service brake force application measurement to the one done by SB5.5.2.1 permit to diagnose the correct release also in case of major fault of force application sub-function	BSM2.1.1	AdDepFrSBrRemRelCom	BSM2.1.1	AdDepFRSBrForRelMeas	SB9.4	x	Giraudo		
BSM2.13	SYSTEM	Brake System Management	Definition	AdDepFrSBrForRelMeas is the information of remote release correctly applied		BSM2.1.1			AdDepFrSBrForRelMeas			Giraudo		
BSM2.14	SYSTEM	Brake System Management	Functional	If remote release is not successfull (command of remote release active and brake force still applied) a major fault shall be set	To activate protection against dragging brake also with SB5.5.2.1.1 monitoring faulty	BSM2.1.1	AdDepFrSBrRemRelCom	BSM2.1.1	MajFaultBSM211.1	SB9.4	x	Giraudo		
BSM2.15	SYSTEM	Brake System Management	Definition	MajFaultBSM211.1 is the fault information of not correct remote release application		BSM2.1.1			MajFaultBSM211.1			Giraudo		
BSM2.16	SYSTEM	Brake System Management	Functional	The remote release monitoring shall be crosschecked with SB5.5.2.1.1 force appl monitoring and in case of inconsistency a major fault generated	Permanent check of diagnostic consistency.	BSM2.1.1	AdDepFRSBrForRelMeas AdDepFRSBrForAplMeas	BSM2.1.1 SB5.5.2.1.1.	MajFaultBSM211.2	SB9.4	x	Giraudo		
BSM2.17	SYSTEM	Brake System Management	Definition	MajFaultBSM211.2 is the fault information of brake release detection inconsistency between BSM2.1.1 and SB5.5.2.1.1		BSM2.1.1			MajFaultBSM211.2			Giraudo		
BSM2.18	SYSTEM	Brake System Management	Functional	BSM2.1.1 shall define the remote release status as Released force: it shall provide the percentage of maximum adhesion depedent friction service brake force released by remote release. Faulty: if remote release is not succesfull in release completely the expected force	Information that will be used by SB5.1.2.1 to calculated the available frition brake force	BSM2.1.1	AdDEpFrSBrForRelMeas AdDepFrSBrRemRelCom MajFaultBSM211.1 AdDepFrSBrForMax	BSM2.1.1 BSM2.1.1 BSM2.1.1 Parameter	AdDepFrSBrRemRelStatus	SB9.4	x	Giraudo		
BSM2.19	SYSTEM	Brake System Management	Definition	AdDepFrSBrRemRelStatus is the the information of Remotly released force/faulty remote release		BSM2.1.1			AdDepFrSBrREmRelStatus			Giraudo		

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BSM2.20	SYSTEM	Brake System Management	Functional	The service brake remote release shall be possible only if the service brake system is enabled	The remote release can be done only by remote commands, requiring an operating brake system	BSM2.1.1	SBrEnable	BSM2.1.1	AdDepFrSBrRemRelCom	SB10.3	x	Giraudo		
BSM2.21	SYSTEM	Brake System Management	Functional	The permanent isolation of the force which is remotly released shall remove the remote release command insisting on that force	To guarantee the consistency of isolation status	BSM2.1.1	AdDepFrSBrIsolStatus	SB10.3	AdDepFrSBrRemRelCom	SB10.3	x	Giraudo		
BSM2.22	SYSTEM	Brake System Management	Functional	The remote release shall be inhibited if the TrainSBrForMin is not available	Inexhaustibility requirement	BSM2.1.2	AdDepDynSBrAvFor AdIndDynSBrAvFor AdDepFrSBrAvFor TrainSBrForMin	SB5.1 SB4	AdDepFrSBrRemRelCom	SB10.4	x	Giraudo		
BSM2.23	SYSTEM	Brake System Management	Functional	BSM2.1.1 shall permit the driver or maintenance operator to permanentely isolate by centralized command totally or partially the Adhesion dependent Friction Service brake applied force	This is a consequence of requirement about permanent isolation of SB10.3	BSM2.1.1	AdDepFrSBrIsolCentrCom	Driver, Maintenance Operator	AdDepFrSBrIsolRemCom	SB10.3	x	Giraudo		
BSM2.24	SYSTEM	Brake System Management	Definition	AdDepFrSBrIsolCentrCom is the remote command by any user to permantly isolate adhesion dependent friction service brake portion of force		User			AdDepFrSBrIsolCentrCom			Giraudo		
BSM2.25	SYSTEM	Brake System Management	Functional	The driver shall be allowed to disabled the holding brake function SB7 at train level	If the SB7 Holding brake function is in major fault emergency brake is applied on the whole train. To guarantee running capability it shall be possible to remove the emergency brake	BSM2.1.2	HBrEnDis	Driver	HBrEnabled	SB7, Driver HMI	x	Giraudo		
BSM2.26	SYSTEM	Brake System Management	Definition	HBrEnabled is the information of the status of the holding brake activation: if active HBrEnabled = active, if not active HBrEnabled = not active		BSM2.1.2			HBrEnabled			Giraudo		
BSM2.27	SYSTEM	Brake System Management	Functional	If the holding brake is disabled the driver shall be continuesly awared by the driver HMI	The driver shall be continuesly awared of a degraded condition of the train which remind him to change the normal habits	Driver HMI	HBrEnabled	BSM2.1.1	HBrDisabled	Driver	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.28	SYSTEM	Brake System Management	Functional	If the Holding brake is disabled the driver shall take care of the temporary immobilization of the train by applying the proper service or emergency brake command at any stop or in case of roll back	Safety function exported to the driver	Driver	HBrDisabled	DriverHMI	TrSBrReqUs, SBrReqUs	SB	x	Giraudo		
BSM2.29	SYSTEM	Brake System Management	Functional	The driver shall be allowed to activate a degraded mode to manage the service brake command in case of major faults of sub-functions SB1 and SB2	Note: This function is what actually is called back-up brake in case of electronic control of brake pipe is in major fault	BSM2.1.2	MajFaultAnySB1 MajFaultAnySB2 SBrDegrCommDr	SB1 SB2 Driver	SBrDegr	SB9.1		Giraudo		
BSM2.30	SYSTEM	Brake System Management	Definition	SBrDegrCommDr is the command selecting the SB degraded mode		Driver			SBrDegrCommDr			Giraudo		
BSM2.31	SYSTEM	Brake System Management	Definition	SBrDegr is the information that driver has selected the Service Brake degraded mode		BSM2.1.2			SBrDegr			Giraudo		
				BSM2.2 - EMERGENCY BRAKE MANAGEMENT								Giraudo		
BSM2.32	SYSTEM	Brake System Management	Functional	BSM2.2.1 shall manage automatically the reaction to any major fault of emergency brake		BSM2.2.1	MajFaultEBx	EB	EBrReqBSM AdDepDynBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom AdDepDynEBrIsolRemCom AdIndDynEBrIsolRemCom AdDepFrEBrIsolRemCom AdIndFrEBrIsolRemCom	EB10.1 EB10.2 EB10.3 EB10.4 EB10.1 EB10.2 EB10.3 EB10.4	x	Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.33	SYSTEM	Brake System Management	Definition	EBrReqBSM is the request to apply the emergency brake by brake system itsself via BSM sub-function		BSM2.2.1			EBrReqBSM			Giraudo		
BSM2.34	SYSTEM	Brake System Management	Definition	AdDepDynEBrRemRelCom is the command of remote realease of adhesion dependent dynamic Emergency brake force portion which is in failure		BSM2.2.1			AdDepDynEBrRemRelCom			Giraudo		
BSM2.35	SYSTEM	Brake System Management	Definition	AdIndDynEBrRemRelCom is the command of remote realease of adhesion independent dynamic Emergency brake force portion which is in failure		BSM2.2.1			AdIndDynEBrRemRelCom			Giraudo		
BSM2.36	SYSTEM	Brake System Management	Definition	AdDepFrEBrRemRelCom is the command of remote realease of adhesion dependent friction Emergency brake force portion which is in failure		BSM2.2.1			AdDepFrEBrRemRelCom			Giraudo		
BSM2.37	SYSTEM	Brake System Management	Definition	AdIndFrEBrRemRelCom is the command of remote realease of adhesion independent friction Emergency brake force portion which is in failure		BSM2.2.1			AdIndFrEBrRemRelCom			Giraudo		
BSM2.38	SYSTEM	Brake System Management	Definition	AdDepDynEBrIsolRemCom is the remote command of permanent isolation of adhesion dependent dynamic Emergency brake portion of force		BSM2.2.1			AdDepDynEBrIsolRemCom			Giraudo		
BSM2.39	SYSTEM	Brake System Management	Definition	AdIndDynEBrIsolRemCom is the remote command of permanent isolation of adhesion independent dynamic Emergency brake portion of force		BSM2.2.1			AdIndDynEBrIsolRemCom			Giraudo		
BSM2.40	SYSTEM	Brake System Management	Definition	AdDepFrEBrIsolRemCom is the remote command of permanent isolation of adhesion dependent friction Emergency brake portion of force		BSM2.2.1			AdDepFrEBrIsolRemCom			Giraudo		
BSM2.41	SYSTEM	Brake System Management	Definition	AdIndFrEBrIsolRemCom is the remote command of permanent isolation of adhesion independent friction Emergency brake portion of force		BSM2.2.1			AdIndFrEBrIsolRemCom			Giraudo		
BSM2.42	SYSTEM	Brake System Management	~~Functional~~	~~BSM2.2.2 shall permit the driver to bypass any undue emergency brake request coming from any actor~~	-	~~BSM2.2.2~~	-	-	-	-	~~x~~	Giraudo	-	-

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.43	SYSTEM	Brake System Management	Functional	The emergency brake remote release command can be activated only as reaction to a major fault, when necessary to guarantee the operation of the train.	The remote release permit to release an undue emergency brake force applied due to a major fault to permit the run of the train	BSM2.2.1	MajFaultEBx	EB	AdDepDynEBrRemRelCom AdIndDynEBrRemRelCom AdDepFrEBrRemRelCom AdIndFrEBrRemRelCom	EB10.1 EB10.2 EB10.3 EB10.4	x	Giraudo		
BSM2.44	SYSTEM	Brake System Management	Functional	BSM2.2.1 shall monitor the remote release execution monitoring the adhesion dependent friction service brake applied force	A indipenden emergency brake force application measurement to the one done by EB5.5.2.1 permit to diagnose the correct release also in case of major fault of force application sub-function	BSM2.2.1	AdDepFrEBrForApPl	EB5.5.2.1.2	AdDepFREBrForRelMeas	EB9.4	x	Giraudo		
BSM2.45	SYSTEM	Brake System Management	Definition	AdDepFrEBrForRelMeas is the information of remote release correctly applied		BSM2.2.1			AdDepFrEBrForRelMeas			Giraudo		
BSM2.46	SYSTEM	Brake System Management	Functional	If remote release is not successfull (command of remote release active and brake force still applied) a major fault shall be set	To activate protection against dragging brake also with EB5.5.2.1.1 monitoring faulty	BSM2.2.1	AdDepFrEBrRemRelCom	BSM2.2.1	MajFaultBSM221.1	EB9.4	x	Giraudo		
BSM2.47	SYSTEM	Brake System Management	Definition	MajFaultBSM221.1 is the fault information of not correct remote release application		BSM2.2.1			MajFaultBSM221.1			Giraudo		
BSM2.48	SYSTEM	Brake System Management	Functional	The remote release monitoring shall be crosschecked with EB5.5.2.1.1 force monitoring and in case of inconsistency a major fault generated	Permanent check of diagnostic consistency.	BSM2.2.1	AdDepFREBrForRelMeas AdDepFREBrForApplMeas	BSM2.2.1 EB5.5.2.1.1.	MajFaultBSM221.2	EB9.4	x	Giraudo		
BSM2.49	SYSTEM	Brake System Management	Definition	MajFaultBSM221.2 is the fault information of brake release detection inconsistency between BSM2.2.1 and EB5.5.2.1.1		BSM2.2.1			MajFaultBSM221.2			Giraudo		

ID	Level	Main Function	Requirement classification	Requirement text	Rationale	Actor	Input information	Input source	Output information	Output destination	Requirement External to EDV	Owner	Reviewer comments	Status
BSM2.50	SYSTEM	Brake System Management	Functional	BSM2.2.1 shall define the remote release status as Stand by: remote release command not actve Released: if remote release command is active and the adhesion dependent friction brake is fully released. Faulty: if remote release command is active an the release is not successfull		BSM2.2.1	AdDEpFrEBrForRelMeas AdDepFrEBrRemRelCom MajFaultBSM221.1 AdDepFrEBrForMax	BSM2.2.1 BSM2.2.1 BSM2.2.1 Parameter	AdDepFrEBrRemRelStatus	EB9.4	x	Giraudo		
BSM2.51	SYSTEM	Brake System Management	Definition	AdDepFrEBrRemRelStatus is the the information of Remotly released force/faulty remote release		BSM2.2.1			AdDepFrEBrREmRelStatus			Giraudo		
BSM2.52	SYSTEM	Brake System Management	Functional	The emergency brake remote release shall be inhibited if an emergency brake is active OR if >1 major fault is active	The emergency brake guaranteed performances are single fault tolerant.	BSM2.2.1	MajFaultEBx EBrReq	EB EB	AdDepFrEBrRemRelCom	EB10.4	x	Giraudo		
BSM2.53	SYSTEM	Brake System Management	Functional	BSM2.2.1 shall permit the driver or maintenance operator to permanentely isolate by centralized command totally or partially the Adhesion dependent Friction emergency brake applied force	This is a consequence of requirement about permanent isolation of EB10.3 electrically controlled	BSM2.2.1	AdDepFrEBrIsolCentrCom	Driver, Maintenance Operator	AdDepFrEBrIsolRemCom	EB10.3	x	Giraudo		
BSM2.54	SYSTEM	Brake System Management	Definition	AdDepFrEBrIsolCentrCom is the remote command by any user to permantly isolate adhesion dependent friction emergency brake portion of force		User			AdDepFrEBrIsolCentrCom			Giraudo		
BSM2.55	SYSTEM	Brake System Management	Functional	The driver shall be allowed to activate a degraded mode to manage the emergency brake command in case of major faults of sub-functions EB1 and EB2	Note: This function is what actually is called back-up brake in case safety loop is in major fault	BSM2.2.2	MajFaultAnyEB1 MajFaultAnyEB2 EBrDegrCommDr	EB1 EB2 Driver	EBrDegr	EB9.1	x	Giraudo		
BSM2.56	SYSTEM	Brake System Management	Definition	EBrDegrCommDr is the command selecting the EB degraded mode		Driver			EBrDegrCommDr			Giraudo		
BSM2.57	SYSTEM	Brake System Management	Definition	EBrDegr is the information that driver has selected the emergency Brake degraded mode		BSM2.2.2			EBrDegr			Giraudo		

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				ABT - AUTOMATIC BRAKE TEST								Giraudo		
ABT.1	SYSTEM	Automatic Brake Test	Functional	ABT shall manage the automatic brake test checking the functionality of brake system		ABT					x	Giraudo		
ABT.2	SYSTEM	Automatic Brake Test	Functional	ABT11 shall send a WSPtestReq to LAM1 when WSP test shall be performed	The goal of ABT is to check that brake system works properly, so ABT use the normal functionalities described in other requirements to perform the ABT. The only test which requires a dedicated function is the command of WSP test. This command is received by LAM1 function. Note: It can be supposed that the brake test functions are managed by BSM1, ie ABT should be sub-function of BSM	ABT11	WSPTestStart	BSM2	WSPtestReq	LAM1	x	Giraudo		
ABT.3	SYSTEM	Automatic Brake Test	Definition	WSPtestReq is the request to start the test to LAM1 subfunction		ABT11			WSPtestReq			Giraudo		
ABT.4	SYSTEM	Automatic Brake Test	Definition	WSPTestStart is the request of starting the WSP test by ABT test procedure		ABT			WSPTestStart			Giraudo		