



Improving safety on Finnish railways by prevention of trespassing

Anne Silla



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Suomen rautatieliikenteen turvallisuuden parantaminen luvattomia radanylityksiä estämällä.
Anne Silla. Espoo 2012. VTT Science 27. 49 p. + app. 43 p.

Abstract

This study investigated trespassing accidents, trespassing and related countermeasures to provide information for prevention of trespassing accidents on Finnish railways. The study includes five complementary substudies, of which two included accident analyses and three collected information on railway trespassing by means of surveys, interviews and field observations. The main results showed, for example, that (1) trespassing is frequent in Finland and, contrary to the overall improvement of railway safety in Finland, the number of trespasser fatalities has not fallen over the past decade; (2) there are specific sites of frequent trespassing on Finnish railways; (3) both the victims in trespassing accidents and the observed trespassers were typically adults and males and the victims were frequently intoxicated; (4) the risk related to railway trespassing was associated with trespassing behaviour, and (5) at selected sites fencing and landscaping can stop trespassing almost entirely, but the effects of a prohibitive sign are much more limited. Overall, a systems approach is recommended for prevention work along with a shared responsibility between stakeholders such as government, railway organisations, various authorities and communities, because the problem is broad and multifaceted and the elements of the rail safety system are interrelated. The recommended countermeasures for preventing railway trespassing vary from under- and overpasses, physical barriers and prohibitive signs to enforcement and education. Selection of the most effective or suitable countermeasure depends on the effectiveness of different measures, location and the characteristics of trespassing.

Keywords railway safety, train-pedestrian collisions, trespassing, fatalities, Finland

Suomen rautatieliikenteen turvallisuuden parantaminen luvattomia radanylityksiä estämällä

Improving safety on Finnish railways by prevention of trespassing. **Anne Silla**. Espoo 2012. VTT Science 27. 49 s. + liitt. 43 s.

Tiivistelmä

Tässä tutkimuksessa selvitettiin luvattomia radanylityksiä, niihin liittyviä onnettomuuksia ja luvattomien radanylitysten estämiseksi toteutettuja toimenpiteitä turvallisuustyön tueksi. Tutkimus sisältää viisi osatutkimusta, joista kahdessa analysoitiin onnettomuusaineistoja ja kolmessa selvitettiin luvattomia radanylityksiä kyseilyiden, haastatteluiden ja kenttämittausten avulla. Tutkimuksen tulokset osoittavat muun muassa, että (1) luvattomat radanylitykset ovat yleisiä Suomen rataverkolla eikä kuolleiden luvattomien radanylittäjien lukumäärä ole vähentynyt viime vuosikymmenen aikana samalla tavalla kuin muissa rautatieliikenteen onnettomuuksissa kuolleiden henkilöiden lukumäärä, (2) Suomen rataverkolla löytyy useita paikkoja, joissa luvattomia radanylityksiä tapahtuu säännöllisesti, (3) luvattomasti rataa ylittävät henkilöt (sekä onnettomuuksissa kuolleet että kenttämittauksissa havaitut) olivat useimmiten aikuisia ja miehiä ja onnettomuuksissa kuolleet henkilöt olivat usein alkoholin vaikutuksen alaisina, (4) ihmisten kokemana luvattomiin radanylityksiin liittyvä riski ja heidän ylityskäyttäytymisensä olivat yhteydessä toisiinsa ja (5) aitaamisella ja maisemoinnilla voidaan estää luvattomat radanylitykset miltei kokonaan, kun taas kieltoimerkin vaikutus on selvästi rajallisempi. Yleisesti turvallisuustyön suositellaan perustuvan järjestelmäajatteluun, koska ongelma on laaja ja monimuotoinen. Vastuun luvattomien radanylitysten estämisestä tulisi jakautua rautatieorganisaatioiden, useiden eri alojen (mm. terveydenhuolto, koulutus, valvonta, kaavoitus) viranomaisten ja kuntien kesken. Luvattomien radanylitysten estämiseksi toteutettavat toimenpiteet vaihtelevat fyysisistä toimenpiteistä ja kieltoimerkistä valvontaan ja valistukseen. Toimenpiteiden tehokkuuden ja sopivuuden varmistamiseksi päätöksen kussakin paikassa toteutettavasta toimenpiteestä tulisi perustua tietoon toimenpiteiden estovaikutuksista sekä kyseessä olevan paikan ja siellä tapahtuvien luvattomien radanylitysten ominaisuuksiin.

Avainsanat railway safety, train-pedestrian collisions, trespassing, fatalities, Finland

Preface

This study was conducted primarily at VTT Technical Research Centre of Finland. In addition to VTT, several organisations provided financial support and made it possible for me to execute the work. First, I would like to acknowledge the Finnish Transport Agency and the Finnish Transport Safety Agency for their financial support of several national projects. The research related to railway trespassing was originally initiated by the Finnish Transport Agency (formerly Finnish Rail Administration), and special thanks are due to Mrs Kirsi Pajunen for her valuable comments during these projects. In addition, I would like to thank the Henry Ford Foundation and the Finnish Foundation for Technology Promotion for their grants in support of my work. The TransportNET Marie-Curie 2006–2008 Programme offered me an Early-Stage Training Fellowship, enabling me to study for two years in Karlsruhe, Germany. During my TransportNET involvement I had the wonderful opportunity to participate in intensive doctoral studies related to transportation and to work on projects in an international research environment. Also, an informal graduate school at VTT led by Professor Matti Kokkala deserves every appreciation for their useful discussions and valuable support.

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Otaniemi, September 17th, 2012

Anne Silla

Academic dissertation

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List of original publications

The dissertation is based on the following articles referred to in the text by their Roman numerals (I–V):

- I Silla, A. & Kallberg, V.-P. (2012). The development of railway safety in Finland. *Accident Analysis and Prevention*, 45, 737–744.
- II Silla, A. & Luoma, J. (2012). Main characteristics of train-pedestrian fatalities on Finnish railroads. *Accident Analysis and Prevention*, 45, 61–66.
- III Silla, A. & Luoma, J. (2009). Trespassing on Finnish railways: identification of problem sites and characteristics of trespassing behaviour. *European Transport Research Review*, 1, 47–53.
- IV Silla, A. & Luoma, J. (2012). Opinions on railway trespassing of people living close to a railway line. *Safety Science*, 50, 62–67.
- V Silla, A. & Luoma, J. (2011). Effect of three countermeasures against the illegal crossing of railway tracks. *Accident Analysis and Prevention*, 43, 1089–1094.

Author's contributions

Anne Silla is the responsible author of articles I–V. Specifically she conducted the detailed planning and execution of the studies, and the analysis and reporting of the results of each publication. As co-authors, Luoma and Kallberg have provided support in terms of discussions and review (Kallberg in article I and Luoma in articles II–V).

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*Article III of this publication is not included in the PDF version.
Please order the printed version to get the complete publication
(<http://www.vtt.fi/publications/index.jsp>).*

1. Introduction

1.1 Significance of train-pedestrian collisions

1.1.1 Train-pedestrian collisions in the context of rail safety

Rail transport needs to take place safely, without injuring passengers or employees, and without damaging property or the environment (Elms 2001). Rail transportation has been considered one of the safest modes of transport for some time. Risk comparisons for the EU Member States show that rail travel together with civil aviation are the safest modes of transport per travelled passenger-km. Specifically, for the years 2001 and 2002, the onboard fatality risk (fatalities per 100 million passenger-km) was 0.035 for civil aviation and rail travel and 0.7 for private automobiles and 0.07 for buses and coaches (European Transport Safety Council 2003). In other words, risk during rail travel is 95% lower than travelling by private automobile.

In spite of the overall positive safety image of rail transport, fatalities caused by rail accidents do occur; the number of fatalities resulting from railway accidents (excluding suicides) in Finland was 179 (around 20 per year) in 2000–2008 (Finnish Rail Administration 2000–2009). If road users, railway passengers and personnel involved in railway accidents are excluded, 101 fatalities (i.e. 56.4% of all fatalities) can, most probably, be assigned to trespassers. Thus it is clear that railway trespassing occurs on Finnish railways, and most fatalities involving rail vehicles in Finland result from collisions between trains and pedestrians.

Finland is not the only country where such a high proportion of people killed in railway accidents are trespassers. In the European Union, more than half of all fatal injuries (excluding suicides) in 2006 were sustained by trespassers (Lundström 2008). Similar proportions have been reported in the United States (Savage 2007), New Zealand (Patterson 2004) and the Cape Town metropolis in South Africa (Lerer and Matzopoulos 1996). These results suggest that collision between trains and pedestrians (i.e. trespassing accidents) is a leading fatal train-related accident type worldwide.

Compared with road vehicles, trains are heavy, cannot stop quickly, and frequently move fast. Long braking distances and high speeds mean that even if an engine driver sees a pedestrian on the track, the distance is seldom long enough

to stop the train in time. For example, comparing train-pedestrian collisions with pedestrian accidents in road traffic shows that collisions between trains and pedestrians are less common but are more likely to cause death or irreparable damage, such as amputation of limbs (e.g. Blazar et al. 1997, Shapiro et al. 1994).

Train-pedestrian collisions are classified as (unintentional) accidents or (intentional) suicides¹. The focus of this study is on trespassing accidents and not on suicides; however, it is important to discuss the distinction between them. As opposed to accidents, suicides involve people intentionally putting themselves in harm's way of a train. It is frequently challenging to determine the type of collision that occurred, because in many cases there is insufficient information to make a definitive classification (Mishara 2007). In addition to practical issues (such as insufficient information), accurate identification of railway suicides can be tricky due to the social, legal, financial or ethical implications of assigning suicide as a cause of death (Lobb 2006). Because such a classification is needed for statistical purposes, the European Railway Agency (2008) has developed guidelines for distinguishing suicides from trespassing accidents. Specifically, the evidence of suspected suicide includes factors such as a suicide note, behaviour demonstrating suicidal intent, previous suicide attempts or prolonged depression.

1.1.2 Cost of accidents and fatalities

A traffic accident with casualties is both an immeasurable human tragedy and a huge loss of economic resources (Lindberg 2005). There are many ways to classify rail accident costs, but one that is frequently used includes three components of valuation: direct economic costs, indirect economic costs, and a value of statistical life (VSL) (e.g. HEATCO 2005, Hiltunen 2006, Trawén et al. 2002). The direct costs include e.g. those of health care and rehabilitation, property damage and administration, whereas the indirect costs include e.g. lost production capacity and reduced well-being of people.

The monetary value of mortality risk reduction is commonly referred as VSL, which reflects the monetary value of a small reduction in mortality risk in a population that would prevent one statistical death. The empirical estimates of VSL vary between studies around the world, ranging from less than USD 200,000 to USD 30 million. The handbook on estimation of external costs in the transport sector (Maibach et al. 2008) highlights that in order to overcome the huge differences between countries, a uniform approach should be elaborated. The different external cost estimates from previous EU research projects (e.g. Nellthorp et al. 2000) use an average value of 1.5 million euro (ranging from 1 to 3 million, depending on valuation methods and uncertainty ranges). Overall, it is recommended to use an

¹ Train-pedestrian collisions can also be classified as homicides. Homicides, however, are not discussed in this dissertation since they are generally not included in the discussion on railway safety.

average value per fatality of 1.5 million euro adjusted for purchasing power parity (PPP) and for gross domestic product (GDP) per capita in different countries (Maibach et al. 2008). The reason for using country-specific values for VSL is to avoid misallocation of resources. This suggests that in a richer country the willingness to pay for a defined risk reduction is higher than in a poorer country, as the marginal utility gained by spending the same amount for something else is lower (HEATCO 2005).

In addition to the above accident costs, train-pedestrian fatalities have the potential to cause serious work-related stress and trauma for engine drivers, other railway staff, rescue employees and witnesses to the event (e.g. Mishara 2007, Rådbo et al. 2005, Wildson 2008). Consequently, there are additional accident costs in the form of equivalent value of trauma and the cost of lost working time by a person traumatised by a fatality on the railway. Furthermore, these events result in considerable interruptions and delay (primary and secondary) and thus additional accident costs to railway companies. Robinson (2003) estimated that the total average cost of railway suicide in the United Kingdom is £1,352,641 (a little less than 2M€, in 2003). His calculation included the total costs to society (value of a life lost and equivalent value of trauma) and the direct costs to industry (cost of lost working time and train delay). Therefore, if using the same estimation for Finnish train-pedestrian fatalities, the trespasser fatalities in Finland result in around 20M€ yearly costs on average.

1.2 Pedestrian behaviour

1.2.1 Pedestrians as part of the transport system

Crossing conditions for pedestrians vary by transport mode. In the railway environment, pedestrians are always legally responsible for the safe crossing of railway lines. In addition, they are obliged to use railway-crossing sites, which are specially marked for that purpose. Railway crossings outside these dedicated places are prohibited by Finnish law and subject to a fine (Finlex 2006). In the road environment, both drivers and pedestrians are responsible for ensuring safe interactions. Traffic rules include specific obligations for both road-user groups. For example, at dedicated pedestrian crossings the drivers of motor vehicles are obliged to give way to pedestrians.

The emphasised responsibility of pedestrians in the rail environment suggests that engine drivers do not expect to encounter pedestrians as road drivers do. Because of the long braking distances and high train speed, an engine driver rarely has the possibility to stop the train in time when detecting a pedestrian on the tracks. Consequently, as opposed to road traffic where some crashes are due to driver-related contributing factors (e.g. driver fails to observe pedestrians), train-pedestrian collisions in the railway environment are always interpreted to result from error or risky behaviour on the part of the pedestrian.

Route decisions pedestrians take before crossing a street, or in this case a railway line, are decisions made at strategic level (Michon 1985). At the tactical

level pedestrians perceive and assess their environment, evaluate their physical and mental abilities and, based on that, determine their actions and adapt them accordingly if necessary. Unfortunately, this decision-making process sometimes fails and accidents or near misses happen. These failings are assumed to be frequently related to misjudgement or inattention. Inattention can result from e.g. intoxication, preoccupation, listening to music or speaking on a mobile phone.

The evaluation of risk related to a crossing event by a pedestrian can be considered more demanding in the railway than road environment, because of the lower number of encounters with passing vehicles and the relative simplicity of the railway environment. Consequently, the low number of encounters suggests that railway trespassers have less experience, and less information, regarding interaction with passing vehicles (e.g. speed, sound, frequency).

Pedestrians are often considered as 'vulnerable road users', primarily for two reasons: (1) when pedestrians are involved in a crash they are totally exposed, having no shield to protect them, and (2) the difference in mass between them and motorised vehicles is very large (Shinar 2007). In the railway context, the difference between masses is even greater and the likelihood of being seriously injured or killed in a train-pedestrian collision is therefore very high.

1.2.2 Risky behaviour

Every time pedestrians cross a railway track they are faced with a choice between (1) crossing a potentially dangerous track at an illegal spot and (2) using an official and safer route (e.g. level crossing, over- or underpass) dedicated to that purpose but which might cost more time and effort. Specifically, pedestrians need to evaluate the risks (i.e. costs) and benefits of each option (which does not mean that they do this at every crossing). In general, the risk of train-pedestrian collision is highest when using an illegal path across the railway lines and lowest when using an over- or underpass separating the pedestrian completely from rail traffic. After analysing the frequency or likelihood of an event and its consequences, the considered risk can vary between negligible and intolerable. Since train-pedestrian collisions occur frequently, we know that some pedestrians consider the risk related to trespassing to be tolerable and often select that option. This means that savings in time and effort from unsafe crossings constitute a reinforcement that is sufficient to outweigh the risk of being hit by a train (Lobb 2006).

The concept of risk has been widely discussed in driver behaviour studies through two fundamental approaches. One is based on the task-capability theory of Fuller (2005) and the zero-risk theory of Näätänen and Summala (1976), which deal with risk adaptation and argue that drivers have a target risk of crashing of zero. This is achieved by attempting to maintain a level of task difficulty within target boundaries. The other approach, the risk homeostasis theory of Wilde (1982), postulates a concept of target risk (see also Smeed 1949 and Peltzman 1975). According to Wilde (1986, 1994), the target risk, determined by the expected costs and benefits of behaviour, is that level of accident risk at which the

individual believes that the overall utility of his or her action is maximised. Whenever a person perceives a discrepancy between target risk and experienced risk in one or the other direction, they make some behavioural adjustment to restore the balance.

Studies investigating pedestrians' road crossing behaviour in risky situations (e.g. Díaz 2002, Holland and Hill 2007, Zhou and Horrey 2010) have used the theory of planned behaviour (TPB) (Ajzen 1991), according to which the attitude towards the behaviour, subjective norm and perceived behavioural control are indirectly linked to behaviour via intention.

Thus, intention is assigned a key role in the prediction of actual behaviour. The perceived behavioural control is one of the predictors of both behaviour and intention. The perception of the ease or difficulty of performing a behaviour may be expected to vary as a function of the perceived situation. The other predictors of intention are attitude towards the behaviour (i.e. a person's evaluation of the behaviour) and subjective norms (i.e. perceived social pressure to perform the behaviour or not).

Based on the results, the model appears to predict the behavioural intentions of pedestrians. Specifically, Holland and Hill (2007) found that younger people are generally more likely to intend crossing a road in risky situations. Díaz (2002) showed that young pedestrians have a more positive attitude towards committing violations, have a more positive intention to commit violations, and report more violations, errors, and lapses than adults. Furthermore, Holland and Hill (2007) found that women were less likely to intend crossing a road in risky situations than men and perceived more risk.

In the context of this study, the model is important when looking at control beliefs affecting perceived behavioural control. As mentioned by Holland and Hill (2007), these beliefs describe the extent to which a person believes that they are in control of their behaviour or risk in this particular situation, or the extent to which such behaviour is believed to affect the risk. Based on this it can be assumed that the smaller the pedestrian evaluates the risk to be, the greater the probability of an unsafe crossing.

Furthermore, risk-taking behaviour has largely been studied in a road safety context, especially among young drivers (e.g. Hatfield and Fernandes 2009, Jonah 1986). These studies argue that young drivers may engage in risky driving inadvertently (i.e. without realising that it is risky), partly through inexperience and error. Young drivers may choose to adopt behaviours that they recognise as risky when the balance between the perceived (possible) costs of the behaviour and the perceived (possible) benefits of the behaviour is judged to be favourable. In a trespassing context the possible costs are related to a collision with a train or getting a fine, whereas the benefits are most often related to savings in time and effort or the status in peer groups, especially among youth. Moreover, Hatfield and Fernandes (2009) propose that the perceived riskiness of the behaviour may be considered as either a cost or a benefit, depending partly on an individual's attitude to taking risks. Here they refer to 'risk-proneness' or 'risk-aversion'.

According to Lobb (2006), the risk judgement of a trespasser is based on the positive and negative value of the possible outcome, the probability of an unwanted

event, and other factors such as the constraints of time and available information. Moreover, Lobb (2006) points out that the choice between alternatives is much more sensitive to the relative probability than to the relative magnitude of the consequences. Train-pedestrian collisions are rare events and therefore it is not surprising that the horrible but very unlikely consequence of trespassing on the tracks has less control over behaviour than the smaller but certain benefit of savings in time and effort.

1.2.3 Trespasser profile

Trespassers cross railway lines at places not marked for that purpose, or walk illegally and/or loiter in the railway area. A number of studies have suggested that the main reason for trespassing is taking a short cut from point A to point B because the authorised route is assessed to be too far away (e.g. Lobb et al. 2001, Rail Safety and Standards Board 2005, Robinson 2003). Other reasons for trespassing are, for example, related to recreational purposes (taking a walk along the tracks), hanging around (drinking alcohol, smoking, applying graffiti) or even to committing vandalism.

Many studies have shown that trespassers involved in accidents are usually adults and males (e.g. Centers for Disease Control 1999, George 2007, Patterson 2004). More specifically, many studies suggest that adults are the biggest group (e.g. Centers for Disease Control 1999, George 2007, Patterson 2004, Pelletier 1997). However, there are also results supporting that youngsters are a big group among trespassing victims (Lobb et al. 2003). Concerning gender, based on collected trespassing data, males trespass more frequently than females (e.g. Lobb et al. 2001, Railway Safety and Standards Board 2007). Men are also predominant among the fatalities in trespasser accidents (e.g. Centers for Disease Control 1999, George 2007, Patterson 2004, Pelletier 1997). Furthermore, some studies have found that many trespassers involved in accidents were intoxicated by alcohol or drugs (e.g. Centers for Disease Control 1999, George 2007, Lerer and Matzopoulos 1996, Patterson 2004, Pelletier 1997).

Regarding timing, the findings are inconsistent. Specifically, Pelletier (1997) found that fatality accidents typically occurred at night on Friday, Saturday and Sunday, and Lerer and Matzopoulos (1996) found that they occurred at peak commuter times. Furthermore, according to Patterson (2004) the majority of killed and injured trespassers are reasonably evenly spread throughout the day. However, when assessing only non-injury trespasser incidents, most of them occurred during the afternoon peak (Patterson 2004) or with observable peaks in the mid-afternoon and mid-to-late evening periods (Railway Safety and Standards Board 2005).

1.3 Possibilities to reduce railway trespassing

1.3.1 Prevention

Prevention of trespassing in Finland is a challenge, because unlike in some countries, railways are not usually isolated from the surrounding areas by fences given the substantial length of the railway lines. Specifically, 5,794 kilometres of railway lines are currently in use (Finnish Rail Administration, 2008). Some studies suggest that train-pedestrian accidents occur in urban areas, often in or near a railway station (e.g. Lerer and Matzopoulos 1996, Lobb et al. 2003, Pelletier 1997, Savage 2007). The problem with trespassing occurs especially in cities that are split by railway lines. Railway lines have always divided communities, sometimes more so over the years. Moreover, new developments within the city such as living areas, shopping areas and schools are often located on both sides of the railway lines, increasing people's need to cross the tracks. Nelson (2008) points out that the division of communities generates tension between the railway authorities, who are responsible for ensuring that the railway can be crossed safely by restricting the points at which the public can cross it, 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.

According to Finnish law, crossing a railway line is only permitted at sites especially marked for that purpose. The penalty for breaking the law is a fine of an unspecified amount (Finlex 2006). However, although trespassing is illegal, clear and regularly used footpaths across railway lines are found in many places, making it safe to assume that trespassing is frequent.

Now that the problem is recognised, the question remains as to how trespassing accidents and fatalities can be prevented. In the road environment the most common ways to reduce the number of pedestrian fatalities include behavioural (i.e. education and skill training) and engineering (i.e. improving the pedestrians' visibility and reducing drivers' speeds) approaches. In general, both could be considered applicable to the railway environment, but since trespassing means crossing the railway lines at places not marked for that purpose, many steps targeting driver behaviour such as lowering train speed are unrealistic. Therefore, engineering solutions in the railway environment should concentrate on physical measures such as building over- or underpasses.

According to Savage (2007), there is an increasing need to understand the contributing factors of trespassing and what can be done to reduce the annual number of fatalities. It has been indicated by many researchers (e.g. Law 2004, Rail Safety and Standards Board 2005, Savage 2007) that trespassing tends to be specific to location, and solutions should be tailored to specific locations and factors in order to make implemented countermeasures effective. Therefore, the potential countermeasures should also vary depending on the nature of the trespassers. Clearly there is a need for collecting information on railway trespassers as a basis for prevention. Characterising trespassers has previously focused on profiling them

on the basis of reported incidents and accidents (e.g. George 2007, Pelletier 1997, Rail Safety and Standards Board 2005). However, it is important to distinguish between the characteristics of trespassers in general and the characteristics of the subset of trespassers who sustain fatal and non-fatal injuries (Savage 2007). Evidently the total number of trespassers is much larger than the number of casualties. Moreover, as mentioned by Savage (2007), analysing the reported incidents and accidents gives only a partial picture of the profile of trespassers. Consequently, investigations of trespassing behaviour (including no accidents) could provide useful information. Without good understanding of the problem, the risk remains that the allocated resources are wasted or the implemented measures may be counterproductive (Savage 2007).

1.3.2 Countermeasures

Several measures have been introduced to counter the trespassing problem. Suggested interventions include limitation of pedestrian access to railroad areas, public education, reward or punishment, and various technical solutions (e.g. Rail Safety and Standards Board 2005). 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.

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 fell from 59% to 40% and after three 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 may be more effective than education in reducing unsafe behaviour in the vicinity of railway stations, and substantially more effective than communication in raising awareness.

Although several studies argue that public education on the danger of railways can be effective (e.g. Lobb et al. 2003, Savage 2006, Savage 2007), it is not easy to change the behaviour of trespassers. To have greater influence on trespassers' behaviour, information campaigns should be combined with physical measures or supplement them with incentives or enforcement procedures (Lobb et al. 2003).

An important part of prevention work is to get people to understand the risks related to railway trespassing. Here the risk refers both to the likelihood of a stated hazardous event and to its consequences, which can be economical, physical or

mental. As highlighted by Fuller (2000), controlling the amount of risk people are willing to take is at the core of accident prevention.

1.3.3 System approach

Overall, there is no reason to believe that trespasser fatalities are unavoidable. On the contrary, modern prevention work should exploit a system approach. For example, the Swedish Vision Zero approach (e.g. Johansson 2009, Larsson et al. 2010) argues that all severe injuries can, in principle, be avoided. This, together with the Dutch Sustainable Safety approach (Wegman et al. 2005), are practical examples of a safe system approach, which is well known and promoted for use in achieving safe road systems globally (e.g. Bliss and Breen 2009, CEMT/CM 2006, Johnston 2010). The system approach is based on the ideas of Haddon (1968), who introduced a matrix emphasising a system-wide approach by identifying risk factors before the crash, during the crash and after the crash, in relation to the persons, vehicles and environment. This system approach including human-vehicle-environment interactions has also been applied in Finland (see e.g. Häkkinen 1978, Häkkinen and Luoma 1991).

The Vision Zero approach is not limited to the road transport system. In 2008 the Swedish government extended the policy to suicides (Wahlbeck 2009). The underlying logic of Vision Zero is shared responsibility between the system providers and the system users (Johansson 2009). When applying the idea to the railway environment, the system designers and enforcers are responsible for the level of safety within the entire rail transport system, and are thus responsible for designing the infrastructure in such a way that it is adapted to the capabilities and limitations of humans through proper planning (e.g. separation of railway tracks from surrounding areas). In return, pedestrians are responsible for following the basic rules set by the system designers and being fit to take part in traffic (unaffected by alcohol or other drugs). In addition, Vision Zero suggests that if road users fail to follow the rules or injuries occur, the system designers are required to redesign the system, including rules and regulations. Overall, this approach calls for acceptance of shared overall responsibilities and accountability between system designers and system users (OECD/ITF 2008).

The safe system approach highlights that all of the elements in the rail safety system are interrelated, and that the responsibility for safety should be shared across all players (Johnston 2010). Consequently, the implementation of an ambitious safe system approach requires a new way of thinking. It builds on existing countermeasures, but due to the shared responsibility it requires a much greater commitment and involvement by government, several authorities, railway organisations, communities and individuals. Political and top-level commitment is essential to ensuring the availability of resources for safety work and assigning ambitious safety targets (Johnston 2010). In addition, the effective execution of Vision Zero requires coordinated effort (Johnston 2010). In the UK, the Rail Safety and Standards Board (2005) suggests that a multifaceted approach, using a mix of measures

designed to be directed at specific issues, can be effective in discouraging access to railway lines. Based on the system approach, the underlying logic can be taken even further by integrating the combined measures with coordinated efforts to increase the effectiveness of safety work.

1.4 Purpose of the study

The principal aim of this study is to investigate trespassing accidents, trespassing and related countermeasures to provide reliable information for prevention of trespassing accidents on Finnish railways. Although the trespassing problem in general has been recognised for years, specific information on the extent of the problem, sites where trespassing occurs, characteristics of trespassing, and effective countermeasures has been lacking or insufficient, since no detailed study on railway trespassing has previously been conducted in Finland. In addition, it has been found that foreign studies are based mostly on reported incidents and fatalities, which does not necessarily show the magnitude and characteristics of trespassing (i.e. exposure).

Consequently, further research was needed to understand the trespassing behaviour and trespassing accidents in Finland. Five complementary substudies were designed to contribute to the prevention of trespassing, thereby improving safety on Finnish railways.

The main research questions are listed as follows:

1. How significant is the role of trespassing in railway safety in Finland?
2. What are the main characteristics of train-pedestrian accidents?
3. What are the main characteristics of trespassing?
4. Which of the selected engineering countermeasures are effective in preventing trespassing, and which countermeasures do people prefer?
5. What type of approach would be the most beneficial for preventing train-pedestrian accidents, especially those involving trespassing?

The purpose of the first substudy was to examine the railway accidents in Finland from 1959 to 2008. The objective was to describe and model the trends in the development of railway safety. One aspect of the study includes the identification of different types of accidents (e.g. trespassing accidents). (Research question 1)

The aim of the second substudy was to describe the main characteristics of train-pedestrian collisions on Finnish railways from 2005–2009 (e.g. frequency of fatalities, timing of collisions and characteristics of persons killed). (Research question 2)

The main purpose of the third substudy was to identify sites of frequent trespassing and describe trespassing behaviour and characteristics at selected sites, and to explore opinions about possible countermeasures to prevent trespassing. (Research questions 3, 4 and 5)

1. Introduction

The fourth substudy was designed to collect opinions on railway trespassing from people living close to the railway line. Specifically, this study focuses on issues such as whether people assess trespassing as a serious problem, what sort of countermeasures they assess as effective, the assessment of their own behaviour and overall trespassing safety, and their awareness of the legality of trespassing and trespassing fatalities. (Research questions 3, 4 and 5)

The purpose of the fifth substudy was to investigate the effects of three countermeasures on the frequency of trespassing and the characteristics of trespassing behaviour. The countermeasures include landscaping, building a fence and prohibitive signs. (Research questions 4 and 5)

In the following, the substudies are presented in integrated form. Finally, the main findings are discussed and recommendations made for a successful approach to preventing trespassing accidents and for future study.

2. Method

2.1 Accident analyses (substudies I and II)

Substudies I and II include analyses of statistical data to describe the railway safety situation in Finland. Specifically, substudy I concentrates on railway accidents from 1959 to 2008, whereas substudy II focuses on train-pedestrian collisions from 2005 to 2009.

The data for substudy I were collected mainly from the statistics of the Finnish railway operator (VR Group Ltd.) and the Finnish Rail Administration (Finnish Transport Agency since the start of 2010). Fatalities by accident category and number of train-kilometres from 1959 to 2008 were covered for the whole Finnish railway network, including private tracks. Only accidents caused by rolling stock in motion were included.

Fatal accidents have been reported to be more likely than less severe accidents. In addition, fatalities resulting from accidents are the most reliable measure of safety, since the definition of the term has not varied over the years as much as that of reportable injury accidents.

The model introduced by Evans (2007, 2010, 2011) is used to describe numerically the trends in the development of railway safety. The model assumes that fatalities occur randomly in year t at a mean rate λ_t per year; λ_t is assumed to be given by

$$\lambda_t = \alpha k_t \exp(\beta t)$$

where k_t is a variable describing exposure to accidents in year t , α is a scale parameter, and β is a parameter measuring the long-term annual rate of change in fatalities per unit of exposure (train-kilometres). The model assumes that the mean number of fatalities per unit time is proportional to exposure and to an exponential function of time, which represents the effects of general improvements in railway safety taking place over the long term (Evans 2010). The model was fitted using negative binomial regression.

The data for substudy II were collected from five primary sources: (1) the Finnish rail operator (VR Group Ltd.), (2) the Finnish Transport Agency, (3) the Finnish Police, (4) the Rescue Department and (5) Statistics Finland. The resulting data-

base includes all cases from the police reports and death certificates of Statistics Finland that satisfied the criteria of intentional or unintentional train-pedestrian fatality. The databases of the Finnish Police and Statistics Finland are the only official sources of information on the seriousness and intentionality of an event. Other databases provided additional information such as time and location of occurrence, victim's pre-crash behaviour, type of event and type of train.

2.2 Surveys (substudies III and IV)

The survey in substudy III was directed to engine drivers to explore sites of frequent trespassing. The survey in substudy IV was directed to people living close to a railway line to explore their views on trespassing.

In the survey form (used in substudy III), drivers were asked about the locations where they had frequently observed trespassers and for their suggestions on potential preventive measures. The survey form included a map of the area close to the workplace and a table for listing problematic sites. In addition, drivers could refer to problematic sites elsewhere in Finland.

The survey forms were delivered to the engine drivers' mailboxes at work, and were made available to all engine drivers. In total, 1,500 survey forms were distributed of which 96 were returned. Due to the relatively low response rate (6%) the results were considered qualitative only.

Survey forms in substudy IV were sent to 1,500 households in the city of Lappeenranta in Eastern Finland. The sample size was approximately 2% of the population of the city. Address information for the survey was retrieved from the Population Register Centre. The information was requested for a random sample of households from preselected local districts (10 out of 52) that were assumed to be of interest to the study (Figure 1).

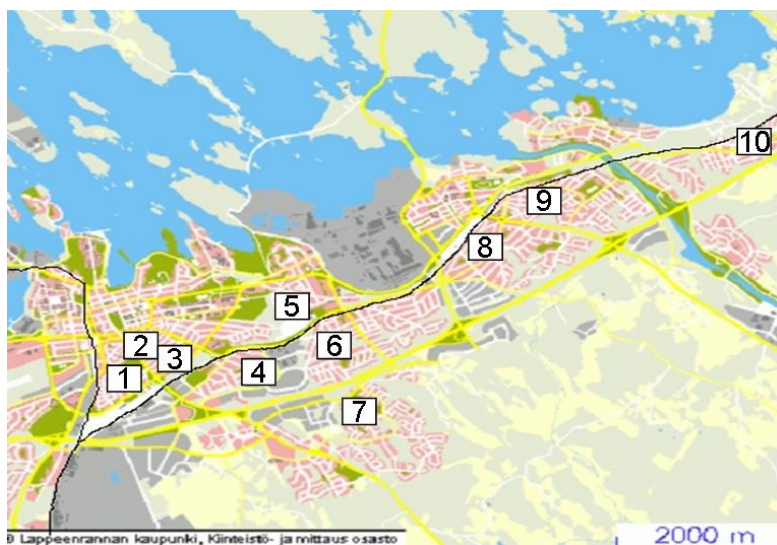


Figure 1. Map of the city of Lappeenranta (City of Lappeenranta 2007). The black line from bottom left to upper right shows the passenger traffic railway. The numbers show the survey locations. The additional local district (11) is located north of local district 2.

Based on the locations of residential areas and other activities, it was assumed that many residents of these areas might have a need to cross the railway, although the distance between the local districts and the railway varied. In addition, one local district was included because some respondents indicated that they were living there rather than the options given on the survey form. Contact information was requested from the Population Register Centre for the oldest person living in each household.

The survey form contained four types of questions: (1) recollection of frequency and characteristics of trespassers and their behaviour, (2) preference of potential means to prevent trespassing, (3) assessment of respondents' own trespassing and the perceived safety of trespassing, and (4) awareness of regulations regarding walking in the railway area and trespassing fatalities. In addition, the respondents could provide additional comments and were asked to indicate their age, gender and the local district where they lived in order to explore potential differences by respondent characteristics.

Overall, 33.5% of the survey forms were completed ($n = 502$), the response rate varying from 27% to 40% by local district.

2.3 Field observations (substudies III and V)

Three locations in the Lappeenranta area were selected for observation of trespassers and for investigation of the effects of three countermeasures. The final selection criteria included the following: (a) it was possible to execute measurements with the help of cameras with motion detectors, (b) the amount of trespassers was relatively high, and (c) the legal rail crossing site was located less than 500 m from the trespassing location.

Video cameras equipped with motion detectors were used to count trespassers and identify trespassing behaviour. The cameras (AVN-4090E, 37(Dia) x 99(L) mm) were small and not easily detectable by trespassers. 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 second. The camera functioned independently and only required the batteries to be changed once a week.

The measurements in substudy III were taken in May, allowing data to be collected almost round the clock due to the ambient light in Finland at that time of year. The data included 19 days of observations.

The tested countermeasures in substudy V 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) Landscaping included removal of the existing path across the railway line, steepening the banks 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 "KULKU KIELLETTY" ('No trespassing'). The sign was erected on both sides of the railway line. No additional enforcement was introduced during data collection.

After-phase measurements were carried out 1 year after before-phase measurements. Both measurements were carried out in May. The data of both phases included 10 days for landscaping, 11 days for fencing and 17 days for the prohibitive sign.

2.4 Trespasser interviews (substudy III)

Approximately 4 months after the before-phase measurements, some trespassers at the same research locations were interviewed. The interview specifically focused on their movements in the railway area, their possibilities and willingness to

change their routes, how dangerous they thought trespassing is, and their awareness of regulations regarding walking in the railway area. In addition, they were asked what would stop them from trespassing.

The interviews, conducted over 2 days at each of three locations, took place between 7:30 a.m. and 5:00 p.m. In total, 46 trespassers were interviewed.

3. Results

3.1 Development of railway safety especially in regard to trespassing

The results of substudy I show that the level of railway safety in Finland has greatly improved over the past five decades. The total number of railway fatalities (excluding suicides) shows no clear falling or rising trend during the 1960s, but since the early 1970s the annual number of fatalities has dropped from around 100 to 20. The estimated overall annual reduction per year from 1970 to 2008 is 5.4% (95% confidence interval from -8.2% to -2.6%). The improvement of railway safety per million train-kilometres is highest (8.3%) for employees, followed by road users at level crossings (5.0%), passengers (4.4%) and others (mainly trespassers) (3.6%).

The number of fatalities in the category *others* has dropped from 286 in the first decade (1959–1968) to 106 in the last decade (1999–2008) of the observation period (Figure 2). Since the late 1980s there has been an upward trend in trespassing fatalities. Over the past 10 years, most railway fatalities have been in this category. During 2000–2008, the yearly number of *others* killed was between 6 and 17.

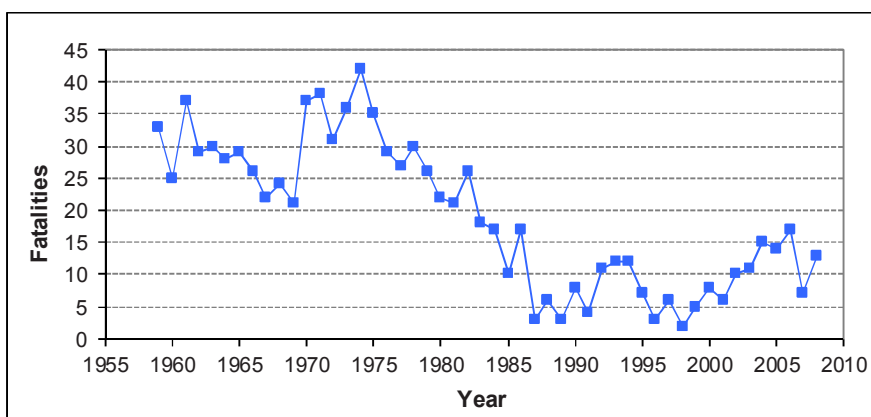


Figure 2. Annual number of fatalities in the category *others* (mainly trespassers) 1959–2008.

The results of substudy II including 2005–2009 show that a total of 311 train-pedestrian collisions occurred on the Finnish railway network. Of this number 264 (84.9%) were classified as suicides (intentional events), 35 as accidents (unintentional events) and 12 as unclassified events. Comparison of these two datasets shows that the number of fatalities in the group *others* (substudy I) is higher than the actual number of trespassing fatalities (even if the unclassified events are included). Thus it can be concluded that some of the suicides have inadvertently been classified as *others* in the statistics of the Finnish railway operator. Therefore, the earlier assumption that the group *others* in substudy I includes mainly, but not exclusively, trespassers is correct.

3.2 Characteristics of trespassing

3.2.1 Frequency of trespassing

The survey given to engine drivers identified around 100 locations of trespassing in Finland (substudy III). At three selected sites with frequent trespassing, the average number of daily trespassers varied from 18 to 70.

In addition, the results showed that people living close to a railway line were quite aware that trespassing occurs in their neighbourhood (substudy IV). Only 10.8% of the respondents indicated that they had never seen people trespassing. Frequent trespassing is also confirmed by the fact that roughly 69% of the people living close to a railway line indicated that they had crossed the railway line at a spot not marked for that purpose. However, it should be noted that the survey was conducted in a city known to be prone to trespassing.

3.2.2 Timing

The results of substudy II reveal that trespasser fatalities in Finland occurred slightly more often during the afternoon rush hour (between 3 p.m. and 6 p.m.) than at other times of day.

Trespassing was most common between 11 a.m. and 7 p.m. (substudy III). The quietest phase was between 11 p.m. and 6 a.m., when only 2.3% of trespasses occurred. Forty per cent of people living close to a railway line who responded to a survey (substudy IV) answered that they could not define any specific time of day when trespassing is frequent. Other respondents had observed trespassing most frequently in the afternoon (38.7%), followed by morning (35.6%), evening (32.6%), noon (23.0%) and night (10.9%).

Furthermore, 40.6% of people living close to a railway line indicated that trespassing occurs less than once a week, followed by 23.7% who indicated that it occurs daily, 17.9% who said that it occurs a couple of times a week, and 7.4% who said that it occurs once a week. Only 10.8% of the respondents indicated that they had never seen people trespassing. These results suggest that the respondents were quite aware of trespassing.

3. Results

Trespasser fatalities were quite evenly distributed by time of year and month (substudy II). The months with the least fatalities were February, May and June. In regard to weekdays, trespasser fatalities occurred most frequently at the end of the week (from Friday to Sunday).

3.2.3 Gender and age

Most victims of trespassing accidents and most trespassers are male. Specifically, the proportion of males among the victims of accidents was 77% (substudy II) and in trespasser observations 63% (substudy III).

Table 1 shows that the majority of both victims of trespassing accidents and trespassers were adults or elderly people (substudies II, III and IV). In addition, people living close to a railway line assessed considered youngsters to be frequent trespassers (substudy IV).

Table 1. Proportion of victims of trespassing accidents and trespassers by age group.

	Victims of accidents (%)	Trespassers (%)	
	Substudy II	Substudy III	Substudy IV ¹
Children (under 12))	2.9	10.1	21.7
Youngsters (12–20)	20.0	35.6	71.5
Adults (21–65)	65.7	54.3	85.7
Elderly (66–)	11.4		30.9
Total	100.0	100.0	

¹ Respondents were allowed to indicate one or more options.

Specifically, the accident statistics show that approximately half of all fatal accidents happened to people aged 10–29 years (substudy II). In addition, the 20–29 year age group was clearly overrepresented when comparing the proportion of accident victims to the whole Finnish population.

Overall, there are no substantial differences in the characteristics of victims of trespasser accidents compared to characteristics of trespassers. Consequently, there is no clear indication that any gender or age group is better at avoiding accidents.

3.2.4 Sites, route selection and type of travel

Both trespassing fatalities and trespassing tended to concentrate in areas where the population density is high and the train traffic is dense (substudy II and III) and travelling is a part of everyday life. Specifically, most interviewed trespassers were going shopping, jogging or on their way to school or work (substudy III). Eighty per cent of them explained that the route was the shortest and fastest alternative (although the official route was not more than 300 m away). Other answers included that it was easy to use the route because there was already an existing path (9%),

and that it had become a habit to use a specific route (11%). Seventy per cent of the trespassers were alone and 23.2% in groups of two (substudy III). Larger groups were rare. Most trespassers (55.3%) were neither carrying nor having anything with them, 31.7% were carrying their bicycle, 11.3% were walking their dog(s), 1.6% were equipped with poles (i.e. Nordic walking), and a few trespassers had something else like a pram or scooter.

3.2.5 Type of behaviour and intoxication of victims

Trespasser accidents occurred most frequently in situations where a person was crossing (38.5%) or lying/sitting (34.6%) on the tracks (substudy II). Also, some people were walking along the tracks. Sixty-nine per cent of accident victims were intoxicated by alcohol, medicines and/or drugs (substudy II).

3.2.6 Perceived safety

Half of the interviewed trespassers assessed that trespassing is either slightly dangerous (17%) or very dangerous (33%) (substudy III). Many of the interviewees considered trespassing safe when they are careful and were more worried about children, elderly people, intoxicated people and those whose attention is somehow distracted.

People living close to a railway line assessed more frequently that trespassing is slightly dangerous (40.2%) or very dangerous (43.3%).

The effect of the perceived safety of trespassing on respondents' own trespassing was significant ($\chi^2(3)=110.15$, $p < 0.001$) (substudy IV). Specifically, 98.0% of the respondents who indicated that they had not trespassed answered that trespassing is slightly or very dangerous, while the corresponding percentage for respondents who had trespassed was only 76.8% (Figure 3).

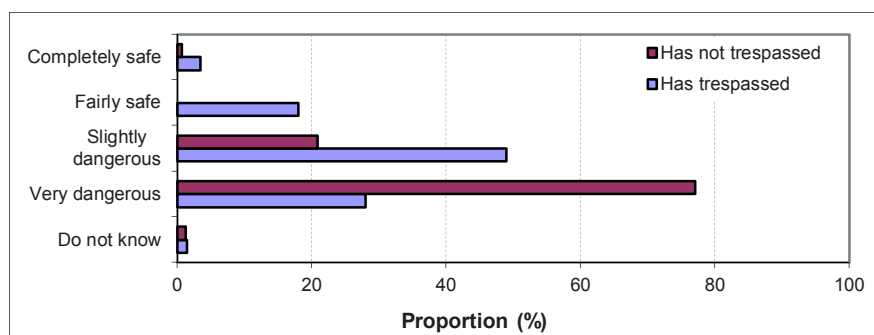


Figure 3. Respondents' perceived safety of trespassing versus their own trespassing.

3. Results

In addition, the older the respondents were, the smaller was the proportion of respondents who assessed trespassing as completely or fairly safe. Specifically, the average rating for respondents older than 60 years was 3.46, followed by age group 45–60 (3.26), age group 30–44 (3.11), age group 20–29 (2.83) and respondents younger than 20 (2.00).

3.2.7 Awareness of legality

Overall, 59% of the interviewed trespassers considered trespassing illegal, 15% considered it legal and 26% did not know (substudy III). A few respondents indicated that they had never even thought about the legality of their act. Some of the respondents also said that it must be legal, as there is no sign to indicate otherwise.

Despite the leading introduction to the survey (substudy IV), 18.2% of people living close to a railway line indicated that crossing the tracks at an unofficial site is legal. Trespassing was considered to be illegal by 81.0% and 0.8% did not know. Males (22.0%) considered trespassing to be legal more frequently than females (14.2%) ($\chi^2(1)=4.90$, $p < 0.05$). The effect of respondents' age on awareness of legality was also significant ($\chi^2(4)=16.82$, $p < 0.05$), with typically higher percentages of legal answers for younger respondents. In addition, the effect of awareness of legality on the respondents' own reported trespassing was significant ($\chi^2(1)=8.64$, $p < 0.05$), with a more substantial proportion (82.0%) trespassing among respondents who indicated trespassing to be legal compared with those who considered it illegal (66.1%). Finally, if the respondent considered trespassing legal, it was less likely that he or she would indicate that trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing illegal (85.7%) ($\chi^2(3)=36.06$, $p < 0.001$).

3.3 Effectiveness and preference of countermeasures

3.3.1 Effectiveness of countermeasures (substudy V)

The before-after study was designed to investigate the effects of three countermeasures – landscaping, building a fence and prohibitive signs – on the frequency of trespassing. The fencing reduced trespassing by 94.6%, followed by landscaping (91.3%) and prohibitive signs (30.7%) (Figure 4).

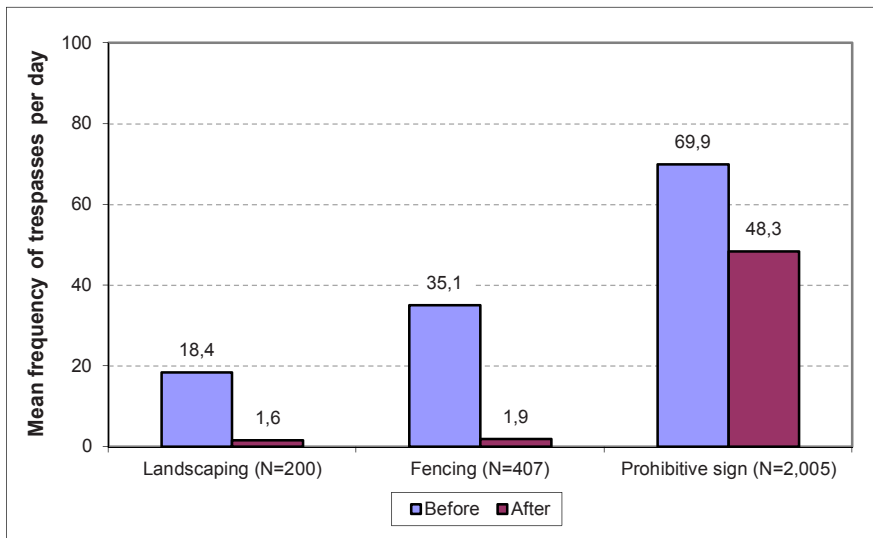


Figure 4. Frequency of trespasses per day before and after countermeasure installation.

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 a t-test was performed. The results showed the effect of each countermeasure on the frequency of trespassing to be 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, an additional distribution-independent non-parametric Mann-Whitney U test was performed. The results also showed the effect of each countermeasure on the frequency of trespassing to be 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. 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. The results show that a prohibitive sign lowered the amount of illegal crossings only during the day and not at night. For the other countermeasures, no clear differences were found.

3. Results

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

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	-

Overall, landscaping appeared to reduce trespassing by males more than that by females. In addition, it 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 it.

Landscaping reduced trespassing relatively well for all but groups of more than two. Notably, most groups of more than two involved youngsters. Furthermore, the effect of fencing and a sign did not vary substantially by size of group.

Finally, after the installation of landscaping, no trespassers were carrying or had anything with them. The effect of the fencing was relatively low 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.

Cost-benefit analysis of the implemented countermeasures was carried out for two scenarios: scenario 1 was based on the actual number of trespassers at each site and scenario 2 on the mean value of trespassers. Both scenarios showed that the benefits of each countermeasure were substantially higher than the cost. The

benefit-cost ratio was highest for the prohibitive sign, but the differences among the countermeasures were not substantial if the calculation was based on the mean value of trespassers (scenario 2).

3.3.2 Preference of countermeasures (substudy III and IV)

The most effective preventive measures according to engine drivers were fencing, followed by information campaigns, prohibitive signs, imposition of a fine and building an underpass or overpass. Information about the danger of trespassing should in their opinion be delivered to children in nearby schools and to people living close to railway tracks. They also proposed information campaigns in the local papers and on radio and television, and placing fact sheets about the danger of trespassing close to railway tracks. Furthermore, they felt that the police should run occasional enforcement campaigns at sites where trespassing occurs frequently. Finally, camera surveillance and increasing the number of guards were also suggested as complementary forms of preventing trespass.

The most frequently suggested countermeasures by trespassers included building a fence or an underpass/overpass. Unsurprisingly, trespassers were seemed more willing to accept fencing if the distance to the closest official crossing site was relatively short, but in the case of a relatively long distance they tended to prefer an overpass or underpass. In addition, those questioned supported enforcement or imposition of a fine, installation of a prohibitive sign and information provided by various means.

Figure 5 shows that among people living close to a railway line, the most frequently supported countermeasures were building of an over- or underpass, followed by fencing off the tracks and education at schools concerning the dangers of walking on or across railway tracks (substudy IV). Only 6.8% of the respondents indicated that nothing could be done to resolve the problem.

3. Results

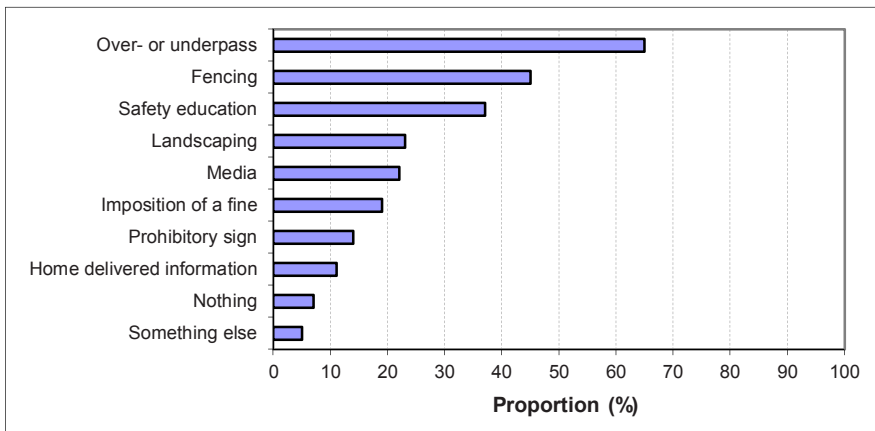


Figure 5. Preference of possible countermeasures (N = 501). Respondents were allowed to indicate one or more options.

4. Discussion

The principal aim of this study is to investigate trespassing accidents, trespassing, and related countermeasures to provide information for prevention of trespassing accidents on Finnish railways. Although the trespassing problem has long been recognised in Finland, information on its extent and detail has been either lacking or insufficient because no detailed studies on railway trespassing have been conducted before. This study, based on five complementary substudies, is therefore designed to investigate various aspects of railway trespassing as a platform for prevention work. Of these substudies two concentrate on accidents and three include surveys, interviews and field observations.

The five research questions in the study are: (1) How significant is the role of trespassing in railway safety in Finland, (2) what are the main characteristics of train-pedestrian accidents, (3) what are the main characteristics of trespassing, (4) which of the selected engineering countermeasures are effective to prevent trespassing and which countermeasures do people prefer, and (5) what type of approach would be the most beneficial for preventing train-pedestrian accidents, especially those involving trespassing. The following discussion follows these research questions. Finally, the main contribution and limitations of the study are discussed.

4.1 Role of trespassing in railway safety in Finland

The results show that railway trespassing is frequent in Finland and that the number of trespasser fatalities on railways has not diminished over the past decade, as opposed to other types of railway accidents. For example, the results of trespasser counts show roughly 40 daily trespasses on average at the selected research locations. These results suggest that trespassing needs special attention in railway safety work.

4.2 Main characteristics of trespassing accidents and trespassing

This study shows that victims in trespassing accidents and observed trespassers were typically adults and males and that trespassers killed in accidents were usually intoxicated. These results are in line with earlier studies (conducted in other

countries) concerning the characteristics of trespassers (e.g. Centers for Disease Control 1999, George 2007, Patterson 2004). In addition, the majority of trespassers were alone and were frequently not carrying anything with them.

The results show that perceived risk has proven to be predictive of trespassing behaviour. Specifically, trespassing was considered dangerous by (1) 98.0% of the respondents in the survey, who indicated that they had not trespassed, followed by (2) 76.8% of the respondents who indicated that they had trespassed and (3) 50% of the interviewed trespassers.

At least some of the interviewed trespassers were aware of the accident risk. Supporting this is the fact that more than 17% of trespassers considered trespassing to be very dangerous, yet they were still trespassing and unwilling to use the longer route even though the official crossing was fairly close. Furthermore, many of the interviewed trespassers indicated that they consider trespassing safe when they are careful. They assumed that they are able to cross the tracks safely but that other trespassers' behaviour may be risky. Indeed, previous research has shown that people do tend to believe that they are less likely to experience negative events than their peers. This belief allows people to take risks, because the estimate of personal risk is lower than the actual figure and thus the paradoxical belief is, "it will not happen to me." (E.g. Hatfield et al. 2006, McKenna 1993, Weinstein and Klein 1996). Of course, it is possible that some of the interviewees wanted to appear more responsible than they actually are.

The result that perceived risk affects crossing behaviour is supported by Ajzen's (1991) model of planned behaviour, which indicates that the perception of the ease or difficulty of performing a given behaviour may be expected to vary as a function of the situation as perceived by the person. This confirms the assumption that the smaller the pedestrian evaluates the risk to be, the greater the probability of an unsafe crossing.

In addition, the effect of awareness of legality on the respondents' own reported trespassing was significant, with a more substantial proportion trespassing among respondents who indicated trespassing to be legal compared to those who considered it illegal.

The trespasser interviews show that the main reason for trespassing is taking a shortcut, which confirms the results of earlier studies (Lobb et al. 2001, Rail Safety and Standards Board 2005, Robinson 2003). Many trespassers had used the route for years, and according to them it was easy to use because there were already clear paths across the railway tracks.

In summary, these results suggest that the main characteristics of trespassing in Finland do not differ much from those found in other countries, and based on the results the perceived risk was associated with trespassing behaviour.

4.3 Effectiveness and preference of selected engineering countermeasures

The results of the before-after study show the largest drop in the frequency of daily trespasses with fencing (94.6%), followed by landscaping (91.3%) and a prohibitive sign (30.7%). These results suggest that physical barriers can stop trespassing almost entirely. In turn, the effect of a prohibitive sign is much more limited.

Furthermore, the results reveal some tendencies of how the effects of countermeasures can vary with the characteristics of trespassers. However, given the limited number of trespassers, these results should be interpreted with caution.

The prohibitive sign reduced the number of illegal crossings only during day-time and not at night (although the darkness was not comprehensive). No specific explanation for this was found. In addition, landscaping sharply reduced the proportion of children and adults trespassing, and the prohibitive sign effectively reduced trespassing by children. The effect of fencing was roughly similar for all age groups. Furthermore, landscaping and fencing substantially affected trespassing with bicycles and dog(s), most likely because trespassing became too awkward physically. It can be assumed that people who trespass with their dog(s), for example, are on a leisure walk and might be more willing to change their route since their time may be more flexible.

Opinions on possible countermeasures were collected from engine drivers, trespassers and people living close to a railway line. The main results of the engine driver interviews showed that in most cases the most powerful preventive measures would be fencing (high, strong and long fences possibly combined with other measures), information campaigns, prohibitive signs, imposition of a fine and building an underpass or overpass. Both the interviewed trespassers and people living close to a railway line indicated that the most effective measures to prevent trespassing would include fencing off the tracks or building an underpass. However, building an underpass did not belong to the most frequently suggested countermeasures among engine drivers. This finding suggests that engine drivers were more realistic and included the costs of countermeasures in their assessment. Specifically, it can reasonably be assumed that engine drivers are aware of the limited resources available for countermeasures and that building an underpass is one of the most expensive. Trespassers and people living close to a railway line primarily suggested countermeasures that were the most convenient for them. People living close to a railway line also believed that education in schools concerning the dangers of walking on or across railway tracks is important.

In summary, these results suggest that building physical barriers such as landscaping or fencing is effective in preventing railway trespassing, in addition to which people prefer these types of countermeasures. However, the results also show that there is a need to tailor the countermeasures to the characteristics of the trespassers to ensure that the most appropriate ones are applied.

4.4 Beneficial approach to preventing train-pedestrian accidents and especially trespassing

The previous chapters show that (1) the prevention of trespassing is an important railway-safety topic in Finland, (2) many important characteristics of trespassing accidents and trespassing behaviour have been identified, and (3) there are effective countermeasures available. However, these facts raise the general question as to which type of approach should be applied to effectively prevent trespassing accidents.

Prevention of trespassing is challenging, given that in Finland there are 5,794 kilometres of railway lines and all pedestrians walking close to railway lines are potential trespassers. The size of the railway network, variety of trespassing behaviours and the large set of potential countermeasures suggest that effective prevention work cannot be the responsibility of any single organisation. In addition, the approach should be systemic and generic even though detailed and site-specific information about trespassing accidents and behaviour is utilised. Consequently, as emphasised by a systems approach, the responsibility for prevention work should be shared between government, railway organisations, communities and authorities responsible for public health, education, enforcement, railways and urban planning. Without a systems approach, no substantial reduction of trespassing accidents can be expected.

4.5 Contribution and limitations of the study

The main contribution of this study derives from the previous paucity of information about trespassing in Finland. In short, this study (1) reveals that trespassing is frequent in Finland and that, in contrast to the general improvement of railway safety, the number of trespasser fatalities has not diminished during the past decade, (2) shows that there are specific sites of frequent trespassing on Finnish railways, (3) identifies the main characteristics of observed trespassers and trespasser victims in trespassing accidents, (4) compiles information related to the behaviour of trespassers, and (5) evaluates the effectiveness of selected engineering countermeasures, which is important because so few published evaluations are available.

From a methodological point of view, the study incorporates a balanced set of data-collection methods including accident analyses, surveys, interviews and field observation, which provide a versatile description of the problem. The results have helped practitioners and researchers understand and form a relatively extensive picture of the problem, which can be used when developing and implementing effective countermeasures. While earlier studies have focused on trespassing accidents, this study provides information about both trespassing accidents and behaviour. In addition, the conducted surveys and interviews enable the problem to be seen from the viewpoints of engine drivers, people living close to a railway line and trespassers. Finally, the cameras with motion detectors introduced in this study provide an innovative and effective way to gather data on railway trespassing.

Further, the results show that the risk related to railway trespassing was associated with the trespassing behaviour.

However, this study has limitations that should be kept in mind when generalising the results. First, it must be noted that the results from trespasser counts, concerning e.g. the age and hour distribution, might be biased from the site selection criteria. Secondly, due to a somewhat biased sample for age and a relatively low response rate, the results of the neighbourhood survey should be viewed with caution. However, it is assumed that the age bias had no substantial influence on the results and the results are useful, as there is not that much information available about people's perceptions in this domain. The response rate could be improved in upcoming surveys by increasing the number of gift vouchers (or other prizes) to be raffled among respondents. Thirdly, the results of the neighbourhood survey may have some limitations regarding social desirability (Edwards 1953). However, social desirability should not be seen as a major problem due to the anonymity of the respondents (Lajunen and Parker 2000). Additionally, trespassers' behaviour might be affected by surveys, interviews and the realisation from the implemented countermeasures that someone is paying attention to their safety. Fourthly, the field data in the after phase were collected one year after the installations. Thus, the results are limited to the short-term effects of the preventative measures, especially in the case of prohibitive signs if no enforcement is introduced. Another limiting factor is that each countermeasure was installed at one site, possibly creating some bias. 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.

5. Implications and recommendations

It is recommended that railway trespassing be considered a key issue in railway safety, because collisions between trains and pedestrians are a leading fatal train-related accident type in Finland (1). In addition, the number of trespasser fatalities has not fallen as much as fatalities in other accident categories (1), thus the results highlight the need for prevention of railway trespassing.

Overall, it is recommended that prevention work be based on a systems approach because the trespassing problem is broad and multifaceted, and all of the elements in the rail safety system are interrelated. Consequently, the responsibility for prevention work should be shared between government, railway organisations, several authorities and communities. The involvement of cities is especially important since they are responsible for local and regional urban and traffic planning. Specifically, on the grounds of shared responsibility, the cities where problem spots are located should be actively involved in planning and implementing preventive measures. In addition, these cities should explore the possibilities of contributing to the costs of implementing relevant measures.

Effective prevention work requires recognition of the extent and details of the problem; thus the information collected during this study provides a good platform for the task. Coordinated action, as emphasised by the systems approach, is essential in order to coordinate and manage the implementation of single and/or combined countermeasures and to follow their effectiveness. Furthermore, it is important to take advantage of previous/ongoing practices and experiences (both national and international) and to exploit them so as to ascertain that available funding for prevention work will be used efficiently.

A large number of countermeasures have been proposed for the prevention of railway trespassing. Based on the results of this study, there is no clear indication that any gender or age group is better at avoiding accidents (i.e. is clearly under- or overrepresented); thus prevention work should concentrate on a general reduction in exposure. The most effective countermeasures include those that limit the exposure to risk, especially in cities where population density is high and train traffic is dense. First of all, this target calls for high-class urban and traffic planning for a limited need to cross railway lines and building of a sufficient number of under- or overpasses. Specifically, the cities should be planned in such a way that people's need to cross railway lines is minimised. This planning can be reinforced by land-

scaping and fencing, which have been found to be highly effective (V) and preferred by the public and engine drivers (III, IV). If the required resources for building physical barriers are not available or the site is not suitable for such measures, the use of prohibitive signs is recommended, especially if the message can be reinforced with effective enforcement. Regardless of the obtained results, more research is needed to collect more information on the effectiveness of countermeasures (e.g. applicability of the results at other sites and regions).

The results of this study also support the findings of earlier studies that there is no single generic solution to prevent trespassing (e.g. Law 2004, Rail Safety and Standards Board 2005, Savage 2007). On the contrary, trespassing tends to be somewhat specific to location (III, IV, V) and therefore there is a need to tailor the countermeasures to locations and to the characteristics of trespassers. Understanding the location and trespasser characteristics is important, since it gives a better grasp of the factors affecting risky behaviour and points the way in applying the most effective or suitable countermeasure(s) (II and III).

Information campaigns are worth considering in raising awareness, because a substantial number of interviewed trespassers and people living close to a railway line considered trespassing to be safe, and so many trespassers and people living close to a railway line assumed trespassing to be legal. However, to have sufficient influence on trespassers' behaviour, it is recommended to reinforce information campaigns by combining them with physical measures or supplementing them with incentives (rewards for safe behaviour) or enforcement procedures (Lobb et al. 2003). It should be noted that when planning education campaigns to prevent trespassing, Operation Lifesaver (2008) should be considered as an additional aid.

One of the main aspects of safety education should focus on schoolchildren, since their ability to perceive and assess the risks related to trespassing is limited. Thus schoolteachers together with other authorities should be strongly involved in traffic safety education, in order to increase pedestrians' awareness of the rules related to railway crossing and increase their understanding of the risks related to railway trespassing. Especially schools near railway lines should be a primary target group (see e.g. the Finnish Transport Safety Agency 2011). Another target group could be elderly people whose information processing, visual and motor capabilities necessary for safe railway crossing are reduced.

Finally, there is a strong need worldwide for further research in the area of trespassing. Future research could provide a far more comprehensive insight into e.g. actual behaviour of trespassers and effective countermeasures.

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ARTICLE I

The development of railway safety in Finland

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The development of railway safety in Finland

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ABSTRACT

This study reviews the development of railway safety in Finland from 1959 to 2008. The results show that the level of safety has greatly improved over the past five decades. The total number of railway fatalities did not show any obvious decreasing or increasing trend during the first decade, but since the early 1970s the annual number of fatalities has decreased from about 100 to 20. The estimated overall annual reduction per year from 1970 to 2008 was 5.4% (with a 95% confidence interval from -8.2% to -2.6%). The reduction in subcategories per million train-kilometres from 1959 to 2008 was 4.4% per year for passengers, 8.3% for employees, 5.0% for road users at level crossings and 3.6% for others (mainly trespassers). The safety improvement for passengers and staff was probably influenced by the introduction of central locking of doors in passenger cars and improved procedures to protect railway employees working on the tracks. The number of road users killed at level crossings has fallen due to the installation of barriers and the construction of overpasses and underpasses at crossings with dense traffic, removal of level crossings, and an improvement of conditions such as visibility at crossings. The number of trespasser fatalities has seen the least decline. Key plans for the future include further reduction of the number of level crossings on the state railway network from the current roughly 3500–2200 by 2025, and involving communities in safety work related to railway trespassers.

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1. Introduction

Rail transportation has been considered one of the safest modes of transport for some time. Risk comparisons for the EU Member States show that rail and air travel are the safest modes of transport per travelled passenger-kilometre. Specifically, for the years 2001 and 2002, the fatality risk (fatalities per 100 million passenger-kilometres) was 0.035 for air (civil aviation) and rail travel, and 0.95 for road transport (ETSC, 2003). In addition, train and bus travel has the lowest passenger fatality risk per time spent travelling, with two fatalities per 100 million person travel hours. The risk is more than 12 times less than for car travel (ETSC, 2003).

In spite of the positive safety record of rail transport, fatalities in rail traffic do occur and the average yearly number of fatalities (excluding suicides) in Finland was 19.9 during the period 2000–2008 (Finnish Transport Agency, 2011).

On the European scale, the level of railway safety in Finland is roughly at the median based on yearly railway fatalities (excluding suicides) per million train-kilometres (Eurostat, 2007,

2010). As in most European countries, the largest share of railway accident fatalities in Finland involves trespassers (persons other than passengers and railway employees killed by rolling stock in motion outside level crossings) and road users at level crossings (Eurostat, 2007, 2010; Finnish Transport Agency, 2011). Furthermore, in Finland a greater share of all railway accidents occur at level crossings than in most other countries (Eurostat, 2010). However, in a recent comparison of fatal railway accident rates and trends on Europe's mainline railways, the number of fatal train collisions and derailments in Finland was too small to allow reliable comparison of Finland with other countries (Evans, 2011).

Analysis of historical accident data provides useful background information when evaluating previous safety work and when planning future safety strategies. For example, in Great Britain, the research has focused on fatal transport accidents (Evans, 2003a,b), railway risks and valuation and the costs of preventing rail fatalities (Evans, 2005), along with fatal train accidents on Britain's mainline railways (Evans, 2006, 2007, 2008, 2009). Furthermore, studies investigating the effect of privatisation or economic deregulation on railway safety have been carried out in Great Britain (Evans, 2007), the USA (Savage, 2003) and Japan (Evans, 2010).

This study examined railway accidents in Finland from 1959 to 2008. The objective was to describe and model the trends in the development of railway safety.

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2. Method

2.1. Data

The data for analysis were collected mainly from the statistics of the Finnish railway operator (VR Group Ltd.) and the statistics of the Finnish rail administration (RHK, part of the Finnish Transport Agency since the beginning of 2010). The Finnish State Railways (VR Group Ltd. since 1995) started publishing yearly railway accident and damage statistics in 1959 (State Railways, 1960). The Finnish rail administration (RHK) was established in 1995 and has released yearly railway statistics since its foundation. The accident statistics of RHK are based on data received from the rail operator (there is currently only one rail operator in Finland). The data covers the accidents from the whole Finnish railway network, including private tracks. Metros and tramways are excluded.

Over the years, the accident and damage statistics for railways have undergone several changes (State Railways, 1994). The first important one came in 1985, when the railway administrations in the Nordic countries agreed to harmonise their statistics to improve comparability. According to the Nordic guidelines, only accidents involving fatalities or serious injuries, or accidents causing damage of more than 5000 UIC-francs (a virtual currency unit used by the International Union of Railways) need to be reported (State Railways, 1986). The second substantial change came in 1993, when the limit for reported damage was increased to 10,000 ECU (1 ECU = 1 €). Therefore, since 1993 some features included in the statistics have in certain respects made them incompatible for comparison with those of previous years. In addition, some other changes have taken place over the years, such as new explanations for the concepts used, new information to be collected and minor changes in the classification or table contents.

The data used in this study include the numbers of fatalities in different accident categories, number of all reported level crossing accidents, passenger-kilometres, train-kilometres and number of staff from 1959 to 2008. The data includes only railway accidents caused by rolling stock in motion. Therefore, fatalities that occurred when no train or construction machine was moving are excluded.

The data for 1959–2005 were collected during a national project from the statistics of the Finnish railway operator. This was later extended to 2006–2008 from the statistics of the Finnish Rail Administration. The information on train-kilometres was collected from three sources: for 1959 and 1960 from the railway operator; for 1970–2005 from UIC's Railis database; and for 2006–2008 from the Finnish Rail Administration. There was no information available about train-kilometres for 1961–1969; therefore the numbers have been interpolated from the information from 1960 and 1970. The information on the Finnish population and number of registered vehicles was collected from Statistics Finland (2010). The development of railway safety in Finland was evaluated based on fatalities alone, except for level crossings, where also all reported accidents were included. Fatalities resulting from accidents are the most reliable measure of safety, since the definition of the term is clear and practically all fatal accidents have been included in the statistics. The number of injury accidents or resulting injuries is less reliable, because the definitions of reportable injury accidents have varied during the period in question. It is also the case for property-damage-only accidents. The number of fatalities is a suitable measure also in the sense that when improving the level of safety, the most important aim is to reduce the number of fatalities (and serious injuries).

It should be noted that single accident counts are not reliable indicators of safety, especially when the numbers are small. Consequently, the changes in the true level of safety can easily be masked by random variation in accident counts. For example, if the long-term average of the annual number of fatalities is 9, the

approximate 95% confidence interval of the observed number of fatalities in any year is $9 \pm 2 \cdot \sqrt{9}$. Therefore, the observed annual number of fatalities can vary between 3 and 15 even when there are no significant changes in safety.

Suicides were not included in this study because they have not been included in the accident and damage statistics of the Finnish rail operator since 1985. In Finland, the share of railway suicides of all suicides is small, approximately 4% in 2006 (Peltola and Aittoniemi, 2008). However, suicides represent a significant share of all railway fatalities, since in Finland approximately 70% of railway fatalities are suicides. In general, around 50 railway fatalities that can be classified as suicides occur in Finland each year.

In the following analysis annual data were used except for passenger and employee fatalities, where the data were grouped into 5-year periods, because there were a large number of years with zero fatalities.

2.2. Accident model

Models were fitted to data to describe numerically the trends in the development of railway safety. We used the model introduced by Evans (2007, 2010, 2011). The model assumes that fatalities occur randomly in year t at a mean rate λ_t per year; λ_t is assumed to be given by

$$\lambda_t = \alpha k_t \exp(\beta t)$$

where k_t is a variable describing exposure to accidents in year t , α is a scale parameter, and β is a parameter measuring the long-term annual rate of change in accidents per unit of exposure. Depending on the model, k_t is either train-kilometres, passenger-kilometres, number of employees, population, or the number of level crossings. The model assumes that the mean number of accidents per unit time is proportional to exposure (e.g. train-kilometres) and to an exponential function of time, which represents the effects of general improvements in railway safety taking place over the long term (Evans, 2010). The model was fitted by Negative Binomial regression for fatality data and by Poisson regression for accident data (level crossing accidents). However, as noted by Evans (2007, 2010), the decision of whether to use Poisson or Negative Binomial distribution makes little difference to the results.

3. Results

3.1. Descriptive statistics

The annual fatality data used in the analysis is presented in Table 1. The category *Road users* means road users killed in level crossing accidents. In the category *Others* practically all cases concern trespassers (i.e. pedestrians walking on the track or crossing the track outside level crossings).

The total annual number of railway accident fatalities fell from about 100 to around 20 during the observation period, and most fatalities were either road users or others. At the same time the population of Finland grew from 4.4 to 5.3 million, and the number of train-kilometres increased by 25% from 42.5 to 53.3 million. The number of level crossings was reduced from 7570 to 4218. Of the 4218 level crossings at the end of 2008, 3515 were on the state railway network and 703 on private railways.

Fig. 1 shows that the trends of road user fatalities at level crossings and fatalities of others have been quite similar with three exceptions. First, the fatalities of others seemed to have a decreasing trend from 1961 to 1970, when there was a sharp increase back to the level of 1961. Second, the fatalities of others were at an exceptionally low level from 1987 to 1991. And third, there was an increasing trend in the fatalities of others from 1996 to 2006.

Table 1
Annual number of fatalities and potential explanatory variables on Finnish railways 1959–2008.

Year	Number of fatalities				All	Number of train-km (million)	Population (million)	Number of level crossings
	Passengers	Employees	Road users	Others				
1959	4	9	34	33	80	42.5	4.41	7570
1960	4	8	43	25	80	45.3	4.45	7583
1961	3	10	43	37	93	45.0	4.48	7740
1962	7	12	42	29	90	44.7	4.51	7893
1963	8	9	55	30	102	44.4	4.54	7921
1964	8	7	46	28	89	44.1	4.56	7952
1965	10	8	51	29	98	43.8	4.57	7815
1966	12	7	55	26	100	43.5	4.59	7752
1967	7	8	47	22	84	43.2	4.62	7826
1968	3	9	40	24	76	42.9	4.63	8008
1969	7	4	42	21	74	42.6	4.61	8110
1970	5	5	53	37	100	42.3	4.60	7851
1971	6	9	57	38	110	41.4	4.63	8016
1972	11	4	45	31	91	43.4	4.65	7968
1973	9	6	57	36	108	44.4	4.68	7975
1974	9	2	54	42	107	46.1	4.70	7972
1975	5	1	33	35	74	44.4	4.72	7915
1976	1	3	51	29	84	43.3	4.73	7864
1977	4	2	32	27	65	42.4	4.75	7726
1978	3	4	32	30	69	41.5	4.76	7415
1979	2	2	24	26	54	43.0	4.77	7362
1980	4	1	35	22	62	44.9	4.79	7092
1981	3	1	22	21	47	45.5	4.81	8395
1982	3	0	35	26	64	44.5	4.84	7947
1983	3	2	26	18	49	43.8	4.87	7836
1984	8	0	25	17	50	43.3	4.89	7710
1985	2	1	27	10	40	43.5	4.91	7556
1986	0	0	20	17	37	38.3	4.93	7484
1987	3	1	19	3	26	43.4	4.94	7368
1988	4	1	12	6	23	42.0	4.95	7293
1989	4	0	14	3	21	39.3	4.97	7163
1990	0	2	26	8	36	41.0	5.00	6974
1991	9	1	20	4	34	40.1	5.03	6634
1992	1	3	16	11	31	40.2	5.05	6200
1993	0	0	8	12	20	40.9	5.08	6161
1994	3	3	12	12	30	41.3	5.10	5970
1995	1	1	8	7	17	41.0	5.12	5761
1996	3	1	5	3	12	40.6	5.13	5500
1997	1	1	13	6	21	44.1	5.15	5398
1998	10	1	11	2	24	44.5	5.16	5283
1999	1	0	10	5	16	44.3	5.17	5210
2000	2	0	10	8	20	44.8	5.18	5162
2001	2	0	12	6	20	45.5	5.19	5107
2002	0	0	4	10	14	47.2	5.21	4956
2003	0	0	6	11	17	48.1	5.22	4846
2004	2	0	7	15	24	48.7	5.24	4635
2005	0	0	8	14	22	48.2	5.26	4510
2006	1	0	5	17	23	50.9	5.28	4430
2007	0	1	10	7	18	52.6	5.30	4334
2008	0	0	8	13	21	53.3	5.33	4218

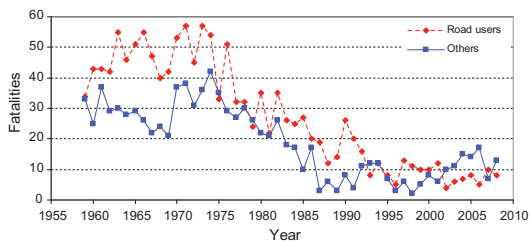


Fig. 1. Annual number of road user fatalities at level crossings and fatalities of others 1959–2008.

No evident explanation for these exceptions could be confirmed. It is possible, however, that the peculiarities described above were influenced by small changes in the process of classification of cases into suicides or trespassing accidents.

Interestingly, the development of railway fatalities is similar to the development of road accident fatalities until the early 1980s, as shown in Fig. 2. Thereafter the number of railway fatalities has decreased more than the number of road fatalities. The 1960s were a period of rapid motorization when the number of cars increased by a factor of four. Even though the vehicle fleet continued to grow throughout the 1970s the number of level crossing accidents was approximately halved during 1970–1980 and halved again during 1980–1995. The trend is similar to the development of all road accident fatalities, which fell from an all-time high of 1156 in 1972 to

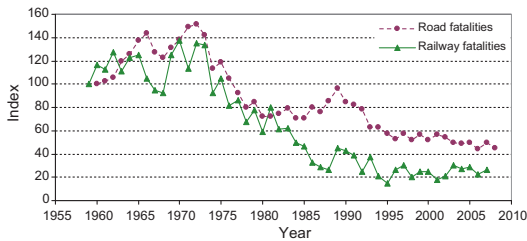


Fig. 2. Development of the annual number of road accident and railway accident fatalities. The indices have a value of 100 in 1960, when the number of road accident fatalities was 765 and the number of railway fatalities was 80.

551 in 1980 and 404 in 1996. It should be noted that fatalities of road users at level crossings are included in both statistics.

The 5-year fatality data concerning passengers and employees are presented in Table 2. Fatalities among railway employees include only accidents caused by rolling stock in motion. Therefore, fatalities that occurred during, e.g. track works where no train or construction machine was moving are excluded. Instead, these are included in occupational accident statistics. This means that fatalities caused by, e.g. falling from heights and electrocution are excluded from the railway accident statistics. Therefore the figures presented here provide only a partial picture of all fatalities among railway employees, and especially personnel working on the tracks. Correspondingly, the passenger fatalities and the fatalities of others include only accidents caused by rolling stock in motion.

During the observation period the number of both employee and passenger fatalities decreased from approximately eight per year to less than one per year. The development of employee fatalities has been especially remarkable, since during the last 10 years only one employee was killed in a railway accident. The number of employees has decreased by 67% from 35,511 to 11,754, and the number of passenger kilometres has increased by 58% from 2.3 to 3.6 billion.

The increase in the number of passenger fatalities to 40 in 1964–1968 from 26 in 1959–1963 in Table 2 makes an exception to the overall decreasing trend. There were no major multiple-fatality accidents during the latter period that would have explained the

increase. Other obvious explanations for this increase could not be found either. It is possible, however, that the exceptionally low figure of 26 in 1959–1963 may not reflect correctly the actual state of safety but was influenced by random variation, which is always inherent in accident counts.

Potentially the most disastrous railway accident types are train collisions and derailments, where the risk of multiple passenger fatalities is greatest. During the study period two such major accidents occurred: four people died in a derailment in Jokela in 1996 and 10 in a derailment in Jyväskylä in 1998. Table 3 summarises the information on fatal train collisions and derailments. Unfortunately, data on individual accidents have only been included in the statistics since 1996. For earlier years only annual numbers of fatalities are available; thus the number of fatal collisions in the first two decades is uncertain. For 1959–1968, for example, we only know for certain that the number of fatal collisions was between two and six because the six fatalities occurred in two different years. The three fatalities concerning derailments in the same period occurred in different years. Therefore we know that they resulted from three different accidents.

It seems that the number of fatal train collisions and derailments has decreased from the first to the last half of the observation period. The reasons for this positive development are not clear. It cannot be excluded, however, that the reduction in fatal train collisions may be due to at least partly to changes in the allocation of accidents to different categories. In the course of this study we managed to trace and correct some classification errors, but there may still be some inaccuracies in the data that cannot be corrected because of the lack of records on individual accidents, especially in the early decades.

The implementation of automatic train protection (ATP) started in the early 1990s and gathered pace following the two major derailments in 1996 and 1998. Although there have been no fatal train collisions or derailments in the last decade, the data in Table 3 are too sparse for estimating the impacts of ATP on fatal accidents.

In addition to the analysis of fatalities, the improvement of level crossing safety was analysed based on all reported level crossing accidents with or without casualties. Table 4 shows that the number of level crossings (including private tracks) has decreased over the years from 7570 in 1959 to 4218 in 2008. Specifically, in the

Table 2

Number of passenger and employee fatalities and potential explanatory variables on Finnish railways over 5-year periods from 1959 to 2008.

Period	Passenger fatalities	Railway employee fatalities	Average annual passenger-km (million)	Average number of staff members	Average annual train-km (million)
1959–1963	26	48	2306	35,511	44.4
1964–1968	40	39	2115	34,184	43.5
1969–1973	38	28	2407	27,666	42.8
1974–1978	22	12	3025	28,909	43.5
1979–1983	15	6	3235	28,501	44.3
1984–1988	17	3	3096	25,499	42.1
1989–1993	14	6	3167	19,765	40.3
1994–1998	18	7	3246	15,141	42.3
1999–2003	5	0	3352	12,245	46.0
2004–2008	3	1	3640	11,754	50.7

Table 3

Number of fatal train collisions and derailments and resulting fatalities on Finnish railways over 10-year periods from 1959 to 2008.

Period	Train collisions		Derailments	
	Fatal accidents	Fatalities	Fatal accidents	Fatalities
1959–1968	2–6	6	3	3
1969–1978	3–7	8	0	0
1979–1988	0	0	0	0
1989–1998	0	0	2	14
1999–2008	0	0	0	0

Table 4
Number of level crossings, number of level crossing accidents and number of registered vehicles from 1959 to 2008.

Year	Number of level crossings		Number of level crossing accidents		Number of registered vehicles
	With an active warning device	Without an active warning device	With a warning device	Without a warning device	
1959	205	7365	39	154	228,918
1960	202	7381	57	197	256,892
1961	207	7533	56	223	301,586
1962	368	7525	50	227	349,888
1963	363	7558	55	212	393,920
1964	407	7545	52	216	464,255
1965	398	7417	29	211	544,856
1966	399	7353	27	239	602,092
1967	401	7425	34	200	655,757
1968	396	7612	40	193	685,475
1969	393	7717	30	197	752,696
1970	379	7472	31	193	828,010
1971	413	7603	37	190	880,056
1972	407	7561	55	173	947,906
1973	418	7557	46	169	1,028,120
1974	429	7543	32	146	1,076,208
1975	456	7459	36	130	1,139,967
1976	504	7360	32	119	1,181,473
1977	563	7163	33	111	1,227,646
1978	637	6778	39	121	1,270,802
1979	682	6680	27	118	1,329,558
1980	679	6413	33	130	1,392,827
1981	752	7643	31	114	1,452,631
1982	748	7199	23	104	1,532,697
1983	798	7038	31	103	1,597,956
1984	842	6868	15	97	1,667,987
1985	864	6692	18	90	1,746,615
1986	890	6594	25	97	1,828,949
1987	911	6457	31	94	1,919,719
1988	930	6363	11	76	2,034,166
1989	957	6206	44	79	2,180,532
1990	973	6001	27	78	2,233,059
1991	975	5659	17	80	2,218,067
1992	967	5233	19	66	2,230,516
1993	972	5189	18	58	2,156,009
1994	971	4999	15	51	2,150,950
1995	959	4802	9	41	2,181,239
1996	955	4545	12	35	2,229,222
1997	952	4446	14	38	2,242,318
1998	963	4320	11	28	2,328,990
1999	948	4262	14	34	2,403,327
2000	943	4219	8	44	2,465,822
2001	940	4167	11	49	2,499,154
2002	933	4023	9	33	2,539,953
2003	925	3921	12	40	2,626,999
2004	886	3749	11	41	2,727,160
2005	848	3662	9	55	2,818,965
2006	833	3597	9	51	2,906,415
2007	842	3492	11	37	2,989,881
2008	849	3369	13	45	3,150,296

Statistics Finland (2010).

1960s and early 1970s the number of level crossings remained quite steady and even increased slightly. The effective removal of level crossings began in the mid-1970s when increased attention was paid to road safety in general. At the same time, an increasing number of remaining level crossings were fitted with active warning devices. Specifically, 2.7% of level crossings were equipped with active warning devices in 1959 while the corresponding number in 2008 was 20.1%.

Level crossing accidents decreased quite steadily from the late 1960s to the mid-1990s. This increase coincided with rapid growth of the motor vehicle fleet. Most level crossing accidents occurred at level crossings without an active warning device such as automatic barriers or light and sound warning devices, and the proportion did not change much during the observation period even though the number and proportion of level crossings with warning devices increased substantially.

3.2. Accident models

Fig. 3 shows the model fitted to the annual data on all fatalities in Table 1, assuming that fatalities have a negative binomial distribution. The annual rate of change in the fatality rate is -4.5% per year with a 95% confidence interval from -6.5% to -2.5% . The estimated fatality rate in 2008 is 0.34 fatalities per million train-kilometres, giving an estimated mean number of fatalities in 2008 of 18. Based on the modelling results the railway fatality rate has fallen by a factor of 10 from 1959 to 2008. However, it is also clear from Fig. 3 that the model overestimates the trend during the first decade when the actual fatality rate did not show any significant decrease. Therefore, the real reduction in the fatality rate from 1959 to 2008 is clearly less than the model indicates.

In order to improve the fit of the model, the same model was fitted to the annual data from 1970 to 2008. The results show a

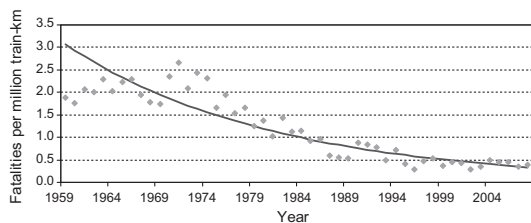


Fig. 3. Total number of fatalities per million train-kilometres on Finnish railways from 1959 to 2008.

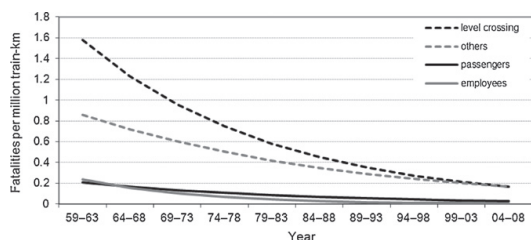


Fig. 4. Trends in fatalities per million train-kilometres on Finnish railways from 1959 to 2008.

stronger decrease (–5.4% per year with a 95% confidence interval from –8.2% to –2.6%) in the annual rate of change in the fatality rate than the model for the whole period. According to this model the fatality rate decreased by a factor of 9 from 1970 to 2008. The estimated fatality rate in 2008 was 0.29 fatalities per million train-kilometres, giving an estimated mean number of fatalities in 2008 of 16.

The models for different fatality categories were first calculated by using train kilometres as exposure variable for all categories. Fig. 4 shows these models fitted to the data in Table 1 (road user fatalities and fatalities of others) and Table 2 (passenger and employee fatalities). Fig. 4 shows that the absolute decrease in fatality rates was greatest for road users at level crossings followed by others (mostly trespassers), and much smaller for passengers and employees.

Furthermore, separate models were calculated for the rates in all four fatality categories using different exposure variables: passenger-kilometres for passenger fatalities, number of staff members for employee fatalities, the number of level crossings for road users killed in level crossing accidents, and Finnish population for trespasser fatalities. Table 5 presents a summary of these models and the models where train-kilometres were used as an exposure variable.

The trends per million train-kilometres in different victim categories in Table 5 show that the annual rate of change was most

Table 6
Estimated annual rates of change in level crossing accident rates and estimated mean accident rates in 2008 with 95% confidence limits.

	Estimated annual rate of change over 1959–2008 (95% confidence limits in brackets)	Estimated mean accident rates in 2008 (95% confidence limits in brackets)
Level crossing accidents per million registered vehicles	–9.2% (–9.4%, –9.0%)	8.78 (8.20, 9.41)
Level crossing accidents per million train-km	–3.9% (–4.1%, –3.8%)	1.04 (0.98, 1.11)
Level crossing accidents in crossings with a warning device per 1000 level crossings with a warning device	–6.7% (–7.1%, –6.3%)	7.05 (6.12, 8.13)
Level crossing accidents in crossings without a warning device per 1000 level crossings without a warning device	–2.7% (–2.9%, –2.5%)	8.12 (7.55, 8.73)

favourable for employees (–8.3%), followed by road users (–5.0%), passengers (–4.4%) and others (–3.6%). The annual number of passenger fatalities per billion passenger-kilometres fell at a rate of 5.5% per year, indicating that from 1959 to 2008 the number of passenger fatalities dropped by a factor of 16. Correspondingly, the number of employee fatalities per 1000 employees fell by a factor of 19, the number of fatalities of road users per 1000 level crossings by a factor of 6, and the number of fatalities in the category others per million inhabitants by a factor of 6.

The mean annual rates of change per million train-kilometres for different fatality categories in Table 5 range from –5.0% for road users to –3.8% for the category others, except for employees for which the corresponding rate is –8.3%. With this exception the rates are fairly close to each other. This fact together with overlapping confidence intervals of the rates suggests that the rates do not substantially differ from each other.

The model estimates for the mean fatality rates in 2008 in the rightmost column of Table 5 are close to the observed numbers in Tables 1 and 2. The estimated mean fatality rate of road users in 2008, for example, is 5.9 (the product of 1.40 in Table 5 and the 4.2 thousand level crossings in the last row of Table 1), when the observed number in Table 1 is 8.

Regarding all reported level crossing accidents, Table 6 shows the results after fitting the model to the annual data in Table 4, assuming that level crossing accidents have a Poisson distribution. The estimated annual rate of change in the accident rate is –9.2% per year per million registered vehicles and –3.9% per year per million train-kilometres. The estimated rate of change per million train-kilometres was somewhat smaller than the corresponding rate for road user fatalities at level crossing accidents (–5.0%, see Table 5).

According to Table 6, level crossing accidents per registered vehicle decreased much more than level crossing accidents per

Table 5
Estimated annual rates of change in fatality rates from 1959 to 2008 and estimated mean fatality rates in 2008 with 95% confidence limits.

		Estimated annual rate of change over 1959–2008 (95% confidence limits in brackets)	Estimated mean fatality rates in 2008 (95% confidence limits in brackets)
Total	Per million train-km	–4.5% (–6.5%, –2.6%)	0.34 (0.19, 0.59)
Passengers	Per billion passenger-km	–5.5% (–10.0%, –1.0%)	0.30 (0.08, 1.10)
	Per million train-km	–4.4% (–8.9%, 0.0%)	0.03 (0.01, 0.10)
Employees	Per thousand employees	–5.8% (–10.8%, –0.9%)	0.02 (0.00, 0.08)
	Per million train-km	–8.3% (–13.2%, –3.5%)	0.00 (0.00, 0.02)
Road users	Per thousand level crossings	–3.5% (–5.5%, –1.5%)	1.40 (0.79, 2.49)
	Per million train-km	–5.0% (–7.0%, –3.0%)	0.15 (0.09, 0.27)
Others	Per million inhabitants	–3.7% (–5.7%, –1.7%)	0.97 (0.79, 2.47)
	Per million train-km	–3.6% (–5.6%, –1.6%)	0.16 (0.09, 0.28)

train-kilometre. During the observation period the number of registered motor vehicles increased rapidly (from 0.2 million to 3.2 million). It seems likely, however, that the number of motor vehicles traversing level crossings did not necessarily increase as much as the vehicle fleet because at the same time the number of level crossings was reduced.

The decrease in the number of accidents at level crossings with a warning device per number of such crossings was higher (6.7% per year) than the decrease in number of accidents at such level crossings without a warning device (2.7% per year), and the difference was statistically significant (Table 6). A potential explanation is that the reduction in the number of level crossings has concerned especially passive level crossings (without an active warning device) where there was little road traffic and therefore relatively small accident potential. Consequently, the average volume of road traffic per passive level crossing (and respective accident potential) increased with time. For level crossings with an active warning device the average volume of road traffic per level crossing probably decreased with time as the number of level crossings with such a warning device increased year by year, because warning devices were implemented first at level crossings with large volumes of road traffic. The differences in development of the average volume of road traffic per level crossing between level crossings with and without an active warning device may therefore largely explain the differences in accident trends between the two level crossing categories.

4. Discussion

The main results of this study showed that the level of railway safety in Finland has greatly improved over the five decades from 1959 to 2008. A similar decreasing trend of train accidents has also been found in other countries (see, e.g. Evans, 2007, 2010, 2011). The development of railway accident fatalities was similar to that of road accident fatalities from 1960 until the early 1980s. Thereafter numbers of fatalities decreased more on railways than on roads.

The total number of railway fatalities did not show any obvious decreasing or increasing trend during the first decade, but since the early 1970s the annual number of fatalities has fallen from about 100 to 20. The estimated overall annual reduction per year from 1970 to 2008 was 5.4%. The improvement of railway safety concerns all victim categories: passengers, railway employees, road users at level crossings and others (mainly trespassers). The annual reduction in fatalities per million train-kilometres from 1959 to 2008 was 4.4% for passengers, 8.3% for employees, 5.0% for road users at level crossings and 3.6% for others (mainly trespassers).

The models used in this study were similar to those used by Evans (2007, 2010, 2011) to preserve comparability with earlier international studies. The models were simple in the sense that they included only one variable describing exposure. More complex model forms including several explanatory variables could have been used, but interpretation of the results would probably have become difficult because of multicollinearity problems. Even though such models could have increased the information on which variables have affected the development of railway safety, it is questionable whether the true effects of different variables could have been quantified with reasonable accuracy. It also became clear during the study that data were not available on all variables that could and probably would have influenced the development of railway safety since 1959. For example, data on the number of road vehicles traversing level crossings annually or frequency of trespassing probably have a major influence on railway accidents, but such information was not available. When data on major explanatory variables is missing there is little point in building models based on secondary variables.

The reduction in fatalities was most spectacular for railway employees: between 1999 and 2008 there was only one employee fatality, whereas during the first decade of the observation period the number was 87. Potential reasons for the reduction of employee fatalities include the introduction of new guidelines and procedures to protect railway employees working on the tracks, as well as a reduction in the number of people working on the tracks since human labour has largely been replaced by machines. It is also possible that the volume of major track construction and maintenance works decreased during the observation period.

The number of passenger fatalities decreased from 66 in the first decade to eight in the last decade of the observation period. Most passenger fatalities concern falling from a moving train or people boarding or getting off the train. The decline in passenger fatalities was probably brought about by the introduction of central locking of doors in passenger trains, which took place at the turn of the century. Another issue that might have had an influence on the increased safety of passengers is the replacement of old wooden passenger carriages with steel carriages in the 1980s. The stairs in the old carriages were outside the doors, whereas in the new carriages the stairs are inside. Jumping from and especially onto a moving train became much more difficult after the introduction of the new carriages.

The most disastrous railway accidents are typically train collisions and derailments where multiple passenger fatalities are more likely than in other types of accidents. The number of fatal train collisions and derailments fell from between eight and 16 in the first half of the 50-year observation period to two in the latter part, which indicates a positive development of safety. However, it cannot be ruled out that part of this reduction is due to changes in the categorisation of accidents. Some but not necessarily all classification errors could be detected and corrected during this study. The number of fatalities in train collisions and derailments decreased less, from 17 to 14, because of two major derailments in 1996 and 1998 resulting in four and 10 fatalities. Because of these two accidents the implementation of automatic train protection (ATP) that had begun in the early 1990s was accelerated. Currently ATP covers practically all railway sections on the Finnish state-owned railway network (excluding some railway sections with low traffic volumes and used only by freight trains). The accident data, however, is too sparse to allow for the estimation of the effects of ATP on safety.

The annual number of level crossing accidents was fairly stable during the 1960s and typically close to 250 resulting in around 50 fatalities. Then the numbers started to decline, such that since the mid 1990s the annual number of accidents has been about 50 and the number of fatalities close to 10. The levelling off since the mid-1990s is in agreement with the results of the European analysis, which showed that the rate per train-kilometre of serious accidents at level crossings has remained largely unchanged during the last 20 years (Evans, 2011).

The decrease in the number of road users killed at level crossings was affected by the removal of level crossings, the construction of overpasses or underpasses at crossings with dense traffic, the installation of barriers and the improvement of conditions such as visibility at crossings (e.g. by clearing vegetation and other obstacles from sight lines). The removal of level crossings and construction of overpasses or underpasses have focused on railway sections where the maximum speed is over 140 km h⁻¹ and on railway sections where dangerous goods are frequently transported. According to the Finnish Railway Agency's guidelines, level crossings are not allowed on track sections where the train speed exceeds 140 km h⁻¹. The improvement of conditions is important for safety especially at level crossings situated on minor gravel roads (like most level crossings in Finland), where traffic volumes are often less than 10 vehicles per day and the crossings have no active warning devices. These are the level crossings where most

accidents happen. However, improvement of visibility at the crossings to achieve adequate sight conditions is not always possible and in these cases accident risk has been reduced, for example, by setting a driving ban for long and slow vehicles or reduced spot speed limits for trains (Kallberg, 2008).

The improvement of safety at passive level crossings is challenging because it is not feasible to provide any significant number of them with automatic barriers or flashing lights and bells. In addition to the measures mentioned above, the safety of level crossings on minor roads can be improved by, e.g. reducing the speeds of road vehicles so that drivers have more time to stop before the railway if needed (e.g. by installing stop signs or speed bumps), improving the vertical alignment of the road, or introducing technical solutions to help drivers spot an approaching train (e.g. in vehicle devices in cars to warn of approaching trains). The number of accidents per level crossing was higher for active than passive level crossings until the 1990s. This does not, however, mean that passive crossings were safer than active ones, because traffic volumes on the road are typically much higher at active crossings.

The number of fatalities in the category *Others* (mainly trespassers who cross the railway lines at places that are not meant for that purpose or who are walking along the tracks illegally or loitering in the railway area) decreased from 286 in the first decade to 106 in the last decade of the observation period. Over the past 10 years, most railway fatalities have been in this category. The number of trespasser fatalities has not decreased as much as have fatalities in other categories. The prevention of trespassing is hard, because nearly everyone is a potential trespasser and the railway lines in Finland, unlike in some other countries, are usually not isolated from the surrounding areas by fences. Trespassing is most frequent in cities that are divided by railway lines (Silla and Luoma, 2008). Railway lines have always divided communities, and in some cases this separation has become even more marked over the years. This means that new developments within the city such as living areas, shopping areas and schools are often located on both sides of the railway lines, increasing people's need to cross the tracks. However, stakeholders in the railways have only limited possibilities to improve matters. The railway authorities can reduce trespassing by restricting the access to railway lines (e.g. by building fences or landscaping) at locations where trespassing is frequent, but due to the great number of such locations, it is important that stakeholders in society (e.g. policy makers, urban planners and school teachers) also participate in prevention. In spite of this shared responsibility, these fatalities affect the image of railways and their safety level as experienced by the general public.

Consequently, there is still work to be done to improve the safety of Finnish railways. The implementation of safety management systems has made safety work more organised and enhanced preventive safety work in order to recognise safety risks before they lead to accidents. A key strategy for the future includes the removal of 1500 level crossings by 2025; according to estimates, this will reduce the number of level crossing fatalities by 50% (Finnish Rail Administration, 2006). Additionally, more research is needed to find solutions for increasing the safety of passive level crossings.

Another goal is to involve communities in the safety work related to railway trespassers in order to decrease the large amount of trespassing accidents.

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ARTICLE II

**Main characteristics of
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Main characteristics of train–pedestrian fatalities on Finnish railroads

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ABSTRACT

The aim of this study was to describe the frequency of fatalities, timing of collisions and characteristics of persons killed in train–pedestrian collisions on Finnish railways during 2005–2009. In addition, the Finnish results were compared with those collected in Sweden. The Finnish data were combined from five different sources. The results showed that 311 pedestrians were killed in train–pedestrian collisions, including 264 suicides, 35 accidents and 12 unclassified events. For each event type, most of the victims were male. Most suicide victims were in the 20–29 year age group and on average younger than people who chose some other form of suicide. About half of all victims were intoxicated by alcohol, medicines and/or drugs. Both suicides and accidents occurred most often at the end of the week but no specific peak for time of year was found. Suicides occurred most frequently from afternoon to night and accidents during the rush hours. Most train–pedestrian fatalities happened in densely populated areas. In conclusion, the effective prevention of railway suicides and accidents calls for a systems approach involving effective measures introduced by authorities responsible for urban planning, railways, education and public health.

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1. Introduction

Among all fatal railway accidents in Finland, train–pedestrian fatalities are the most frequent accident type (European Railway Agency, 2010). During 2006–2008 a total of 211 people were killed in railway accidents in Finland; if road users, railway passengers and railway personnel involved in railway accidents are excluded, 185 fatalities remain. Thus 87.7% of all the fatalities on Finnish railroads are train–pedestrian fatalities, sustained by trespassers (i.e. pedestrians walking on the track or crossing the track outside level crossings) and people who commit suicide.

The statistics of the European Railway Agency (2010) show that 80% of train–pedestrian fatalities on Finnish railways were suicides during 2006–2008. However, it is frequently challenging to determine whether or not a given death is an (unintentional) accident or a (intentional) suicide, since in many cases there is insufficient information to make a definitive classification (Mishara, 2007). This concerns both railway fatalities (Mishara, 2007) and road traffic fatalities (Hernetkoski and Keskinen, 1998). In addition to practical issues (such as insufficient information), the accurate identification of railway suicides can be complicated due to the social, legal, financial or ethical implications of assigning suicide as a cause of death (Lobb, 2006). Given that such a classification is needed

for statistical purposes, the European Railway Agency (2008) has developed guidelines for distinguishing suicides from trespassing accidents. Specifically, the evidence of suspected suicide includes factors such as a suicide note, behaviour demonstrating suicidal intent, previous suicide attempts or prolonged depression.

On average, 1000 suicides per year have been committed in the 21st century in Finland (Official Statistics of Finland, 2011a). Compared with the neighbouring countries, suicides are more common per inhabitant in Finland than in Denmark, Norway or Sweden, but less common per inhabitant than for example in the Baltic countries or Russia (National Institute for Health and Welfare, 2008).

Official Statistics of Finland (2011b) shows that the most frequently used suicide method in Finland during 2006–2008 was hanging for men (32%) and poisoning with medicines for females (52%). Four to five per cent of all suicides were railway suicides. In other European countries the proportion of railway suicides has been relatively similar, for example 5% in Sweden (Rådbo et al., 2005), 6% in Austria (Deisenhammer et al., 1997), 7% in Germany (Baumert et al., 2005) and 5% in England and Wales (Symonds, 1994).

Railway suicides constitute a relatively small percentage of total suicides committed in Finland. However, the societal costs of suicides, as well as unintentional train–pedestrian fatalities, are high. In addition to the loss of human life, train–pedestrian collisions cause considerable delays (primary and secondary) to railway traffic and a serious work-related stress factor and trauma for engine drivers, other railroad and rescue employees and to people who witness the event (e.g. Mishara, 2007; Rådbo et al., 2005; Wildson,

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Table 1
Variables in combined database by source of information.

Variable	Source of information
Gender and age	Statistics Finland, Finnish Police
Location and time	Finnish rail operator, Rescue Department, Finnish Transport Agency
Intentionality	Statistics Finland, Finnish Police
Pre-crash behaviour	Finnish Police, Finnish rail operator
Use of alcohol	Statistics Finland
Mental health	Statistics Finland, Finnish Police
Information on self-destruction	Statistics Finland, Finnish Police
Information on suicide note or farewells	Statistics Finland, Finnish Police
Train	Finnish rail operator

2008). Specifically, the situation is traumatic to engine drivers who in most cases see the victim alive before the accident and the body afterwards (Cothereau et al., 2004).

Railway suicide is a highly lethal suicide method. Specifically, the studies conducted in the Netherlands (Van Houwelingen et al., 2010), Germany (Erazo et al., 2005; Schmidtke and Ober, 1991), Austria (Deisenhammer et al., 1997) Denmark (Lindekilde and Wang, 1985) and Australia (De Leo and Krysinska, 2008) showed that approximately 90% of all railway suicides result in death.

The main aim of this study was to describe the frequency of fatalities, timing of collisions and characteristics of persons killed in train–pedestrian collisions on Finnish railways.

The results should provide us with useful information on train–pedestrian collisions and make it possible to investigate similarities and differences between different types of events (suicide, accident, unknown). This knowledge in turn will help identify focal areas for future research, and help determine general preventive strategies for train–pedestrian collisions or separate strategies for different types of events. For example, Mishara (2007) indicated that prevention strategies for reducing trespassing accidents are not necessarily similar to those for preventing suicides, because as opposed to accidents, suicides consist of persons deliberately putting themselves in situations where they will be struck by a train.

2. Method

The analysis included train–pedestrian fatalities during 2005–2009. Five primary sources of data were used for the analysis: (1) the Finnish rail operator (VR Group Ltd.), (2) the Finnish Transport Agency, (3) Finnish Police, (4) the Rescue Department and (5) Statistics Finland. A combined database was established as follows: First, the number of events was based on police reports and death certificates received from Statistics Finland. These are the only official sources of information on the seriousness and intentionality of an event; however, the information did not match perfectly between them, and some cases were included in one but not the other. If a case was included in the Statistics Finland database but there was no police report, the cause was assumed to be an imperfect search function in the database of the Finnish police – specifically, a lack of necessary keywords for identifying all target cases. If a case was included in the database of the Finnish police but not in that of Statistics Finland, the assumed cause was insufficient information on the death certificate (e.g. train or railway tracks not mentioned). Thus all cases in both official databases were included in the combined database even if unconfirmed in one of them.

Secondly, the databases of other organisations provided specific information on the time of occurrence, place, victim's pre-crash behaviour and type of train involved. Consequently, the combined database included information related to time of occurrence, age and sex of the victim, place, victim's pre-crash behaviour, type of

event, type of train, intoxication and mental health. Table 1 summarizes all included variables by source of information.

The final data included all cases from the police reports and death certificates of Statistics Finland that satisfied the criteria of intentional or unintentional train–pedestrian fatality. The unintentional fatalities of railway employees or those that had occurred at level crossings were excluded based on the classification of official railway statistics.

Information concerning intoxication (alcohol, medicines and drugs) was gleaned from the death certificates of Statistics Finland. Although the decision to measure the alcohol/medicine/drug level is made by the coroner, the measurement is done in almost all cases. Thus, all victims with no information on alcohol level were assumed not to be intoxicated. Specifically, alcohol and medicines are tested for in all victims and drugs generally in all victims except the elderly. A blood alcohol level of 0.05% or more is entered on the death certificate.

Information concerning mental health, self-destruction and suicide note or farewells was collected from the death certificates of Statistics Finland and from police reports. In several cases the information in the police reports was augmented based on interviews with close relatives.

The main results are presented in frequency tables. For more detailed insight into the results, the Finnish data was examined by gender, age and type of event (excluding unknown cases). Chi-square tests were applied to these analyses. Due to some age groups having a low number of observations the age groups were combined into two groups: less than 30 years and 30 years or more (excluding one unknown case).

3. Results

During the 5-year observation period, a total of 311 train–pedestrian fatalities occurred on the Finnish railway network. Of this number 264 (84.9%) were classified as suicides, 35 as accidents and 12 as unclassified events. The overall number of completed suicides in the Finnish population covering the same time period was 5109. Thus, fatal railway suicides accounted for 5.2% of all suicides over the 5-year period, ranging from 4.6% in 2006 to 5.7% in 2009.

3.1. Gender and age

Table 2 shows that in all types of train–pedestrian fatalities most victims were males (71% of suicides, 77% of accidents and 100% of unknown events). The male/female ratio for suicides was 2.4:1 and for accidents 3.4:1.

Approximately half of the suicide victims (44.3%) were 20–39 years old and 51.4% of all accidents happened to people aged 10–29 years. There were no significant differences between genders or among age groups in incidence of accidents or suicides. In addition, there was no significant association between gender and age.

Table 2
Victim's gender and age by type of event.

Variable/level		Type of event			Total
		Suicide	Accident	Unknown	
Gender	Male	187	27	12	226
	Female	77	8	0	85
	Total	264	35	12	311
Age	0–9	0	1	0	1
	10–19	38	5	0	43
	20–29	66	13	5	84
	30–39	51	4	1	56
	40–49	39	4	1	44
	50–59	49	2	3	54
	60–69	14	2	0	16
	70–79	5	3	1	9
	80–89	2	1	0	3
	Unknown	0	0	1	1
	Total	264	35	12	311

People who commit railway suicide are on average younger than people who choose some other suicide method (Fig. 1). For example, the proportion of suicide victims under 40 years of age was 58.7% among railway suicides and 33.6% among all suicides. Fig. 1 also shows that by comparison with the population, railway fatalities are substantially overrepresented (suicides at age 20–39 years and accidents at age 20–29 years).

3.2. Pre-crash behaviour

Table 3 shows that a majority of suicide victims waited on the tracks for a while before the train arrived (60.2%, if *unknown* cases were excluded). Less frequent behaviours included running or jumping in front of the train and walking in front of the train or along the tracks.

Accidents happened most frequently in situations when a person was crossing the track (38.5%) or was lying/sitting on the tracks (34.6%). In addition, some people were walking along the tracks. Interestingly, every victim except one who was lying/sitting on the tracks before the crash was intoxicated. There was no significant difference between genders or age groups in pre-crash behaviour of suicides or accidents.

3.3. Intoxication and mental health

Among all train–pedestrian fatalities, 153 victims (50.5%) were intoxicated by alcohol, medicines and/or drugs (Table 4). Males (55.5%) were more frequently intoxicated than females (37.3%) ($\chi^2(1)=7.90, p<0.01$). Furthermore, the victims of accidents were more frequently intoxicated (68.6%) than in suicides (48.9%)

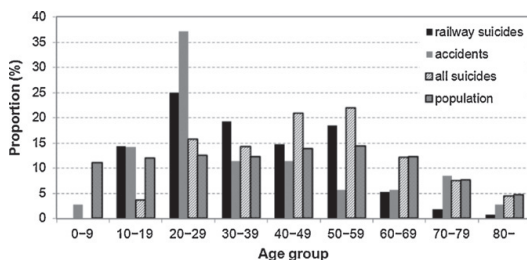


Fig. 1. Train–pedestrian fatalities by age group. The comparison includes railway suicides and accidents during 2005–2009, all suicides in Finland in 2009 (Official Statistics of Finland, 2011a) and the population of Finland in 2009 (Statistics Finland, 2010).

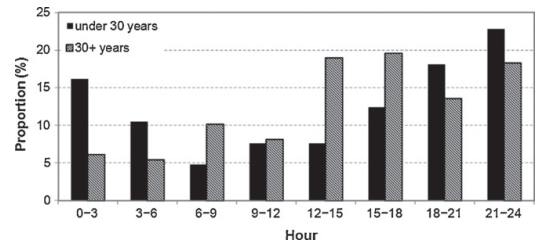


Fig. 2. Railway suicides by age group and time of day ($N=222$).

($\chi^2(1)=4.80, p<0.05$). There was no significant difference between age groups in the frequency of intoxication.

The suicide victims suffered from mental health problems much more frequently (39.2%) than accident victims (2.9%) ($\chi^2(1)=17.50, p<0.001$).

Female suicide victims suffered from mental health problems more frequently (58.4%) than male suicide victims (31.2%) ($\chi^2(2)=16.98, p<0.001$) (*unknown* cases were excluded). There was no significant difference between age groups in the frequency of mental health problems of suicide victims.

According to close relatives interviewed by the police, 27.3% of suicide victims had tried to commit suicide previously or had threatened to do so. This behaviour was more likely for females (37.6%) than males (18.7%) ($\chi^2(1)=11.96, p<0.01$). There was no significant difference between age groups in self-destructive behaviour.

Among the suicide victims, 18.2% left a suicide note and 5.3% said goodbye to their close relatives by SMS or phone call. There was no significant difference between genders or age groups in leaving farewells.

3.4. Time of occurrence

Train–pedestrian fatalities were quite evenly distributed by month (Table 5). Most suicides (52.3%) were committed in May, July, August, November or December and most accidents in March and November. However, due to the small amount of accidents the latter result should be interpreted with caution.

Both suicides (49.2%) and accidents (65.7%) occurred most frequently at the end of the week (from Friday to Sunday).

Suicides occurred most often in the afternoon, evening and after midnight. By contrast, accidents occurred most frequently during the afternoon rush hour (between 3 p.m. and 6 p.m.). The effect of age on hour distribution of suicides was statistically significant ($\chi^2(7)=19.40, p<0.01$), with people less than 30 years old committing suicide most frequently during evening and night time (between 6 p.m. and 3 a.m.), whereas older people committed suicide most frequently between noon and midnight (Fig. 2). There was no other significant difference between genders, age groups or type of events in time of occurrence (month, day and hour).

3.5. Place, location and train

Train–pedestrian fatalities concentrated in areas where the population density is high and the train traffic is dense. Out of all train–person fatalities, 24.1% occurred at currently or formerly used railway stations or in their vicinity (not more than 100 m away). The proportion is about the same for both suicides and accidents.

Table 3
Victim's pre-crash behaviour by type of event.

Behaviour	Suicide	Accident	Unknown	Total
Lying, standing, sitting, crouching or kneeling on the track (waiting/loitering on the tracks)	133	9	2	144
Running or jumping in front of the train	48	0	1	49
Walking in front of the train	20	2	0	22
Walking on the tracks	15	4	3	22
Crossing the tracks	2	10	0	12
Other	3	1	0	4
Missing	43	9	6	58
Total	264	35	12	311

Table 4
Victim's intoxication and mental health by type of event.

Variable/level		Type of event			
		Suicide	Accident	Unknown	Total
Intoxication	Alcohol, medicines and/or drugs	128	24	1	153
	No alcohol	134	11	5	150
	Unknown	2	0	6	8
	Total	264	35	12	311
Mental health	Depression	61	0	1	62
	Other mental health problems (often also include depression)	42	1	0	43
	No mental health problems	160	33	1	194
	Unknown	1	1	10	12
	Total	264	35	12	311

4. Discussion

The main aim of this study was to describe the frequency of fatalities, timing of collisions and characteristics of persons killed in train–pedestrian collisions on Finnish railways. The results showed that most of the victims were males in all types of fatal train–pedestrian collisions. The gender ratio for railway suicides

is similar to that found in Sweden (Rådbo et al., 2005), Germany (Erazo et al., 2004) and Austria (Deisenhammer et al., 1997). In addition, the result showing that most of the people killed unintentionally in train–pedestrian accidents were males is supported by findings from other studies (e.g. George, 2007; Patterson, 2004; Rail Safety and Standards Board, 2007). In summary, the results suggest that the Finnish gender ratios are pretty similar to those in earlier studies.

People who commit railway suicide are on average younger than people who choose some other suicide method. This has been found in many countries, such as Sweden (Rådbo et al., 2005), the Netherlands (Van Houwelingen and Beersma, 2001), Germany (Schmidtke, 1994) and Denmark (Lindekilde and Wang, 1985). The same applies to Finland, but the proportion of young suicide victims is even higher than for example in Sweden. Although no evident explanation for the high proportion of young suicide victims is available, Van Houwelingen et al. (2010) have proposed that young people may choose railway suicide as a method due to the high levels of impulsivity at that age and not having access to alternative means, such as medication. Overall, these results suggest a special focus on young people in the prevention of railway suicides.

The majority of suicide victims seemed to be waiting in the vicinity of the track for a while before the train arrived. This result is in agreement with the Swedish (Rådbo et al., 2005), German (Dinkel et al., 2011) and Australian (De Leo and Krysinska, 2008) results. The accidents happened most often in situations where a person was crossing the track. This is in agreement with our earlier results showing that trespassers are typically looking for the shortest and fastest route or using an existing path (Silla and Luoma, 2009).

Among all train–person fatalities, almost half of the victims were intoxicated by alcohol, medicines and/or drugs. In addition, males – who consume 63% of alcohol in Finland (Mustonen et al., 2009) – were more frequently intoxicated than females. Furthermore, 39.2% of suicide victims had mental problems before the event. This was more frequent among female victims who also had tried to commit suicide or threatened to do so more often than males. Overall, these results are supported by earlier results. Specifically, an Australian study (De Leo and Krysinska, 2008) showed that a positive blood alcohol content was found in 47.3% of young suicide victims and in 29.8% of all train suicide victims. In addition, De Leo

Table 5
Fatal train–person collisions by time of occurrence (month, day and hour) and by type of event.

Variable/level		Type of event			
		Suicide	Accident	Unknown	Total
Month	January	19	4	2	25
	February	14	0	0	14
	March	15	5	1	21
	April	24	2	2	28
	May	27	1	0	28
	June	18	1	0	19
	July	31	4	1	36
	August	26	4	3	33
	September	15	2	1	18
	October	21	3	0	24
	November	26	6	1	33
	December	28	3	1	32
	Total	264	35	12	311
Weekday	Monday	33	2	0	35
	Tuesday	32	4	0	36
	Wednesday	35	5	3	43
	Thursday	34	1	0	35
	Friday	41	7	2	50
	Saturday	44	9	4	57
	Sunday	45	7	3	55
	Total	264	35	12	311
Hour	0–3	21	4	1	26
	3–6	15	3	1	19
	6–9	15	4	2	21
	9–12	19	0	1	20
	12–15	35	1	0	36
	15–18	35	6	1	42
	18–21	37	2	0	39
	21–24	45	4	2	51
	Unknown	42	11	4	57
	Total	264	35	12	311

and Kryszynska (2008) documented a psychiatric diagnosis in 40.4% of all train suicide victims. A considerable proportion (65%) of documented history of psychiatric disorder has also been documented in the Netherlands (Van Houwelingen and Kerkhof, 2008) and in one county in Denmark (81%) (Lindekilde and Wang, 1985).

The proportion of intoxicated victims was even higher for accidents (68.6%) than for suicides (48.9%). The finding that many accident victims who were killed were intoxicated with alcohol or drugs is supported by several previous studies (e.g. George, 2007; Lerer and Matzopoulos, 1996; Patterson, 2004; Pelletier, 1997).

Train–pedestrian fatalities were not concentrated to any specific months, although somewhat lower frequencies of suicides were found for January to March. In Sweden more suicides were committed during the summer months (April to September) than during the winter months (October to March) (Rådbo et al., 2005) and in Australia almost half of railway suicides occurred during April–May and September–October (De Leo and Kryszynska, 2008). The Finnish results might be related to environmental factors: During January, February and March the ground is typically covered with snow and thus access to railway tracks is more difficult than at other times of year.

Suicides occurred most frequently at the end of the week (from Friday to Sunday). Somewhat similar results were obtained in Australia where the highest frequencies of railway suicides were observed on Thursdays and Fridays (De Leo and Kryszynska, 2008). In Sweden and other European countries, however, railway suicides happened more frequently during weekdays than during weekends (Rådbo et al., 2005). To some extent, the Finnish results might be explained by Finnish alcohol consumption statistics, which show that two thirds of the alcohol consumption is concentrated on weekends (Mustonen et al., 2009).

Railway suicides in Finland happened most often in the afternoon, evening and after midnight and people less than 30 years old committed suicide more frequently during evening and night time (between 6 p.m. and 3 a.m.), whereas older people committed suicide most frequently between noon and midnight. The results of earlier studies in Austria (Deisenhammer et al., 1997), Sweden (Rådbo et al., 2005) Turkey (Özdoğan et al., 2006), Germany (Erazo et al., 2004) and Australia (De Leo and Kryszynska, 2008) are inconsistent. Overall, the results suggest that there are considerable differences between countries for the time of occurrence of railway suicides.

Both suicides and accidents concentrated in areas where population density is high and the train traffic is dense. Of all fatalities, approximately a quarter occurred at currently or formerly used railway stations or in their vicinity (not more than 100 m away). Approximately the same result has been found in Sweden (Rådbo et al., 2005). In Australia 20.5% of suicides were recorded at stations (De Leo and Kryszynska, 2008).

In conclusion, the present results show the main demographic groups and the type of behaviour that should be focused on. There is no reason to assume that train–pedestrian fatalities are unavoidable. By contrast, the effective prevention of railway suicides and accidents calls for a systems approach involving effective measures introduced by authorities responsible for urban planning, railways, education and public health. Such measures include limitation of pedestrian access to railway areas, public education, reward or punishment and various technical solutions (e.g. Lobb, 2006; Rail Safety and Standards Board, 2007).

Given that train–pedestrian fatalities are strongly concentrated near big cities where the population density is high and train traffic is dense, limitation of pedestrian access to the tracks could be used in these areas. High-risk locations should be identified and effective fencing or landscaping should be introduced; Silla and Luoma (2011) have shown that these measures can reduce trespassing by more than 90%. However, the effects of such measures on suicides

might be more limited. As indicated by Law et al. (2009), simply restricting the access to railway lines has nothing to do with the attempter's suicidal intent. Thus, it is possible that suicidal persons move to some other location with easier access to railway tracks or decide to use some other method. However, Rådbo et al. (2008) argue that there is little evidence to support that reducing availability to one method would simply transfer the problem to another method. As the attempt has been complicated or even inhibited by building a fence, it gives the person more time to think about their intended act and they will possibly also realise its irrationality. In addition, information about these hot spots can also be used to reduce train speed in high-risk areas.

Surveillance performed by station staff and/or technically has also been proposed as a measure to identify and intervene with potential suicide victims just before they attempt suicide (e.g. Dinkel et al., 2011; Mishara, 2007). Rådbo et al. (2005) pointed out that pre-suicidal behaviour such as walking and loitering close to or on the tracks enables the early detection of suicidal persons and potentially also enables timely intervention, such as early breaking of a train or intrusion of station staff.

The above measures can be supported by educational measures, such as the safety education of schoolchildren, since more than half of all railway accidents happen to people aged between 10 and 29 years and the ability of small children to perceive and assess the risks related to trespassing is limited (e.g. Silla and Luoma, 2012).

Public health organisations can play a significant role in the prevention of train–pedestrian fatalities as well, especially railway suicides.

The results of this study show that more than half of the railway suicide victims were intoxicated and a substantial number of victims suffered from depression or other mental health problems. The use of alcohol while sad or depressed conveys an increased risk of self-reported suicide attempts among young people not reporting suicidal ideation (Schilling et al., 2009). Therefore, improved public health policy focusing on the use of alcohol and drugs as well as on mental health problems would be an essential part of the strategy for preventing the overly frequent suicides and accidents that occur on railways. In addition, as already proposed by Van Houwelingen and Kerkhof (2008), it is important to systematically and explicitly seek dialogue about suicidal intent with patients in mental health services. Many results of this study can be utilised to identify high-risk persons and assess various risks. For example, information on pre-crash behaviour will help better understand the behaviour of people who are at risk of committing a railway suicide: if a patient indicates a specific suicide plan including typical characteristics of railway suicide, this suggests that the plan might be quite likely. Furthermore, Van Houwelingen and Kerkhof (2008) point out that it is important to discuss the negative consequences of a train suicide to the patients themselves, to their friends, close relatives and also to frequent commuters. This discussion would aim at decreasing the perceived attractiveness of railway suicides, and all suicides in general.

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ARTICLE IV

**Opinions on railway
trespassing of people living
close to a railway line**

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Opinions on railway trespassing of people living close to a railway line

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ABSTRACT

A survey was designed to investigate opinions on railway trespassing of people living close to a railway line. The results showed that 89.2% of the respondents ($n = 502$) recalled that they had seen trespassing in their neighbourhood and, based on their observations, adults are the largest group trespassing. Overall, 68.9% of the respondents had personal experience of trespassing although 83.5% considered trespassing to be fairly or highly dangerous and 81.0% assumed it to be illegal. The respondents supported countermeasures such as building an underpass or fencing off the tracks, and only a few of them indicated that nothing could be done to resolve the problem. In addition, education in schools on the dangers of trespassing was suggested. These results allow practitioners and researchers to see the problem from a local perspective and thus develop a better understanding. This in turn helps design effective countermeasures.

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1. Introduction

Train–pedestrian collisions are considered to be one of the most important railway safety issues worldwide. For example, in the European Union, more than half of all fatal injuries (excluding suicides) were sustained by trespassers in 2006 (Lundström, 2008). Similar proportions have been reported in the United States (Savage, 2007), New Zealand (Patterson, 2004) and the Cape Town metropolis in South Africa (Lerer and Matzopoulos, 1996). In Finland, of all railway fatalities excluding suicides in 2004–2006, 68% were trespassers (Eurostat, 2007).

Trespassers are people who are illegally on railway property (Lobb et al., 2001). They are crossing the railway lines at places not intended for that purpose or are loitering or walking in the railway area (i.e. using railway property for activities unrelated to railway operations). Most frequently the motive for trespassing is as simple as taking the shortest or most convenient route from one place to another (e.g. Lobb et al., 2001; Rail Safety and Standards Board, 2007).

A wide range of initiatives has been launched to counter the trespassing problem. In Canada, a community trespass prevention programme has been set up and a problem-solving model developed as part of the programme C.A.R.E. (Community, Analysis, Response and Evaluation). This model includes a template for the Neighbourhood Trespassing Survey to collect more detailed information about the trespassing problem and its underlying causes through problem analysis (Law, 2004).

In New Zealand, two studies included anonymous surveys in an attempt to identify awareness of the illegality of walking across tracks, as well as the perception of risk (Lobb et al., 2001) and trespassers' attitudes (Lobb et al., 2003). The first study evaluated a programme of educational and environmental (access prevention by fences) interventions designed to reduce crossing of the rail corridor at a suburban station in Auckland. The survey was conducted before and after the interventions. The programme slightly increased the awareness of the illegality of walking across the tracks. However, the perception of risk did not change. The results also suggested that, in comparison with other age groups and females, teenagers and males had less safe attitudes and self-stated behaviour with regards to trespassing.

The second study evaluated a programme of interventions designed to reduce the crossing of a rail corridor at a city station (Lobb et al., 2003). These interventions included rail safety education in school, punishment and reinforcement. The surveys were delivered to all the boys at the participating school immediately before and after the interventions. In the after-intervention survey, the boys reported significantly less illegal crossings, greater knowledge of the illegality of trespassing (from 19% to 42%) and some increase in safety attitudes compared to before the survey.

In addition to the interventions introduced in the above studies, several other countermeasures exist to deter trespass. These countermeasures include e.g. limitation of pedestrian access by different means (using signage, attendance of station staff or security personnel and landscaping) and various technical solutions such as warning devices, closed-circuit television with or without a link to audio announcement and/or motion detectors and cameras with motion detectors (see e.g. Rail Safety and Standards Board, 2007). Regardless of the large number of proposed countermeasures,

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there is little published research evaluating the efficacy of any of these interventions (see Silla and Luoma, 2011).

Some studies have investigated issues such as location, time of day, injuries and personal characteristics of trespassers based on reported incidents and fatalities (Centers for Disease Control, 1999; Cina et al., 1994; George, 2007; Lerer and Matzopoulos, 1996; Patterson, 2004; Pelletier, 1997; Rail Safety and Standards Board, 2007). The main findings of these studies suggest that trespassers are usually adults and males (e.g. Centers for Disease Control, 1999; George, 2007; Patterson, 2004). Furthermore, some studies have found that many trespassers who were killed were intoxicated with alcohol or drugs (e.g. Centers for Disease Control, 1999; George, 2007; Lerer and Matzopoulos, 1996; Patterson, 2004; Pelletier, 1997). Regarding timing, the findings were inconsistent. Specifically, Pelletier (1997) found that fatality accidents typically occurred at night on Friday, Saturday and Sunday, and Lerer and Matzopoulos (1996) found that they occurred at peak commuter times. Furthermore, according to Patterson (2004), the majority of killed and injured trespassers are reasonably evenly spread across the day. However, when assessing only the non-injury trespasser incidents, most of them occurred during the afternoon peak (Patterson, 2004) or with observable peaks in the mid-afternoon and mid-to-late evening periods (RSSB, 2007). Moreover, compared to other forms of pedestrian accidents, collisions between trains and pedestrians are less common but they are more likely to cause death or irreparable damage such as amputation of limbs (see e.g. Blazar et al., 1997; Shapiro et al., 1994).

As mentioned by Savage (2007), analysing the reported incidents and accidents gives only a partial picture of the profile of trespassers. Consequently, the investigation of trespassing behaviour (including no accidents) could provide useful information. The first attempt to address this issue in Finland was made by Silla and Luoma (2008), who identified sites of frequent trespassing on Finnish railways and observed trespassing behaviour at selected sites. The information was gathered with the help of a survey directed at engine drivers, trespasser interviews and investigation of trespassing behaviour at three selected sites with the help of cameras equipped with motion detectors. Silla and Luoma (2008) found, for example, that trespassing seems to concentrate near cities where the population density is high and rail traffic is dense. Detailed analysis of trespasser behaviour enabled the characteristics of trespassers at selected sites to be determined.

The present study was designed to obtain complementary information to our earlier study by collecting opinions on railway trespassing from people living close to a railway line. Specifically, this study focused on issues such as whether people assess trespassing as a serious problem (e.g. recollection of frequency and characteristics of trespassers and their behaviour), what sort of countermeasures they assess as effective, the assessment of their own behaviour and overall trespassing safety, and their awareness of the legality of trespassing and trespassing fatalities. The results are important for designing effective countermeasures, as earlier results based on a survey directed at engine drivers and interviews of trespassers covered only limited numbers of relevant aspects of the problem. These aspects include potential needs for information campaigns, preference of various countermeasures and new ideas for prevention based on familiarity with local circumstances.

2. Method

2.1. Subjects

Survey forms were sent to 1500 households in the city of Lappeenranta in Eastern Finland. The sample size was approximately 2%

of the population of the city. Address information for the survey was retrieved from the Population Register Centre. The information was requested for a random sample of households from preselected local districts (10 out of 52) that were assumed to be of interest to the study. Based on the locations of residential areas and other activities, it was assumed that many residents of these areas might have a need to cross the railway, although the distance between the local districts and the railway varied. In addition, one local district was included because some respondents indicated that they were living there rather than the options given on the survey form. Contact information was requested from the Population Register Centre for the oldest person living in each household.

The city of Lappeenranta was selected for survey because our earlier study (Silla and Luoma, 2008) showed that the area is very prone to trespassing. Specifically, the tracks divide the city into two parts (Fig. 1), which leads to frequent crossing of the tracks. There is a 4 km stretch of track, including 12 identified locations with frequent trespassing.

2.2. Mailing

The form was mailed with a covering letter requesting voluntary cooperation with the survey. The covering letter provided no specific instruction as to who in the household was expected to answer to the questions. A stamped envelope addressed to VTT was included for the participant to use in returning the form. The survey was anonymous to reduce the tendency of giving socially desirable answers; however, this made it impossible to determine which individuals returned the forms. A separate form enabled respondents to provide their contact information and take part in a raffle. Two gift vouchers were later sent to the winners.

2.3. Survey form and data analysis

The survey form was based on the Neighbourhood Trespassing Survey (Law, 2004). The form contained four types of questions: (1) recollection of frequency and characteristics of trespassers and their behaviour, (2) preference of potential means to prevent trespassing, (3) assessment of respondents' own trespassing and the perceived safety of trespassing, and (4) awareness about regulations regarding walking in the railway area and trespassing fatalities. In addition, the respondents could provide additional comments and were asked to indicate their age, gender and the

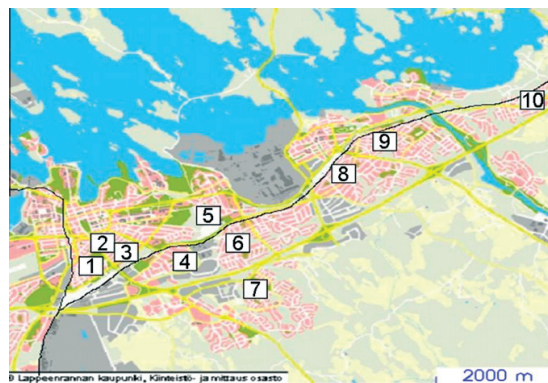


Fig. 1. Map of the city of Lappeenranta (City of Lappeenranta 2007). The black line from bottom left to upper right shows the passenger traffic railway. The numbers show the survey locations. The additional local district (11) is located north of local district 2.

Table 1
Number of returned survey forms by local district.

Local district	1	2	3	4	5	6	7	8	9	10	11	Missing	Total
No. of answers	93	77	52	36	21	75	29	30	58	10	5	16	502

local district where they lived in order to explore potential differences by respondent characteristics.

The words *trespasser* and *trespassing* were not used in the survey. Instead, the questions referred to people who are crossing the railway lines at unofficial/official places. The definitions of official and unofficial places were shown at the beginning of the survey.

The χ^2 test was used to determine the statistical significance of these relationships. The *p*-value is given where statistical testing has been done. However, no statistical analysis was applied if one or more options could be selected.

Overall, 33.5% of the survey forms were completed, the rate varying from 27% to 40% by local district. The highest return rates were from local districts situated near the tracks on the east side of the railway line (4, 6 and 8 in Fig. 1). The number of returned survey forms by local district is shown in Table 1. It must be noted that the small number of returned survey forms, especially in local district 11, might have influenced some of the statistical analysis (such as the inability to find differences in ratings of safety by district).

The sample was somewhat biased for age, probably because the address information was retrieved for the oldest person living in the household. Specifically, 37.5% of respondents were older than 60 years and 31.1% were aged from 45 to 60 years.

3. Results

3.1. Recall of trespassing

Respondents were asked whether they had seen people trespassing, and if so, how often this happened based on their observations. Overall, 40.6% of the respondents answered that trespassing occurs less frequently than once a week, followed by 23.7% who said that it occurs daily, 17.9% who said that it occurs a couple of times a week and 7.4% who said that it occurs once a week. Only 10.8% of the respondents indicated that they had never seen people trespassing. These results suggest that the respondents were quite aware of trespassing.

It was assumed that some of the local districts chosen for the study are more prone to trespassing than others because of their location in relation to the railway lines. This means that people living in these local districts have an obvious need to cross the railway line but the number of legal crossing places is limited (e.g.

residential areas 4 and 6 situated on the other side of the railway line from the city centre, or area 1 in the city centre at the junction of two railway lines, see Fig. 1). Indeed, when integrating the first three and the last two categories of frequency, the effect of local district on frequency of observed trespassing (once a week or more) was significant ($\chi^2(10) = 49.12$, $p < 0.001$), with the most frequent trespassing in local district 4 (75.0%), followed by local district 6 (69.3%), local district 5 (66.7%) local district 11 (60.0%), and local district 1 (59.3%). Among the other local districts the percentages varied between 50.0% and 29.3%.

Respondents were asked whether trespassing occurs at a certain time of day, and if so, what the most frequent times are based on their observations (one or more options could be selected). Forty percent of the respondents answered that they could not define any specific time of day when trespassing is frequent. Other respondents had observed trespassing most frequently in the afternoon (38.7%), followed by morning (35.6%), evening (32.6%), noon (23.0%) and night (10.9%).

Furthermore, the respondents were allowed to define special occasions when they frequently observed trespassers. The most frequent responses included the start and end of ice hockey matches (local districts 5 and 6 are close to an indoor skating rink) and commuting times. Some people also indicated weekends and personal business trips. The answers dealing with seasonal variation were ambiguous: some respondents indicated that trespassing occurs particularly in summer, while others considered it more frequent in winter.

In addition, respondents were asked in which age group the trespassers belong based on their observations (one or more options could be selected). People assessed that most trespassers are adults (21–65 years) (85.7%), followed by youngsters (12–20 years) (71.5%), the elderly (over 65 years) (30.9%) and children (under 12 years) (21.7%).

3.2. Preference of potential countermeasures

The respondents were asked which countermeasures they preferred to prevent trespassing (one or more options could be selected). The survey form included the alternatives for potential countermeasures listed in Fig. 2. The results showed that the respondents most frequently supported building of an over- or underpass (supported by 65.3% of respondents), followed by fencing (supported by 44.5% of respondents) and safety education (supported by 37.5% of respondents).

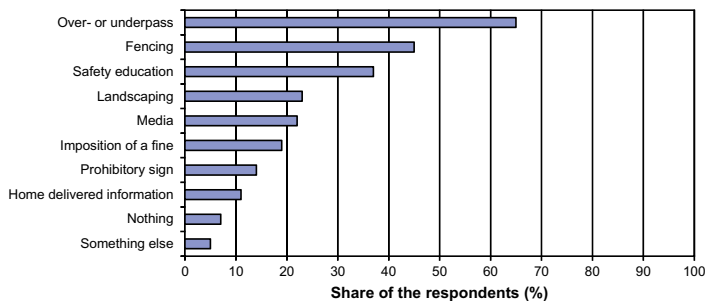


Fig. 2. Preference of possible countermeasures ($N = 501$). Respondents were allowed to indicate one or more options.

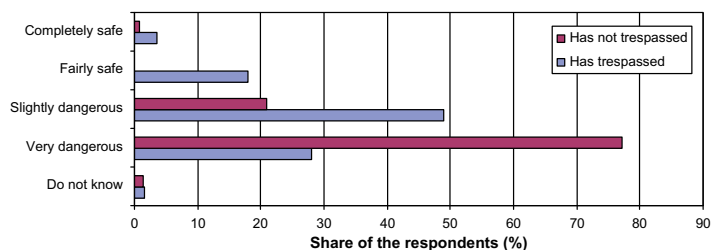


Fig. 3. Respondents' perceived safety of trespassing versus their own trespassing.

tion at school concerning the dangers of walking on or across railway tracks (supported by 36.5% of respondents). Only 6.8% of the respondents indicated that nothing could be done to remove the problem.

3.3. Assessment of own trespassing behaviour and perceived safety

The respondents were asked whether they had ever trespassed themselves (yes or no). Overall, 68.9% of the respondents had crossed the railway line at a spot that is not marked for that purpose ($N = 493$). The effect of gender on assessment of own trespassing behaviour was significant ($\chi^2(1) = 4.31, p < 0.05$), with higher percentages for males (73.1%) than females (64.3%). In addition, younger respondents were more likely than older respondents to indicate that they had trespassed ($\chi^2(4) = 10.57, p < 0.05$). Specifically, all respondents younger than 20 years had trespassed, followed by age group 20–29 (76% had trespassed), age group 30–44 (70% had trespassed), age group 45–60 (74% had trespassed) and respondents older than 60 years (61% had trespassed).

The effect of local district on own trespassing was significant ($\chi^2(10) = 53.98, p < 0.001$), with the highest percentage in local district 4 (97.2%) followed by local district 5 (81.0%), local district 6 (81.3%), local district 11 (80.0%) and local district 3 (78.8%). In other local districts the percentages varied between 39.7% and 70.6%.

Furthermore, the respondents were asked how they assess the safety of trespassing, on a 4-point scale from completely safe to very dangerous. Overall, 83.5% indicated that trespassing is either slightly dangerous (40.2%) or very dangerous (43.3%). Furthermore, 12.4% considered trespassing as fairly safe, 2.7% as safe and 1.4% did not know. The effect of local district on assessment was not significant.

The effect of the perceived safety of trespassing on respondents' own trespassing was significant ($\chi^2(3) = 110.15, p < 0.001$). Overall, 98.0% of the respondents who indicated that they have not trespassed answered that trespassing is slightly or very dangerous,

while the corresponding percentage for respondents who had trespassed was only 76.8% (Fig. 3).

In addition, the older the respondents were, the smaller was the proportion of respondents who assessed trespassing as completely or fairly safe. Specifically, the average rating for respondents older than 60 years was 3.46, followed by age group 45–60 (3.26), age group 30–44 (3.11), age group 20–29 (2.83) and respondents younger than 20 (2.00).

3.4. Awareness of the legality of trespassing and trespassing fatalities

The respondents were asked whether according to them it was legal to cross the tracks at locations other than sites specifically marked for that purpose. However, this was somewhat of a leading question because at the top of the survey form it was indicated that *pedestrians should cross the railway only at sites that are specifically marked for that purpose. It is possible to recognise these sites from at least the planking between the rails, which makes it easier to cross over. In practice people cross the tracks also at unofficial sites, which are often formed by regularly used walkways.*

Despite the leading introduction, 18.2% of the respondents indicated that crossing the tracks at an unofficial site is legal. Trespassing was considered to be illegal by 81.0% and 0.8% did not know. Males (22.0%) considered trespassing to be legal more frequently than females (14.2%) ($\chi^2(1) = 4.90, p < 0.05$). The effect of respondents' age on awareness of legality was also significant ($\chi^2(4) = 16.82, p < 0.05$), with typically higher percentages of legal answers for younger respondents. In addition, the effect of awareness of legality on the respondents' own trespassing was significant ($\chi^2(1) = 8.64, p < 0.05$), with a more substantial share (82.0%) trespassing among respondents who indicated trespassing to be legal compared with those who considered it illegal (66.1%). Finally, if the respondent considered trespassing legal, it was less likely that he or she would indicate that trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing illegal (85.7%) ($\chi^2(3) = 36.06, p < 0.001$).

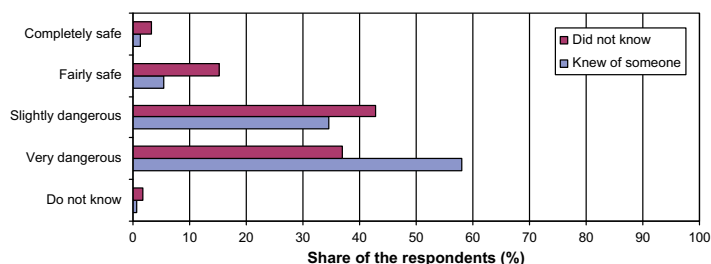


Fig. 4. Perceived safety of trespassing versus knowledge of a killed trespasser ($N = 489$).

Table 2
Main content and number of received comments.

Comment	Number of comments	Total
Proposition of countermeasures		89
Over- or underpass	45	
Fencing	18	
Safety education	9	
Modification of unofficial crossings to official	7	
Improved enforcement	4	
Landscaping	2	
Other	4	
Information about the observed trespassing site		20
Comments on other people's trespassing behaviour		19
Assessment of implemented measures		13
Reporting own behaviour (with no implications)		12
People should be more cautious		3
Other/unclear		4
Total		160

In addition, the respondents were asked whether they knew of someone who had been killed as a result of trespassing. Overall, 30.3% of the respondents knew of a killed trespasser. The effect of awareness of trespassing fatalities on the assessment of perceived safety was significant ($\chi^2(3) = 21.85, p < 0.001$). Fig. 4 shows that 92.6% of respondents who knew someone who had been killed because of trespassing considered trespassing to be slightly or very dangerous, while the corresponding percentage for those who did not know a killed trespasser was 79.8%.

3.5. Additional comments

At the end of the survey form there was free space for additional observations or opinions on trespassing. In total, 160 comments were received (Table 2).

More than 60% of the comments focused on potential countermeasures. Some of them included a recommendation to introduce a given countermeasure either at the selected site or in general in the city of Lappeenranta. Another group of comments concerned the assessment of implemented measures, including specific improvements of a measure (e.g. fences should be high and strong enough so as not to be easily climbed or broken) or opinions on the effectiveness of a measure (e.g. several positive comments about the new level crossing built in the Lappeenranta area in 2004). Furthermore, several comments included information about the observed trespassing sites in the city of Lappeenranta, other people's trespassing behaviour (mainly related to their beliefs why people are trespassing) and reports of respondents' own behaviour (e.g. places/situations where they have trespassed).

4. Discussion

This survey was designed to investigate trespassing from the point of view of people living close to a railway line. The data including 502 respondents was collected in a city that is prone to trespassing, especially in local districts close to the railway line. The results showed that the respondents were quite aware that trespassing occurs in their neighbourhood. Only 10.8% of the respondents indicated that they had never seen people trespassing.

According to the respondents' observations, trespassing occurs throughout the day. Specifically, 40.0% of respondents indicated that it is not possible to define any specific time of day when trespassing is frequent. Nevertheless, trespassing seemed to be most popular at those times when people normally move from one place to another, which means normal commuting times and in the

evenings when making personal business or leisure trips. According to the trespasser counts, which were carried out at selected sites in the same city as the present survey, trespassing occurred most frequently between 11 a.m. and 7 p.m. (Silla and Luoma, 2008). The results of other previous research related to the time when trespassing occurs are inconsistent. However, while earlier results have been based either on the number of fatalities and/or on the number of reported incidents, the present study utilised people's observations and our earlier study information collected by field observations. Consequently, our earlier and present study provided more reliable and consistent results on overall trespassing behaviour compared with many earlier studies.

Overall, 85.7% of respondents in the present study indicated that according to their observations, adults are the largest group trespassing. The other group that clearly stands out is youngsters. The finding that adults are the largest group trespassing is in line with previously obtained results (e.g. Centers for Disease Control, 1999; Patterson, 2004; Pelletier, 1997; Silla and Luoma, 2008). Furthermore, there are results supporting the fact that youngsters are also a large group trespassing (Lobb et al., 2003).

The respondents indicated that the most effective countermeasures to prevent trespassing include building an underpass or fencing off the tracks. The respondents also believed that education at school concerning the dangers of walking on or across railway tracks is important. Furthermore, only 6.8% of the respondents indicated that nothing could be done to resolve the problem. The proposed countermeasures are in line with our earlier results from trespasser interviews (Silla and Luoma, 2008).

Roughly 69% of the respondents had crossed the railway line at a spot not marked for that purpose. This supports the fact that trespassing occurs a lot in the city of Lappeenranta. Males indicated more frequently than females that they had trespassed, which is in agreement with previously obtained results (e.g. Lobb et al., 2001; RSSB, 2007; Silla and Luoma, 2008). Men are also predominant among the fatalities in train–pedestrian accidents (e.g. Centers for Disease Control, 1999; Cina et al., 1994; Patterson, 2004).

Overall, 83.5% of the respondents considered trespassing to be slightly or very dangerous. The corresponding percentage among interviewed trespassers in the same city was much lower (50%) (Silla and Luoma, 2008). This difference can be explained by the result showing that the more dangerous people think trespassing is, the more infrequent is their own trespassing. Consequently, these results suggest that those who are trespassing tend to consider trespassing safer on average than those who do not trespass. However, it must be noted that the differences in ratings of perceived safety might also be influenced by different methods used in data collection.

There was a significant effect of awareness of legality on respondents' own trespassing: among the respondents who indicated trespassing to be legal, the more substantial share was trespassing compared to respondents who considered trespassing illegal. Given that 18.2% of the respondents assumed that trespassing is legal, it is worth considering information campaigns as one form of preventing trespassing. The effect of delivered information concerning the dangers of trespassing is also supported by the finding that it appeared to have some effect on the respondents' sense of the danger of trespassing if the respondent knew of a killed trespasser. Even though there are studies stating that public education concerning the danger of railways can be effective (e.g. Lobb et al., 2003; Savage, 2006, 2007), it is important to remember that it is not easy to change the behaviour of trespassers. Pedestrians face risky situations and potential accidents every time they cross the railway tracks. They are faced with the choice between crossing a potentially dangerous railway track from an illegal place and spending more time and effort using an alternative safer route especially meant for that purpose. As mentioned by Lobb (2006),

the choice between alternatives is much more sensitive to the probability than to the magnitude of consequences. Even though train–pedestrian collisions are catastrophic and tragic, they are rare events and therefore it is not surprising that some pedestrians evaluate the risk of trespassing as tolerable. This means that the horrible but very unlikely consequence of trespassing on the tracks has less control over behaviour than the smaller but certain benefit of savings in time and effort. Therefore, to have sufficient influence on trespassers' behaviour, it is recommended to reinforce information campaigns by combining them with physical measures (such as prohibitive signs or fencing) or supplementing them by incentives (rewards for safe behaviour) or enforcement procedures (such as punishment or police enforcement) (Lobb et al., 2003; Silla and Luoma, 2008).

One of the main areas of the safety education should concentrate on school children, since their ability to perceive and assess the risks related to trespassing is limited. Especially schools near to railway lines should be the primary target group. The Finnish Transport Safety Agency (2009) emphasises correctly that the education at schools should concentrate on issues such as the following: playing or loitering in the railway area is prohibited, railway lines can only be crossed at official crossings, trains and other railway vehicles always have priority, train speeds are high, and trains are heavy and their stopping distance is long.

There are a couple of limitations to this study that should be considered when applying the results. First, due to a somewhat biased sample for age and a relatively low response rate, the results should be viewed with caution. However, it is assumed that these results are useful despite their potential bias, as there is not that much information available about people's perceptions in this domain. The age bias is not considered to have a substantial influence on the results, since based on our earlier study more than half of trespassers in the Lappeenranta area are adults (Silla and Luoma, 2008). The response rate could be improved in upcoming surveys by increasing the number of gift vouchers (or other prizes) to be raffled among the respondents. Secondly, the results may have some limitations regarding social desirability (i.e. the tendency to answer self-report items in such a way as to deliberately or subconsciously represent oneself in a favourable light), which might have biased the results (Edwards, 1953). However, as argued by Lajunen and Parker (2001), social desirability should not be seen as a problem due to the anonymity of the respondents.

In conclusion, the opinions and recollections of people living close to the railway line helped to build a relatively extensive picture of the problem. In short, a vast majority of people are aware of trespassing in their neighbourhood, they have their own experience about trespassing although they consider trespassing dangerous and illegal, and they support countermeasures such as building an underpass or fencing off the tracks. These results allow practitioners and researchers to see the problem from the local people's perspective and thus provide an improved understanding of the

problem. The increased knowledge helps to design effective countermeasures.

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ARTICLE V

**Effect of three
countermeasures against
the illegal crossing of
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Effect of three countermeasures against the illegal crossing of railway tracks

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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

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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.

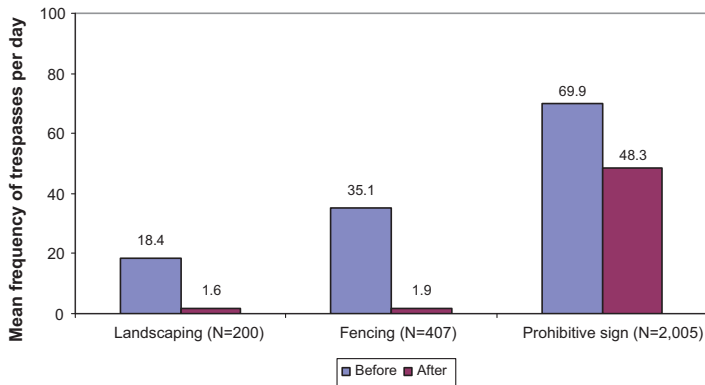


Fig. 3. Frequency of trespasses per day before and after countermeasure installation.

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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Title	Improving safety on Finnish railways by prevention of trespassing
Author(s)	Anne Silla
Abstract	<p>This study investigated trespassing accidents, trespassing and related countermeasures to provide information for prevention of trespassing accidents on Finnish railways. The study includes five complementary substudies, of which two included accident analyses and three collected information on railway trespassing by means of surveys, interviews and field observations. The main results showed, for example, that (1) trespassing is frequent in Finland and, contrary to the overall improvement of railway safety in Finland, the number of trespasser fatalities has not fallen over the past decade; (2) there are specific sites of frequent trespassing on Finnish railways; (3) both the victims in trespassing accidents and the observed trespassers were typically adults and males and the victims were frequently intoxicated; (4) the risk related to railway trespassing was associated with trespassing behaviour, and (5) at selected sites fencing and landscaping can stop trespassing almost entirely, but the effects of a prohibitive sign are much more limited. Overall, a systems approach is recommended for prevention work along with a shared responsibility between stakeholders such as government, railway organisations, various authorities and communities, because the problem is broad and multifaceted and the elements of the rail safety system are interrelated. The recommended countermeasures for preventing railway trespassing vary from under- and overpasses, physical barriers and prohibitive signs to enforcement and education. Selection of the most effective or suitable countermeasure depends on the effectiveness of different measures, location and the characteristics of trespassing.</p>
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Nimeke	Suomen rautatieliikenteen turvallisuuden parantaminen luvattomia radanylityksiä estämällä
Tekijä(t)	Anne Silla
Tiivistelmä	<p>Tässä tutkimuksessa selvitettiin luvattomia radanylityksiä, niihin liittyviä onnettomuuksia ja luvattomien radanylitysten estämiseksi toteutettuja toimenpiteitä turvallisuustyön tueksi. Tutkimus sisältää viisi osatutkimusta, joista kahdessa analysoitiin onnettomuusaineistoja ja kolmessa selvitettiin luvattomia radanylityksiä kyselyiden, haastatteluiden ja kenttämittausten avulla. Tutkimuksen tulokset osoittavat muun muassa, että (1) luvattomat radanylitykset ovat yleisiä Suomen rataverkolla eikä kuolleiden luvattomien radanylittäjien lukumäärä ole vähentynyt viime vuosikymmenen aikana samalla tavalla kuin muissa rautatieliikenteen onnettomuuksissa kuolleiden henkilöiden lukumäärä, (2) Suomen rataverkolta löytyy useita paikkoja, joissa luvattomia radanylityksiä tapahtuu säännöllisesti, (3) luvattomasti rataa ylittävät henkilöt (sekä onnettomuuksissa kuolleet että kenttämittauksissa havaitut) olivat useimmiten aikuisia ja miehiä ja onnettomuuksissa kuolleet henkilöt olivat usein alkoholin vaikutuksen alaisina, (4) ihmisten kokemana luvattomiin radanylityksiin liittyvä riski ja heidän ylityskäyttäytymisensä olivat yhteydessä toisiinsa ja (5) ai- taamisella ja maisemoinnilla voidaan estää luvattomat radanylitykset miltei kokonaan, kun taas kieltomerkin vaikutus on selvästi rajallisempi. Yleisesti turvallisuustyön suositellaan perustuvan järjestelmäajatteluun, koska ongelma on laaja ja monimuotoinen. Vastuun luvattomien radanylitysten estämisestä tulisi jakautua rautatieorganisaatioiden, useiden eri alojen (mm. terveydenhuolto, koulutus, valvonta, kaa- voitus) viranomaisten ja kuntien kesken. Luvattomien radanylitysten estämiseksi toteutettavat toimenpiteet vaihtelevat fyysisistä toimenpiteistä ja kieltomerkistä valvontaan ja valistukseen. Toimenpiteiden tehokkuuden ja sopivuuden varmistamiseksi päätöksen kussakin paikassa toteutettavasta toimenpiteestä tulisi perustua tietoon toimenpiteiden estovaikutuksista sekä kyseessä olevan paikan ja siellä tapahtuvien luvattomien radanylitysten ominaisuuksiin.</p>
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