

Station Passenger Barrier Systems and Their Impact on Metro Transport Services [†]

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Abstract: The prevention of passengers' access to the tracks is crucial for current urban railway transport. The "Safety first" principal led to the need to separate the platform from the train tracks as a measure of passengers' protection. Due to this, many train stations around the world are equipped with barrier (screen) security systems. However, the requirements for passengers' comfort are high as well. Automated transport should ensure the trains are on time and passengers' exchange at stations is smooth. Therefore, it is necessary that station passenger barrier systems comply with the line signalling systems. Preventing or reducing additional delays is essential to provide efficient transport services and maximum line capacity while ensuring passenger safety. This report provides the operation outcomes for different train lines with implemented advanced station barrier systems for passengers—automatic platform doors (vertical or horizontal) and beam barriers—and indicates the strong and weak points of the given solutions.

Keywords: safety; passengers; metro transport; transport service

1. Introduction

For contemporary railway transport, it is crucial to prevent passengers' access to the tracks. Stations' platforms are often overcrowded. This could lead to serious accidents. Automated operations must guaranty passengers' safety. This is achieved by the implementation of barrier systems such as platform screen doors (PSDs) and infrared beams. These are also known as Passenger Protection Equipment (PPE) [1].

PSDs are a physical separator between the train and the station platforms. This solution is implemented in many stations around the world. The choice of PSD types may vary depending on the operator's goals. In addition to preventing people falling onto the tracks, PSDs could contribute to the control of a station's climatization and decreasing the piston effect on the platforms. The strongest positive effect of PSDs is decreasing passengers' critical incidents to zero. They also eliminate long interruptions in transport services caused by objects falling onto the tracks.

In addition to their positive impact, platform barriers might lead to some operation disruptions. Adding a system of PPE complicates the overall signalling scheme of automated railway systems and deviations in any of its components will lead to operation outages. Particularly, in case a platform door is required to reopen and then close again, this will add some more seconds to a train's dwell time and cause a delay according to the timetable. In the end, all these are reflected onto passenger comfort [2].

A station's PPE also requires additional interface units for communication with the trains and graphical user interfaces and, further, for higher-qualified train dispatchers and maintenance staff [3].



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2. Material and Methods

This article is based on observations made during the passenger operation of metro lines M1 and M3 in Sofia and metro Line M4 in Budapest. The aim of this report is to compare the work behaviour of various platform security solutions implemented on different metro lines and the impact they have on the line's operation.

On lines M1 and M3 in Sofia, platform screen doors (PSDs) are used. Their primary purpose is to prevent passengers from falling from the platform edge onto the railway tracks.

As the dynamic vehicle clearance gauge is greater than the construction dimensions of the trains, preventive measures are taken to ensure that no person can be trapped in the openings between the PSDs and the trains.

The M3 is the newest line in Sofia. It has a Grade of Automation 3 (GoA 3) signalling system. This means that accelerating and stopping the train is under the control of the system, not the train driver. The PSD type used is half-height PSDs (also known as 'platform gate doors'). Figure 1a shows a typical half-height 3D model of such PSDs. On both sides, there are fixed driving panels and the sliding doors that open and close are in between. Figure 1b shows the complete PSD structure at Krasno Selo Station on the M3 Line in Sofia.

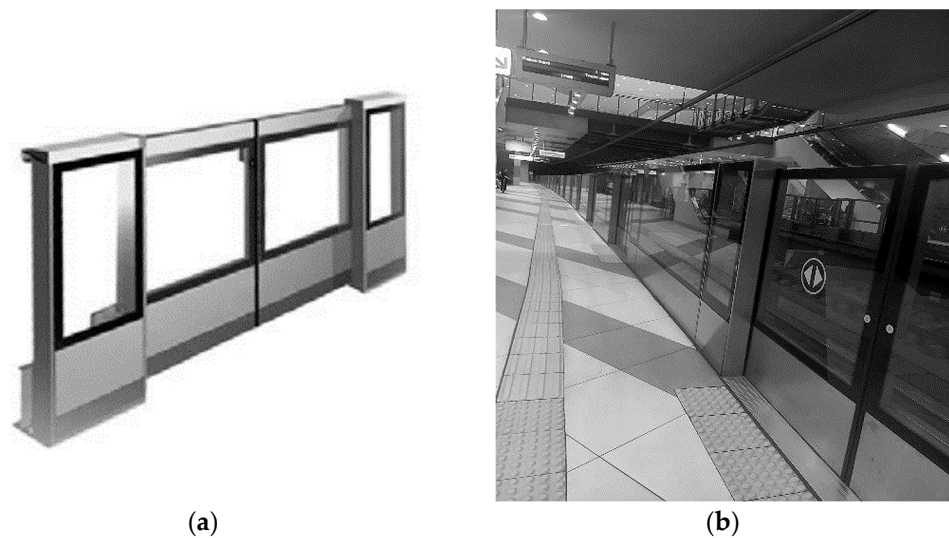


Figure 1. Half-height platform screen doors: (a) 3D model (Photo: Knorr Bremse); (b) Krasno Selo Station, Sofia M3 Line.

In addition to the sliding doors, this structure includes emergency escape doors, platform end doors (for maintainers' access to tracks) and fixed panels. These are metal–glass structures installed along the platforms. They are made of transparent glass material, so the passengers can see through them to the track and the opposite platform. The PSD structure is a physical obstacle for the passengers at the edge of the platform when there are no trains and reduces the piston effect [4,5]. The control of the PSDs is connected to the railway signalling system zone controller. The PSD controller receives information from the zone controller of whether there is a train in the station, whether a train has come to a standstill and about the train doors' state (opened/closed). The PSD controller provides information to the zone controller about the state of the platform doors. According to the safety requirements, the use of PSDs should not allow the opening of the doors in case the passengers might be exposed to harmful risks. In a normal operation, the PSDs should open only when a train is berthed in the station within the stopping window [6]. The electrical potential of the PSDs' metal frame is equalized to the potential of the vehicle; therefore, a platform insulation layer is laid under the finished floor for about 1.20 m along the platform edge to protect passengers when touching the PSDs/trains while staying on the platform.

The M1 Line is the first line in Sofia. Originally, there were no PSDs installed there. However, after some accidents with passengers falling/jumping on the tracks, the line was retrofitted with vertical Rope-type screen doors. Figure 2a shows a typical 3D model of The Rope-type doors move upwards. Due to their light construction compared to half-height PSDs, they are much easier to install and maintain as they require less metallic framework for support [7]. Figure 2b shows the implanted vertical platform screen doors at Opalchenska Station on the M1 Line in Sofia. They can handle multiple train types at the same platform.

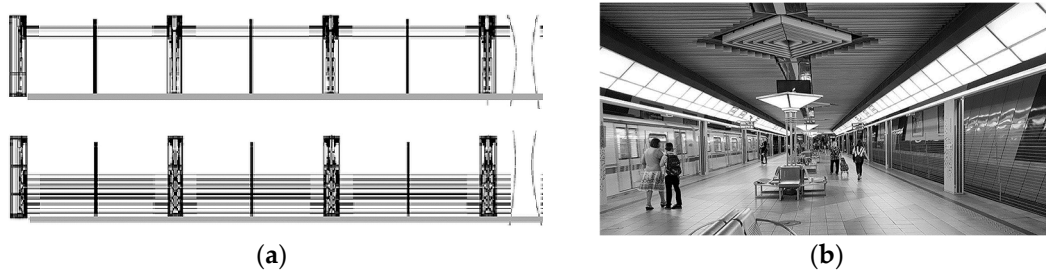


Figure 2. Rope-type screen doors: (a) 3D drawing (Photo: Knorr Bremse); (b) Opalchenska Station, Sofia M1 Line.

These doors provide a transparent view and do not allow passengers to climb over them throw objects onto the tracks. However, there is no interface between the train signalling system and the platform doors. The driver controls the propulsion and braking of the train (GoA1). The PSD system includes speed sensors. The platform doors automatically open when an approaching train is detected with a speed less than 5 km/h and close when the train goes above it.

The M4 Line is the newest in Budapest. This line has the most advanced signalling system, GoA4, and provides unattended train operations (UTOs). As such, it must be certain that no person can become injured between the platform and the train, or that no person or object can access below the edge of the platform [3,4]. To secure the platform edges, a track infrared-beam monitoring device is used. The infrared light barriers react when detecting persons or larger objects. The infrared beam barrier system allows the use of a heterogeneous vehicle fleet. Like the PSD solution on the M3 Line, here the train may only leave the platform if light barriers (light grids) indicate a free zone. In order to not be disturbed by the normal movement of passengers onto the platform, the infrared beam protective equipment is installed beyond the platform edge. As the train is unattended (no personnel onboard), the relevant signal/alarm is triggered in the operations control centre. Figure 3 shows an image of the platform at Zákóczy tér Station with a train and the infrared beam barrier.



Figure 3. Zákóczy tér Station, Budapest, M4 Line (Photo: *Railway Gazette International*).

The observations of passengers' exchanges for all the three metro lines were taken in similar environments—passenger operation at rush hour at underground stations. A temperature range between 17 and 20 °C and a normal dust level were assumed at all locations. The factors with the most weight were the presence of an interface between trains and platforms and the Grade of Automation (Table 1).

Table 1. Observed conditions for passengers' exchanges.

Conditions	Line M3 Half-Height PSDs	Line M1 Rope-Type (Vertical) PSDs	Line M4 Infrared Beam Barrier
Station type	Underground	Underground	Underground
Period of the year	July 2023	July 2023	July 2023
Grade of Automation	GoA3	GoA1	GoA4
Interface between train and platforms	Yes	No	Yes
Repetition of passengers' exchanges observed per day	20	20	20

It was not intended to compare the exploitation data of station barriers to that of the theoretical ones, but to consider the specific consequences of having installed platform barriers to trains' normal operation. For several days in the summer, passengers' exchanges were observed for about an hour daily. The rush hour which was intended as the headway between trains was shorter and the repetition of the passengers' exchanges was more intensive. The stations for lines M1 and M3 were inspected in person, while the information about the M4 Line in Budapest was collected remotely with the support of an onsite specialist.

3. Results

The results of the observations are structured into the tables below. Dwell time effects due to the choice of the station barriers are shown in Table 2.

Table 2. Dwell time effects based on selected passenger barrier solution.

Time Parameters	Line M3 Half-Height PSDs	Line M1 Rope-Type (Vertical) PSDs	Line M4 Infrared Beam
Platform doors opening, s	3–4	3	N/A
Platform doors closing, s	3–4	3	N/A
Platform doors reopening/closing again, s	8	6	N/A
Dwell time prolongation, s	2 + N8 *	None **	None

Obviously, the times for door opening/closing for both M3 and M1 were similar. However, there were the following specifics:

- * As the PSD operation on Line M3 is aligned with the trains' control systems, the PSDs open one second after the train doors open and close again one second after the train doors close. Thus, this adds two seconds to the dwell time. The full duration of door reopening and closing is added again for how many (N) times the platform doors need to be reopened and closed again (for any reason).
- ** On Line M1, the Rope-type platform doors are not synchronized to the train doors, but with the train movement. The vertical doors start to open at train arrival (at train speeds less than 5 km/h) and they are completely open when the train is stopped. Also, the platform doors start to close once the train starts to move. This means that even in case the platform doors need to be reopened and closed again, this does not affect the dwell time.

On Line M4, there are no psychical doors (N/A = not applicable). There is no impact to the dwell time during normal operation.

The observed advantages and disadvantages for the different barrier solutions are listed in Tables 3–5, respectively.

Table 3. Half-height PSDs on Line M3 in Sofia observations.

Advantages	Disadvantages
A physical obstacle prevents passengers and big objects falling onto the tracks when there is no train at the station. Passengers' safety is 100% guaranteed. Delays at stations due to passengers' abnormal behaviour are reduced. In case of a failure, the corrective maintenance can be performed from the platform side and without stopping train operation. The PSD structure provides sound and light indications for door opening/closing and problems. It also can accommodate emergency call boxes or other electrical devices if needed. They decrease the trains' piston effect in the tube.	Possible to climb over the PSDs and throw objects onto the tracks. Half-height PSDs = 1.56 m. Precise train positioning needed. Relatively higher efforts for maintenance. A failure can cause operation disruption and operation delay. The PSD structure requires grounding and platform floor insulation along the platform (about 1.2 m). The gabarits of service vehicles passing on the lines must be considered.

Table 4. Rope-type (vertical) PSDs on Line M1 in Sofia observations.

Advantages	Disadvantages
A physical obstacle prevents passengers and big objects falling onto the tracks when there is no train at the station. When closed, passengers' safety is 100% guaranteed. No delays at stations due to passengers' abnormal behaviour. Allows heterogeneous vehicle fleet. Currently, three types of trains serve the M1 Line. In case of a failure, corrective maintenance can be performed from the platform side and without stopping train operation. The PSD structure provides sound and light indications for door opening/closing and problems. It can also accommodate emergency call boxes.	Possibility of passengers and big objects falling on the tracks when there is train at the station. Due to the columns of the platforms, precise train stopping is still required. There are still efforts needed for installation and maintenance. No interface connection to the line signalling system. The piston effect cannot be decreased.

Table 5. Infrared beam barriers on Line M4 in Budapest observations.

Advantages	Disadvantages
Much lighter solution than the PSDs in matters of installation and maintenance. Precise positioning of a vehicle is not required. Limited preventive maintenance. No massive structure on the platform. No grounding or platform floor insulation required.	They cannot really prevent a person or an object from falling onto the tracks, but they surely detect it. Maintenance should be carried out from the tracks. The tunnels must be kept clean. The dust can cause operation disruptions. Cannot support platform climatization. No additional equipment can be accumulated.

4. Discussion

Station barrier systems are mandatory measures for passengers' safety. The types of barriers come with their own specific advantages and disadvantages. While the PSDs on Line M3 in Sofia could 100% guarantee passengers' safety, they come with a massive structure and more maintenance needs. Due to the line Grade of Automation 3 and relevant interface between the PSDs and the trains, an obstacle at the platform doors will result in a noticeable delay that will need to be compensated. On the other hand, the infrared beam barriers on the M4 line in Budapest should not add additional time to the dwell time normally. However, this solution allows potential passenger violations which could disturb train operation and decrease the comfort of the transport service. The Rope-type PSDs on Line M1 in Sofia address the needs of the operation of several fleet

types with different lengths and distances between doors. However, when the train is shorter than the PSD opening, at the time of the passenger exchange the access to the tracks remains unsupervised.

5. Conclusions

The choice of using PSDs or infrared beam barriers for passengers should be made based on a precise judgement of the given situation. It is all about the passengers' safety and the comfort of the transport service. The outcomes of the solution for preventing access to the tracks should be understood and considered appropriately. In case of crowded platforms, the PSDs seem to be the preferable solution. However, when the passengers' behavioural culture is high, a similar effect could be achieved with infrared barriers. Choosing the station barrier type is a complex task and it strongly depends on the signalling systems that the transport operators plan to use, the fleet types, station architectures, the limitations of retrofitting possibilities and others and should be considered case by case separately.

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