



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

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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 kyselviden, 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 lövtyy useita paikkoia. joissa luvattomia radanylityksiä tapahtuu säännöllisesti, (3) luvattomasti rataa vlittävät henkilöt (sekä onnettomuuksissa kuolleet että kenttämittauksissa havaitut) olivat useimmiten aikuisia ja miehiä ja onnettomuuksissa kuolleet henkilöt olivat usein alkoholin vaikutuksen alaisina, (4) ihmisten kokema luvattomiin radanylityksiin liittyvä riski ja heidän ylityskäyttäytymisensä olivat yhteydessä toisiinsa ja (5) aitaamisella 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, kaavoitus) viranomaisten ja kuntien kesken. Luvattomien radanylitysten estämiseksi toteutettavat toimenpiteet vaihtelevat fyysistä 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.

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

- Supervisor Professor Tapio Luttinen Aalto University Finland
- Reviewers Professor Per Gårder University of Maine USA

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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).

Contents

Abs	stract	t	3
Tiiv	vistel	mä	4
Pre	face.		5
Aca	adem	ic dissertation	7
Lis	t of o	riginal publications	8
Aut	hor's	contributions	9
1.	Intro	duction	12
	1.1	Significance of train-pedestrian collisions	12
		1.1.1 Train-pedestrian collisions in the context of rail safety	12
		1.1.2 Cost of accidents and fatalities	13
	1.2	Pedestrian behaviour	14
		1.2.1 Pedestrians as part of the transport system	14
		1.2.2 Risky behaviour	15
		1.2.3 Trespasser profile	17
	1.3	Possibilities to reduce railway trespassing	18
		1.3.1 Prevention	18
		1.3.2 Countermeasures	19
		1.3.3 System approach	20
	1.4	Purpose of the study	21
2.	Meth	nod	23
	2.1	Accident analyses	23
	2.2	Surveys (substudies III and IV)	24
	2.3	Field observations	26
	2.4	Trespasser interviews (substudy III)	26
3.	Res	ults	28
	3.1	Development of railway safety especially in regard to trespassing	28
	3.2	Characteristics of trespassing	29
		3.2.1 Frequency of trespassing	29

		3.2.2	Timing	29	
		3.2.3	Gender and age	30	
		3.2.4	Sites, route selection and type of travel	30	
		3.2.5	Type of behaviour and intoxication of victims	31	
		3.2.6	Perceived safety	31	
		3.2.7	Awareness of legality	32	
	3.3	Effecti	veness and preference of countermeasures	32	
		3.3.1	Effectiveness of countermeasures (substudy V)	32	
		3.3.2	Preference of countermeasures (substudy III and IV)	35	
4.	Disc	ussion		37	
	4.1	Role c	f trespassing in railway safety in Finland	37	
	4.2	Main o	characteristics of trespassing accidents and trespassing	37	
	4.3	Effectiveness and preference of selected engineering countermeasures 39			
	4.4	Benefi	cial approach to preventing train-pedestrian accidents and		
		espec	ially trespassing	40	
	4.5	Contri	bution and limitations of the study	40	
5.	Impl	ication	s and recommendations	42	
References44					

Appendices

Articles I–V

Article III of this publication are 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 misal-location 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 suicide in the United Kingdom is £1,352,641 (a little less than $2M\in$, 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 $20M\in$ 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-propensity' 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 trainpedestrian 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)

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 database 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 trainpedestrian 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.

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).

	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	54.2	85.7		
Elderly (66–) 11.4		54.5	30.9		
Total	100.0	100.0			

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

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).





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 is glightly or the respondent trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is slightly or the respondent trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is slightly or the respondents who considered trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is slightly or very dangerous (72.7%) compared to the respondents who considered trespassing is glightly or very dangerous (72.7%) compared to the respondents who considered trespassing is glightly or very dangerous (72.7%) compared to the respondents who considered trespassing is glightly or very dangerous (72.7%) compared to the respondents who considered trespassing is g

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.

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

	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	-

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

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.



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 trainpedestrian 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 daytime 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 sitespecific 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 trainrelated accident type in Finland (I). In addition, the number of trespasser fatalities has not fallen as much as fatalities in other accident categories (I), 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 underor 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 underor 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 landscaping 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.

References

- Ajzen, I. (1991). The theory of planned behaviour. Organisational behaviour and human decision processes 50, 179–211.
- Blazar, P.E., Dormans, J.P. & Born, C.T. (1997). Train injuries in children. Journal of Orthopaedic Trauma 11, 126–129.
- Bliss, T. & Breen, J. (2009). Implementing the recommendations of the World reports on road traffic injury prevention – Country guidelines for the conduct of road safety management capacity reviews and the specification of lead agency reforms, investment strategies and safe system projects. Washington, D.C., USA: World Bank Global Road Safety Facility.
- CEMT/CM (2006). Road safety Achieving ambitious road safety targets. European Conference of Ministers of Transport / Council of Ministers. CEMT/CM(2006)20.
- Centers for Disease Control (1999). Injuries among railroad trespassers in Georgia, 1990–1996. Mortality and morbidility weekly report 48, 537–541.
- City of Lappeenranta (2007). Lappeenranta karttapalvelu [Lappeenranta map view]. http://kartta.lappeenranta.fi (accessed September 4, 2007).
- Díaz, E. (2002). Theory of planned behaviour and pedestrians' intentions to violate traffic regulations. Transportation Research Part F 5, 169–175.
- Edwards, A.L. (1953). The relationship between the judged desirability of a trait and the probability that will be endorsed. Journal of Applied Psychology 33, 90–93.
- Elms, D. (2001). Rail safety. Reliability Engineering and System Safety 74, 291–297.
- European Railway Agency (2008). Implementation guidance for annex 1 and appendix to directive 2004/49/EC. European Railway Agency's Safety Unit. November 30, 2008.
- European Transport Safety Council (2003). Transport safety performance in the EU a statistical overview. Brussels, Belgium. http://www.etsc.eu/oldsite/ statoverv.pdf (accessed January 22, 2010).

- Evans, A.W. (2007). Fatal train accidents on Britain's main line railways: End of 2006 analysis. Working paper. London, UK: Centre for transport Studies, Imperial College London.
- Evans, A.W. (2010). Rail Safety and rail privatisation in Japan. Accident Analysis and Prevention 42, 1296–1310.
- Evans, A.W. (2011). Fatal train accidents on Europe's railways: 1980–2009. Accident Analysis and Prevention 43, 391–401.
- Finlex (2006). Railway Act 555/2006. http://www.finlex.fi/en (accessed June 6, 2007).
- Finnish Rail Administration (2008). Rail Network. http://www.rhk.fi/in_english/ rail_network (accessed February 25, 2009).
- Finnish Rail Administration (2000–2009). Finnish Railway Statistics. Separate publication for each year. Helsinki. 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008 and 2009. http://www.rhk.fi/tietopalvelu/tilastot (accessed February 25, 2010).
- Finnish Transport Safety Agency (2011). Rautatieturvallisuustietoa [Information on railway safety]. http://www.rautatieturvallisuus.fi/rautatieturvallisuus (accessed February 11, 2011).
- Fuller, R. (2000). The task-capability interface model of the driving process. Recherche Transports Sécurité 66, 47–59.
- Fuller, R. (2005). Towards a general theory of driver behaviour. Accident Analysis and Prevention 37, 461–472.
- George, F.B. (2007). Rail-trespasser fatalities, developing demographic profiles. Cadle Creek Consulting. Contracted by Federal Railroad Administration.
- Haddon, W. Jr. (1968). The changing approach to epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. American Journal of Public Health 58, 1431–1438.
- Hatfield, J., Soames Job, R.F., Hesketh, B. & Joung, W. (2006). The development of messages and experiences to reduce road-related illusory vulnerability and risky driving for young drivers. Final report for the Motor Accidents Authority of NSW. http://www.irmrc.unsw.edu.au (accessed June 12, 2007).
- Hatfield, J. & Fernandes, R. (2009). The role of risk-propensity in the risky driving of younger drivers. Accident Analysis and Prevention 41, 26–35.

- HEATCO (2005). State-of-the-art in project assessment. Specific Support Action: Developing Harmonised European Approaches for Transport Costing and Project Assessment. Sixth Framework Programme 2002–2006. Deliverable 2. http://heatco.ier.uni-stuttgart.de (accessed January 12, 2009).
- Hiltunen, L. (2006). Liikenneonnettomuuskustannusten muodostuminen ja kohdentuminen [The structure and distribution of traffic accident costs]. Finnra reports 50/2006. Finnish Road Administration.
- Holland, C. & Hill, R. (2007). The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations. Accident Analysis and Prevention 39, 224–237.
- Häkkinen, S. (1978). Tapaturmateoriat ja niiden kehittäminen [Accident theories and their development]. Report No 36/1978. Espoo, Finland: Helsinki University of Technology, Laboratories of Industrial Economics and Industrial Psychology.
- Häkkinen, S. & Luoma, J. (1991). Liikennepsykologia [Traffic psychology]. Hämeenlinna, Finland: Otatieto Oy.
- Johansson, R. (2009). Vision Zero Implementing a policy for traffic safety. Safety Science 47, 826–831.
- Johnston, I. (2010). Beyond "best practice" road safety thinking and systems management – A case for culture change research. Safety Science 48, 1175–1181.
- Jonah, B.A. (1986). Accident risk and risk-taking behaviour among young drivers. Accident Analysis and Prevention 18, 255–271.
- Lajunen, T. & Parker, D. (2000). Are aggressive people aggressive drivers? A study of the relationship between self-reported general aggressiveness, driver anger and aggressive driving. Accident Analysis and Prevention 33, 243–255.
- Larsson, P., Dekker, S.W.A. & Tingvall, C. (2010). The need for a systems approach to road safety. Safety Science 48, 1167–1174.
- Law, W. (2004). Trespassing on railway lines A community problem-solving guide. 8th International Level-Crossing Symposium & Managing Trespass Seminar. Sheffield, UK. 13–16 April 2004.

- Lerer, L.B. & Matzopoulos, R. (1996). Meeting the challenge of railway injury in a South African city. Lancet 348, 554–556.
- Lindberg, G. (2005). Measuring the Marginal Social Cost of Transport. Research in Transport Economics 14, 155–183.
- Lobb, B. (2006). Trespassing on the tracks: A review of railway pedestrian safety research. Journal of Safety Research 37, 359–365.
- Lobb, B., Harre, N. & Suddendorf, T. (2001). An evaluation of a suburban railway pedestrian crossing safety programme. Accident Analysis and Prevention 33, 157–165.
- Lobb, B., Harre, N. & Terry, N. (2003). An evaluation of four types of railway pedestrian crossing safety intervention. Accident Analysis and Prevention 35, 487–494.
- Lundström, A. (2008). Accidents to unauthorised persons and suicides. Presentation at the Seminar on Trespassers on Railway Lines and Suicides, Lille, France, April 3, 2008. The European Railway Agency.
- Maibach, M., Schreyer, C., Sutter, D., van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B. & Bak, M. (2008). Handbook on estimation of external costs in the transport sector. Produced within the study – Internalisation measures and policies for all external cost of transport – IMPACT. Commissioned by: European Comission DG TREN. Delft, the Netherlands, February 2008. http://ec.europa.eu/transport/sustainable/ doc/2008_costs_handbook.pdf (accessed February 12, 2009).
- McKenna, F.P. (1993). It won't happen to me: Unrealistic optimism or illusion of control? British Journal of Psychology 84, 39–50.
- Michon, J.A. (1985). A critical view of driver behaviour models: what do we know, what should we do? In: Evans, L. & Schwing, R. (Eds.). Human behavior and traffic safety. New York, USA: Plenum Press. Pp. 485–520.
- Mishara, B.L. (2007). Railway and metro suicides –understanding the problem and prevention potential. Crisis 28, 36–43.
- Nellthorp, J., Sansom, T., Bickel, P., Doll, C. and Lindberg, G. (2000). Valuation Conventions for UNITE (UNIfication of accounts and marginal costs for Transport Efficiency). Fifth Framework RTD Programme. Leeds, UK. April 2001. University of Leeds, Institute for Transport Studies.

- Nelson, S. (2008). The railway is not an island: building partnerships with the wider community. 10th World Level Crossing Symposium. Paris, France. June 24–27, 2008. Compendium of papers.
- Näätänen, R. & Summala, H. (1976). Road-user behaviour and traffic accidents. Amsterdam and New York: North-Holland/American Elsevier.
- OECD/ITF (2008). Towards zero: Ambitious road safety targets and the safe system approach. http://www.internationaltransportforum.org/Pub/pdf/08Towards ZeroE.pdf (accessed November 15, 2011).
- Operation Lifesaver (2008). Rail safety education. http://www.oli.org/index.php (accessed April 28, 2008).
- Patterson, T. (2004). Analysis of trespasser accidents. New Zealand: Land Transport Safety Authority.
- Pelletier, A. (1997). Deaths among railroad trespassers. The role of alcohol in fatal injuries. JAMA 277, 1064–1666.
- Peltzman, S. (1975). The effects of automobile safety regulation. Journal of Political Economy 83, 677–726.
- Rådbo, H., Svedung, I. & Andersson, R. (2005). Suicides and other fatalities from train-person collisions on Swedish railroads: A descriptive epidemiologic analysis as a basis for system-oriented prevention. Journal of Safety Research 36, 423–428.
- Rail Safety and Standards Board (2005). Trespass and access via the platform end. Final Report. Halcrow Group Limited in partnership with Human Engineering. http://www.rssb.co.uk (accessed June 12, 2007).
- Robinson, B. (2003). Railway suicide strategy. Paper to Rail Safety and Standards Board.
- Savage, I. (2006). Does public education improve rail-highway crossing safety? Accident Analysis and Prevention 38, 310–316.
- Savage, I. (2007). Trespassing on the railroad. Prepared for Research in Transport Economics: Railroad Economics. Amsterdam, the Netherlands: Elsevier Science.
- Shapiro, M.J., Luchtefeld, W.B., Durham, R.M. & Mazuski, J.E. (1994). Traumatic train injuries. The American Journal of Emergency Medicine 12, 92–93.

- Shinar, D. (2007). Traffic safety and human behaviour. Elsevier Science. Emerald Group Publishing Limited.
- Smeed, R.J. (1949). Some statistical aspects of road safety research. Journal of the Royal Statistical Society 112, 1–34.
- Trawén, A., Maraste, P. & Persson, U. (2002). International comparison of costs of a fatal casualty of road accidents in 1990 and 1999. Accident Analysis and Prevention 34, 323–332.
- Wahlbeck, K. (2009). Background document for the Thematic conference on prevention of depression and suicide. Luxembourg: European Communities.
- Wegman, F., Dijkstra, A., Schermers, G. & van Vliet, P. (2005). Sustainable Safety in the Netherlands: the vision, the implementation and the safety effects. Contribution to the 3rd International Symposium on Highway Geometric Design. Chicago, Illinois, USA. 26 – July 2, 2005. SWOV, Leidschendam.
- Weinstein, N.D. & Klein, W.M. (1996). Unrealistic optimism: present and future. Journal of Social and Clinical Psychology 15, 1–8.
- Wilde, G.J.S. (1982). The theory of risk homeostasis: implications for safety and health. Risk Analysis 2, 209–225.
- Wilde, G.J.S. (1986). Beyond the concept of risk homeostasis: Suggestions for research and application towards the prevention of accidents and lifestyle-related disease. Accident Analysis and Prevention 18, 377–401.
- Wilde, G.J.S. (1994). Target Risk. Canada: PDE Publications.
- Wildson, M. (2008). UK experience of trespass and suicide. In: Paper presented at the Seminar on Trespassers on Railway Lines and Suicides, Lille, France. April 3, 2008. The European Railway Agency.
- Zhou, R. & Horrey, W. (2010). Predicting adolescent pedestrians' behavioural intentions to follow the masses in risky crossing situations. Transportation Research, Part F 13, 153–163.

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Title	Improving safety on Finnish railways by prevention of trespassing
Author(s)	Anne Silla
Abstract	This study investigated trespassing accidents, trespassing and related counter- measures 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 exam- ple, that (1) trespassing is frequent in Finland and, contrary to the overall improve- ment 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 trespass- ers were typically adults and males and the victims were frequently intoxicated; (4) the risk related to railway trespassing was associated with 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 re- sponsibility 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 over- passes, physical barriers and prohibitive signs to enforcement and education. Selection of the most effective or suitable countermeasure depends on the effec- tiveness of different measures, location and the characteristics of trespassing.
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Nimeke	Suomen rautatieliikenteen turvallisuuden parantaminen luvattomia radanylityksiä estämällä
Tekijä(t)	Anne Silla
Tiivistelmä	Tässä tutkimuksessa selvitettiin luvattomia radanylityksiä, niihin liittyviä onnetto- muuksia ja luvattomien radanylitysten estämiseksi toteutettuja toimenpiteitä turval- lisuustyön 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 vuosikym- menen 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 kokema 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 monimuo- toinen. Vastuun luvattomien radanylitysten estämisestä tulisi jakautua rautatieor- ganisaatioiden, useiden eri alojen (mm. terveydenhuolto, koulutus, valvonta, kaa- voitus) viranomaisten ja kuntien kesken. Luvattomien radanylitysten estämiseksi toteutettavat toimenpiteet vaihtelevat fyysistä toimenpiteistä ja kieltomerkistä val- vontaan ja valistukseen. Toimenpiteiden tehokkuuden ja sopivuuden varmistami- seksi päätöksen kussakin paikassa toteutettavasta toimenpiteestä tulisi perustua tietoon toimenpiteiden estovaikutuksista sekä kyseessä olevan paikan ja siellä tapahtuvien luvattomien radanylitysten ominaisuuksiin.
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Improving safety on Finnish railways by prevention of trespassing

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