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RBR 2020/12 - Reliability, Availability, Maintainability and Safety (RAMS) Consultancy Services

Safety of passengers standing on platforms while high speed trains are passing by

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1. Introduction

1.1 Scope and Purpose

The purpose of this document is to develop a specific study on the safety of passengers standing on platforms while high speed trains are passing by without stopping.

The document will present the solutions identified for different high speed railway infrastructures in operation with the aim of identifying some typical scenarios and evaluate their applicability to Rail Baltica Project. A dedicated risk analysis will also be developed to evaluate the risk associated to the scenarios and the safety protections to be applied to mitigate the risk.

1.2 Document Description

This document is organized as follows:

- Section 1 introduces the scope of this safety study, the reference documents, acronyms and definitions;
- Section 2 presents a description of Rail Baltica network with reference to railway and station characteristics;
- Section 3 provides an overview on the applicable solutions that can be taken into account to mitigate the risk related to a high speed train passing through a station;
- Section 4 provides an overview of the solutions applied in different railway systems in Europe and worldwide;
- Section 5 presents the methodology adopted for the risk assessment;
- Section 6 summarizes the outcomes of the performed analyses;
- Section 7 highlights the conclusions of the safety study.

1.3 Definitions and Acronyms

1.3.1 Definitions

Term	Definition	Source
Accident	An unintended event or series of events that results in death, injury, loss of a system or service, or environmental damage	EN 50126-1:2017
Hazard	A condition that could lead to an accident	Reg. 402/2013

Term	Definition	Source
Risk	The frequency of occurrence of accidents and incidents resulting in harm (caused by a hazard) and the degree of severity of that harm	Reg. 402/2013

1.3.2 Acronyms

Acronym	
ALARP	As Low As Reasonably Practicable
ERTMS	European Rail Traffic Management System
FRMCS	Future Railway Mobile Communication System
HST	High Speed Train
RB	Rail Baltica
SIL	Safety Integrity Level
TSI	Technical Specification for Interoperability

1.4 References

1.4.1 Standards and Regulations

[S.1] Commission Implementing Regulation (EU) 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the ‘infrastructure’ subsystem of the rail system in the European Union, 2014

[S.2] Commission Implementing Regulation (EU) No. 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No 352/2009, 2013

[S.3] Commission Implementing Regulation (EU) 2015/1136 of 13 July 2015 amending Implementing Regulation (EU) No 402/2013 on the common safety method for risk evaluation and assessment, 2015

[S.4] EN 61508: Functional safety of electrical/ electronic/ programmable electronic safety-related systems, 2010

1.4.2 Project References

[R.1] Operational Plan of the Railway – Final Study Report, Rail Baltica, 2018

[R.2] System Safety Plan, P0023865-1-H4, Rail Baltica, 2021

[R.3] Rail Baltica Track Layout v2.8, Rail Baltica, 2021

[R.4] Architectural, Landscaping and Visual Identity Design Guidelines for Rail Baltica- Station Elements, RBDG-MAN-031B, Rail Baltica, 2021

1.4.3 Other References

[O.1] Assessment of Potential Aerodynamic Effects on Personnel and Equipment in Proximity to High-Speed Train Operations, USA Federal Railroad Administration, 1999

[O.2] High-Speed Train Station Platform Geometric Design – Technical Memorandum 2.2.4, Parsons Brinckerhoff, 2010

[O.3] The Aerodynamic Effects of Passing Trains to Surrounding Objects and People, USA Federal Railroad Administration, 2009

[O.4] Station design on high speed railway in Scandinavia, Chalmers University of Technology (Göteborg, Sweden), 2013

[O.5] Countermeasures to Mitigate Intentional Deaths on Railroad Rights-of-Way: Lessons Learned and Next Steps, USA Federal Railroad Administration, 2014

2. Rail Baltica Description

2.1 General System Description

The Rail Baltica (RB in the following) project will provide a new railway line connecting the three EU Member States Estonia, Latvia and Lithuania and connecting them to the Central European railway network. The railway line will be part of the North Sea – Baltic corridor of the European TEN-T core network (called Rail Baltica II). In addition, the potential and feasibility of a future extension of the railway to Helsinki, (called FinEst link) is subject of investigated in a separate project.

The RB transport infrastructure Project will consist in a standard gauge double-track railway line of about 870 km in length for both passenger and freight transport, electrified with 2x25 kV AC traction supply system and the line will route from Tallinn through Pärnu – Rīga – Panevėžys – Kaunas to the Lithuanian-Polish border, with a connection from Kaunas to Vilnius. From the Polish border the line will continue for 400 km until Warsaw, where there is connection to the European TEN-T rail network.

The design speed will be up to 120 km/h for freight trains on main track, up to 249 km/h for high speed trains on main track, with a minimum speed of 100 km/h in the passing loops. The maximum operational speed will be 234 km/h for passenger trains.

The line will comply with INF TSI (Commission Regulation 1299/2014/EU, [S.1]) – traffic code P2-F1 and will be equipped with ERTMS L2 BL3 Signalling system and FRMCS Communication System.

The following parameters are also settled in the basic design:

- Level crossing with roads: No level crossing;
- Gauge crossing with 1520 mm Railways: No gauge crossing in mainline;
- Access for maintenance and emergency services access to the main line every 2 or 3 km and in specific areas;
- Type of track: Ballasted track;
- Distance between track centres 4.5 m for the main line and 3.8 m for passenger line with speed up to 200 km/h;
- Maintenance walking path 0,8m at 3.0m from the track centres;
- Vertical clearance for road bridges and tunnels 7.02 m (249 km/h) / 6.43m (200 km/h);
- Fencing will be used on both sides of the railway along the entire Rail Baltica line.

The RB project (Figure 1) includes:

- **Multimodal terminals**: Muuga (Estonia); Salaspils (Latvia) and Kaunas (Lithuania);
- **Passenger Stations**: Tallinn, Pärnu, Riga Central, Riga Airport, Panevėžys, Kaunas, Vilnius and regional stations (joint opening to service of regional stations with international stations will be decided in the future);
- **11 Mainline Design sections**: 3 in Estonia, 4 in Latvia and 4 in Lithuania.

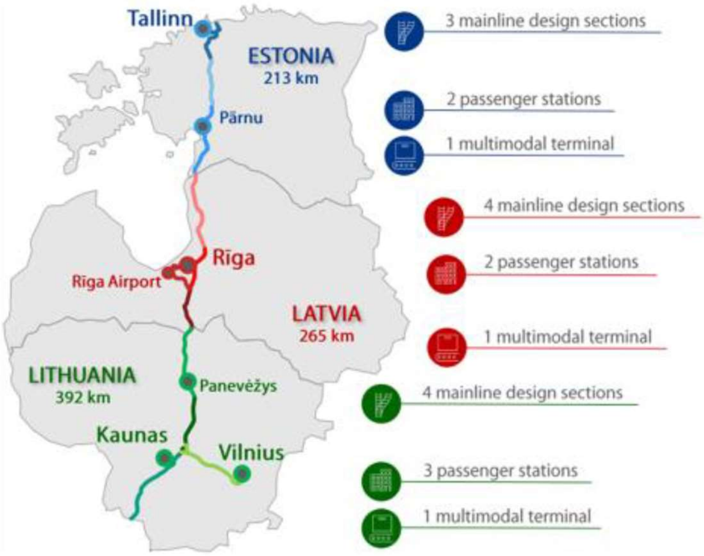

Figure 1: Map of RB Line

The Rail Baltica Operational Plan (Ref. [R.1]) and the Track Layout (Ref.[R.3]) estimates that there will be several regional train stations and stops in each Baltic country. According to last revision of the Track Layout, in addition to the stations where also High Speed Trains are foreseen to stop (Tallinn, Pärnu, Riga Central, Riga Airport, Panevėžys, Kaunas, Vilnius), the following stations – all above ground - are currently foreseen to be dedicated only to regional services:

- 13 regional stations in Estonia;
- 17 regional stations in Latvia;
- 11 regional stations in Lithuania.

Some additional details are provided in the following paragraphs for each country.

2.2 Rail Baltica Railway Line and Regional Stations characteristics

2.2.1 Estonia

The length of the railway line in Estonia from Tallinn to the border of Latvia is planned to be 213 km.

The line will pass by / go through the major cities of Tallinn, Rapla and Pärnu.

According to the current revision of the Track Layout (refer to [R.3]), on this section 13 regional passenger stations will be built over the railway line as summarized in the following table; for each station it is indicated if 2 or as minimum 4 tracks are foreseen, meaning that regional trains will use the diverging tracks to stop and high speed trains will pass through the central tracks. Platforms are located externally to the track.

Baltic State	Regional Passenger Stations	Number of tracks
Estonia	Soodevahe Station	2
	Assaku Station	2
	Luige Station	2
	Saku Station	2
	Kurtna Station	4
	Kohila Station	4
	Rapla Station	4
	Järvakandi Station	4
	Kaisma Station	2
	Tootsi Station	4
	Urge Station	2
	Surju Station	2
	Häädemeste Station	4

Table 1: Regional Stations in RB Railway in Estonia

2.2.2 Latvia

The length of the railway line in Latvia from the border of Estonia to the border of Lithuania is planned to be 265 km.

The line will pass by / go through the major cities of Vangazi, Riga and Misa.

According to the current revision of the Track Layout (refer to [R.3]), on this section 17 regional passenger stations will be built over the railway line as summarized in the following table; for each station it is indicated if 2 or as minimum 4 tracks are foreseen, meaning that regional trains will use the diverging tracks to stop and high speed trains will pass through the central tracks. Platforms are located externally to the track.

Baltic State	Regional Passenger Stations	Number of tracks
Latvia	Salacgrīva Station	4
	Tuja Station	4
	Skulte Station	4
	Ādaži Station	4
	Vangaži Station	2
	Saurieši Station	2
	Acone Station	2
	Slāvu tilts Station	2
	Torņakalns Station	2
	Zasulauks Station	2
	Imanta Station	2
	Salaspils Station	2
	Baldone Station	2
	Jaunmārupe Station	2
	Olaine Station	2
	Kekava Station	2
	Bauska Station	4

Table 2: Regional Stations in RB Railway in Latvia

2.2.3 Lithuania

The length of the railway line in Lithuania from the border of Latvia to the Polish border is planned to be 392 km, including the section to Vilnius from Kaunas.

The line will pass by / go through the major cities of Ramygala, Kaunas and Vilnius.

According to the current revision of the Track Layout (refer to [R.3]), on this section 11 regional passenger stations will be built over the railway line as summarized in the following table; for each station it is indicated if 2 or as minimum 4 tracks are foreseen, meaning that regional trains will use the diverging tracks to stop and high speed trains will pass through the central tracks. Platforms are located externally to the track.

Baltic State	Regional Passenger Stations	Number of tracks
Lithuania	Joniškėlis Station	4
	Ramygala Station	2
	Pasraučiai Station	4
	Ruciunai Station	2
	Jonava Station	2
	Kaunas Airport Station	4
	Palemonas Station	4
	Marijampolė Station	2
	Kaišiadorys Station (Kaunas-Vilnius section)	4

Baltic State	Regional Passenger Stations	Number of tracks
	Vievis Station (Kaunas-Vilnius section)	4
	Lentvaris Station (Kaunas-Vilnius section)	4

Table 3: Regional Stations in RB Railway in Lithuania

3. Context Overview

One of the most important aspects in the design of high speed railway stations is safety for people waiting at platforms, with particular reference to the cases where non-stopping trains pass through a station at very high speed. This scenario could be applicable to pure high speed lines where trains operate with different stopping patterns or to mixed traffic high speed lines where high speed trains only stop at a few stations while the other stations are used for regional traffic.

Besides the obvious risk that someone can fall down onto the track and get hit by a train, the big issue with station passages at high speed is the air streams generated by trains and the forces on people and objects that they can exert.

The passing train can produce airflow velocity and changes in static pressure that are destabilizing to people in proximity to the train. The aerodynamic effect felt by a person in proximity to a passing train is primarily in the form of airflow. The turbulent and unsteady airflow induced by the train is a transient event, occurring during the train passage and persisting for a short time afterwards.

Airflow velocity induced by a passing train, particularly the airflow induced from the wake, is considered to be the more serious effect in destabilizing people and objects alongside the track.

The velocity of these air streams increases significantly as train speed gets higher and may cause objects to be thrown up onto platforms (in winter time in the Nordic climate blocks of ice or snow could be thrown up by passing trains). Air streams from passing trains may also generate a so called slipstream effect which could cause people or objects to be sucked towards a passing train if they are situated too close to the platform edge.

In addition to the actual risk related to aerodynamics of passing trains, it is also important to consider the risk perceived by passengers waiting at the platform; the perceived risk might cause discomfort for people at speeds that are considerably lower than the speed associated with actual risks.

In an American study that summarizes research on how high speed trains affect people on platforms it is concluded that a train passage at 240 km/h (150 mph) could be a serious safety issue for a person standing 2 metres (6.6 ft.) away from the platform edge (Ref. [O.1]).

In the following paragraphs, possible types of solutions are discussed, while in the next chapter the state of the art for some high-speed railways in operations is presented.

The easiest solution would consist in the application of a speed restriction at the pass-through stations for HST (which in the open line can run with a speed up to 249 km/h), but it will have an obvious impact on the timetable, as even short speed reductions are time consuming since the distances required for braking and accelerating are long.

As a consequence, if no speed restrictions are foreseen for the high speed trains passing the stations, some alternative mitigations shall be foreseen in the pass-through stations to protect passengers.

There are different opinions regarding the measures to be applied in case of stations with trains passing at high speed, which include definition of appropriate safety zones or additional physical or procedural measures.

A requirement was reported in the TSI "2008/217/EC – Commission Decision of 20 December 2007 concerning a technical specification for interoperability relating to the 'infrastructure' sub-system of the trans-European high-speed rail system", where it was stated (refer to section 4.2.20.1) that passengers should not be given access to platforms at which a train passes with speed ≥ 250 km/h; this TSI is no more applicable and has been replaced by a new TSI [S.1], but no similar requirements are reported thereby. According to [S.1], aerodynamic actions from passing trains shall be taken into account as set out in EN 1991-2 for infrastructures adjacent to the railway. The policy of the Swedish Transport Administration says, based on tests from the 1990s, that passenger trains could pass platforms, equipped only with safety zones, with speeds up to 240 km/h. In the Norwegian High Speed Railway Assessment – NHSRA as well as in the California High-Speed Train Project it is advocated that further safety measures should be taken when the speed through station exceeds 200 km/h (Ref. [O.2]). However it should be mentioned that there are other parameters besides speed that affect the risks on platforms, like available space on the platform and crowdedness.

In conclusion, we can summarise the possible technical solutions in the following four types, as detailed in the next sections:

- Separate passing tracks;
- Platform safety zone;
- Restricted access to platform;
- Safety fence with gates.

3.1 Separate passing tracks

The common way in many countries with High Speed railways to prevent people on platforms to be exposed to the risks associated with passing high speed trains is to have separate passing tracks that are not located right next to a platform. Stopping trains will then reach the platforms by switching onto platform loops and passengers will have at least the width of one track between themselves and a passing train. To provide additional safety and feeling of safety, some kind of fixed barrier (wall or fence) could be built between the passing track and the stopping track.

A significant negative aspect with separate passing tracks is the considerably increased construction and maintenance costs. The solution also makes the station more space consuming, which might be a serious issue when fitting a new High Speed Train station in the existing built environment.

3.2 Platform safety zone

For stations where separate through-tracks are not feasible but high passing speed still desired, there are different alternative possible measures that can be implemented on platforms in order to protect people from passing trains. These measures could be used on both new stations and when adapting old stations for high speed traffic.

The traditional measure to prevent passengers on platforms to get too close to passing trains is to mark out a safety zone on the part of the platform closest to the platform edge. The zone is either marked with paint or with a paving that differs from the rest of the platform; the width of the safety zone is dependent on the maximum allowed speed on the track adjacent to the platform. Visual warnings could also be enhanced by audible warnings when the passing train approaches the station. Compared with any type of barrier described in the following paragraphs the solution with safety zones and warnings is relatively cheap to install with low operation and maintenance costs.

Figure 2: Platform signages

The following table summarizes the recommended distances for public from passing trains in various countries according to [O.3].

Country	Maximum Speed	Platform safe distance
Great Britain	≤ 201 km/h	1.5 m
France	≤ 160 km/h	1.0 m
	≤ 200 km/h	1.8 m
Germany	≤ 160 km/h	1.0 m
	≤ 200 km/h	1.5 m
	≤ 230 km/h	2.2 m
China	≤ 160 km/h	1.7 m
Japan	≤ 95 km/h	0.8 m
	≤ 250 km/h	2.5 m
Russia	≤ 200 km/h	2.0 m

Table 4: Platform safety distances

The current typical layout of Rail Baltica stations according to the content of RB Design Guidelines (Ref. [R.4]) shows that 2 metres are currently foreseen between the safety line and the platform edge with an additional buffer of 1 metre. For stations where the maximum train speed is about 200 km/h this distance could be considered sufficient enough to ensure that passengers behind the safety line are not affected by a high speed train passing by, while for stations where high speed trains are passing at maximum speed (249 km/h) also the presence of the buffer area 1 metre wide should be partly included in the safe distance to ensure a width of 2.5 m.

3.3 Restricted access to platform

A solution could be to close the admittance to the platform for all passengers when a high-speed train is approaching ensuring that there are no passengers standing out on the platform. When a regional train arrives, people can stand on the platforms applying the common precautions (e.g. audio messages asking to wait behind the yellow line until the train stops / signages on the platform as foreseen in §3.2).

3.4 Safety fence with gates

Another possible solution could be to install a fence on the platform with the purpose to prevent people from getting close to passing trains. Fences could be mounted right on the platform edge or at the edge of the safety zone depending on the maximum speed of passing trains. Fences could be made with openings in between (passive barriers) or with automatic gates that opens when a train stops (active barriers).

This fence should be around 1 m high, equipped with openings / sliding gates every 6 – 10 m. According to British Railway suggestions, for trains passing at 200 km/h the fence shall be installed at least 1.5 m from the platform edge (Ref. [O.3]). With a distance of 1.5 m from the passing train, the aerodynamic effect will still be strong, but most people would not be affected much. If it is possible to make the distance longer – and the platform wider - the comfort for the passengers will be bigger. According to [O.1], in case of trains passing with a speed of 240 km/h the distance should be 2.0 m as a minimum.

The automatic gates make the solution more expensive to install and results in higher costs of operation and maintenance. There are also high availability requirements on the proper functioning of the gates since a failure could cause delays; this kind of gates is installed in some stations in Japan (refer to §4.5).

It should be mentioned that the safety zones described above primarily refer to passenger trains and not to freight trains; conventional freight trains have worse aerodynamics than passenger trains and would require wider safety zones for the speeds mentioned in the tables. However, since freight trains are run with lower speeds than passenger trains, they are normally not representing the most restrictive case when it comes to the safety zones.

When active barriers are applied, it is essential to ensure that no passengers will remain in the safety zone, i.e. the track side of the barrier, when the barrier is closing/closed. Detectors could be installed, ensuring that in such case the speed of a passing train is limited to acceptable level.

4. Solutions Applied in Europe and Worldwide

This chapter presents the solutions that have been applied in some European and Extra European High Speed railway infrastructures.

4.1 Italy

High Speed Train railway line in Italy is fully dedicated to high speed trains only; there are two stations in which not all trains are stopping, Reggio Emilia (between Milano and Bologna) and Afragola (between Roma and Napoli). In these stations there is no speed restriction, trains run at the maximum operation speed (up to 300 km/h) and the passing tracks are installed in the centre of the station. In the case of Reggio Emilia, there is a fence between the passing and stopping tracks, as shown in Figure 6 below, with the purpose of not allowing passengers to cross the tracks rather than reducing the aerodynamic effects caused by the train. There are no constraints related to the presence of passengers on the platform while the train runs through the station – on the passing tracks - at high speed.

Figure 3: Example of passing track with fixed fences in Italy (Reggio Emilia station)

In Afragola station, instead, there is no physical separation between the passing and the stopping tracks, as shown in the below figure.

Figure 4: Example of passing tracks without fences in Italy (Afragola station)

4.2 Germany

On the German line Hamburg - Berlin, which is a conventional line that has been upgraded for high speed traffic, fences are built on several stations where trains pass with speed up to 230 km/h. These fences are mounted two metres from the platform edge with openings distributed evenly along the platform (refer to Figure 5). This solution does not provide a completely safe platform environment since it still possible to enter the safety zone while a train is passing, but it highlights the safety zone and makes people stand further away from the platform edge. Platform fences also provide a greater experience of comfort and perceived safety for passengers on platforms. The German fences are used in combination with visual and audible warnings, and warning signs. It is a fairly cheap solution with no operation cost and a few maintenance requirements.

Figure 5: Example of fixed platform fences in Germany (Hamburg-Berlin line, Paulinenaue Station)

In Germany, the minimum distance from the edge of the platform is 2.2 m for speed up to 230 km/h (Ref. [O.3]).

4.3 France

On the High Speed Train railway line in France passing tracks are foreseen with a physical separation between them and the stopping tracks. Fixed barriers are installed for stations with through tracks for speed of 200 km/h or more, as shown in Figure 6 below. No trains are permitted to travel above a speed of 200 km/h when passing a station platform on conventional lines; in these stations the distance from the nearest edge of rail is at least 2.5 m (Ref.[O.3]).

Figure 6: French high speed station (St. Raphael) with separate through tracks and passive barriers

4.4 United Kingdom

The solution commonly applied in United Kingdom for the high speed line HS1 (Paris-London) foresees to reduce train speed to about 200-220 km/h (from 300 km/h) and to close the admittance to the platform for all passengers when a no stopping high-speed train is approaching, ensuring that there are no passengers standing out on the platform. For regional stations where high speed trains are passing through, trains have dedicated separate tracks.

The below figure shows the case of a station along the high-speed line where Intercity (Eurostar)/Regional trains stop (the track visible in the picture), while high-speed trains pass through a dedicated track on the other side of the platform, that is properly fenced-off from the platform used by boarding/alighting passengers of the Intercity/Regional trains.

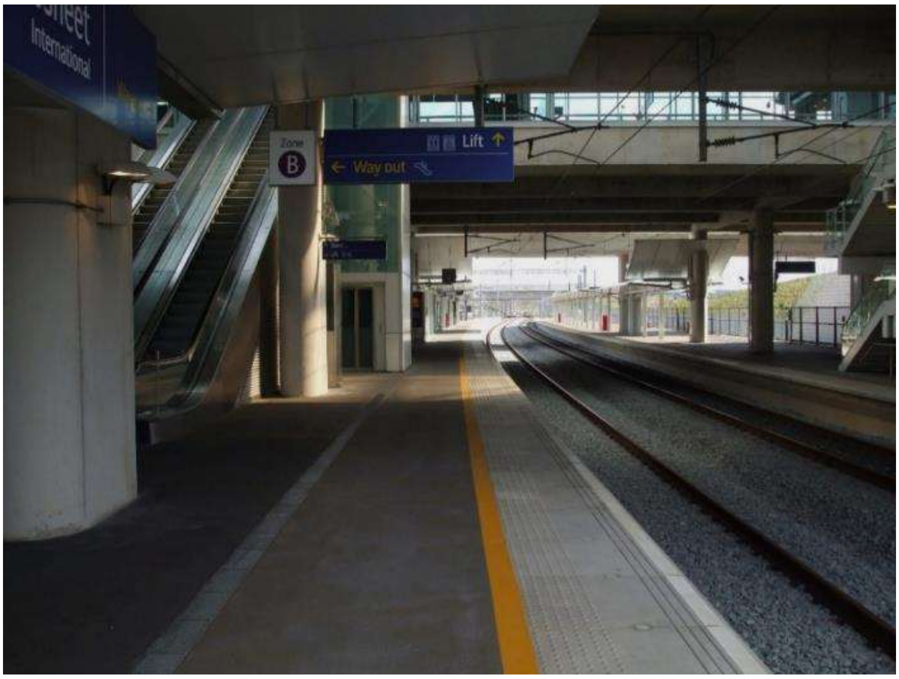

Figure 7: Intercity/Regional trains Platform on the High Speed line HS1 (Ebbsfleet Station)

The solution is even more drastic in a second station (Ashford International) of the HS1 line, where the pass-through HST are running on an elevated track; furthermore, the operating procedure foresees that no platform access for passengers is allowed until just before the train arrives (as it is stopping at the platform).

Figure 8: Intercity/Regional trains Platform on the High Speed line HS1 (Ashford International Station)

4.5 Japan

In Japan, platform fences are frequently used on Shinkansen High Speed Trains stations, both the type with openings but also fences with automatic gates that open when a train has stopped at the platform.

In the Atami Station, a protective fence prevents people from wandering too close to the edge of the platform; an attendant is present to operate the gates to allow passengers to pass when a train is stopped at the station (Ref.[O.3]).

Figure 9: Platform fences with gates in Japan (Atami Station)

Automatic gates can be seen in Figure 10 related to Shin-Kōbe Station. This solution provides a high level of safety since the safety zone is completely blocked when a train is not stopped at the platform. However, the automatic gates make the solution more expensive to install and result in higher costs of operation and maintenance. There are also high availability requirements on the proper functioning of the gates since a failure could cause delays.

Figure 10: Platform fences with automatic gates in Japan (Shin-Kōbe Station)

According to the collected information, it seems that separate passing tracks are foreseen in stations where high speed trains are passing through.

Figure 11: High Speed Train passing through a station in Japan

In Japan, the minimum distance from the edge of the platform is 2.5 m for speed up to 250 km/h (Ref. [O.3]).

In Japan, automatic gates have been installed also in railway stations where no high speed trains are passing (e.g. Meguro Station, part of Yamanote Line). The opening and closing of the platform doors are interlocked with the opening and closing of train doors and with remote monitoring of the automatic platform gates' operational status; train doors have to be aligned to the gate opening, therefore this solution is not feasible where different train configurations are foreseen like in the Rail Baltica railway.

Figure 12: Platform fences with automatic gates in Japan (Meguro Station)

Furthermore, in some stations a “wire-style” platform gate that is raised when the train stops at the platform has been installed. The gates are programmed to be opened automatically when a train arrives and stops at the correct location in station (train position is detected through some sensors). To prevent passengers from being injured by moving wires, infrared sensors are installed on the platform side of the gates.

Figure 13: Platform fences with wires in Japan (Sakurajima Station) – side view

Figure 14: Platform fences with wires in Japan (Sakurajima Station) – front view

4.6 South Korea

On the High Speed Train railway line operated by KTX in South Korea high speed tracks at stations are separated from the regional tracks and a fixed barrier (concrete barrier and metal fence) is foreseen between them and the stopping tracks, as shown in Figure 15 below. No speed reduction is applied for high-speed trains passing through the stations.

Figure 15: Example of separated tracks in South Korea

4.7 Other Countries

In Spain, high speed lines are dedicated to high speed trains only, therefore the scenario related to a high speed train passing through a regional station is not applicable.

In Norway, the recommended distance from the edge of the platform is 1.5 m for speed up to 200 km/h while in Sweden is 2.0 m for speed up to 240 km/h. In Norway, when possible separate tracks for passing trains are foreseen otherwise platform fences shall be installed (Ref. [O.4]).

In China, the recommended distance from the edge of the platform is 1.7 m for speed up to 160 km/h (Ref. [O.3]).

In Russia, the recommended distance from the edge of the platform is 2.0 m for speed up to 200 km/h (Ref. [O.3]).

In USA, even if there are stations where trains are passing at 240 km/h with only safety line (i.e. no fences are foreseen nor additional tracks), studies have been developed concluding that train passage at 240 km/h could be a serious safety issue for a person standing 2 metres away from the platform edge (Ref.[O.1]).

4.8 Summary of existing systems

The below table summarizes what has been described in the previous paragraphs for what concerns stations of different countries where high speed trains are passing through and where specific solutions have been applied.

Country	Passing Tracks	Only Traditional Safety Zone	Restricted Access to Platform	Passive Safety Fence	Active Safety Fence	Notes
Italy	X					Fence between tracks
Germany				X		
France	X					Wall between tracks
United Kingdom	X		X			Tracks fenced-off
Japan	X				X	
South Korea	X					Wall between tracks

Table 5: Comparison of solutions adopted by different countries

5. Risk Analysis Methodology

5.1 Introduction

According to the currently foreseen Track Layout [R.3], the scenario related to passengers standing on platforms while high speed trains passing by is applicable for Rail Baltica Project.

With reference to the regional passenger stations, only in some stations it is foreseen to have four tracks (refer to §2.2). In these stations, two high speed tracks in the middle and a passing loop on each side of the main tracks are foreseen with more than 6 m to the edges of the platforms. With this configuration, the aerodynamic effect from a passing high-speed train will not reach the passengers on the platforms and therefore no special safety arrangement are necessary. This concept for the track layout is used in many countries around the world (e.g. Germany, Italy and France, refer to §4).

In the other regional stations, only two main tracks are foreseen through the stations, therefore some additional protections shall be foreseen.

The current typical layout of Rail Baltica stations according to the content of RB Design Guidelines (Ref. [R.4]) is reported in the following pictures, showing that 2 metres are currently foreseen between the safety line and the platform edge.

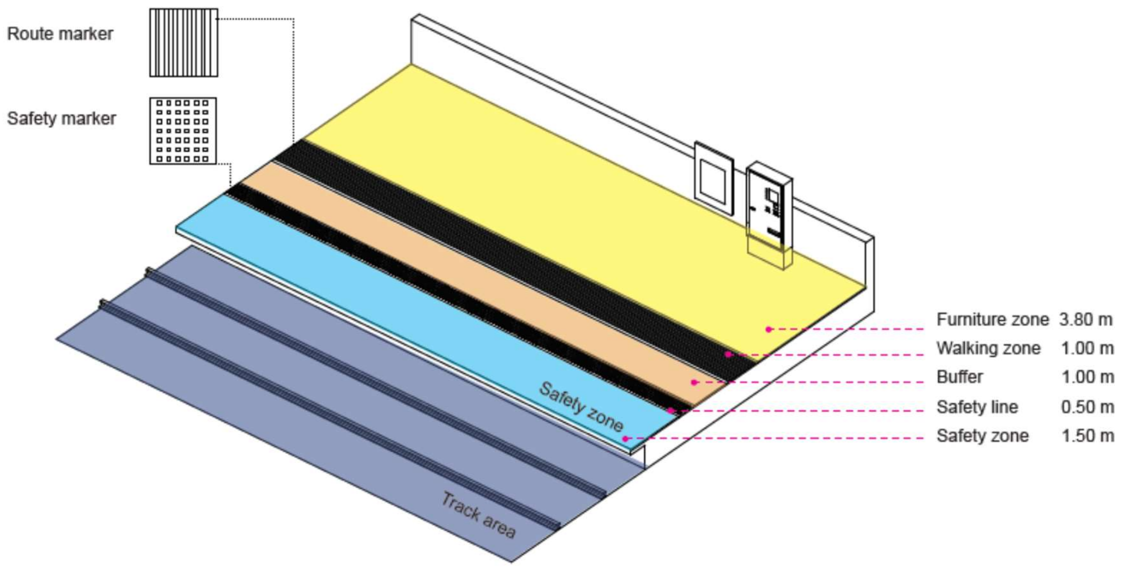

Figure 16: RB Station Platform Areas

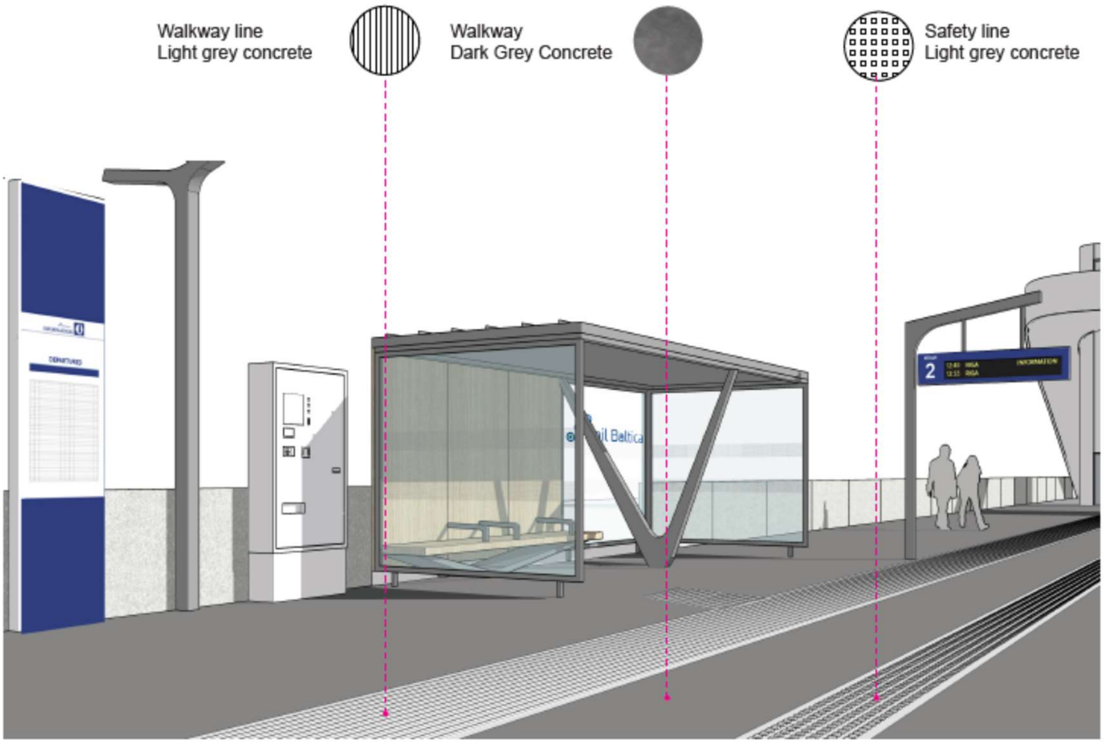

Figure 17: RB Station Platform – 3D view

For stations where the maximum train speed is about 200 km/h, the distance foreseen for the safety line in the above pictures could be considered sufficient enough to ensure that passengers behind the safety line are not affected by a high speed train passing by, while for stations where high speed trains are passing at maximum speed (249 km/h) also part of the buffer area should be included in the safe distance to ensure a width of 2.5 m. Nevertheless the application of additional measures should be taken into account to ensure that passengers remain behind the line when a train is passing through the station.

A schematic representation of the scenario under analysis is provided in the below figure.

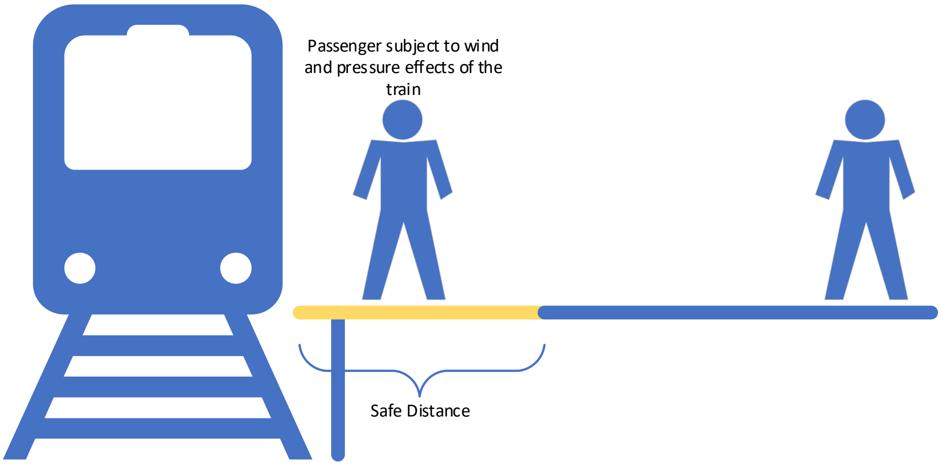

Figure 18: Scenario schematic representation

For the above scenario, a qualitative risk analysis has been performed to evaluate the effects of the different solutions that could be envisaged. The methodology applied for this analysis is provided in the following paragraphs while the related results are reported in §6.

It has been conservatively assumed in all scenarios analysed in the present document that all stations are unattended, as this is currently planned for the majority of them.

5.2 Risk Management Process

The general concepts related to the risk management process have been defined in the "System Safety Plan" [R.2] where the risk matrix to be applied during the project lifecycle has been defined.

		Severity			
		S4 - Insignificant	**S3 - Marginal**	**S2 - Critical**	**S1 - Catastrophic**
Frequency	**F1 - Frequent**	Undesirable	Intolerable	Intolerable	Intolerable
	F2 - Probable	Tolerable	Undesirable	Intolerable	Intolerable
	F3 - Occasional	Tolerable	Undesirable	Undesirable	Intolerable
	F4 - Rare	Negligible	Tolerable	Undesirable	Undesirable
	F5 - Improbable	Negligible	Negligible	Tolerable	Undesirable
	F6 - Highly Improbable	Negligible	Negligible	Negligible	Tolerable

Table 6: Risk Matrix

In the table below the classification of the severity of the consequences is reported.

Category	Consequence Interpretation
S1 - Catastrophic	Affecting a very large number of people and resulting in multiple equivalent fatalities (likely more than 10)
S2 - Critical	Affecting a very small number of people and resulting in at least one fatality
S3 - Marginal	No possibility of fatality, severe or multiple minor injuries only
S4 - Insignificant	Possible minor injuries

Table 7: Consequence severity categories

In the table below the classification of the frequency of the hazard occurrence is reported.

Category	Description	Frequency of Occurrence (Per year)
F1 - Frequent	Likely to occur frequently. The event will be frequently experienced.	> 10
F2 - Probable	Will occur several times. The event can be expected to occur often.	$1 \cdot \div 10$
F3 - Occasional	Likely to occur several times. The event can be expected to occur several times.	$1\ 10^{-1} \cdot \div 1$
F4 - Rare	Likely to occur sometime in the system life-cycle. The event can reasonably be expected to occur.	$1 \cdot 10^{-3} \cdot \div 1\ 10^{-1}$
F5 - Improbable	Unlikely to occur but possible. It may be assumed that the event may exceptionally occur.	$1 \cdot 10^{-5} \cdot \div 1\ 10^{-3}$
F6 - Highly Improbable	Extremely unlikely to occur. It can be assumed that the event will not occur.	$\leq 1 \cdot 10^{-5}$

Table 8: Occurrence frequency categories

The hazard that is addressed by this study is the following:

- **passenger standing on the platform while a train is passing at high speed.**

The possible accident that may be caused by the hazard considered in this study is the following:

- **passenger subject to wind and pressure effects of the train falls on the platform or is hit by objects thrown by the train (possible injury) or falls into the tracks (possible fatality).**

The possible causes of the accident, or concurrent causes, may consist in (voluntary acts like suicides are excluded):

- passenger distracted (e.g. on the phone) or unaware of the risk (e.g. children);
- impaired people (e.g. PRM, blind, deaf);
- platform overcrowding;
- platform slippery conditions (e.g. ice).

The following paragraphs present the methodology that has been applied to perform the qualitative risk analysis.

5.3 Analysis of the Scenarios

The risk analysis will be applied to the following scenarios, representing possible design and / or procedural solutions to address the hazard:

- A: Separate passing tracks (4 tracks or more):
    - A1: No physical protection of passing tracks,
    - A2: Physical protection of passing tracks;
- B: No separate passing tracks (2 tracks):
    - B1: Platform safety zone,
    - B2: Safety fence on platform with passive gates,
    - B3: Safety fence on platform with active gates – half height,
    - B4: Restricted access to platform – half height,
    - B5: Safety fence on platform with active gates – full height (about 2 m),
    - B6: Restricted access to platform – full height (about 2 m).

In all scenarios it is considered that the train passes through the station at its maximum design speed of 249 km/h, which is the worst case for the risk assessment. From the operational point of view, although there are no speed limitations specified by the TSIs for “through” trains, they actually exist in the high speed lines in operation as defined by the National Safety Authority or the Infrastructure Manager. Reductions at regional stations will then possible, although they must be decided by the RB Rail and the Infrastructure Managers of RB project and would certainly have some impacts on the HST schedule.

As for freight trains, although the aerodynamic effects may differ from those of passenger trains as mentioned earlier, it is considered that the risk being analysed is much lower due to the significantly lower design speed (120 km/h). This is clearly confirmed by the analysis of the effects of trains at different speeds presented in ref. [O.3].

5.3.1 Scenario A1 – Separate passing tracks without physical protection

The passing tracks are in the centre of the stations, they are separated by a fence that has the function of preventing the crossing of tracks by people (passengers, staff). The distance of the platform edge to the fence is of more than 4 m, therefore there is no dangerous aerodynamic effect of passing trains on people standing on the platform. The frequency of the accident would be **Improbable** (**F5**) due to possibility of voluntary trespassing (e.g. suicides).

The following picture presents the solution proposed for this scenario.

Figure 19: Scenario A1

5.3.2 Scenario A2 – Separate passing tracks with physical protection

The passing tracks are in the centre of the stations, but they are not separated by any fence and therefore there is the possibility to cross the tracks, although this is clearly forbidden. But the event cannot be considered impossible (late passengers, lazy staff). The distance of the platform edge to the fence is of more than 4 m, therefore there is no dangerous aerodynamic effect of passing trains on people standing on the platform, but there could be a case of people crossing.

The following picture presents the solution proposed for this scenario.

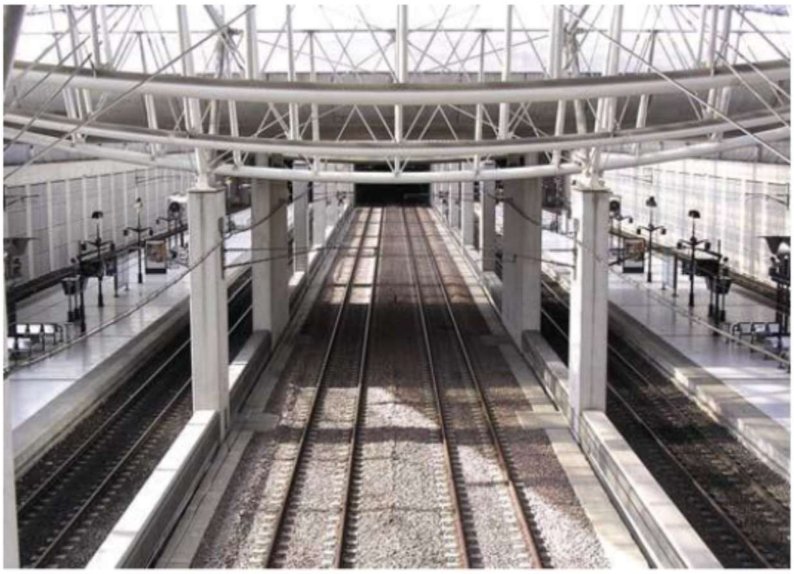

Figure 20: Scenario A2

The frequency of the accident would still be **Highly Improbable** (**F6**), as deliberate acts (e.g. suicides) are excluded from the study and illegal crossing at the time of HST passing through is considered very unlikely.

5.3.3 Scenario B1 – Platform safety zone

The passing tracks are the same as the stopping tracks, therefore the distance of the platform edge to the kinematic envelope of the train is minimal and there is an objective risk of the hazard evolving into the accident. In this scenario the following mitigations are considered:

- definition of a safety zone at the side of the platform edge, of at least 2.5 m width along the whole platform length, marked with visible painting and identified by warning signs;
- procedure not allowing to stand on the safety zone at any time while there are no trains stopping at the platform, accompanied by public announcements or audible/visual warnings reminding this requirement.

With this solution, there would be no effect on passengers while a train is passing at high speed, if everybody would comply with the requirement and if impaired people (e.g. blind people) or distracted passengers would not exist. It is therefore considered that a certain amount a people may be seriously exposed to the risk. The following picture presents the solution proposed for this scenario.

Figure 21: Scenario B1

Considering the number of HST passing through the 23 regional stations with 2 tracks only (refer to §2.2), which are 32 per day on average considering both platforms (reference is made to the service patterns in year 2056 in the Operational Plan, ref. [R.1]), there are about 736 run-through per day, and about 270,000 per year (2.7 10^5).

There are no data available on unvoluntary accidents of people falling down into the track for any reasons, especially due to a passing train.

A rough estimation can be made by considering the general probability that a person standing on the platform moves close to the edge of the platform (distracted person, overcrowding, blind person, etc.) concurrently with the passage of a train at high speed (exposure time):

- probability of a person standing near the edge of the platform: safety zone is marked but still it can be assumed that 10% of people may be in that location (10^{-1}); this figure considers a normal crowding of the regional station, in the order of 100 passengers, and the possibility of distracted people / children approaching the edge of the platform. The assumption related to the number of people on the platform is substantiated by the approach commonly applied that considers an average platform occupation of about 30% of the regional train capacity (i.e. 300 passengers);
- exposure time of the person while the train is passing: 6 s per passage (at 249 km/h). Considering 16 hours of regional service per day, this means that the exposure time would be 0.01% of total time of service (10^{-4});
- the probability of having a person near the edge of the platform during the passage of a train at high speed is the product of the above probabilities, that is 10^{-5} per run-through.

Therefore, the frequency of the accident in a year would be 2.7 10^5 * 10^{-5} = 2.7, which corresponds to **Probable** (**F2**).

5.3.4 Scenario B2 – Safety fence on platform with passive gates

This scenario is similar to B1 for what concerns the tracks layout and the following mitigations are considered:

- Installation of a fence along the whole platform length at least 2.5 m far from the platform edge, provided with openings that are always open or can be opened by passengers, thus visually delimitating a safety zone that is also identified by warning signs (marking of the safety zone same as in B1);
- procedure not allowing to stand on the safety zone at any time while there are no trains stopping at the platform, accompanied by public announcements or audible/visual warnings reminding this requirement.

With this solution, there would be no effect on passengers while a train is passing at high speed, if everybody would comply with the requirement, including impaired people (e.g. blinds) or distracted passengers. Due to the physical barrier, it is therefore considered that only a minimum amount of people may be seriously exposed to the risk.

The following picture presents the solution proposed for this scenario.

Figure 22: Scenario B2

In this case, the estimation of the probability that a person standing on the platform moves close to the edge of the platform while a train passes at high speed is the following:

- probability of a person standing near the edge of the platform: safety fence is present, thus reducing the probability with respect to scenario B1 due to the physical delimitation of the safety area, but still it can be assumed that 1 out of 100 people may be in that location (10^{-2}); this figure is mainly referred to people that voluntarily cross the barrier (vulnerable individuals like drunk people, suicides, etc.);

- exposure time of the person while the train is passing: 6 s per passage (at 249 km/h). Considering 16 hours of regional service per day, this means that the exposure time would be 0.01 % of total time of service (10^{-4});
- the probability of having a person near the edge of the platform during the passage of a train at high speed is the product of the above probabilities, that is 10^{-6} per run-through. It is noted that this probability, which is a combination of the two above mentioned events, is more conservative to resulting frequency of suicides in a year in the UK railways (about 300 out of 3 10^{9} train passages at platform, i.e. 1 10^{-7} per train passage), according to the data provided in the ERA Railway Safety Performance report on 2016 and in the Rail Accident Investigation Board (RAIB) presentation on accidents at Platform Train Interface (PTI) in year 2015/2016.

Therefore, the frequency of the accident in a year would be 2.7 10^{5} * 10^{-6} = 2.7 10^{-1}, which corresponds to **Occasional** (**F3**).

5.3.5 Scenario B3 – Safety fence on platform with active gates – half height

This scenario is similar to B1 for what concerns the tracks layout and the following mitigations are considered:

- Installation of a fence along the whole platform length at least 2.5 m far from the platform edge and around 1 m high, provided with gates that are automatically controlled so that to be opened only when a train is stopping at the platform (marking of the safety zone same as in B1);
- technical interface of the gates with any system that is able to detect the presence (or entry) of the train at the station, either via intelligent cameras, or detectors on the tracks, or any other means (interlocking of the signalling system with the platform gates would require relevant design, validation and safety approval process).

Due to the physical barrier always closed when HSTs pass through, it is considered that no people may be seriously exposed to the risk, except in case of intentional acts (e.g. people that want to commit suicide can trespass the gate).

In case of malfunction of the automatic gates, the gates shall be kept open and a procedure shall be foreseen not allowing to stand on the safety zone at any time while there are no trains stopping at the platform, accompanied by public announcements or audible/visual warnings reminding this requirement. A speed reduction for high speed trains passing through shall be foreseen as well. In these degraded conditions, the scenario becomes similar to scenario B2 (passive gates).

The following picture presents the solution proposed for this scenario.

Figure 23: Scenario B3

In this case, the estimation of the probability that a person standing on the platform moves close to the edge of the platform while a train passes at high speed is the following:

- probability of a person standing near the edge of the platform: safety fence with automatic gates is present, thus reducing the probability with respect to scenario B2, it can be assumed that only in case of people that are willing to pass beyond that clear physical obstacle (e.g. for suicide), the event may occur, and 1 out of 1,000 people may be in that location (10^{-3});

- exposure time of the person while the train is passing: 6 s per passage (at 249 km/h). Considering 16 hours of regional service per day, this means that the exposure time would be 0.01 % of total time of service (10^{-4});

- the probability of having a person near the edge of the platform during the passage of a train at high speed is the product of the above probabilities, that is 10^{-7} per run-through.

Therefore, the frequency of the accident in a year would be $2.7\ 10^{5} * 10^{-7} = 2.7\ 10^{-2}$, which corresponds to **Rare** (**F4**).

5.3.6 Scenario B4 – Restricted access to platform – half height

This scenario is similar to B1 for what concerns the tracks layout and the following mitigations are considered:

- Installation of a barrier with gates (turnstiles) before entering the platform of around 1 m high, automatically controlled so that to be opened only when a stopping train is approaching the station (marking of the safety zone same as in B1);
- technical interface of the gates with any system that is able to detect the presence (or entry) of the train at the station, either via intelligent cameras, or detectors on the tracks, or any other means (interlocking of the signalling system with the platform access gates would require relevant design, validation and safety approval process).

Due to the physical barrier always closed when HSTs pass through, it is considered that no people may be seriously exposed to the risk, except in case of intentional acts (e.g. people that want to commit suicide can trespass the gate).

In case of malfunction of the automatic gates, the gates shall be kept open and a procedure shall be foreseen not allowing to stand on the safety zone at any time while there are no trains stopping at the platform, accompanied by public announcements or audible/visual warnings reminding this requirement. A speed reduction for high speed trains passing through shall be foreseen as well. In these degraded conditions, the scenario becomes similar to scenario B1 (no fence along the platform edge).

The following picture presents the solution proposed for this scenario.

Figure 24: Scenario B4

In this case, the estimation of the probability that a person standing on the platform moves close to the edge of the platform while a train passes at high speed is the following:

- probability of a person standing near the edge of the platform: restricted access with automatic gates is present, with a probability similar to that of scenario B3; it can be then assumed that 1 out of 1,000 people may be in that location (10^{-3});
- exposure time of the person while the train is passing: 6 s per passage (at 249 km/h). Considering 16 hours of regional service per day, this means that the exposure time would be 0.01 % of total time of service (10^{-4});
- The probability of having a person near the edge of the platform during the passage of a train at high speed is the product of the above probabilities, that is 10^{-7} per run-through.

Therefore, the frequency of the accident in a year would be $2.7\ 10^{5} * 10^{-7} = 2.7\ 10^{-2}$, which corresponds to **Rare** (**F4**).

5.3.7 Scenario B5 – Safety fence on platform with active gates – full height

This scenario is similar to B3 for what concerns the tracks layout and the characteristics of the gates apart an increased height (2 m).

Due to the physical barrier always closed when HSTs pass through, it is considered that no people may be seriously exposed to the risk (the height of the gates would also prevent suicide).

In this case, the frequency of the accident can be assumed to be **Improbable** (**F5**).

In case of malfunction of the gates the same actions described for Scenario B3 have to be implemented.

5.3.8 Scenario B6 – Restricted access to platform – full height

This scenario is similar to B4 for what concerns the tracks layout and the characteristics of the barrier with gates apart an increased height (2 m).

Due to the physical barrier always closed when HSTs pass through, it is considered that no people may be seriously exposed to the risk (the height of the gates would also prevent suicide).

In this case, the frequency of the accident can be assumed to be **Improbable** (**F5**).

In case of malfunction of the gates of the barrier the same actions described for Scenario B4 have to be implemented.

6. Outcomes

6.1 Results of risk assessment

The results of the risk assessment of the scenarios defined in the previous chapter, where the frequency of the hazard evolving into an accident with potentially 1 fatality has been estimated, are reported in the following figure.

		Severity			
		S4 -Insignificant	S3 -Marginal	S2 -Critical	S1 - Catastrophic
Frequency	F1 - Frequent	Undesirable	Intolerable	Intolerable	Intolerable
	F2 - Probable	Tolerable	Undesirable	B1	Intolerable
	F3 - Occasional	Tolerable	Undesirable	B2	Intolerable
	F4 - Rare	Negligible	Tolerable	B3, B4	Undesirable
	F5 – Improbable	Negligible	Negligible	A1, B5, B6	Undesirable
	F6 - Highly Impr.	Negligible	Negligible	A2	Tolerable

Figure 25: Risk Assessment of the different scenarios

It can be seen that all scenarios of type B are in the ALARP region, except for B1 that foresees only the safety area and has naturally the highest level of risk. Scenarios B2, B3 and B4 are in the same risk class, however B3 and B4 represent better solutions from the safety point of view (lower frequency, refer to §5.3), although they are technically more complex than scenario B2 that only foresee physical barriers with no automation. B5 and B6 are in the Tolerable risk due to the provision of full height barriers.

Scenarios A1 and A2 are respectively in the Tolerable and Negligible risk class. Scenario A1 is characterized by a higher frequency than A2 as there is still the possibility of trespassing, but requires the construction of a more complex station with 4 tracks and the related switches for the movements onto the stopping tracks.

It is remarked that in all type B scenarios the physical solutions are considered to be accompanied by public announcements or audible/visual warnings.

6.2 Functional Analysis

The following table compares some possible hazardous events associated to a high speed train passing through a station with the aim to evaluate the effectiveness of the proposed solutions in preventing injuries / fatalities.

The hazardous events that have been currently identified are the following:

- Accidental fall / slip / trip;
- Voluntary act (e.g. trespassing, suicide, exhibitionism);
- Trolley / luggage movements due to air pressure;
- Ice / pieces of ballast thrown into the platform by the passing train.

Possible hazardous events linked to passing HST	Effectiveness in preventing injuries / fatalities							
	Scenario A1	Scenario A2	Scenario B1	Scenario B2	Scenario B3	Scenario B4	Scenario B5	Scenario B6
Accidental injury	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Track Trespasser	No	Yes	No	No	No	No	Yes	Yes
Trolley movement	Yes	Yes	No	Partly	Yes	Yes	Yes	Yes
Ice / piece of ballast on platform	Yes	Yes	No	Partly	Partly*	Yes	Partly*	Yes
* Depending on the design of active gates (fence or continuous elements)								

Table 9: Functional Safety Analysis

6.3 Sensitivity analysis

6.3.1 Station Overcrowding

The risk assessment made in §5.3 considers normal conditions of train operations and presence at platforms. In case of disturbances (train delays and overcrowding of platforms for any reasons), the probability of a person standing near the edge of the platform will increase for the duration of the disturbance.

In such situations, it can be assumed that the probability of the scenarios will vary as follows:

- Scenario A1 and Scenario A2: no changes due to the distance of passing tracks from the platform;
- Scenario B1: probability of a person standing near the edge of the platform increased 5 times (5 out of 10 people may be in that location, i.e. 5 10^{-1}), same exposure time. Therefore, the frequency of the accident in a year would be 2.7 10^{5} * 5 10^{-5} = 13.5, which corresponds to **Frequent** (**F1**);
- Scenario B2: probability of a person standing near the edge of the platform increased 5 times (5 out of 100 people may be in that location, i.e. 5 10^{-2}), same exposure time. Therefore, the frequency of the accident in a year would be 2.7 10^{5} * 5 10^{-6} = 1.35, which corresponds to **Probable (F2**);

- Scenario B3 and Scenario B4: probability of a person willing to pass beyond that clear physical obstacle increased 5 times (5 out of 1,000 people may be in that situation, i.e. 5 10^{-3}), same exposure time. Therefore, the frequency of the accident in a year would be 2.7 10^{5} * 5 10^{-7} = 1.3 10^{-1}, which corresponds to **Occasional (F3)**;

- Scenario B5 and Scenario B6: no changes due to the presence of full height active fences that should only open when trains stop at the station.

		Severity			
		S4 -Insignificant	S3 -Marginal	S2 -Critical	S1 - Catastrophic
Frequency	F1 - Frequent	Undesirable	Intolerable	**B1**	Intolerable
	F2 - Probable	Tolerable	Undesirable	**B2**	Intolerable
	F3 - Occasional	Tolerable	Undesirable	**B3, B4**	Intolerable
	F4 - Rare	Negligible	Tolerable	Undesirable	Undesirable
	F5 – Improbable	Negligible	Negligible	**A1, B5, B6**	Undesirable
	F6 - Highly Impr.	Negligible	Negligible	**A2**	Tolerable

Figure 26: Risk Assessment of the different scenarios – platform overcrowding

In conclusion, in these situations full height active gates would provide significant benefits in the reduction of the risk.

6.3.2 Malfunctioning of active gates / barriers

The risk assessment made in §5.3 for scenarios with active gates / barriers considers that gates / barriers are correctly working. In case of failures, the gates / barriers shall be kept open and a procedure shall be foreseen not allowing to stand on the safety zone at any time while there are no trains stopping at the platform, accompanied by public announcements or audible/visual warnings reminding this requirement. A speed reduction for high speed trains passing through shall be foreseen as well, therefore impacting also train operations.

A sensitivity analysis has been performed to evaluate which Safety Integrity Level (SIL) should be allocated to the active gates / barriers to achieve the same level of risk of the normal scenario. The following probabilities are associated to each safety level according to EN 61508 (Ref. [S.4]) in case of failure on demand, and have been taken into account in the analysis.

Safety Integrity Level (SIL)	Probability of failures
SIL1	10^{-2} · ÷ 10^{-1}
SIL2	10^{-3} · ÷ 10^{-2}

Safety Integrity Level (SIL)	Probability of failures
SIL3	$10^{-4} \div 10^{-3}$
SIL4	$10^{-5} \div 10^{-4}$

Table 10: Probabilities of failures associated to SIL

It can be assumed that the probability of the scenarios will vary as follows in case of failure of active gates / barriers:

- Scenarios B3 and B5: in case of failures, the scenario becomes similar to scenario B2 (passive gates) as the gates are open. The probability of a person willing to pass beyond that clear physical obstacle is the same as B2 multiplied by the probability of failure of the active gates / barriers:
    - If a SIL 2 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 10^{-1} * 10^{-2} = 2.7 10^{-3}, which corresponds to **Rare (F4)**,
    - If a SIL 3 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 10^{-1} * 10^{-3} = 2.7 10^{-4}, which corresponds to **Improbable (F5)**,
    - If a SIL 4 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 10^{-1} * 10^{-4} = 2.7 10^{-5}, which corresponds to **Improbable (F5)**.
- Scenario B4 and B6: in case of failures, the scenario becomes similar to scenario B1 (safety area) as the barriers are open and there are no protections on the platform except for the safety area. The probability of a person willing to pass beyond that clear physical obstacle is the same as B1 multiplied by the probability of failure of the active gates / barriers:
    - If a SIL 2 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 * 10^{-2} = 2.7 10^{-2}, which corresponds to **Rare (F4)**,
    - If a SIL 3 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 * 10^{-3} = 2.7 10^{-3}, which corresponds to **Rare (F4)**,
    - If a SIL 4 is allocated to the active gates / barriers, the frequency of the accident in a year would be 2.7 * 10^{-4} = 2.7 10^{-4}, which corresponds to **Improbable (F5)**.

The following table compares the results of the analysis above presented.

		Severity S2 -Critical			
		Normal Scenario (i.e. no failures)	**Degraded Scenario with SIL2 gates / barriers**	**Degraded Scenario with SIL3 gates / barriers**	**Degraded Scenario with SIL4 gates / barriers**
Frequency	**F1 - Frequent**	Intolerable	Intolerable	Intolerable	Intolerable
	F2 - Probable	Intolerable	Intolerable	Intolerable	Intolerable
	F3 - Occasional	Undesirable	Undesirable	Undesirable	Undesirable
	F4 - Rare	**B3, B4**	**B3, B5, B4, B6**	**B4, B6**	Undesirable
	F5 – Improbable	**B5, B6**	Tolerable	**B3, B5**	**B3, B5, B4, B6**
	F6 - Highly Impr.	Negligible	Negligible	Negligible	Negligible

Figure 27: Risk Assessment of the different scenarios – malfunctioning of active gates

As shown in the above table, to achieve the same level of risk of the normal scenario the following considerations apply:

- if half height gates / barriers are foreseen (scenario B3 and B4), they can be characterized by a SIL2, which would ensure the same level of risk as in normal scenario;
- if full height gates are foreseen (scenario B5), they can be characterized by a SIL3 so that to attain the same level of risk as in the normal scenario (which was lower than scenario B3);
- if restricted access to platform is foreseen through full height barriers (scenario B6), barriers have to the characterized by a SIL4 so that to attain the same level of risk as in the normal scenario (which was lower than scenario B4).

As anticipated, the high demanding safety requirements for full height active gates (SIL3) and barriers (SIL4) compared to the half height active gates / barriers derive from the fact that the level of risk associated to these scenarios B5 and B6 in normal conditions is lower than the one associated to the half height gates / barriers, but in degraded conditions the scenarios are similar (the gates / barriers are always open) and therefore a more demanding safety requirement is associated to scenarios B5 and B6 to achieve the same level of risk of the normal conditions.

Furthermore, these safety requirements are justified also considering that the stations will be normally not attended.

The designers will have to evaluate the most suitable design solutions for active gates / barriers both considering safety requirements and the avoidance as much as possible of their possible impact on railway operations (e.g. false alarms).

7. Conclusions

The document has presented an analysis of the risk related to the exposure of passengers standing on a platform to the aerodynamic effects of a train passing at high speed, potentially causing the person to be hit by an object, fall on the platform or down into the track, and the evaluation of different solutions to mitigate this risk, which is existing particularly at the regional stations that are currently designed with only 2 tracks and where high speed trains run through in the vicinity of the platform.

An investigation of the solutions adopted in the major high-speed lines worldwide in operation has been conducted, for comparison and substantiation of the proposed solutions.

The study has been concluded with a qualitative risk assessment of the various possible scenarios, consistently with the proposed solutions.

The safest solution is the separation of “through” tracks (for trains not stopping at the station) from loop tracks (for stopping trains), which is the most common existing solution worldwide and is foreseen for part of the RB project. In this case the installation of a fence along the “through” tracks is recommended to prevent trespassing.

For the 2-track stations that are foreseen in RB project, the minimum requirements consider to define a safety area at the platform edge, as foreseen by the RB Design Guidelines, together with procedural measures (passenger announcements and/or visual/audible warnings). It is however highlighted that this solution will not allow reducing the risk to a tolerable level. Implementation of more visible physical barriers with active access control for train boarding or even for entering the platform would significantly reduce the risk (especially in case of specific situations like overcrowding), although they would require more complex technical solutions.

The installation of proper signs regarding the risk of trespassing is recommended to make people aware of the possible consequences.

Figure 28: Trespassing Danger Sign

Figure 29: Platform Warning Signs

With specific reference to the risk of suicide, it is also highlighted that studies have been developed with the aim to evaluate how to prevent them and possible solutions are presented in the following (refer to [O.5] for further details):

- A public awareness campaign, through one or more mass media communication strategies, to alert the general population and encourage those in need of help to ask for it;
- The placement of signs to promote the accessibility of crcomisis hotlines;
- Training of station staff (or others) to identify and intervene with individuals who appear to be exhibiting risk behaviours for suicide.

Figure 30: Suicide Prevention Signs

For a final evaluation of the worthiness of the installation of active access control measures (gates on the platform, access gates to the platform) an overall cost / benefit analysis should be done, including considerations on design and procedural requirements, space constrains at the different stations, operational restrictions for passing through trains, and of course costs considerations, which are outside the scope of this analysis.

In conclusion, each station should be evaluated on a case by case basis, with support from the outcomes of this safety study, considering the feasibility of the different proposed solutions and the characteristics of each station (presence of curves, availability of station staff, reduced train speed due to layout constraints, etc.).