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Safety Distances on Platforms

Danger Zone – Safety Zone

Research Report

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CONTENTS

SAFETY ZONE 31

ABBREVIATIONS

A

AB	Implementing provision
AB-EBV	Implementing Provisions for the Railway Ordinance (SR 742.141.11)
Acela	High-speed train on the Washington – Boston line; from the English 'acceleration' and 'excellence'

B

BAV	Federal Office of Transport (FOT)

D

DB	Deutsche Bahn AG

E

EBV	Ordinance on the Construction and Operation of Railways (Railways Ordinance, SR 742.141.1)
EPFL	Ecole Polytechnique Fédérale de Lausanne

I

IC	Intercity; train made up of standard Type IV coaches, powered by a Re 460 locomotive either at the front or the rear.
ICE	Intercity Express; DB high-speed multiple-unit train
ICN	Intercity tilting train; SBB Class 500 multiple-unit train incorporating tilting technology

L

LOS	Level of service
LRP	Clearance profile

O

ORE	Office de recherche et d'essais de l'Union internationale des chemins de fer (more recently: ERRI European Rail Research Institute)

S

SBB	Swiss Federal Railways
SNCF	Société nationale des chemins de fer français
SR	Systematic collection of Swiss legislation

T

TGV	Train à grande vitesse – An SNCF high-speed train
TGV POS	TGV Paris-Ostfrankreich-Süddeutschland (Class 384000 TGV 'Paris-Eastern France-Southern Germany)
TRB	Transportation Research Board, Washington D.C.

U

UIC	Union internationale des chemins de fer – International Union of Railways

Formula terms

L_{eq}	Energy-equivalent continuous sound level [dB(A)]
P	Pressure [Pa] = [N/m^2]
U	Flow rate [km/h] or [m/s]
V	Train speed [km/h] or [m/s]

1. SUMMARY

The clearly-marked division of platforms into a danger zone and a safety zone should protect passengers from the potential risks posed by trains as they pass through stations.

1.1 Danger zone

The first statutory regulations relating to a danger zone on platforms came into force in 1984. Since then, the speed at which trains pass through stations has continued to increase. Consequently, given these high speeds, the dimensions of the danger zone, which were determined empirically and are directly dependent on train speeds, no longer seem appropriate.

Therefore, in 2003, the Federal Office of Transport decided to undertake a research project.

Studies have shown that, at low speeds, the decisive factor as regards the effects on people waiting on platforms is the size of the rail vehicles. However, where the passing speed is above 80 km per hour, the effect of the airflow is the factor which determines the extent of the hazard.

Aerodynamic research has shown that the effects of the airflow are significantly different depending on the design of the train – high-speed trains with a good aerodynamic profile (e.g. ICN tilting train), conventional passenger trains or freight trains.

The authors of this report therefore suggest that the statutory provisions should be amended so that the type of the train passing the platform is taken into account. This will reduce the existing requirements which trains with good aerodynamic profiles and passenger trains need to meet, but will increase those for freight trains.

1.2 Safety zone

The space on platforms which is available for passengers to use when moving between the platform entrance and the train or between the train and the exits or while waiting for a train has to satisfy conflicting requirements: the passenger safety as trains pass through the station on the one hand and an economic criteria on the other (the high cost of altering platforms or constructing new platforms).

Since the safety zone for passengers not only adjoins the platform's danger zone but also interacts with it, then, logically, any adjustments to the statutory regulations relating to the danger zone will also affect the safety zone.

Examining how passengers behave when proceeding as pedestrians along platforms and studying the dangers to which they are exposed makes it possible to derive safety requirements which it is proposed should be incorporated into the statutory provisions.

The considerations set out here require the dimensions specified for platforms to be taken into account. These will also be presented to the readers of this report.

2. INTRODUCTION

2.1 Background to this report

The primary aim of this report is to document what is contained in the Implementing Provisions for the Railways Ordinance (AB-EBV) as regards safety distances on platforms and to make our findings accessible to those persons who are concerned with these matters.

The first part of the report ('Danger Zone') appeared in July 2005 and formed the basis for the edition of the AB-EBV issued on 2 July 2006.

Thus, whenever this report refers to the 'existing regulations', it means the regulations which applied before July 2006 (as issued in 1984).

The report was subsequently amended to include the results of the measurements made in August and November 2006 (see Section 9.3).

The second part of the report ('Safety Zone') contains the most important records of our work on the safety zone and our consolidated considerations. As such, it highlights the topic of safety on platforms and addresses matters which are not documented in detail in the statutory provisions of the AB-EBV. This part was produced in autumn 2009 (with a supplement in spring 2011) but reflects the edition of the AB-EBV issued on 2 July 2006.

The FOT is grateful to the SBB's technical experts for their support during the various measuring tasks and for the part they played in producing and proofreading the 'Danger Zone' part.

2.2 Layout of the report

The report is structured as follows:

Introduction	Sections 1 to 3
Danger zone	Sections 4 to 11
Safety zone	Sections 12 to 18
Reference documents and Annexes	

3. TERMINOLOGY

Danger zone: The area of a platform where individuals are exposed to a risk to their physical integrity by a train passing through the station.

The width of the danger zone is measured from the track centreline.

Safety zone: The area of a platform which passengers can access and which lies outside the danger zone.

These zones can be represented in cross sectional view as follows:

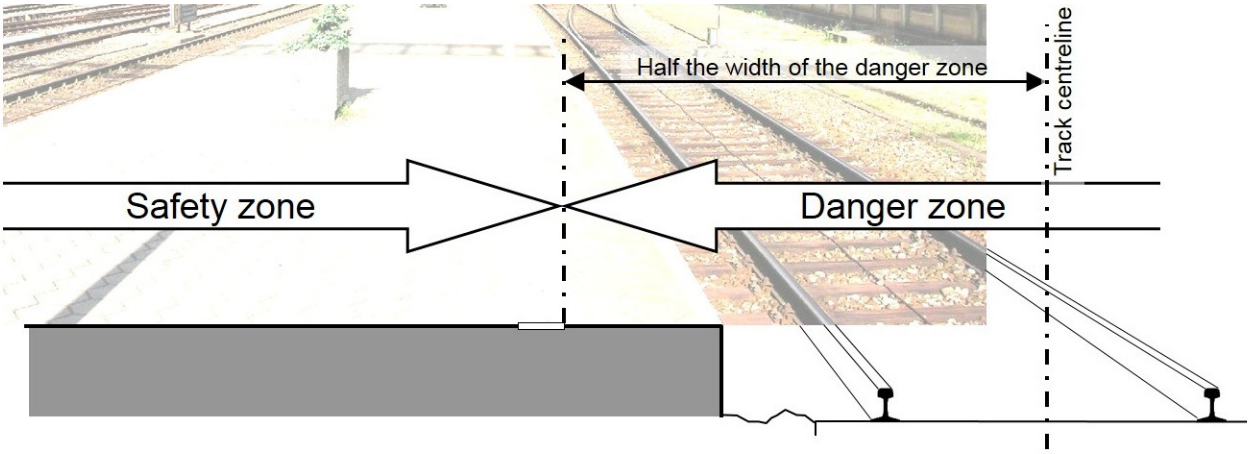

Figure 1 A cross sectional view of the safety zone and the danger zone

The boundary between the zones has been chosen vertically in accordance with the upright posture of a person.

When determining the boundary between the zones, other studies or prescriptions take the rail, the outer surface of the rail vehicle or the edge of the platform as their starting point. But these reference values can vary and may be ambiguous (the inner or outer edge of the rail, a different gap between the edge of the platform and the track depending on the height of the platform) or they can even lead to errors (in the case of a metre gauge railway, for example, on which standard gauge rail vehicles are transported or in the case of three-rail tracks). For these reasons, when determining the boundary between the zones, it is vital to measure from the track centreline.

Narrow gauge: To make the report easier to read, all track widths smaller than standard gauge (1435 mm) are referred to as 'narrow gauge'; this avoids repeating the phrase 'metre gauge and narrow gauge'.

Passenger: This term is used for pedestrians moving along or waiting on platforms.

Danger zone

4. INTRODUCTION

4.1 Subject matter

As a system for conveying passengers, railways have and need changeover places, i.e. platforms, where passengers board and alight. Consideration of changeover places in this report is restricted to publicly accessible platforms.

When considering the effects produced by moving trains, one will mainly consider those aerodynamic effects as a risk to passengers on platforms, as a train passes through a station.

The subject of this part of the research project is how to determine the danger zone on platforms alongside tracks on which trains run.

4.2 Purpose

Since the first edition in 1984, the Implementing Provisions for the Railway Ordinance (AB-EBV) have contained standard values for the size of the danger zone on platforms. The safety distances from the track are determined depending on the speed at which the trains pass through stations, up to a maximum of 160 km/h.

The continuous increase in the speeds at which trains travel past platforms, the empirically determined dimensions of the danger zone in the 1984 AB-EBV, the lack of any standardised regulations between neighbouring countries and the absence of such regulations in other countries – and hence of any common reference base – prompted the Federal Office of Transport (FOT) to conduct a research project into safety distances on platforms. The lessons learned from this research are intended to facilitate the revision of the relevant AB-EBV.

4.3 Scope of the study and area to which it applies

The study included standard gauge railways with a clearance profile in accordance with AB-EBV (further elements in accordance with the UIC clearance profile) at all passing speeds. Narrow gauge railways were included as appropriate.

Thus, the area to which the study applies covers standard gauge railways and, by analogy, narrow gauge railways, taking the different clearance profiles into account; it is expressly limited to those areas alongside the tracks which passengers are able to access freely, i.e. the platforms.

5. REFERENCE DOCUMENTS

This study is based on and essentially refers to the following works:

[1] DB Systemtechnik, 2004, Studie zu aerodynamischen Lasten am Bahnsteig, München (commissioned by the FOT).

[2] EPFL, Laboratoire de mécanique des fluides environnementale, 2005, Questions relatives au souffle provoqué par le passage d’un train, Lausanne. Report to the FOT.

[3] DB Systemtechnik, 2006, Prüfbericht. Messung der zuginduzierten Strömungsgeschwindigkeiten am Bahnsteig Kiesen an der Strecke Bern – Thun. München (commissioned by the FOT).

Further references are given in the list of reference documents.

6. PROCEDURE AND METHODOLOGY

The study was carried out by the FOT (the Construction Department until 2005 and the Safety Department from 2006) with assistance from SBB's technical experts (Infrastructure). It was handled according to the following considerations:

1. Determining permissible and impermissible risks;
2. Determining the study parameters;
3. Study and discussion of parameters and their effects;
4. Summary of the parameters and their main significant effects.

Of the two actors in the study – the train and the passenger – the first is completely driven and therefore under control, whereas the behaviour of the second is more random. Herein lies the study's main limitation: it would, therefore, be presumptuous to expect absolute precision when quantifying the implications which the study considered. This limitation also leads to certain second-degree parameters being excluded right from the outset.

7. DETERMINING PERMISSIBLE AND IMPERMISSIBLE RISKS

The present purpose is to safeguard the physical integrity of people.

Impermissible risks are death as well as external and internal injuries resulting in either temporary or permanent disability. Anxiety is not regarded as an injury. However, the consequences of anxiety need to be discussed if they might give rise to an impermissible risk.

Anything which might adversely affect people's feelings of comfort or well-being is acceptable within the context of this study, provided it does not lead directly to a hazardous situation or to an impermissible risk. The study assumes that any situation which is uncomfortable but not dangerous is permissible. Improving passenger comfort does not, in this instance, fall within the area of responsibility of the regulatory authority; rather, it is the job of the railway companies.

8. DETERMINING THE STUDY PARAMETERS

The authors tried to determine all the parameters which could influence the danger zone. With some of the parameters, there were factors which either amplified or attenuated the effect. These factors are not expressly enumerated but are discussed as part of the examination of each individual parameter. Combinations of two or more parameters are also taken into account when examining the individual parameters.

The following parameters were taken into account in this study:

a. Clearance profile
b. Contact
c. Aerodynamics
d. The effect of surprise
e. Noise level
f. Dust
g. Passenger behaviour on the platform
h. Local circumstances

9. STUDY AND DISCUSSION OF PARAMETERS AND CONSEQUENCES

9.1 Clearance profile

The clearance profile defines the area around the permanent way which has to be kept free of fixed installations so as to ensure safe railway operations. It circumscribes the area inside the structure gauge plus the safety areas (Art. 18 EBV).

In relation to individuals, the main purpose of the clearance profile is to ensure the safety of railway employees. The only other people who directly benefit from the protection afforded by the clearance profile are the train passengers. They are protected by virtue of the external area at window height being free of obstacles.

At a half width of 2.50 m from the track centreline, the clearance profile on standard gauge railways does not meet the safety distance requirements on platforms. We do not intend, therefore, to include the clearance profile in this study of safety distances on platforms.

It must, however, be stated that, subject to other requirements being met, the clearance profile represents the lower dimensional limit (minimum dimension) for every fixed installation, platforms included.

9.2 Contact

Contact is defined as any physical contact between the rail vehicle and the passenger on the platform. Contact must be prevented under all circumstances. In most cases, even if the rail vehicle is travelling at low speed, it results in serious or even fatal injuries to the person standing on the platform (risk to physical integrity).

In order to study the 'Contact' parameter it is necessary to:

- Determine the decisive position of the rail vehicle,
- Determine the decisive position of the person,
- Deduce the ideal location for the boundary between the safety zone and the danger zone (zonal boundary).

<u>The decisive position of the rail vehicle</u>

In addition to the vehicle's static position, excess widths due to the following elements should be taken into account:

a) Open doors and footplates: their limit line is determined by the Implementing Provision to Art. 47 and Implementing Provision 47.2 of the Railways Ordinance, i.e. to 0.20 m beyond the reference line in the case of standard gauge. This results in a limit line of 1,645 mm + 200 mm = 1,845 mm from the track centreline.

b) Poorly tied-down loads (flapping tarpaulins in particular): it is difficult to specify the limit line in such cases. However, a precautionary estimate of between 400 and 500 mm would be plausible and appropriate. In addition to the load dimension of 1,565 mm, this results in a limit line of between 1,965 mm and 2,065 mm from the track centreline.

c) Shipments with an extra-wide load dimension: these exhibit a static width which can extend to the fixed installation boundary line of 1,900 mm for standard gauge railways.[1] The additional variations due to quasi-static transverse inclination plus the sum of various random displacements can, according to UIC Leaflet 505-4, reach a total of approximate 200 mm at a height of 2.5 m above the upper surface of the rail.

For the standard cases a) and c), this produces a decisive position of the rail vehicle with a limit line of between 1.85 and 1.90 m from the track centreline.

In order to protect passengers on platforms, the exceptional case b) needs also to be taken into account. This is done by taking an average limit line figure of 2.0 m from the track centreline.

Curve extensions for small curve radii (R < 250 m) are not taken into account for standard gauge railways. This is because no platform should be constructed with a curve radius of less than 250 m. The extension for radii above 250 m is already incorporated in the determination of the clearance profile.

However, the curve extension is not included in the clearance profile for narrow gauge railways. It must, therefore, always be added in every instance.

Decisive position of the individual

The fundamental assumption to apply is that a person must not set foot across the boundary between the safety zone and the danger zone in the direction of the platform edge; this is something which frequently happens in practice. The assumption implies an incursion into the zonal boundary by the upper body and any luggage carried.

In order to determine a person's decisive position, both the width of the person's feet and the person's clearance profile need to be known. As regards the width of the feet position, mean values taken from specialist medical references (Viel 2000) were used; and the Swiss Standard SN 640 201 (VSS 1992) applies to a person's clearance profile. Under normal circumstances, what counts as a reasonable clearance profile of an individual is the basic dimension of a pedestrian carrying luggage and holding an umbrella or a person in a wheelchair, i.e. a width 0.80 m. As regards the exceptional case b), a width of 0.60 m for a pedestrian without luggage was also taken into account.

From this, it follows that the clearance profile of a person with luggage theoretically projects 0.23 m into the danger zone and that of a person without luggage projects 0.13 m.

Given the fact the person is moving, an additional allowance of 0.10 m must be made for movement according to Swiss Standard SN 640 201.

This results in the decisive position shown below for a person who is moving.

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[1] Examples: Leopard 2 tank with a width of 3.70 m; pre-fabricated components for modular design hotels with a width of up to 3.80 m.

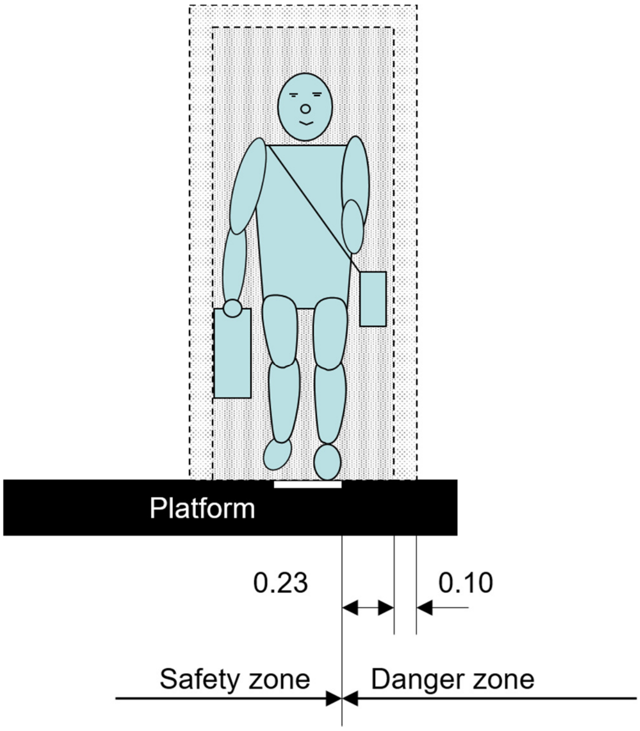

Figure 2 *Decisive position of a person moving along the boundary between the safety zone and the danger zone*

Ideal position of the zonal boundary

In normal circumstances, the distance from the zonal boundary to the track centreline, i.e. (1.85 m to 1.90 m) + 0.33 m = 2.18 m to 2.23 m.

The exceptional case b) takes into account the clearance profile of an individual without luggage. This is done on the assumption that, as regards those individuals with luggage, it is only their luggage which will come into contact with the rail vehicle and that this will not have serious consequences for the individual. This produces a safety distance of 2.00 m + 0.23 m = 2.23 m.

At present, the minimum width for the danger zone from the track centreline is **2.20 m**. It would therefore seem appropriate to use this value for the 'Contact' parameter.

It should be noted that, in the circumstances mentioned above, this figure was determined without any safety supplement (see Swiss Standard SN 640 201). The figure only applies to an instance involving an individual and a rail vehicle travelling at low speed. At higher speeds, other factors such as aerodynamic effects play a more important part (see Section 9.3 ff).

In addition to these factors, pragmatic consideration of the situation pertaining on straight platforms shows that the minimum dimension of 2.20 m is just sufficient to prevent an individual standing on the extreme edge of the safety line with outstretched arm from coming into contact with a slow-moving train.

9.3 **Aerodynamics**

Every passenger has experienced the airflow effect produced on the platform by a train passing at speed. However, so far, there has been no thorough study of this airflow effect. Although there have been several studies into the effects produced by high-speed trains (TGV, Acela in FRA 2003), they are mainly concerned with demonstrating that, compared with the existing rolling stock, new rolling stock does not make working conditions in tunnels any worse. No studies have, however, been carried out of passengers on platforms past which traditional trains travel at traditional speeds. The results of the study carried out by DB at the beginning of the 1990s (measurements on full-size dummies on platforms) could not be found within the company.

This was the reason why the FOT commissioned DB Systems Engineering's Aerodynamics Measurements Department, based in Munich (Germany), to conduct a short study (DB Systems Engineering, 2004) which, using numerous measurements, investigated the airflow effects produced by different types of trains and analysed them with a view to producing a research report.

The research report based on DB Systems Engineering's study served as the basis for this research report.

The FOT made a qualitative estimate in August 2006 during the test run measurements of the TGV POS between Solothurn and Biel (passing speed 175 km/h).

A second series of measurements made by DB Systems Engineering in 2006 on behalf of the FOT exploited synergies from test runs with a test freight train which travelled between Bern and Thun in November 2006 at a speed of 132 km/h.

9.3.1 Theoretical and experimental documents

For a better understanding of the aerodynamic phenomena, the most important theoretical and experimental documents from the 2004 study by DB Systems Engineering are quoted below. The study divided the results into four train categories: ICE trains, passenger trains, regional trains and freight trains.

An extract from the study:

The passage of a train exerts aerodynamic forces on a stationary observer, brought about by rapid changes in pressure and airflows. The following aerodynamic effects are illustrated diagrammatically in Figure 3. They can be sub-divided into the pressure waves from the lead vehicle (bow wave) and the end vehicle (wake), plus the train-induced air flows in the boundary layer of the train as it passes and in the slipstream (comparable with a ship's wake) behind the train.

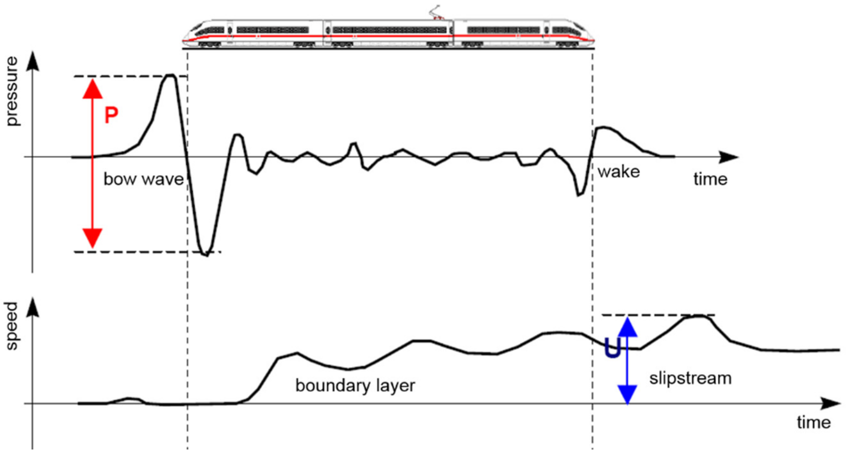

Figure 3 *Idealised representation of the pressure pattern and the train-induced air-speeds as a train passes a platform.*

- Pressure changes in the bow wave and the wake

As it moves, the train displaces the static ambient air, producing what is known as the bow wave. The stationary observer feels a pressure surge, already noticeable a few metres ahead of the front of the train. The amplitude of the bow wave essentially depends on the shape of the front of the train and on the square of its speed.

The pressure wave produced is a brief alternation between an increase and a fall in pressure. As the distance from the train increases, the amplitude of the bow wave drops rapidly. When taking measurements, the amplitude of the bow wave, i.e. the difference P between peak overpressure and peak underpressure, is determined as the characteristic property of the lead vehicle. The amplitude of the wake is always less than that of the bow wave.

- Air flow effects caused by the passage of a train

What is known as the air flow boundary layer is produced by the effects of friction on the outer skin of the train. The physical expression of this boundary layer is that the air in the immediate vicinity of the train is moved along with the train. As a consequence, the air speeds on the platform increase in intensity as the train passes by. With some trains, the maximum velocity U is only reached in the subsequent air flow pattern once the rear end of the train has passed by (the train's 'wake', cf. Figure 3).

The quality of a rail vehicle, or the aerodynamic load on a platform, is expressed in measurement terms by the maximum air speed during the passage of a train. The measurement reading depends on the train's speed, the 'roughness' of the rail vehicles, the sequence of those vehicles in the train composition and the shape of the end vehicle. In this context, roughness includes the depth of the gap between rail vehicles, the distance between them and the extent to which laden vehicles alternate with unladen vehicles. Train compositions made up of different types of rail vehicle or those with deep gaps between the rail vehicles such as car transporter freight trains are aerodynamically less than ideal, whereas high-speed rail vehicles of smooth design are aerodynamically ideal.

End of quotation.

9.3.2 Danger threshold

Any consideration of the dangers posed by aerodynamic effects only makes sense if the danger threshold has been specified.

The values for the pressure wave P remain constantly below 1,000 N/m^2 (1 N/m^2 = 1 Pa); at 3.00 m from the track centreline, a passenger train travelling at a speed of 200 km/h causes a maximum pressure of 780 N/m^2. Other types of trains (an ICE at 200 km/h, freight trains at 100 km/h) generate significantly weaker pressure waves. The maximum values are, therefore, below the initial value of 3,000 N/m^2, at which discomfort begins to be felt, as demonstrated by the European Rail Research Institute in its consideration of Question C 149 (ORE 1985). This value also lies below the danger values.

From this, it can be concluded that the pressure wave is not dangerous. Its effect will, therefore, not be considered further in this study.

As regards determining a permissible maximum figure for the air flow (danger threshold), the study has taken its lead from the Beaufort Scale and has specified a figure of **U = 50 km/h** (13.9 m/s).

Wind strength Beaufort	Designation	Wind speed km/h	Wind speed *m/s*	Effect on land
0	Calm	<1	*<0.3*	No air movement; smoke rises vertically.
1	Light air	1 - 5	*0.3 - 1.4*	Barely noticeable; smoke drifts gently away.
2	Light breeze	6 - 11	*1.7 - 3.1*	Leaves rustle; wind felt on face.
3	Gentle breeze	12 - 19	*3.3 - 5.3*	Leaves and small twigs in constant motion; light flags extended.
4	Moderate breeze	20 - 28	*5.6 - 7.8*	Small branches move; raises dust and loose paper.
5	Fresh breeze	29 -38	*8.1 - 10.6*	Larger twigs and trees in motion; wind clearly audible.
6	Strong breeze	39 - 49	*10.8 - 13.6*	Large branches in motion. Umbrellas difficult to handle. Audible whistling heard in telegraph wires. Walking becomes unsteady.
7	Near gale	50 - 61	*13.9 - 16.9*	Trees sway; resistance felt when walking against the wind.
8	Fresh gale	62 - 74	*17.2 - 20.6*	Large trees in motion; window shutters are opened; twigs break off from trees; considerable inconvenience when walking.
9	Strong gale	75 - 88	*20.8 - 24.4*	Tiles and chimney pots lifted off roofs.
10	Storm	89 - 102	*24.7 - 28.3*	Trees are uprooted; tree trunks break off; major damage to houses.
11	Violent storm	103 - 117	*28.6 - 32.5*	Violent gusts; severe storm damage; severe damage to woodlands; roofs ripped off; thick walls suffer damage; very rare inland.
12	Hurricane	>118	*>32.8*	Most serious storm damage and destruction.

Figure 4 Beaufort Scale

This threshold was also confirmed by information sent to the FOT by the Laboratoire de mécanique des fluides environnementale at the Federal Institute of Technology in Lausanne (EPFL 2005). It also explained that the danger threshold beyond which a person can be thrown to the ground is exclusively based on mechanical and aerodynamic factors (frontal area depending on the body shape exposed to the wind, the person's weight and stance). Generally speaking, this threshold lies in the order of magnitude of 15 m/s (approximately 54 km/h).

9.3.3 Analysis of the results

The studies by DB Systems Engineering in 2004 and 2006 produced pressure values P and air flow speeds U (see Figure 3) for four different types of train (a well-profiled ICE train, long-distance passenger trains, regional and freight trains) at specified passing speeds and specified distances. However, the results were limited to certain speeds specified in advance for the trials – or they were reduced to those speeds for the purpose of the calculations – and to the fixed distances corresponding to the equipment used in the trials. In order to achieve the desired aim of this study, graphs are needed to illustrate the distance from the track centreline as a function of the train's passing speed for a specified air flow danger threshold.

The values in these graphs were ascertained in two stages:

1. Assuming a linear relationship between the speed at which the train was travelling and the wind speed, for every given distance a point was determined at which the train's speed corresponded to the wind speed danger threshold.
2. The graph showing the distance as a function of the train's passing speed is a second-order polynomial and was ascertained for each type of train by means of a Lagrange interpolation. An additional reference point for the train's outer skin was introduced for calculating the Lagrange polynomial. This was taken to be at a distance of 1.60 m from the track centreline where the wind speed and train's passing speed were identical.

This resulted in the graph shown below:

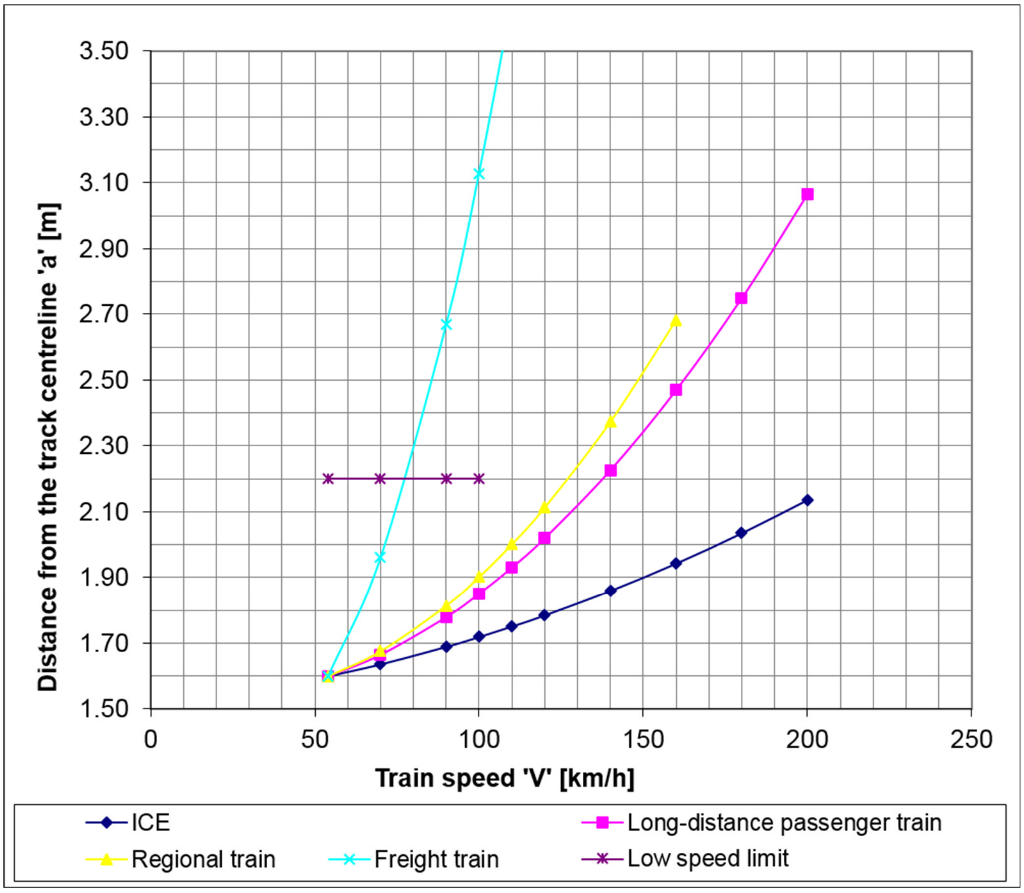

Figure 5 Curve a = f(V) for danger threshold U = 50 km/h.

The results are discussed in the conclusion in Section 10.

Examples of different types of trains are given in **Annex 2**.

9.3.4 A comparison between the two studies

The study by DB Systems Engineering in 2004 was based on various measurement series which were conducted in Germany mostly alongside a platform 24 cm above the upper surface of the rail. In contrast, the study by DB Systems Engineering in 2006 was carried out in Switzerland on platforms 55 cm above the upper surface of the rail. In both cases, the air flow speed was measured as a DB

ICE passed by; it was found that there was good correspondence between the various measurement series.

In all cases (trains with a good or less good profile), the highest air flow measurement depended on the shape of the upper elements of the train. This provided an explanation for the values obtained for freight trains and also for the higher readings after a train had passed by (slipstream) or as a coupled pair of ICN units with a good profile passed by (cf. the Figures in **Annex 2**).

Taking the characteristic case of trains with a good profile (ICE, but also IC) and from the comparison of the two studies, it can be deduced that the lower-lying elements – in the region of the bogies – are the decisive factor as regards the air flow measured on the platforms.

9.4 **Effect of surprise**

9.4.1 Cause

Passengers on platforms only become aware at a very late stage that a train is just about to pass by; this is as true of a quiet passenger train or of a train which cannot be heard because of other noises in the immediate surroundings as it is of a train approaching either at high speed (an intercity tilting train, for example) or at low speed (shunting manoeuvre, coaches being uncoupled).

9.4.2 Reaction

Most people need approximately two tenths of a second (0.2 s) to react to a stimulus.

However, most people, when taken by surprise, react by freezing and only relax once they are able to categorise the change which has occurred to their surroundings. This reaction gap may be short-lived or last for several seconds. If the reaction to surprise is fear or anxiety, this may manifest itself in flight. This also explains why, if rather more rarely, people drop items they are carrying or even, in exceptional cases, lose consciousness. In moments of great fear or anxiety, irrational reactions have been observed.

9.4.3 Conclusion

As regards this study, the reaction to all those situations which may be induced by surprise should mostly be assessed as favourable. People who have been taken by surprise do not tend to move towards the source of the danger; an irrational fearful reaction only seems to set in if the occurrence which triggers such a reaction is very intense or lasts for a lengthy time.

The effect of surprise is not, therefore, a material factor when defining the danger zone.

9.5 **Noise level**

On a platform immediately adjacent to the tracks, the sound pressure level L_{eq} reaches approximately 120 dB (A) for a train (ICN) with a good profile travelling at 160 km/h, for a standard passenger train travelling at 140 km/h or a freight train travelling at 90 km/h.

The noise of the train has, simultaneously, both a beneficial effect and an unfavourable effect.

9.5.1 Beneficial effect

The noise of an approaching train has a beneficial effect because it announces some seconds in advance that it is arriving alongside the platform or passing by.

As the train passes by the platform, its noise makes passengers feel uncomfortable, making them move away from the platform edge.

With the latest trains (for example, those fitted with plastic brake shoe inserts), these beneficial effects are less noticeable or, in the case of quiet high-speed trains, have disappeared completely. For example, assuming local ambient noise levels, an ICN train travelling at 200 km/h (55.6 m/s) can only be heard half a second before it reaches the platform.

9.5.2 Unfavourable effect

Although the noise produced by a train is considerable, neither the volume nor its duration attain values which could be harmful to the human ear.

Looked at in this way, noise is not a material factor when defining the danger zone.

9.6 Dust

The air flow from the passing train stirs up dust, particularly in dry weather. The dust contains mineral and vegetable elements as well as dust from the brake pads. The dust clouds are formed in proportion to the aerodynamic effects. Under the usual conditions experienced in Switzerland, the dust clouds are present for only a short time and their negative effects are therefore limited.

For these reasons, it seemed disproportionate to define or extend the danger zone with regard to this phenomenon; neither was it necessary to examine the subject in any greater depth. The risk from dust is regarded as acceptable.

9.7 Behaviour of people on the platform

It is impossible to control the way people behave. Only structural measures in place on a platform (for example, barriers or doors fitted with mechanical opening devices) can securely prevent every people from accessing the danger zone. Such measures, however, seemed disproportionate. In certain situations, rail passengers can and should be expected to assume some personal responsibility. The safety line is an appropriate and adequate way of making the boundary between the safety zone and the danger zone visible.

However, because of the space required, the decisive position for a person on the platform cannot be precisely determined in respect of the boundary between the zones. This imprecision can be managed by ensuring that the safety line has a minimum width (currently 20 cm and subsequently 30 cm for tactile-visual safety lines) and is painted on in the safety zone.

9.8 Local circumstances

Special local circumstances can heighten the effect of certain phenomena. These may be obstacles which reflect the air blast of the wind, leading to an individual or an object being directly pushed against the train which initially produced this flow. This will be the case in particular in stations and halts in cuttings and tunnels.

Because these are one-off situations, it is not possible here to discuss their individual features; each should be examined on a case-by-case basis. It can, however, be stated that such cases will require additional protective measures.

10. SUMMARY

After examining the various parameters used for this study, it is clear that train-induced air flow is the main factor when it comes to defining the width of the danger zone on platforms. At low speeds, however, it is the outline of the rail vehicles (the clearance profile) which is the decisive aspect. The aerodynamic flow is dependent on the type and speed of the train.

There is no great difference between the case of a 'regional train' and a 'long-distance passenger train'. It is suggested that these two cases be shown by a single envelope.

So as to simplify the design of the safety markings, the safety distances to be applied should be restricted to a few characteristic values covering all the danger curves.

As far as 'freight trains' are concerned, the size of the danger zone would greatly increase if one were to proceed in accordance with the measurement findings. In this case, however, the acoustic stimulus and the bow wave automatically result in people instinctively drawing further back from the edge of the platform. It is therefore proposed that the theoretical dimension of the safety zone be slightly reduced in this case. Speeds above 120 km/h are ruled out for trains of this type.

As regards trains with good aerodynamic profiles, the decisive factor is no longer the effect of the wind but passenger behaviour on the platforms. Therefore, the appropriate envelope should be moved towards the safe side.

The envelopes shown below (drawn with a thick line) are proposed:

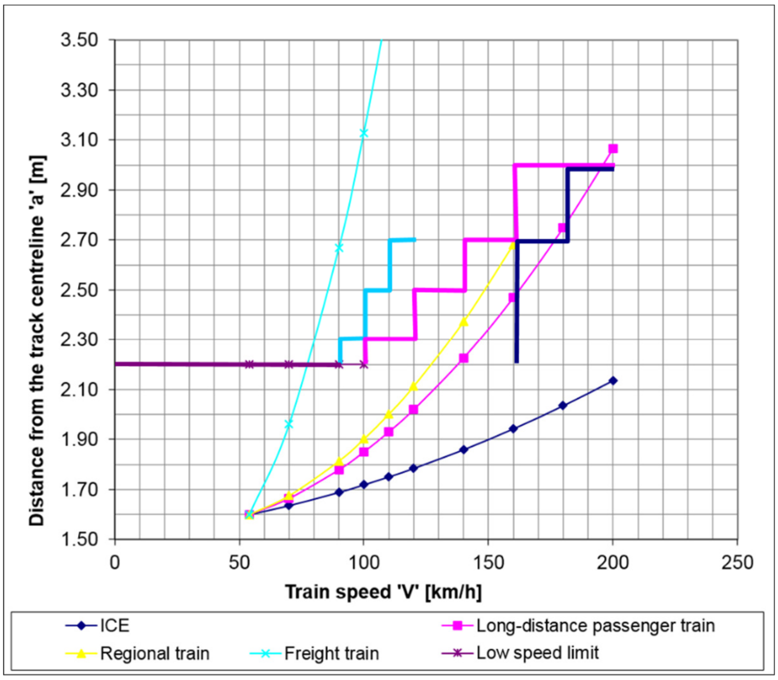

Figure 6 Danger curve envelopes

In every case, the markings (safety lines) are the only way in which the boundary between the safety zone and the danger zone can be identified. Passengers waiting on platforms must therefore be made aware of the danger and they must understand what the markings mean. This means that passengers must be instructed in an appropriate manner. The existing warning board, illustrated below, (Figure 7) is one element of any such instruction.

Figure 7 An example of information for passengers

- *Higher speeds (> 160 km/h)*

With trains travelling at higher speeds (> 160 km/h), the interaction of two negative influences needs to be taken into account. Because these high-speed trains run quietly, there is no early warning; at the same time, because of their high speed, passengers only have a short time to stand back. At these speeds, trains approach at over 45 m/s while people on platforms move at approx. 1 m/s. Their reaction time should also be taken into account.

Let us consider the following practical example: an ICN travelling at 180 km/h (50 m/s). The train driver notices a person standing partly in the danger zone.

- The train driver's reaction time: 0.5 s
- Warning (acoustic horn UIC): 1 s
- Passenger's reaction time: 0.5 s
- Time for taking evasive action: 1 s
- Total: 3 s, i.e. a distance of 150 m for the train.

In our experience, it is impossible to identify the precise position of an individual on the platform from a distance of more than 150 m.

This is also an ideal scenario, i.e. one in which the passenger can be given advance warning. With today's silent passenger trains, passengers waiting on platforms only become aware of an arriving train at the very last moment – only 0.5 to 1.0 seconds beforehand – depending on the noise level and the train's speed. This is why special measures need to be taken if speeds are in excess of 160 km/h. At speeds of more than 200 km/h, it seems logical that any potential contact between the people on the platform and the train must be prevented.

- *Existing regulations*

On the one hand, the existing regulations are too conservative in relation to passenger trains travelling at over 125 km/h and, on the other hand, they are insufficiently rigorous as regards the dangers posed by freight trains. This is why the existing regulations need to be adjusted. **Annex 1** compares the existing regulations (as at 1984) with the results of this study.

- *Other regulations*

Annex 1 also compares the existing regulations with the provisions which apply in France and Germany (as at 2005).

11. CONCLUSION

This study into the main parameters for defining the danger zone on platforms shows that the aerodynamic effects are predominant. These effects differ depending on the type of train. As regards trains travelling at higher speeds, it is the behaviour of the passengers on the platforms which is the determining factor.

11.1 Proposal for standard gauge railways

The aim of the study was to review the provisions to Article 21, paragraph 2 (AB 21.2) as part of the revision of the AB-EBV. Based on the results of the study, we propose the following changes:

First, the zones into which platforms are divided need to be defined precisely:

1 Definition

In order to protect people on platforms from moving trains, a distinction is made between the following zones:

- Danger zone
- Safety zone

The following text is proposed for the danger zone:

2 Danger zone

21 The danger zone is defined in terms of its distance from the track centreline, taking the speed at which trains pass through the station and local circumstances into account.

22 Generally speaking, the danger zone is defined as follows:

Train's passing speed (v) [km/h]			Minimum distance from the track centreline [m]
V_{max} freight trains (usually V_A[1])	V_{max} long-distance passenger trains (usually V_R[1])	V_{max} trains with a good aerodynamic profile (V_N[1])	
0 – 90	0 – 100	(0 – 160 not a determining factor)	2,20
91 – 100	101 – 120		2,30
101 – 110	121 – 140		2,50
111 – 120	141 – 160	161 – 180	2,70
(See Point 23)	161 – 200	181 – 200	3,00

Passing through stations with platforms which can be freely accessed by passengers at v > 200 km/h is not permissible.

23 Particular features

Where the danger is due to reflected wind pressure, additional protective measures should be taken and the dimensions of the danger zone should be increased.

Because of the aerodynamic characteristics of freight trains travelling at more than 120 km/h, a review should be undertaken as to whether the danger zone as specified by Point 22 is sufficient or whether it should be increased.

In addition, special measures need to be taken for higher speeds.

3 Safety zone

33 To guard against the effects of surprise when trains are travelling at speeds of between 161 and 200 km/h, special protective measures should be taken as set out in the FOT Directive ‘Protecting Passengers on Platforms at Train Passing Speeds of more than 160 km/h’ issued on 2 July 2006.

11.2 Proposal for narrow gauge railways

As regards narrow gauge railways, we propose that essentially the same regulations as for standard gauge railways should be applied; but, in addition, the differences in the clearance profile should be taken into account:

1 Implementing provision 21.2 'Standard gauge' is applicable to metre gauge, taking Points 2 and 3 below into account.

2 Danger zone

Dimensions should be adjusted as follows:

21 The distance should be increased by the curve extension in accordance with Art. 18 Leaflet 13 M.

22 Depending on the boundary line, distances can be reduced as follows:

- Metre gauge A	Reduction of 0.20 m
- Metre gauge B (laden transporter wagon/carrier truck)	
- between 0 and 40 km/h	Reduction of 0.20 m
- V > 40 km/h	No reduction
- Metre gauge C	Reduction of 0.40 m

11.3 Transitional provisions

Compared with the safety distances which apply at present to passenger trains, the new safety distances should be reduced and those for freight trains increased. This has consequences for existing stations. To allow for this, the FOT issued a Guideline entitled 'Transitional provisions for configuring the safety zone on existing facilities' on 2 July 2006.

The danger zone is, in contrast, clearly defined. Its width is solely dependent on the speed and the type of train. It should not, therefore, be changed by the transitional provisions.

Safety zone

12. INTRODUCTION

12.1 The subject matter

The safety zone is an area where passengers can wait without being exposed to dangerous risks of interaction with the train – as discussed in the first part of this study.

This part of the research project describes the parameters for defining the safety zone on platforms alongside tracks on which trains run.

12.2 The purpose

Following the clear division of platforms into a danger zone and a safety zone, made in the first part of this study, together with its more detailed consideration of the danger zone, we now turn to the reference documents for the safety zone.

The first edition of the Implementing Provisions for the Railway Ordinance (AB-EBV) in 1984 only contained an indirect definition of the safety zone: it was referred to as the distance to be kept from obstacles but did not at the same time consider the possible dimensions of the danger zone.

So far, the regulations have not included any mention of the capacity and the dimensions of the safety zone. In view of increasing overcrowding on platforms and the fact that a great deal of building activity has left little additional space available, these topics should be covered in the regulations. Set out below are the FOT's findings regarding the safety zone. They will assist with the revision of the AB-EBV which is to take place simultaneously with the revision of the provisions relating to the danger zone.

12.3 Scope of application

The study includes within its scope all the railways in Switzerland. It covers the country's population today and its structural and sociological make-up. Any rarely occurring extreme values compared with the normal distribution of population characteristics will not be investigated.

The scope of the study's application is expressly limited to those areas alongside the tracks which passengers can access freely, i.e. the platforms.

13. REFERENCE DOCUMENTS

This study is essentially based on numerous examples taken from practical experience and concisely described in this report and on the documents mentioned in the list of reference documents.

14. THE NEED TO DEFINE PLATFORM DIMENSIONS

The number of people present on a platform can differ hugely depending on the location – a major interchange station or a stop in a sparsely populated area.

The platform dimensions must satisfy several requirements, of which the main criteria are:

1. The number of people present
2. Cost-effectiveness including the following subordinate criteria:
    a. The useful service life of the structure;
    b. Construction costs.

Since constructing platforms is very costly – usually because the surrounding area is densely built-up and difficult to adapt (residential urban area, an agglomeration of tracks) – platforms are normally designed for a minimum service life of 50 years. As a result, they are very difficult to adapt in line with changing requirements, i.e. an increase in the numbers of passengers using the platform.

It is therefore crucial that their dimensions should be capable of accepting the maximum number of passengers expected over their entire useful service life. This requirement is expressed as follows:

> The safety zone should be defined on the basis of the number of passengers who might be expected on the platform in the foreseeable long term.

Their dimensions are planned in the knowledge that it is difficult to realistically forecast the number of passengers that might be expected over the useful service life of the platform.

15. DEFINING FEATURE OF THE SYSTEM

Railway station platforms have a distinctive feature which must be taken into account when calculating the dimensions of the area (denoted the 'safety zone' in this study) which can be used by passengers: in contrast to generally examined cases of pedestrian flows, where fixed obstacles at the sides frequently limit the area which can be accessed, the safety zone boundary on the track-side edge of railway station platforms is only a virtual boundary (the safety line) and can easily be crossed.

On railway station platforms, the system's physical boundary (the platform edge) is not the same as the boundary of the area which can be safely accessed by passengers (the safety line).

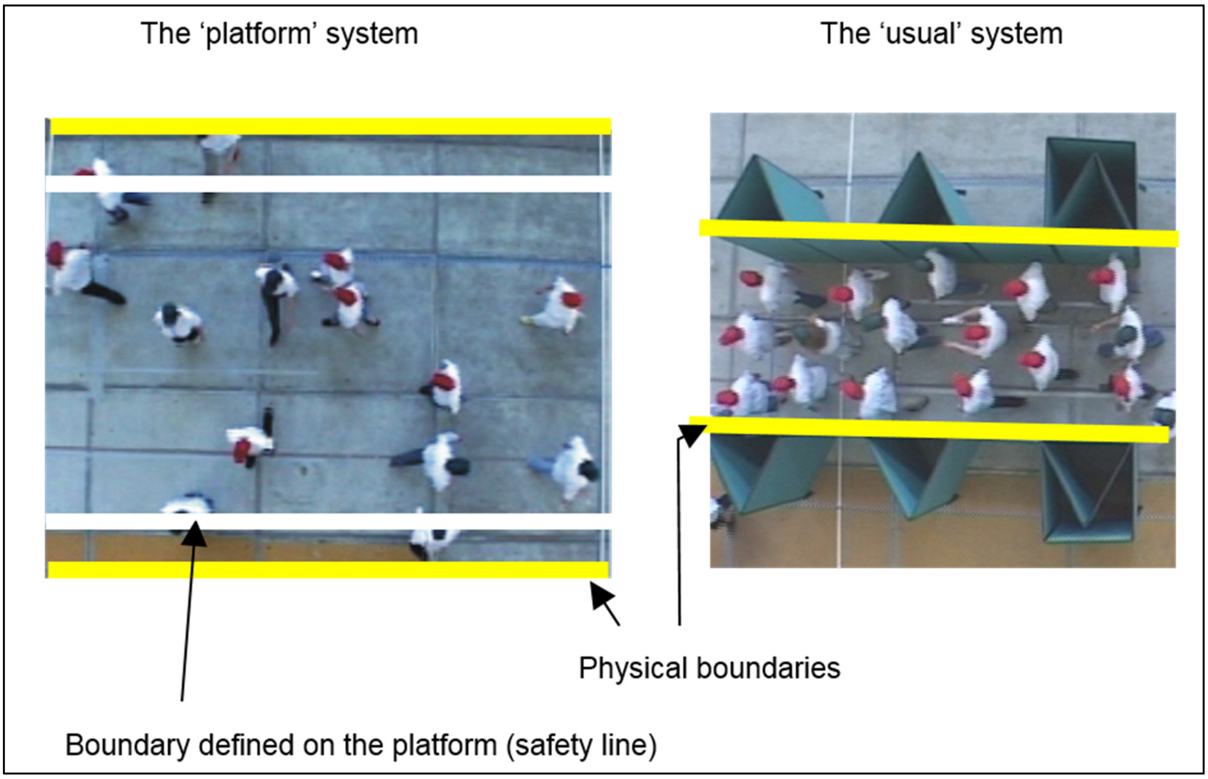

Figure 8 Illustration of different boundaries depending on system

In the case of a platform, it is essential that the system's 'soft' boundary be taken into account.

Because the boundary is not absolute, account must be taken of it being crossed in the following circumstances:

1. People overtaking each other at a narrow point;
2. People passing each other in opposite directions at a narrow point;
3. An increase in passenger density in the safety zone.

The safety line will also, of course, be crossed when

4. Boarding and alighting when the train stops.

Because this study is concerned with protecting passengers from moving trains, this latter point will not be discussed further.

16. MINIMUM DIMENSIONS

16.1 General

In those areas of platforms which passengers use less frequently and, in particular, at small stations, the dimensional criteria stated in Section 14 would result in safety zone dimensions which would not satisfy the minimum safety requirements for platforms, especially when passengers were passing each other in opposite directions or overtaking each other.

Minimum dimensions must therefore be specified for the safety zone.

For any given length of train, the length of the platform has, as a general rule, either no or only a little bearing on the platform's capacity. In this case, it is usually only the lateral dimension which is the decisive factor. The minimum dimensions under discussion are initially restricted, therefore, to a single dimension: the width.

16.2 The space required by passengers

This topic is covered in many publications (see, for example, Weidmann (1993) and its bibliography). This study makes use of its central supporting conclusions.

Swiss Standard SN 640 201 (VSS 1992) specifies the clearance profile for pedestrians as illustrated below, taking account of:

- a basic dimension with or without luggage,
- an allowance for movement and
- a safety supplement

.

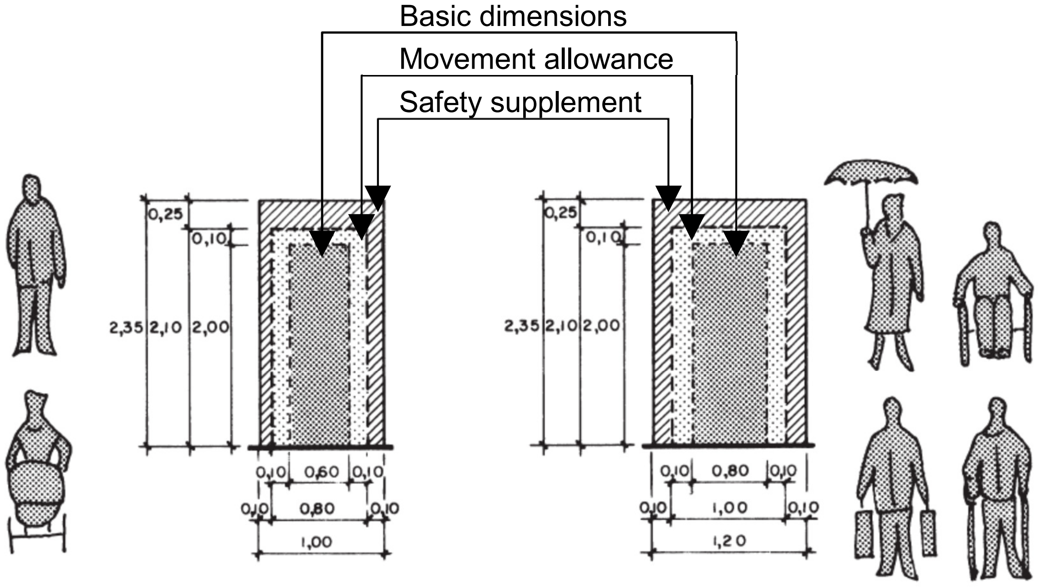

Figure 9 The clearance profile of pedestrians according to Swiss Standard SN 640 201

16.3 People overtaking each other on the platform

In practice, people frequently overtake each other as they pass by lengthy obstacles, for example, the railings by the ramps leading up to the platform. In fact, waiting passengers often use the railings to lean against.

Based on the space required according to Swiss Standard SN 640 201 and on the assumption that people are overtaken on the track-facing side and not the side protected by railings, this produces the following minimum space requirement:

- 0.60 m for a person who is waiting; this only corresponds to the basic dimension because the person is not moving and, consequently, does not need either the movement allowance or the safety supplement.
- 0.90 m for a person who is moving; this does not take account of the safety supplement on the side facing the tracks.

This produces a minimum width of 1.50 m.

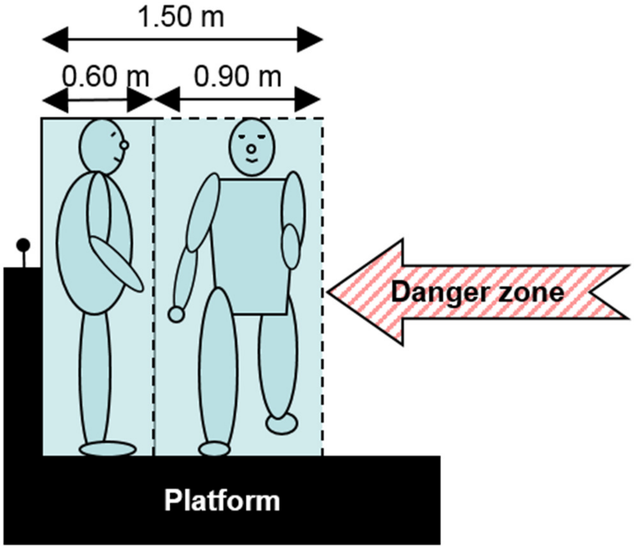

Figure 10 The minimum width when one person overtakes another

Passengers with luggage need more than the 0.90 m stated above. Several factors indicate that the likelihood of this happening should be considered as rather low, mainly because passengers with heavy luggage behave differently; they move towards narrow places less frequently.

It should not be forgotten that the minimum width of 1.50 m corresponds with the current requirements specified in AB-EBV (3.70 m distance between obstacles and the track centreline less the 2.20 m danger zone from the track centreline = 1.50 m) and is already met by many stations. This will avoid the need for any additional major expenditure on infrastructure.

16.4 People passing each other in opposite directions on the platform

As regards people passing each other in opposite directions, the same principles will be applied as for when a passenger without luggage overtakes another:

- 1.00 m for a person moving on the side of the obstacle,

- 0.90 m for a person who is moving; this does not take account of the safety supplement on the track-facing side.

The minimum width when passengers pass each other in opposite directions is thus 1.90 m.

However, this figure is not included in the statutory provisions. It was previously assumed that passenger contraflow on platforms represented the exception. Passenger contraflow only occurs in large stations with several sets of accesses leading up to platforms and a wider safety zone.

In addition, this figure should theoretically be increased by a 0.20 m loss of width towards the railings. The necessary width for any items of luggage should also be factored in.

If the scenario of passengers passing each other in opposite directions needs to be taken account of when calculating platform dimensions, it should not be stated as a minimum dimension but should be taken into account as a dimensional parameter to be included in the main requirement for the dimensions (cf. Sect. 14).[2]

16.5 **Short narrow areas (width < 1.50 m)**

According to the AB-EBV (1984 edition) which apply at present, lower safety distances (less than 1.50 m) are permissible alongside obstacles of limited length. There are numerous railway stations with such features. A review should be carried out to determine whether this provision is appropriate and should therefore be retained or whether it should be rescinded.

A safety zone less than 1.50 m wide will necessarily cause two people who meet (i.e. who pass each other in opposite directions) to cross the zonal boundary and enter the danger zone.

When estimating the risks, the following three factors are of essential importance:

a) The likelihood of a person entering the danger zone;

b) The length of time that such a person would remain in the danger zone;

c) The measures needed to prevent a person entering the danger zone and the cost of any such measures.

These factors were assessed as follows:

a) The likelihood of a person entering the danger zone depends on several circumstances; but especially on:

    a1) the number of people on the platform;
    a2) the length of the narrow area;
    a3) the width of the narrow area.

    These circumstances lead to the following findings:

    a1) Where there is an average or a high number of people on the platform, the main dimensional requirement is the decisive factor; in this instance, it specifies a minimum width of 1.50 m.

    a2) The shorter the length of the narrow area, the lower the probability that people will enter it; the logical deduction from this is that the narrow area should be of limited length.

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[2] The safety zone should be defined on the basis of the number of passengers who might be expected on the platform in the foreseeable long term.

a3) The narrow area must provide a safe space for at least the person who is moving. Therefore, a lower width limit of 0.90 m should be specified.

b) The length of time that a person remains in the danger zone can also be limited by restricting the length of the narrow area. This indicates yet again that it is absolutely essential to restrict that length.

c) Measures to prevent people entering the danger zone generally have far-reaching consequences because they require comprehensive structural adjustments to be made to the area. The associated costs are, therefore, between high and very high. If the likelihood of people entering the danger zone is small, then, for reasons of proportionality, the existing regulation permitting the safety zone to be less wide alongside obstacles of limited length should be retained. Low-cost measures to compensate for this should, however, be implemented in any case.

The following compensatory measures are envisaged:

- Handrails: Anyone taken by surprise by a passing train can hold onto the handrails and counter the aerodynamic effects.
- Safety lines: The safety line allows train drivers to identify a person's position on the platform and, if necessary, issue an acoustic warning (train whistle).

Accordingly, the option of permitting minimum widths must:

- remain limited to short obstacles. The maximum permissible length is specified as being equivalent to the width across the top of the stairs, i.e. to approx. 10 m. A reduced width is also permissible at the less-frequented ends of platforms as long as this does not place restrictions on their future use (dimensions are based on the number of passengers who might be expected on the platform in the foreseeable long term).
- presuppose that compensatory measures are implemented (in particular a handrail).

Painting a safety line on platforms is, in any case, obligatory.

At all events, the safety zone may not fall below the minimum width of 0.90 m.

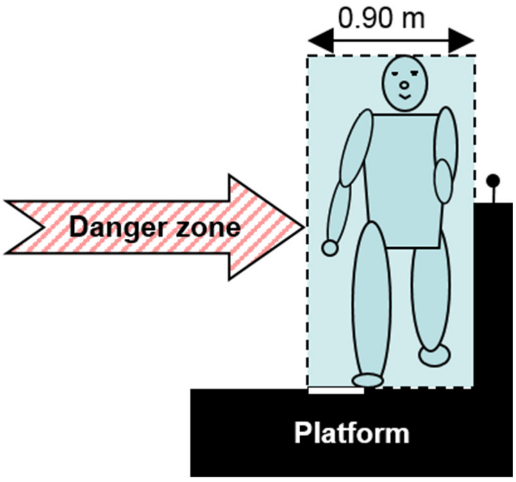

Figure 11 Reduced minimum width alongside obstacles of limited length

16.6 **Applying minimum widths**

It should be noted that minimum widths only represent the minimum dimension necessary for safety. They do not take account of the need to assess platform dimensions based on the number of people using the platform.

Recommendation: the regulations should state as the main requirement that platform dimensions be based on the number of people using the platform, but also take the minimum dimensions into account.

17. PRINCIPLES FOR DEFINING PLATFORM DIMENSIONS

17.1 General

Usually, the reason for defining the dimensions of facilities used by pedestrians is to demonstrate the capacity of the facility. Generally speaking, hazards and risks are not taken into consideration.

In the case of railway station platforms, several specific parameters need to be taken into account when defining the dimensions of facilities used by pedestrians:

a) The 'soft' system boundary: the main feature of the 'platform' system is the 'soft' system boundary mentioned in Section 15.

b) Knowledge of the risk: by entering the danger zone, passengers may risk getting killed.

17.2 The theorem and the principle behind defining the dimensions

The speed at which passengers walk along the platform depends on the density of people present (Daamen 2004, Weidmann 1993 and other authors). As their numbers grow, their speed slows depending on the remaining available space; as a result, passenger density on the platform increases further.

These two points (reduced speed and increased passenger density) are interlinked and form the principle on which the theorem is based.

The theorem:

The greater the passenger density, the higher the risk of entering the danger zone.

The principle on which defining the dimensions is based:

Defining the dimensions of platforms is to be based on the long-term passenger density.

This is to be done by means of an upper limit for passenger density.

17.3 How the theorem is derived

The platform has to fulfil two primary functions:

- on the one hand, it forms the place where passengers assemble while waiting for their train and, on the other,
- it allows passengers to move from one place to another.

Passengers move from one place to another when they transit from the access leading up to the platform to the waiting area, when they are alighting, when they are boarding and when they move along the platform to the exit.

The main danger to which passengers on the platform are exposed is being struck by a moving train. In order to reduce this risk, the platform is divided into a danger zone and a safety zone – the boundary between the two zones being marked.

The danger becomes a reality if **the pedestrian enters the danger zone** at the same time as a train is moving on the relevant track.

The danger zone may be entered for various reasons:

a) Pedestrians instinctively surround themselves with a buffer zone. Depending on sociological and environmental factors, the human body and the buffer zone together occupy an area of between 0.27 and 0.84 m^2.

   Because the danger zone on the platform is freely accessible, pedestrians whose buffer zone suffers interference could attempt to restore this 'minimum personal space' by entering the free space available in the danger zone.

   From the pedestrians' point of view, if their buffer zones suffer interference, this indicates that passenger density is too great.

b) If the pedestrians' walking speed plays a role (i.e. their intention is to minimise the time needed to move from one place to another / need to keep an appointment [time to start work, connection to another means of transport, etc.]), they will try to maintain this speed.

   If the walking speed of a group of pedestrians slows, a pedestrian in a hurry will overtake the slower group. The free area offered by the danger zone on the platform makes overtaking possible.

   Speed is related to density. Density increases as speed slows.

c) As they move, pedestrians have their intended destination in mind. If, on the way to their destination, they meet with an obstacle, they will seek an alternative route in their immediate vicinity in order to reach their intended destination.

   If the safety zone is fully occupied and represents an obstacle which cannot be by-passed or only avoided with difficulty (great density), the free area offered by the danger zone on the platform represents a free alternative area over which to reach their intended destination.

In all three instances, the danger scenario is characterised by excessive density.

QED

A new model based on psychological findings, published by Moussaïd, Helbing and Théraulaz in 2011, takes account of the fact that pedestrians follow the path on which the least number of obstacles obscure their field of vision; in other words, pedestrians look for gaps. This confirms the observation that the danger zone, which represents a free space on the platform, is used more frequently the greater the density of passengers.

17.4 Conclusion drawn from principle of defining dimensions

The principle: *Defining the dimensions of platforms is to be based on the long-term passenger density.*

Conclusion: *The upper limit of passenger density should under no circumstances be exceeded.*

This conclusion follows directly from the way in which the theorem mentioned above was derived.

If the upper limit for passenger density is exceeded, this may present an immediate hazard. This point is covered in detail in the next section.

17.5 Dimensional design values

The concept of density is used in a general sense in the transportation and traffic sciences to describe the traffic status. It is expressed as 'Level of Service' (LOS).

The definition provided by Fruin and the TRB for walking pedestrians is the accepted basis for measurements in this area of research. The values in the table below correspond to the latest definition according to the TRB.

LOS A	*Pedestrian density < 0.18 P/m^2 ; flow ≤ 0.27 P/ms* At a walkway LOS A, pedestrians move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.
LOS B	*Pedestrian density 0.18-0.27 P/m^2 ; flow 0.27-0.38 P/ms* At LOS B, there is a sufficient area for pedestrians to select walking speeds freely, to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians, and to respond to their presence when selecting a walking path.
LOS C	*Pedestrian density 0.27-0.45 P/m^2 ; flow 0.38-0.55 P/ms* At LOS C, space is sufficient for normal walking speeds and for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts and speeds and flow rate are somewhat lower.
LOS D	*Pedestrian density 0.45-0.71 P/m^2 ; flow 0.55-0.82 P/ms* At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Crossing or reverse-flow movements face a high probability of conflict, requiring frequent change changes in speed and position. The LOS provides reasonably fluid flow, but friction and interaction between pedestrians is likely.
LOS E	*Pedestrian density 0.71-1.33 P/m^2 ; flow 0.82-1.25 P/ms* At LOS E, virtually all peds restrict normal walking speed, frequently adjusting gait or shuffling. Space is not sufficient for passing slower peds. Cross or reverse flow movements are possible only with extreme difficulties. Design volumes approach limit of walkway capacity, with stoppages and interruptions to flow.
LOS F	*Pedestrian density ≥ 1.33 P/m^2 ; flow varies* At LOS F, all walking speeds are severely restricted; forward progress is made only by shuffling. There is frequent, unavoidable contact with other peds. Cross- and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued peds than of moving ped flows.

Figure 12 Description of the Levels of Service (LOS) referring to horizontal movement (level walkway)

The criteria stated by Weidmann (1993) based on Pushkarev and Zupan (1975) and those of the TRB (1985) best describe the most varied levels of service.

These criteria are:

K1 Ability to freely choose one's walking speed
K2 Frequency of forced changes of speed
K3 Need to be aware of other pedestrians
K4 Frequency of forced changes of direction

K5 Hindrance when traversing a flow of pedestrians
K6 Hindrance caused by a flow of people from the opposite direction
K7 Hindrance when overtaking
K8 Frequency of unwanted contact

This description of criteria based on density clearly shows that the LOS D conditions (passenger density above 0.45 P/m^2 according to the TRB) are not acceptable on a platform.

Criterion K5 is not included because it is not relevant to platforms which, in comparison with their length, are very narrow.

0.30 to 0.45 P/m^2, LOS C		0.45 to 0.60 P/m^2, LOS D
Speed when encountering contraflow traffic slightly restricted.	K1	Speed can no longer be freely chosen.
No forced changes of speed.	K2	Increasing incidence of forced changes of speed.
Awareness of other pedestrians required.	K3	Awareness of other pedestrians required.
No forced changes of direction.	K4	Changes of direction necessary.
Occasional hindrance from people moving in the opposite direction.	K6	Severe hindrance from people moving in the opposite direction.
Slight hindrance when overtaking; change of direction necessary.	K7	Severe hindrance when overtaking; change of direction necessary.
No unintentional contact.	K8	No unintentional contact.

Figure 13 Description of Criteria K1 to K4 and K6 to K8 for Levels of Service C and D (Weidmann 1993).

An obvious deterioration can be seen from LOS C to LOS D in K1, K2, K4, K6 and K7. At Level of Service D (density > 0.45 P/m^2 according to the TRB), this leads to pedestrians entering the danger zone.

In contrast to road facilities or facilities used by pedestrians (passageways, etc.), where exceeding the dimensional design value might lead to a non-hazardous hold-up, even just briefly exceeding the limit for passenger density on a railway station platform results in over-capacity which directly leads to an increasing number of dangerous situations (pedestrians entering the danger zone). The characteristics of the graduated LOS scale, which the K_i criteria describe in detail, and the specific parameters of the 'platform' system (cf. Section 17.1 above) show that there is a genuine risk beyond LOS D on the side facing the track over which a train might pass (the likelihood of the occurrence is great); in accordance with the current state of knowledge, so as to keep the likelihood of the occurrence at an acceptable safety level, LOS C (density ≤ 0.45 P/m^2 according to the TRB) should not be exceeded.

When carrying out modelling:

a) those areas where passengers are not exposed to any danger (alongside a stationary train, for example) can be excluded. If a greater maximum density in these areas has no negative effects on an area for which a maximum of LOS C has been determined (due to the existence of a hazard), then a higher LOS can be applied in the unaffected areas. However, observations have shown that, as density increases, such differentiation becomes increasingly impossible.

b) the actual risk posed by temporarily exceeding (short duration, for a few seconds) the maximum permissible passenger density can be estimated.

Making assessments of this nature requires sufficient knowledge of dimensional matters across the whole of the system and its parameters.

Exceeding the maximum density as a matter of course in those areas where an actual danger is present is only possible at the cost of drastic restrictions to rail operations and only if the risk remains acceptable.

The limits of modelling

The concepts described below would lead to discrepancies in computational models which assume a uniformly distributed density and in 'agent-based models' which would not take these concepts into account. These discrepancies could result in a false assessment being made of the effective degree of safety on the platform.

a) The phenomenon of blocking access to free areas when passengers are boarding and alighting (see Figure 14a). Modelling which does not take account of the free areas (zero density) produces results which are on the unsafe side and too optimistic.

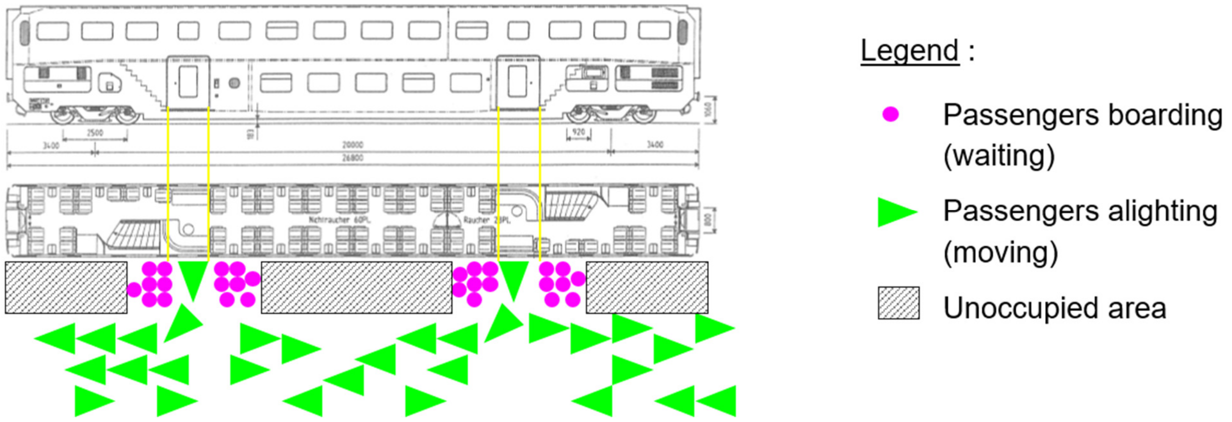

Figure 14a Blocking access to free areas when getting in and out

b) The phenomenon of carrying out evading manoeuvres away from fully occupied zones by using the opposite side of the platform (see Figure 14b). Manoeuvres of this type can be highly risky, especially if obstacles of a certain size are in the way (stairway, waiting shelter, etc.).

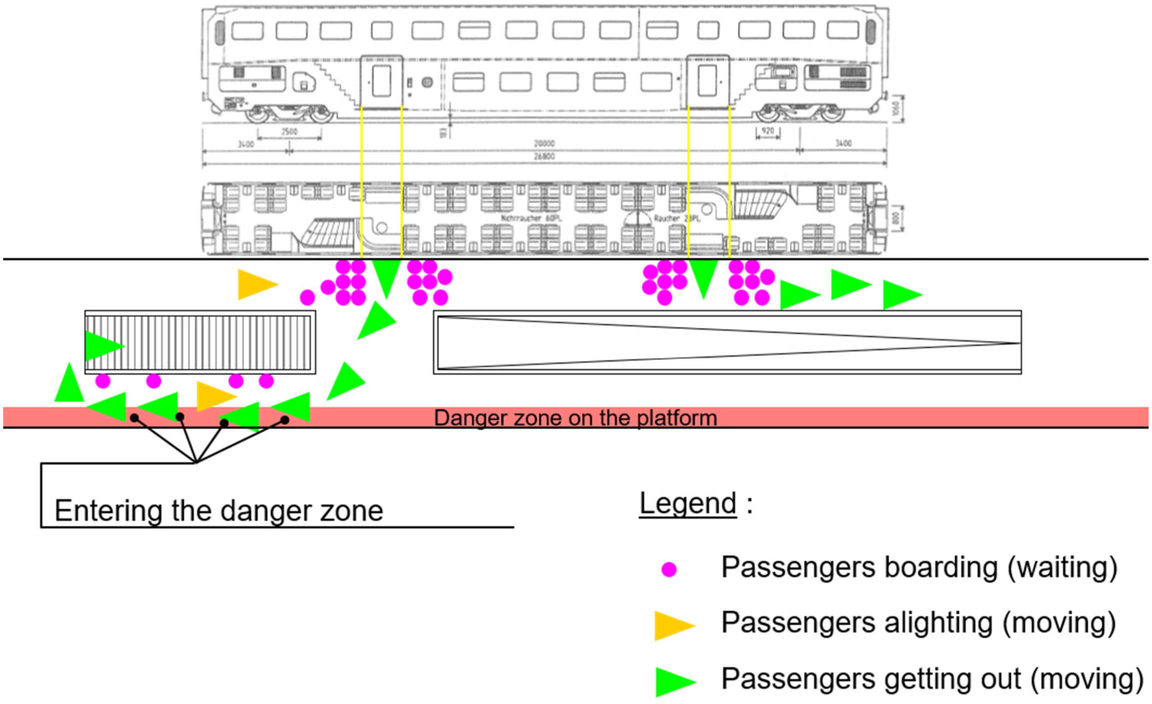

Figure 14b Evading manoeuvres

Employing the phenomenon of queues that form spontaneously and permit a greater density may entail risks. Although this phenomenon can arise on platforms, it should not be taken into account because platform topology often varies greatly from the ideal due to the 'soft' system boundary, non-standard equipment installations and waiting passengers.

17.6 **Risk assessment**

Risk is a function of the frequency with which the 'train' element occurs in the system.

The risk is greatest just before a train arrives and as it is passing through the station: this is due, on the one hand, to the train itself (it is the source of the danger) and, on the other, due to the higher passenger density on the platform just at this moment. The reasons for this are that:

a) passenger density increases up to the moment the expected train arrives;

b) trains follow each other at short intervals because of the way the timetable is structured and/or because the capacity of the railway network is heavily utilised;

c) because of the way the timetable is structured, it is possible for two trains to arrive at the same platform at the same (short) time interval.

Against the background of the current and planned operational characteristics of Swiss railways, the frequency with which the 'train' element will occur in the system is generally high.

Moreover, large concentrations of people generally arise in those stations which also experience high rail traffic density.

It would certainly be an error to treat the risk in those stations where the 'train' element occurred less frequently in a different way. This would particularly be so on account of reason a) mentioned above: the risk would only be low if both elements of the system (the train and the passengers) were not present in the system at the same time. However, the aim of defining platform dimensions is to protect passengers; differentiation would not apply if they did not appear in the system.

For these reasons, the risk matrix reduces to the one single possibility in which the likelihood of occurrence is high.

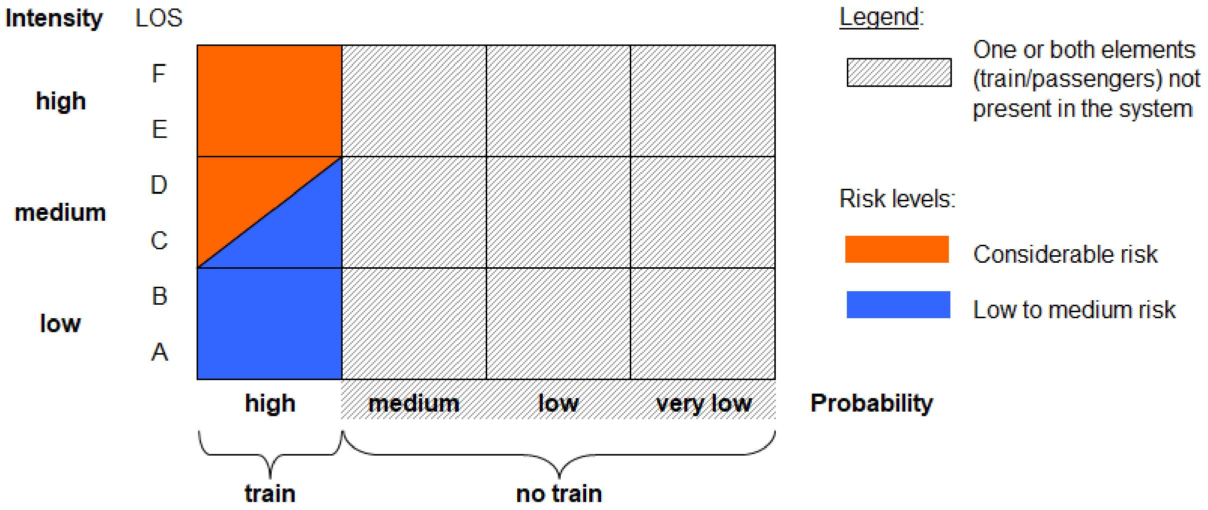

Figure 15 Risk matrix for persons on a platform in relation to the 'train' hazard

18. CONCLUSION

Pragmatic study of the decisive parameters for the safety zone on platforms leads to the conclusion that platform dimensions should be defined on the basis of long-term plans and that specifying minimum widths for the safety zone is unavoidable.

18.1 Proposal for standard gauge railways

As part of the review of the AB-EBV in 2006, it was proposed that the implementing provision to Art. 21, Paragraph 2 (AB 21.2) be amended as follows and also that the following be added to the proposals for the danger zone:

3 Safety zone

The safety zone should be defined on the basis of the number of passengers who might be expected on the platform in the foreseeable long term.

However, the following minimum widths are to be adhered to:

31 1.50 m, as a general rule.

32 A smaller safety distance (min. 0.90 m) is permissible alongside obstacles of limited length (e.g. access points to stairs, waiting shelters: guide length max. 10 m) where there is something to hold on to, and also at the ends of platforms. Passengers must, however, still be able to stand completely outside the danger zone.

18.2 Proposal for narrow gauge railways

Against the background that passengers display the same characteristics, the provisions proposed in Section 18.1 are equally applicable to narrow gauge railways. The following new paragraphs were proposed for inclusion in the AB-EBV:

1 AB 21.2 Standard gauge is applicable to metre gauge assuming Points 2 and 3 below are taken into account.

Because, under normal circumstances, and always at stops, trams run 'on sight', it is possible to reduce the safety zone to the essential minimum width. The following new paragraphs were proposed for inclusion in the AB-EBV:

3 Safety zone

As regards the safety zone for trams, a lower safety distance of at least 0.90 m in accordance with Point 32 AB 21.2 N is generally permissible.

18.3 Transitional provisions

Although the new safety distances (for the danger zone) are reduced for passenger trains, they are increased for freight trains. This also requires transitional provisions for the safety zone in existing stations. These can also be found in the BAV Guideline entitled 'Übergangsbestimmungen für die Ausgestaltung des sicheren Bereichs von bestehenden Anlagen' issued on 2 July 2006.

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ANNEX 1

COMPARISON OF THE VARIOUS REGULATIONS AND STUDY FINDINGS

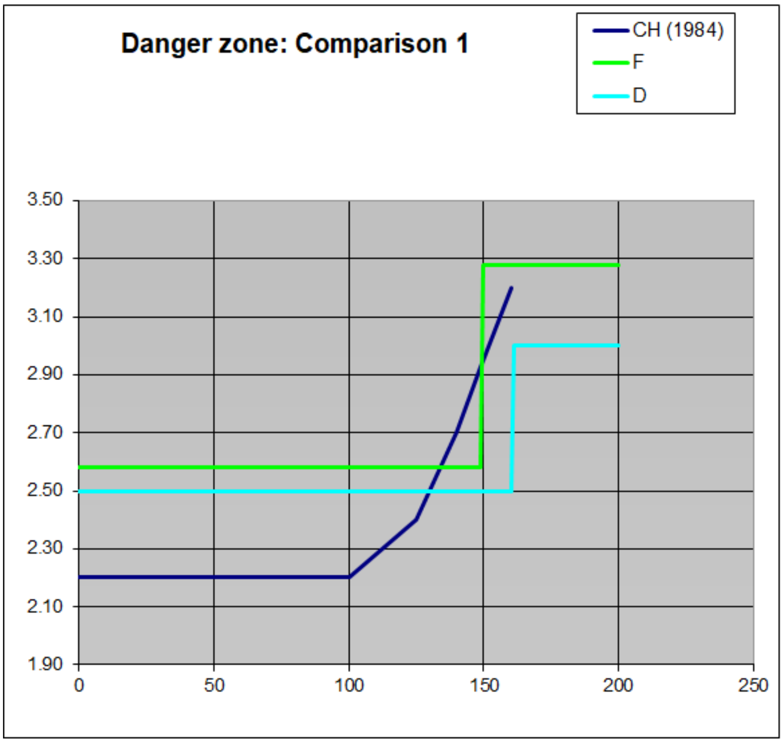

Figure A1.1 *The regulations in France and Germany compared with the AB-EBV edition of 1984*

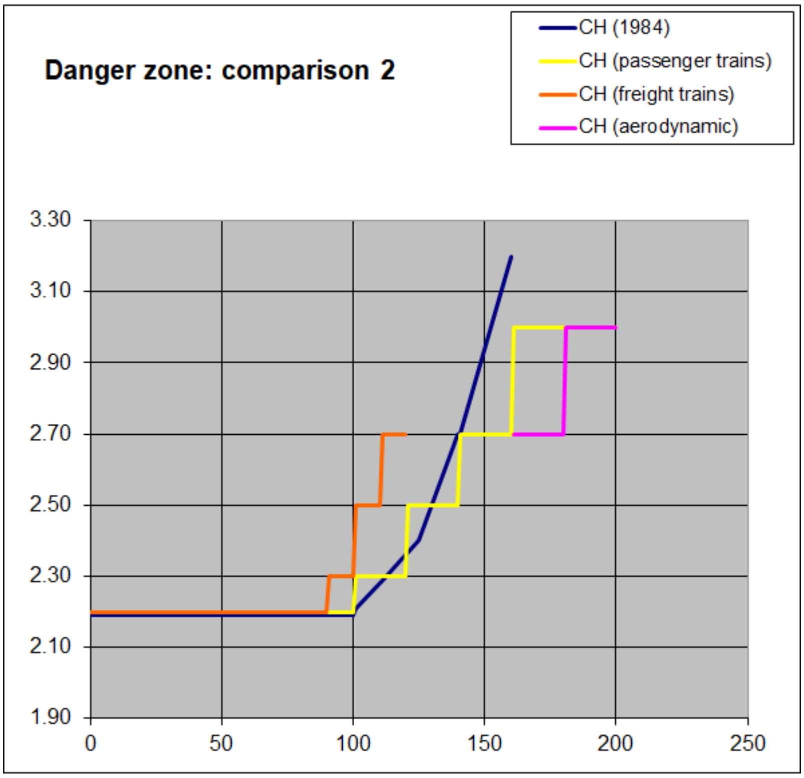

Figure A1.2 *The Swiss regulations (1984 Edition) compared with the findings of this study*

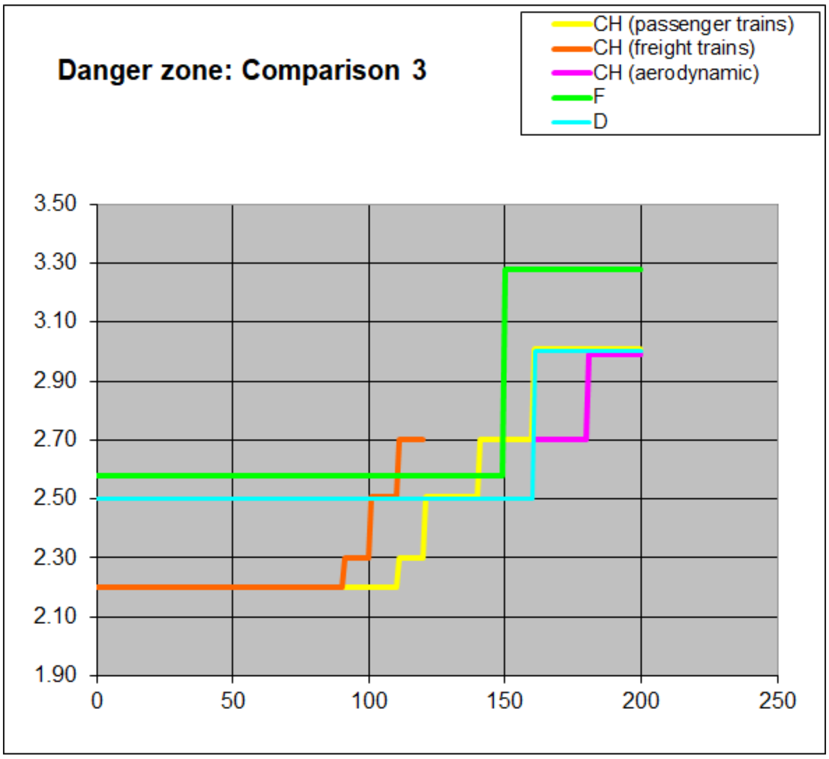

Figure A1.3 The regulations in France and Germany compared with the findings of this study

ANNEX 2

ILLUSTRATIONS OF DIFFERENT TRAINS BY TYPE – TRAIN-INDUCED AIR FLOW SPEED

Note: The air flow speed curves (U), caused by the passage of trains and illustrated below, are only diagrammatic representations of the actual phenomenon (cf. Section 9.3.1 and Figure 5).

Figure A2.1 ICE (category, according to AB-EBV: trains with good aerodynamic profiles)

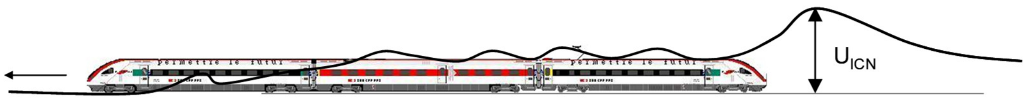

Figure A2.2 ICN (category, according to AB-EBV: trains with good aerodynamic profiles)

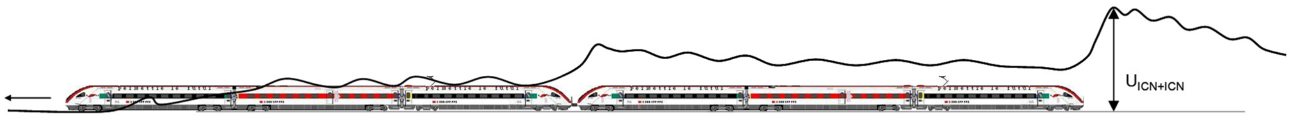

Figure A2.3 2 x ICN (category, according to AB-EBV: trains with good aerodynamic profiles, despite the gap between the two groups of coaches which generates a considerable air flow)

Figure A2.4 Passenger train (category, according to AB-EBV: passenger trains). The same curve is used to illustrate regional trains and passenger trains of DB Systems Engineering 2004 (Section 10)

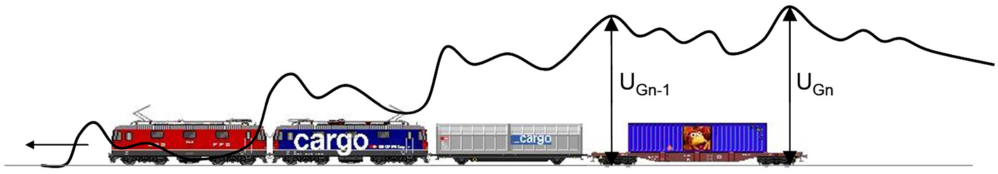

Figure A2.5 Freight train (category, according to AB-EBV: freight trains)