

ARTICLE V

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Effect of three countermeasures against the illegal crossing of railway tracks

Anne Silla*, Juha Luoma¹

VTT Technical Research Centre of Finland, Vuorimiehentie 3, P.O. Box 1000, 02044 VTT, Finland

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ABSTRACT

This study was designed to investigate the effects of three countermeasures – landscaping, building a fence and prohibitive signs – on the frequency of trespassing, which in this case means crossing the track at places where it is forbidden. At each location the official route was no more than 300 m away. The main results showed that the effect of each countermeasure on the frequency of trespassing was statistically significant. Specifically, the fencing reduced trespassing by 94.6%, followed by landscaping (91.3%) and prohibitive signs (30.7%). The majority of illegal crossings were committed alone and the persons trespassing were mostly adults and men. In addition, the results demonstrated some tendencies of how the effects of the selected countermeasures can vary with the characteristics of the trespassers. The main implication of this study is that the building of physical barriers such as landscaping or fencing is recommended for reducing trespassing. However, if the required resources are not available or the site is not suitable for such measures, the use of prohibitive signs is recommended. Further, there is a need to tailor the countermeasures to the characteristics of the trespassers in order to ensure that the most appropriate countermeasures are applied.

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1. Introduction

Trespassing is one of the leading railway safety challenges worldwide (e.g. Lobb et al., 2003; Lobb, 2006; Pelletier, 1997). This is also the case in Finland, where most fatalities involving rail vehicles result from collisions between trains and pedestrians (Eurostat, 2007).

Trespassers are people who cross railway lines at places not marked for that purpose, or who loiter or walk illegally in the railway area. Nearly every pedestrian walking in the area close to the railway lines is a potential trespasser if the railway lines are not effectively isolated from the surrounding areas. While trespassing refers to using the railway as a short cut or even to commit vandalism (Robinson, 2003), the main reason for trespassing seems to be taking a short cut (e.g. Lobb et al., 2001; Rail Safety and Standards Board, 2007). For example, recent trespasser interviews carried out in Finland showed that the route across the railway tracks was the shortest and fastest alternative for trespassers (Silla and Luoma, 2008). Many of them had used the route for years and clear paths across the railway lines had made trespassing easy.

In Finland, 5794 km of railway lines are currently in use (Finnish Rail Administration, 2008). Usually they are not fenced. Trespassing concentrates in urban areas where the population density is

high and rail traffic is heavy (Silla and Luoma, 2008). Railway lines have always divided communities, in some cases increasingly over the years. Thus new developments within the city such as residential areas, shopping areas and schools are frequently located on both sides of the railway lines, increasing people's need to cross the tracks. As pointed out by Nelson (2008), the division of communities generates a tension between the railway authorities, who have the responsibility to ensure that the railway can be crossed safely by restricting the points at which the public can cross the railway, and pedestrians who wish to find the shortest route between two points. Consequently, the railway authorities need applicable information about possible measures to prevent trespassing.

Many studies have argued that trespassing tends to be specific to a location (e.g. Law, 2004; Rail Safety and Standards Board, 2007; Savage, 2007). If this is the case, countermeasures should be tailored to specific characteristics by identifying who is trespassing and why. However, the only published study investigating this issue is our earlier study, which included trespasser interviews (Silla and Luoma, 2008). The main factor that determined the suggested countermeasures was distance to the closest official crossing site. People were more willing to accept fencing if the distance was relatively short, but for a relatively long distance they somewhat preferred an overpass or underpass.

These findings suggest that countermeasures should be tailored to location and environment-related factors. In addition, the countermeasures should possibly also vary in line with trespasser characteristics. Without a good understanding of the problem, the risk remains that allocated resources are wasted or that

* Corresponding author. Tel.: +358 207224517; fax: +358 207227000.

E-mail addresses: anne.silla@vtt.fi (A. Silla), juha.luoma@vtt.fi (J. Luoma).

¹ Tel.: +358 207224533; fax: +358 207227000.

implemented measures may be counterproductive (Savage, 2007).

There are several countermeasures that have been used to deter trespass. Suggested interventions include limitation of pedestrian access to railroad areas, public education, reward or punishment, and different technical solutions (e.g. Rail Safety and Standards Board, 2007). The limitation of pedestrian access can be achieved with e.g. fencing, signage, attendance of station staff or security personnel, and landscaping. Technical solutions include e.g. warning devices, closed-circuit television with or without a link to audio announcements and/or motion detectors, and cameras with motion detectors. The Rail Safety and Standards Board (2007) suggests that a multifaceted approach, using a mix of measures designed to be directed at specific issues, can be effective in discouraging access to the railway lines.

Regardless of the large number of proposed countermeasures, there is little published research evaluating the effectiveness of any of these interventions (Lobb, 2006). Lobb et al. (2001) combined public education and access prevention by fences to reduce trespass at a suburban station in Auckland. The results showed that immediately after these interventions the rate of trespassing decreased from 59% to 40% and after 3 months the decrease was sustained and even slightly enhanced (from 40% to 36%). Furthermore, the reduction was higher for adults (from 65% to 37%) than for children (from 47% to 34%). Lobb et al. (2003) evaluated the effects of rail safety education, continuous punishment and intermittent punishment on reducing the trespass. The target group included pupils in secondary/high school. Lobb et al. (2003) concluded that punishment might be more effective than education in reducing unsafe behaviour in the vicinity of railway stations, and substantially more effective than communications to raise awareness.

The above review suggests that more research is needed to understand trespassing behaviour and to broaden the knowledge related to trespassing. In order to counter the trespassing problem, we identified the sites of frequent trespassing on Finnish railways, investigated trespassing behaviour at selected sites, and explored opinions about possible countermeasures to prevent trespassing (Silla and Luoma, 2008). In addition, we have investigated the opinions on railway trespassing of people living close to the railway line (Silla and Luoma, submitted for publication).

The aim of this study was to investigate the effects of three countermeasures on the frequency of trespassing and the characteristics of trespassing behaviour. The countermeasures included landscaping, building a fence and prohibitive signs. It was assumed that landscaping and fencing are effective countermeasures as they make trespassing physically difficult. However, the effectiveness of these measures might differ with the characteristics of trespassers. Furthermore, these countermeasures are relatively expensive to install, and especially fencing needs maintenance as well. Prohibitive signs were selected as the third countermeasure, as they are inexpensive to install and require limited maintenance. However, it was assumed that the effects of signs on trespassing would not be substantial, because it is well known that pedestrians do not always comply with established prohibitions. For example, Rosenbloom (2009) found in Tel Aviv that 13.5% of the pedestrians arriving in the red-light phase at an intersection crossed the street on red.

2. Method

2.1. Countermeasures

The tested countermeasures included (1) landscaping, (2) building a fence and (3) prohibitive signs. Each countermeasure was tested at one site. The selection of a suitable site for each countermeasure was based on environment-related factors.

The characteristics of the countermeasures were as follows: (1) the landscaping included removal of the existing path across the railway line, steepening the sides of the railway line, planting trees and bushes to form a natural fence, planting grass and decorating the sides with a few large stones. The landscaping was approximately 1.5 m high and 200 m long, the unofficial path being roughly in the middle of it. (2) The fences installed on both sides of the railway line were approximately 1.0 m high and extended roughly 100 m from the unofficial path in both directions. The fencing started at an underpass and continued to a landscaping area. (3) The design of the prohibitive sign was based on existing prohibitive signs used in Finnish rail and road transportation, with the supplemental text "No trespassing". The sign was erected on both sides of the railway line. No additional enforcement was introduced during data collection. The countermeasures are shown in Fig. 1.

2.2. Research locations

All the research locations were selected in the city of Lappeenranta, as our earlier study (Silla and Luoma, 2008) had shown that the area is very prone to trespassing. Lappeenranta is a relatively small city in Eastern Finland. At the time of data collection the city included some 60,000 inhabitants. The age distribution of the inhabitants was as follows: younger than 19 years 19.9%, 19–24 years 8.2%, 25–44 years 24.7%, 45–64 years 29.2% and older than 64 years 17.9%. The transport system is dominated by cars. However, there is a local bus transport system and an extensive network of pedestrian and bicycle paths. Crucially, the tracks divide the city into two parts (Fig. 2), which leads to frequent crossing of the tracks. There is a 4 km stretch of track that includes 12 locations with frequent trespassing. This track section includes five official crossing places.

At each location the official route was no more than 300 m away from the illegal crossing site. Residential areas, shopping areas and schools are located on both sides of the railway lines, increasing people's need to cross the tracks. This is compounded by areas for leisure activities such as an ice hall and outdoor routes within the city. Preliminary site observations showed that the path across the tracks in the vicinity of the prohibitive sign was used more actively than the paths located near fencing or landscaping.

During working days more than 50 trains pass through this railway section, of which 14 are regular passenger trains. The maximum speed limit through the railway section is 140 km/h, but in practice the local topography keeps speeds at 100 km/h or less. During the period 2002–2008 two people were unintentionally killed by rolling stock in motion on this section of railway (VR Group Ltd, 2010). However, neither of these fatalities occurred during the study period.

2.3. Design

The main analysis was based on comparison of trespassing frequency before and after a given countermeasure was set up. The number of working days and weekend days for each location was similar for both the before and after phase. The underlying assumption was that the travel behaviour of people (in terms of timing or starting point and destination) in the area would not change between the before and after measurements.

2.4. Procedure

The landscaping was installed at the end of autumn 2006. The fences were built and prohibitive signs erected in early May 2007, one week before the after-phase measurements.

Video cameras equipped with motion detectors were used to count trespassers. The cameras (AVN-4090E, 37(Dia) × 99(L) mm)

A. Location of landscaping



B. Location of fencing



C. Location of prohibitive signs



Fig. 1. Pictures of research sites after the implementation of countermeasures. (A) Location of landscaping. (B) Location of fencing. (C) Location of prohibitive signs.

were small and not easily detectable by trespassers—one was placed under the eaves of a building and two others about 4 m up two electricity poles. The cameras were therefore assumed not to influence people's behaviour. The motion detectors covered the path used by trespassers with its surroundings, and whenever movement was detected the camera took 15 digital pictures at intervals of 1 s. The camera functioned independently and only required the batteries to be changed once a week.



Fig. 2. Map of the city of Lappeenranta (City of Lappeenranta, 2007). The black line from bottom left to upper right shows the railway line including both passenger and freight traffic. The numbers show the research locations: (1) landscaping, (2) fencing and (3) prohibitive signs.

The data analyses of both phases included 10 days of data for landscaping, 11 days for fencing and 17 days for the prohibitive sign. Before-phase measurements were carried out in May 2006 and after-phase measurements in May 2007. Due to the ambient light in Finland at that time of year, data were collected virtually around the clock. Only a couple of hours at midnight were missed because of darkness. In addition to counting trespassers, the characteristics of trespassers such as gender, age group (children younger than 12 years, youngsters from 12 to 20 years and adults older than 20 years), numbers of people trespassing together, and whether they were carrying anything were classified and documented. All information was collected from video recordings and no interviews were conducted, which means that age assessment may include some minor errors.

3. Results

Fig. 3 shows the frequency of trespassers per day at each location before and after a given countermeasure was installed.

The largest reduction in the number of trespasses was found for fencing (94.6%), followed by landscaping (91.3%) and the prohibitive sign (30.7%). Two statistical tests of significance were performed on the effectiveness of each countermeasure. First, the number of observations was assumed to follow the Poisson distribution. However, when the number of observations is high, the approximation to normal distribution is possible and therefore the *t*-test was performed. The results showed that the effect of each countermeasure on the frequency of trespassing was statistically significant (landscaping $t(18) = 6.40, p < 0.001$, fencing $t(20) = 10.91, p < 0.001$ and prohibitive sign $t(32) = 4.44, p < 0.001$).

Second, due to uncertainty as to whether the number of observations was high enough for the approximation, we performed an additional distribution-independent non-parametric Mann–Whitney *U*-test. The results also showed that the effect of each countermeasure on the frequency of trespassing was statistically significant ($p < 0.001$).

Furthermore, the effectiveness of the countermeasures was assessed by time of day and trespasser characteristics. However, due to the limited amount of data for two countermeasures and some interdependencies, no statistical analyses were performed.

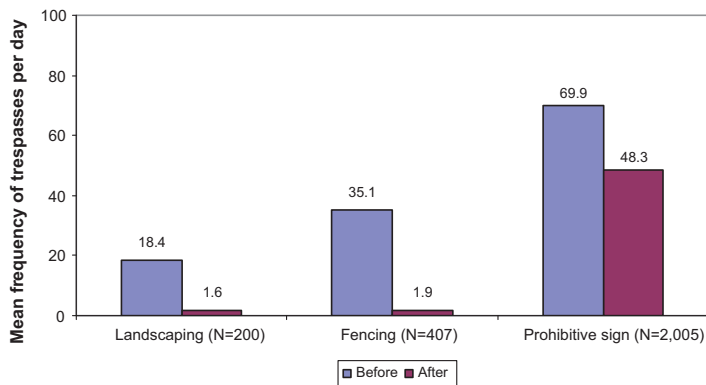


Fig. 3. Frequency of trespasses per day before and after countermeasure installation.

Specifically, the most evident interdependencies before the countermeasures were installed included the following: 94% of the trespassers in groups involving more than two persons were children or youngsters, 86% of people with dogs were adults and all trespassers equipped with poles (i.e. Nordic walkers) were adults.

Table 1 shows the number of trespassers by time of day. The results show that the prohibitive sign lowered the amount of illegal crossings only during the day and not during night. For the other countermeasures, no clear differences were found.

With the above proviso in mind, Table 2 shows the frequency of trespassing and the effectiveness of countermeasures by trespasser category.

Overall, males were trespassing more frequently than females. However, landscaping seemed to reduce trespassing by males more than by females.

Before any installation, the largest age group at each location was adults, followed by youngsters and children. The landscaping was highly effective among children and adults but not that effective among youngsters. The effectiveness of fencing was roughly similar in each age group. The sign was quite effective among children, but relatively few youngsters and adults obeyed the message on the sign.

Overall, in the before phase most trespassers were alone, followed by groups of two. Larger groups were quite rare. Landscaping reduced relatively well trespassing by all but groups of more than two. Notably, most groups of more than two involved youngsters. Furthermore, the effect of the fencing and the sign did not vary substantially by size of group.

In the before phase, most trespassers were travelling without carrying or having anything with them, followed by trespassers carrying their bicycle, trespassers with their dog(s), trespassers equipped with poles (i.e. Nordic walking) and a few trespassers with something else, like a pram or scooter. Although many frequencies are too small to draw any conclusions, some tendencies are worth mentioning. First, after the installation of landscaping no trespassers were carrying or had anything with them. Second, the overall effect of the fencing was high, except for people exercising with poles. In the case of the sign the effect was the opposite, with the highest effectiveness among (adult) people exercising with poles.

4. Costs and benefits

A simple cost–benefit analysis of the implemented countermeasures was carried out. Each countermeasure was compared with the

situation when no countermeasure was implemented. The present value of costs and benefits over 30 years was estimated with a discount rate of 5% (Finnish Rail Administration, 2004).

The cost estimate first assumed the following implementation cost for each countermeasure: landscaping 30,000 €, fencing 30,000 € and signing 5000 €. Secondly, the yearly cost of time lost using an official route instead of trespassing was estimated for those who did not trespass after the implementation of a given countermeasure. The mean lost time per crossing was 0.12 h (distance 2×300 m, walking speed 5 km/h). The monetary value of time for commuting, shopping and leisure was 4.07 €/h (Finnish Rail Administration, 2004).

The benefit estimate included the assessed safety benefits and the depreciation value of the investment. Specifically, the 4 km long railway section (for which the number of fatalities was available) includes 12 trespassing sites, each involving approximately 41 trespassers per day on average (i.e. the mean number of trespassers per site before implementation of the countermeasures). These figures result in 179,580 trespassings per year along a given rail section. There had been two fatal trespassing accidents in the past 7 years, the fatality risk per trespassing then being 1.59×10^{-6} ($2/(7 \times 179,580)$). The monetary benefit of one avoided trespasser fatality is 1,964,161 € (Finnish Rail Administration, 2004). Consequently, the mean benefit per avoided trespassing was 3.08 €. The depreciation value of the investment was 25% of its original value (Finnish Rail Administration, 2004).

Table 3 shows the results of the cost–benefit analysis for two scenarios. Scenario 1 was based on the actual number of trespassers at each site. However, to generalise the results, the same number of trespassers before implementation (mean value of 41 in this case) was used for Scenario 2.

Both scenarios showed that the benefits of each countermeasure were substantially higher than the cost. The benefit–cost ratio was highest for prohibitive signs, but the differences among the countermeasures were not substantial if the number of original trespassers was the same (Scenario 2).

5. Discussion

The aim of this study was to investigate the effects of three countermeasures on the frequency of trespassing at locations where the official route was no more than 300 m away. The main results showed that each implemented countermeasure had a statistically significant effect on the frequency of trespassing. The largest reduction in the frequency of daily trespasses was found for fencing (94.6%), followed by landscaping (91.3%) and a prohibitive sign

Table 1
Number of trespassers by time of day.

	Landscaping			Fencing			Prohibitive sign		
	Before	After	Reduction	Before	After	Reduction	Before	After	Reduction
6:00 a.m.–6:00 p.m.	125	16	–87%	297	12	–96%	861	477	–45%
6:00 p.m.–6:00 a.m.	59	0	–100%	89	9	–90%	323	344	0%

Table 2
Trespassing frequency by trespasser category, before and after installation of countermeasures.

	Landscaping			Fencing			Prohibitive sign		
	Before	After	Reduction	Before	After	Reduction	Before	After	Reduction
Gender									
Male	140	6	–96%	250	13	–95%	734	531	–28%
Female	44	10	–77%	136	8	–94%	450	290	–36%
Age group									
Children	40	0	–100%	30	1	–97%	99	25	–75%
Youngsters	40	16	–60%	86	8	–91%	527	367	–30%
Adults	104	0	–100%	270	12	–96%	558	429	–23%
Group size									
1	112	1	–99%	319	11	–97%	777	516	–34%
2	52	6	–88%	52	10	–81%	316	246	–22%
More than 2	20	9	–55%	15	0	–100%	91	59	–35%
Accompanying									
Nothing	67	16	–76%	168	11	–93%	752	564	–25%
Bicycle	78	0	–100%	157	7	–96%	305	193	–37%
Dog(s)	24	0	–100%	52	0	–100%	119	59	–50%
Nordic walking	15	0	–100%	7	3	–57%	8	1	–88%
Other	0	0	–	2	0	–100%	0	4	–

(30.7%). These results suggest that physical barriers can stop trespassing almost entirely. In turn, the effect of prohibitive signs is much more limited.

The benefits of each countermeasure were higher than the costs, with a somewhat higher benefit–cost ratio for prohibitive signs than other countermeasures. Consequently, the main implication of this study is that all measures can be recommended for reducing trespassing. The selection of the countermeasure depends on the applied safety policy. First, if the high benefit–cost ratio or low costs are emphasised, the use of prohibitive signs is recommended. In addition, the effect of the signs might be improved by effective enforcement. Secondly, if high effectiveness is emphasised, building physical barriers with a somewhat lower benefit–cost ratio is recommended for reducing trespassing.

Furthermore, the results revealed some tendencies of how the effects of countermeasures can vary with the characteristics of trespassers. Given the limited number of trespassers, however, these results should be interpreted with caution.

First, the prohibitive sign decreased the amount of illegal crossings only during the daytime and not at night (although the darkness was not comprehensive). No specific explanation for this was found.

Table 3
Benefits, costs and benefit–cost ratio by measure. Scenario 1 is based on the actual number of trespassers at each site and Scenario 2 is based on the average number of the trespassers before the implementation.

Scenario		Landscaping	Fencing	Prohibitive signs
1	Benefits	246,918 €	487,690 €	313,835 €
	Costs	–69,189 €	–107,402 €	54,809 €
	Benefits–cost ratio	3.6	4.5	5.7
2	Benefits	550,198 €	569,814 €	184,749 €
	Costs	–117,323 €	–120,436 €	–34,322 €
	Benefits–cost ratio	4.7	4.7	5.4

Second, the majority of crossings in both phases were made alone and the trespassers were mostly adults and men. This finding is in line with previous results indicating that adult males are the largest group of trespasser casualties (see e.g. Savage, 2007; Lobb, 2006). However, it is worth noting that the data of the present study was based on trespasser counts and not on reported incidents and fatalities. Consequently, the present results provide information about the behaviour of all trespassers.

Third, landscaping highly reduced the share of children and adults trespassing and the prohibitive sign effectively reduced trespassing by children. The effect of fencing was approximately similar for all age groups. Finally, landscaping and fencing substantially affected trespassing with bicycles and dogs, most likely because trespassing became too awkward physically. Overall, these tendencies demonstrate the need to tailor the countermeasures to the characteristics of trespassers in order to apply the most effective or most suitable countermeasure.

This study had limitations that should be kept in mind while generalising the results. Specifically, the data in the after phase were collected quite soon after the installations. Thus, the results are limited to the short-term effects of the preventative measures. Nevertheless, it is possible to assume that even though signs are considerably less costly to set up than physical countermeasures, they might lose their effectiveness quite rapidly over time, especially if enforcement is not introduced. The effects of physical countermeasures can be assumed to be more long term. However, it is important to consider that physical countermeasures need periodic maintenance, for example due to possible vandalism, in order to retain their effectiveness. Additionally, trespassers' behaviour might be affected by the realisation from the implemented countermeasures that someone is paying attention to their safety. Nevertheless, even if this affects behaviour it does not reduce the influence of the countermeasures. Another limiting factor is that each countermeasure was installed at one site, possibly creating some bias. Furthermore, there exist many other countermeasures to prevent trespassing in addition to those implemented in this study. Consequently, more research is needed to

confirm how well these results can be applied at other sites and in other regions. At the same time, further research can provide far more comprehensive insight into the effect of different measures on trespassing behaviour. Finally, the results of the performed cost–benefit analysis should be treated with caution since it was based on strong assumptions concerning the daily number of trespassers and a small number of fatalities.

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