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A pilot study evaluating the preventive effects of platform-end lengthwise fencing on trespassing, person struck by train and traffic delays

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ABSTRACT

Background: Trespassing at train tracks and "person under train" (PUT) incidents are serious health, societal and transportation concerns. There is a need for developing different measures to prevent these events. Here, we hypothesized that platform-end lengthwise fences (PLF) reduce trespassing, the number of PUT incidents (suicides and accidents), and train traffic delays. *Method:* PLFs were installed as the intervention at one station in Stockholm in 2020. The number of trespassers detected using CCTV-cameras was compared before and after at the intervention station over a total period of 29 months (using incidence rate ratio, IRR). The reduction in the number of PUT (over 20 years) and train traffic delays (over 9 years) was also investigated by IRR, and by using three control groups. *Results:* After installation of PLF there was a significant ~90% reduction in trespasses ($IRR = 0.10$, 95%CI 0.04–0.23; one-sided exact $p < 0.0001$). No PUT incident occurred at the intervention station after the installation, compared to 1.11 per year before installation ($IRR = 0.32$, 95%CI 0–1.82; one-sided exact $p = 0.1216$). There was a significant reduction in delay minutes post installation compared to before the installation (Mann Whitney $U = 0$, upper one-sided exact $p = 0.0357$). The effect of the PLF was also observable in comparison to the three control groups, suggesting that the preventive effect was not due to wider societal events affecting all stations. *Conclusion*: PLF had a large effect on reducing the number of trespasses and the number of delay minutes due to trespasses and PUT incidents. PLF may also have an effect of reducing PUT incidents. *Practical Applications:* PLF is deemed to be relatively easy and cheap to install and thus scalable (as compared to full barriers, e.g., platform screen doors) and may be considered at platform-ends having an exit, provided there is enough space to install them.

1. Introduction

Suicide is a common and serious health problem in railway settings. In the European Union, between 2200 and 2700 suicides occur every year on the railways and suicides cause about three times more deaths than other accidents (Eurostat, 2022). In the Swedish railway and metro system there are about 85 suicides per year due to "person under train" incidents (henceforth refered to as "PUT," an event when a person is struck by a train), which account for approximately 85% of all deaths in the rail bound system. Suicides in the railway and metro system account for 6% of all suicides in Sweden. In addition to suicides, there are also on average 10 PUT incidents due to suicide attempts per year, and furthermore, about 500 other suicide related cases per year require the involvement of first responders (e.g. police, firefighters; Fredin-Knutzén, Andersson, Hadlaczky, & Sokolowski, 2020).

Suicidal behaviors are not the only cause of unauthorized trespassing into the track area. The most common motive is to take a short-cut, in addition to many other less common motives, like thrill seeking, vandalism, theft, or urinating (Rail Safety and Standards Board, 2005). Nevertheless, more than 70% of the train traffic delays caused by trespassing in the Swedish railway is related to suicide and mental illness (Fredin-Knutzén & Wigren, 2019). Delays due to suicides, accidents, and trespassing have serious implications for the efficiency of public and cargo transportation of the Swedish railway system, especially in the Stockholm area (MTR, 2021).

A previous study showed that most cases where individuals were struck by a train in the urban area of Stockholm occurred at or near the station platforms (Rådbo & Andersson, 2012). Another study from the same area concluded that the most lethal locations during suicide attempts were near the tracks, or inside a tunnel, when a train arrives

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(Ceccato et al., 2021).

There are different measures, with varying levels of evidence, aimed at preventing trespassing and/or suicides in the railway system. The most researched measure is the complete restriction of access to the tracks by the use of platform screen doors (PSD) (Chung et al., 2016; Law et al., 2009; Ueda et al., 2015; Xing et al., 2019). However, PSD is an expensive intervention that is often unfeasible or difficult to implement at long platforms or during the use of different train models. To counteract this problem, a toolbox of different, more scalable, measures are being developed within the Restrail project. The toolbox includes measures evaluated by peer-reviewed research, as well as those that have been investigated by infrastructure owners (Restrail Toolbox, 2022). Despite this effort, there is still a need to continue research regarding the prevention of railway suicides (Mishara & Bardon, 2016).

The routine activity approach to understand and analyze criminal behaviors (Cohen & Felson, 1979) is a model sprung from the field of criminology. An adapted version of this model was used by representatives of the Swedish railway industry to theorize as to why fences placed specifically at the ends of a platform where there is an exit to the platform, to restrict access to the tracks beyond the platform area (henceforth referred to as "Platform-end lengthwise fencing" (PLF), see Fig. 1.), could be effective at reducing the number of unauthorized trespasses from that area of the platform towards the line between stations (Fredin-Knutzén et al., 2018). The theory was that PLF, which forces a potential trespasser to walk several meters behind a visually and auditorily transparent barrier, makes the trespasser more observable to bystanders and would thus reduce the motivation for carrying out the trespass. The underlying mechanism for the preventive effects of the lengthwise fence were in line with the "routine activity" approach, which states that crime occurs in the interplay between three factors (Cohen & Felson, 1979) – a likely offender (e.g., a trespasser in the current railway setting), the absence of capable guardians (e.g., a

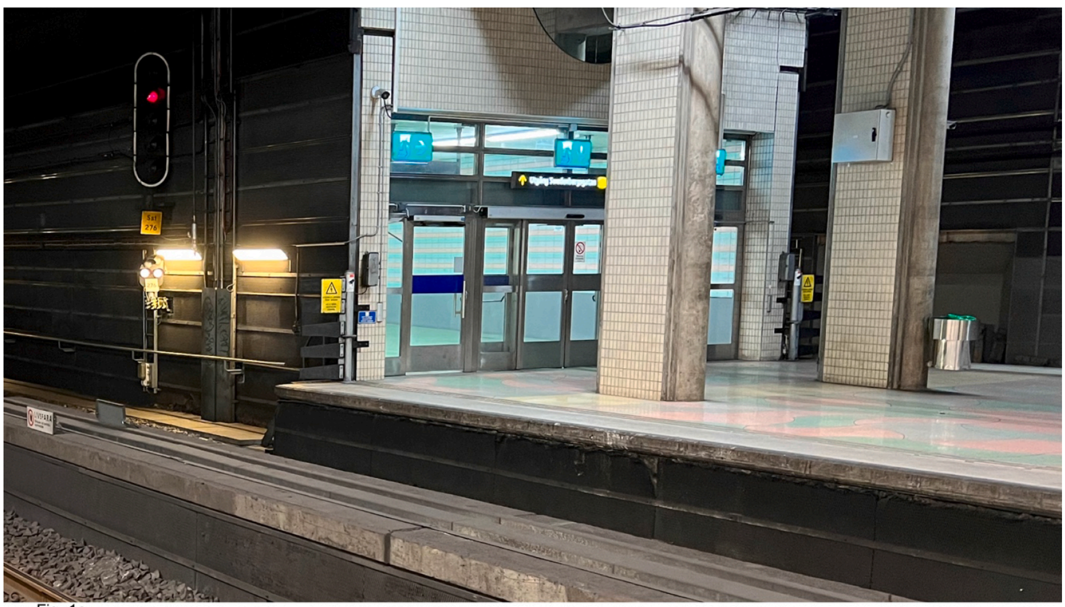

Fig. 1a.

Fig. 1b.

Fig. 1. Photo of a platform end without (A) and with (B) a PLF installed (green arrows). This particular photo shows the 9.4 m long PLF in the north end of the intervention station. PLFs at the intervention station was installed at both the northbound and southbound tracks at each platform end (because there is an exit to the platform at each end). The anti-trespass panels and the three "shark teeth" rows are also new features. See Supplementary Materials for further description of the design.

trespasser located at a place in the railway system, which commuters or surveillance cannot observe), and a suitable target (e.g., an easily accessible track area). According to this approach, a crime (in our case a trespass) will not occur if one of these factors are absent.

As a result of the Fredin-Knutzén et al. (2018) report, the Swedish Transport Administration (STA) built PLF at one railway station in the central part of Stockholm in June–July 2020 (Fig. 1). The platforms of the selected station were longer than the incoming trains, which made PLF possible. Furthermore, the station was also deemed to be problematic due to several lethal accidents involving PUT (Lindberg & Forsberg, 2018).

PLF have not been described in the scientific literature or in the Restrail toolbox previously. The primary hypothesis of this study was that lengthwise fences reduce trespassing. Our secondary hypotheses were that they would also have the effect of decreasing the number of PUT (both suicides and accidents), as well as decreasing train traffic delays caused by trespassing and PUT.

2. Data and methods

2.1. Study design

The effects of installing the fences were evaluated as a quasi-experimental "natural experiment." Trespassing was evaluated by using an interrupted time series (ITS) approach for the intervention station alone, using the pre-period as controls and post-period as cases. No control stations were used since alerting CCTV-cameras located at the track area are unusual in the Stockholm commuter system and there is no other station that would be relevant to use as a control in this aspect.

For the secondary hypotheses of PUT and train traffic delays, we used both the ITS approach as well as a comparison of the intervention station with three different control groups (details follow).

2.2. Data

2.2.1. Sources

Data of trespassing were taken from the recordings from CCTV-cameras installed at the track area (operated by the STA). The CCTV cameras send an alert and records when there is human movement on the track area at approximately 10 m from the platform into the tunnel, but without distinguishing between authorized and unauthorized persons. We manually excluded authorized personnel by identifying their reflective clothing (mandated by law for all railway personnel). To make this distinction, all cases were filtered manually by one of the authors (JFK) viewing the recordings of each detection. This CCTV data collection was performed from November 2019 to June 2022. Data were excluded for the periods of June-July 2020 (during the construction of PLF) and for July 2021 (during a larger maintenance work on the station).

Data regarding suicides and accidents involving PUT, excluding workplace accidents, for the period of June 2002 to June 2022 were extracted from the STA register "Synergi." In particular, information about *when* the event took place, a brief description of the event, and a dichotomous classification of the event coded as suicide or an accident. Only the data registered at the stations were used (and not for the open line between stations). The longest period having available data was analyzed.

Data about delays (>3 min) because of trespassing, suicides, or accidents (excluding workplace accidents) for the period July 2014–June 2022 were taken from the STA register "LUPP" (using internal codes OMÄ01 and OMÄ02). Delays due to other causes were not examined here. This particular period was selected because the same routine of the operative handling of trespassing events was employed in the Stockholm commuter system throughout the entire time period (Fredin-Knutzén et al., 2018).

The public transporter of Stockholm (SL) is responsible for the CCTV-cameras at the platforms (in comparison with the CCTV-cameras at the track area that are an STA responsibility) and the guards patrolling the platform when there is an event. If a suicide attempt occurs, a SL investigator will manually observe the recorded films from the platforms and write a log report of the event. Three written log reports of these events were extracted from SL, having occurred in the period November 2019 to June 2022.

2.2.2. Suicide classification

The data about trespassing did not contain any description of the motives for either suicide or accident events. Whether a delay was related to suicide or other motives was sporadically made by a train traffic controller, depending on the information they had available about the event.

In contrast, the classification of PUT was more comprehensively performed by STA depending on the information from their own investigation as they collect data from several different sources, like witness reports from the train driver and information from the police authorities. The classification was improved from 2015 by introducing a new method of investigating the cases where the motive was unknown, and such cases are investigated by a group of members with representatives from the STA, Swedish transport agency, and the forensic board of medicine (Fredin-Knutzén, Andersson, Hadlaczky, & Sokolowski, 2020). These classifications are the same as the official statistics reported to the government.

2.2.3. Intervention station

PLF at Stockholms södra – station were built during June–July 2020 as part of a larger maintenance project in this section. The intervention station has PLF installed for both tracks (either side of the platform) in each direction (north and south) and has an exit from the platform at both ends. During normal circumstances this station is only operated by commuter trains. Because there were no other stations in the Swedish railway with PLF, this station alone constituted the intervention group. Refer to Fig. 1, and the supplement for a further description about the design of the station and PLF.

2.2.4. Control stations

Control stations were used as a supplementary evaluation of PUT and train traffic delays. The control stations have many similarities to the intervention station with regard to several aspects: similar traffic intensity, populated by similar train models, and same geographic area within the Stockholm region (that shares common features such as political government, healthcare, weather, and trends regarding traveling). During normal conditions, there are mainly commuter trains stopping at the control stations, except for a minority of stations that are also used for regional traffic. However, there are also certain dissimilarities, in particular for the broader control group 1 (see also Table S1).

The accessibility to the tracks from the platform ends was approximatly the same at the intervention station and control stations before the intervention. The platform-ends have been approximately the same at all control stations (except for two stations with PSDs located adjacent to the intervention station, which were excluded) during the entire study period. Refer to the supplement for a brief description.

By using three different control groups, we tried to reduce the risk of confounding variables in different aspects.

Control group 1 consisted of all stations in the Stockholm commuter railway system, excluding the stations next to the intervention station and those stations with PSD. The reason for omitting the closest stations was that delays at the intervention station could, in some circumstances, be registered at the closest station next to the intervention station (refer to the supplement for a more detailed description about delays). In total, this covers 50 stations. This control group was used to adjust for larger societal trends (e.g., the Covid-pandemic).

Control group 2 (which is a subset of control group 1) consisted of the three stations closest to the intervention station, but excluding stations immediately next to the intervention station and those that had PSD installed. These three stations are located where the line is split into two separate sections north of the intervention station and beyond the two stations with PSD (Fig. S1). This control group is pertinent from the perspective of comparing the intervention station with stations located in the central part of the commuter system consisting of a high amount of commuters and train traffic. It was primarily used to correct for how delays are distributed in the railway system, considering that stations in central parts of the railway are more vulnerable to delay events.

Control group 3 (which is another subset of control group 1) were comprised of 19 geographically distinct (southeast) stations, which we could acertain to have the same amount of trains per day as the intervention station. We excluded stations next to the intervention station and those that had PSD installed. This control is primarily used to correct for the possibility that different numbers of trains can affect the results.

2.3. Analyses

The main hypothesis of this study was that PLF would decrease the number of unauthorized trespassing. To test this hypothesis we compared the months post installation (August 2020–June 2022) with the months prior to the installation (November 2019–May 2020), by calculating Incidence rate ratios (IRR) and one-tailed exact p-values at the intervention station.

Our secondary hypothesis was that PLF would decrease the number of PUT. This hypothesis was also tested by IRR at the intervention station, and further complemented by testing the effect compared to the controls by using odds ratio (OR) and one-tailed Fisher's exact tests. The number of PUT occurring during August 2020–June 2022 was compared with the number of PUT years June 2002–May 2020, between the intervention and control stations. When there were zero PUT in the post-period, we used "Woolf's method with Haldane Anscombe correction" to calculate the OR (Ruxton & Neuhäuser, 2013).

Our third hypothesis was that the PLF would decrease the train traffic delay minutes. This was tested with a one-tailed independent samples Mann-Whitney *U* test, and effect size calculated by using an approximated Cohen's *d* comparing before and after the installation at the intervention station. The periods analyzed were August 2020–June 2022 and July 2014–May 2020.

Analyses of IRR and Mann-Whitney U were done in Stata BE v 17.0 (StataCorp, 2005), OR with Woolf's method with Haldane Anscombe correction was calculated with the online-calculator at https://statpages.info/ctab2x2.html (Rosner, 2006). Approximated Cohen's *d* for Mann Whitney *U* test were calculated with the online-calculator at https://www.psychometrica.de/effect_size.html (Lenhard & Lenhard, 2016).

3. Results

3.1. PLF reduced trespassing

During the seven months prior to installation, the monthly average of trespasses occurring at the intervention station was 3.57 (25 trespasses in total), which was reduced to an average of 0.36 during the 22 months post-installation (8 trespasses in total), displayed in Fig. 2. This represented a significant reduction in trespasses after PLF installation (IRR = 0.10, 95% CI 0.04–0.23; one-sided exact $p < 0.0001$). The reduction was not likely to be caused by the pandemic (which caused a reduction in the number of passengers overall; see Fig. S3), as the number of trespasses increased, rather than decreased, during the first three months of the pandemic occurring prior to PLF installation (Fig. 2). Indeed, a pre- versus post-comparison using only the pandemic period months from March 2020 and onward (3 vs. 22 months) showed a larger reduction in trespassing ($IRR = 0.07$, 95% CI 0.03–0.17; one-sided exact $p < 0.0001$). In addition, the effect remained significant even when comparing only against the four pre-pandemic months (before March 2020; 4 vs. 22 months), which had a lower rate of pre-intervention trespasses (Fig. 2; $IRR = 0.16$, 95% CI 0.05–0.47; one-sided exact $p = 0.0004$). Finally, there was no significant difference in the effect of PLF located in the north versus the south end of the platform (9.4 vs 5.4-meter-long fences in each end), as there were 12 versus 4 trespasses in the north and 13 versus 4 trespasses in the south end, during the entire pre- versus post-installation periods (7 vs. 22 months), respectively ($OR = 0.92$, 95% CI 0.19–4.54; one-sided Fisher's $p = 0.693$).

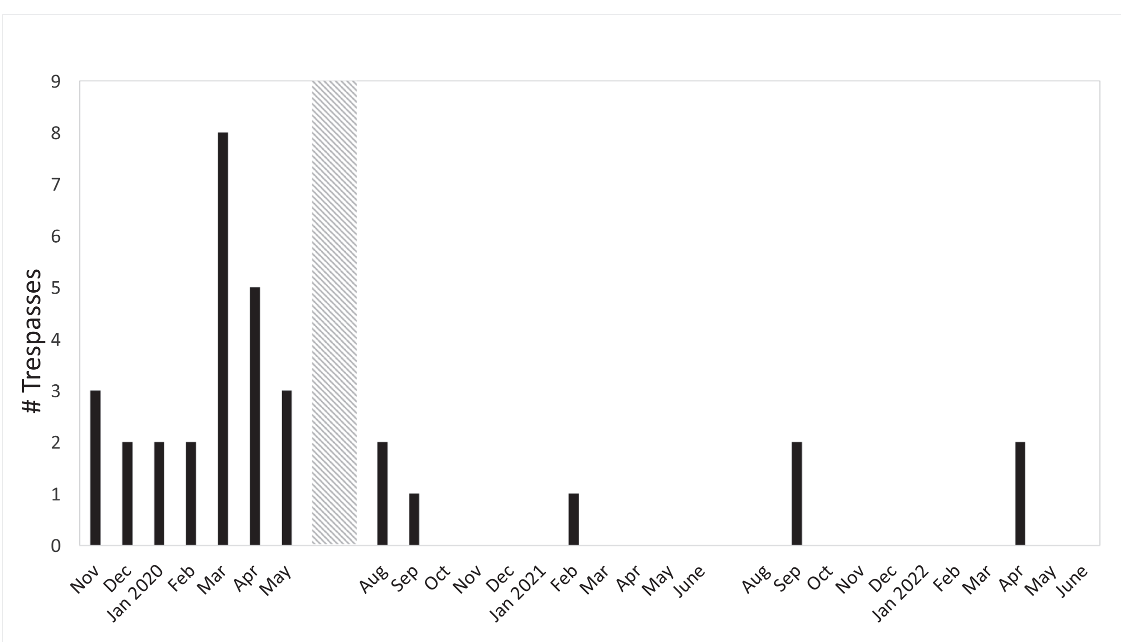

Fig. 2. Trespasses at the intervention station were reduced after installation of PLF in June-July 2020 (thick hatched line).

3.2. No "person under train" (PUT) incident occurred after PLF was installed

There were in total 20 PUT (15 suicides, 5 accidents) at the intervention station during the period June 2002–June 2022. All of them occurred during the 18 years prior to the fence installation (in average 1.11 a year) and none occurred during the two years post-installation. The statistical results, albeit underpowered, showed a non-significant tendency of the lengthwise fences reducing the number of PUT, involving mainly suicides (*IRR* = 0.32, 95% CI 0–1.82; one-sided exact p = 0.1216).

The OR for the number of PUT occurring at the intervention station compared to three different control station groups, similarly showed a non-significant tendency of reduction in the number of PUT occurring at the intervention station; control 1 (*OR*: 0.36, 95% CI 0.02–6.14, One sided Fisher's exact test p = 0.252), control 2 (*OR*: 0.21, 95% CI 0.01–5.04, One-sided Fisher's exact test p = 0.135) and control 3 (*OR*: 0.71, 95% CI 0.03–16.47, One-sided Fisher's exact test p = 0.471).

3.3. PLF decreased train traffic delays

There was in total 90,540 min of delay at the intervention station during the 6 years prior to PLF installation (median = 15,262 or mean = 15,090 min per year), compared to a total of 5,295 min of delay (median = 2,648 or mean = 2,648) across the 2 years post installation (Fig. 3). A Mann-Whitney test showed that this represented a significant and large reduction in delay minutes post installation compared to pre installation (U = 0, upper one-sided exact p = 0.0357; approximated Cohen's d = 2).

In addition, there was also a distinct difference between the intervention station and the control stations (Fig. 3) as the intervention station was the only one with fewer delay minutes during the post intervention period. Together, the results suggested that PLF installation caused a reduction in the amount of train delays at the intervention station *per se*.

4. Discussion

PLF showed a large and significant effect of reducing trespassing from platform-ends, from an average of 3.57 trespassers to 0.36 trespassers a month (*IRR* = 0.101). This supports the hypothesis of a preventive trespassing-effect of using lengthwise fences at platform-ends. Reducing the number of trespasses are likely to affect the number of PUT as well, although we could only observe a non-significant tendency of such a reduction from 1.11 to zero PUT per year (*IRR* = 0.32). The effect of PLF on reducing the number of PUT was also observable when compared to the three control groups, suggesting that the preventive effect was not due to wider societal events affecting all stations. Considering that this intervention does not prevent individuals from jumping or falling in front of a train from the platform, it is likely that the number of PUT will continue to occur, but perhaps less often. To our knowledge there has been three known severe suicide attempts (which was not analyzed here) at the intervention station after the lengthwise fences were built, one during the building period when the fence was installed but not yet completed, and the other two during the post-period. In one of those cases, a person jumped in front of a train in the middle of the platform, but the train managed to stop before collision. The two other cases involved suicide attempters whom were held back by bystanders. It is possible that these persons would have entered the track-area if the lengthwise fences did not exist, which would have made interventions from bystanders less likely. The risk for deadly outcome when attempting suicide by standing at the track area before a train collision is higher, compared to if the person jumps from the platform (Ceccato et al., 2021).

There was also a significant and substantial decrease in delays pre- and post-intervention (approximated Cohen's d = 2.15), which remained observable when comparing with the controls (Fig. 3). Reducing the delays is of major importance for the efficiency of the railway system.

We speculate that the effect of PLF is primarily due to an increased informal social control at the platform-end, which is in line with the model of the routine activity approach (Cohen & Felson, 1979) as argued in a previous report from the Swedish rail industry (Fredin-Knutzén et al., 2018). Although we have not evaluated the effect mechanism of this specific intervention, it could be speculated that it acts as a physical obstacle as well as a motivational barrier. One argument for the fences being motivational obstacles is that even after installation, it remained fairly simple to walk on the anti-trespass panels and/or jump down to the track area and walk into the tunnel (please view this process in the video-film supplement).

The PLF have a high similarity with other suicide preventive measures which only partially restrict the access to means for suicide, for example, "mid-track fence" at railways (Fredin-Knutzén et al., 2022), "suicide guard rail" on hospital windows (Mohl et al., 2012) and "safety nets" at bridges (Hemmer et al., 2017).

We believe that PLF are suitable for stations where there is an exit at the end of the platform (rather than at stations where the exit is in the middle of the platform, or where the exit is at the other end of the platform) and where there is enough space to install a PLF (e.g., trains are shorter than the platforms). It may be particularly relevant at stations where the exit from the platform is covered at the sides (e.g. by a building), which may cause reduced field of view and low social control of the track area. PLF appeared scalable, as there was no difference in the effect when using either 5.4 or 9.4 m long fences. Before building a PLF, a risk analysis considering the specific abilities of the context must be

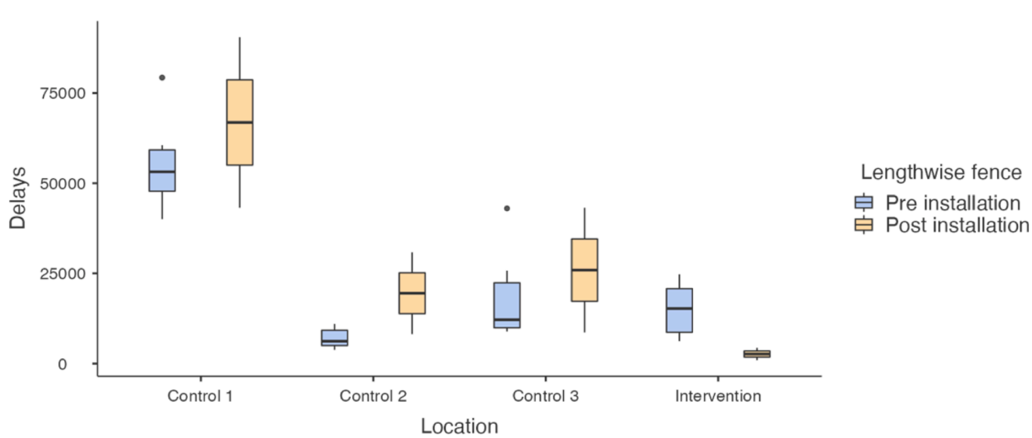

Fig. 3. Train delays (in minutes) due to trespassing, suicides, and accidents at the control stations and the intervention station. Only the intervention station displayed less train delays during the post period.

done. The PLF could, for instance, cause problems related to when longer trains are used at station platforms (e.g., during evacuations in an emergency).

Interventions that mitigate injury risk without removing the risk entirely are the goal of many injury prevention strategies. This makes this intervention, compared to a complete removal of the risk, relatively easy and cheap to install and thus scalable. Scalability is important to gain effects over a total railway system rapidly. While this was not studied here, the cost-effectiveness of this intervention may be high, as the cost of approximately 150,000 Euros for the fence installation should be compared to the benefits of fewer fatalities and traffic delays.

There are limitations within our study. The first and foremost is that the intervention was only implemented at one station, which may affect the validity and generalizability of our findings. In addition, due to the small sample size regarding the trespasses and accidents at the specific station and the hypotheses proposed, we have used one-sided statistical analyses.

To investigate if the effect may have been caused by wider societal changes affecting also other stations, we used three different matched control groups in the evaluation of the number of PUT and train traffic delays. As shown in Table S1, these control groups are not perfect matches compared to the intervention station, since every control group had similarities and dissimilarities compared to the intervention station. Despite the variations in control group compositions, the IRR effects of PLF were supported by all control groups used in the comparisons. Furthermore, the PLF were built during the first three months of the Covid pandemic, which was a period of drastically fewer commuters than before. Fewer commuters (due to the pandemic) may have resulted in a lower level of informal social control at the station overall, and indeed the number of trespasses also appeared to increase during March–May 2020 (Fig. 2). Nevertheless, the results showed that PLF did reduce the number of trespasses when compared to either pre-pandemic months or only to the pandemic months before the intervention was installed. Another factor that affects the number of commuters at the station (and thus potentially the outcomes tested here) is the weather (i.e., seasonality). However, the effect of PLF on the number of trespasses during the same months (e.g., Nov-May in both pre- vs. post-periods), was equally apparent as when comparing to the other post-period months (see Fig. 2) and the results on PUT and train delays was based on compounded yearly data (thus covering all seasons).

One limitation regarding the data on trespassing was that the CCTV-cameras only cover the track area starting approximately 10 m into the tunnel, which means that they do not detect trespassing at the tracks right next to the platform. Another limitation regarding the data on delays was that not all delays were caused by persons actually being at the track-area, as some delays were also caused by threats and unconfirmed notices of persons at the track area. Further, delays could also have been registered at the closest station, even though the event formally happened at another station or the line between stations. Nevertheless, these data limitations should have affected both the intervention station and the control groups to a similar degree.

5. Conclusion

PLF at platform-end exits is a measure that prevents trespassing and traffic delays at the railway. In addition, there is indication that the measure prevents the number of PUT incidents. PLF appear to be a low-cost and scalable intervention. All together, we argue that this measure should be highly prioritized for further investigating since this is a pilot study with several limitations. Research about cost effective and scalable measures for preventing accidents and suicides at the railway is of great importance and should be prioritized to reduce the number of fatalities and to enable the development of efficient railway systems all around the world.

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Ethical permits

Approval from the Swedish Ethical Review Authority (Dnr 2023-01080-01).

Declaration of Competing Interest

JFK was the first author of an initial investigation suggesting effects of PLF in 2018, when working as an external consultant. That investigation was funded by STA and the railway industry in Sweden. AW is employed at STA.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jsr.2023.10.010.

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