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ORIGINAL PAPER

Comparison of road safety in Finland and Sweden

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Abstract
Purpose The main aim of this study is to identify factors behind Finland having a poorer road traffic accident record compared to Sweden. Another aim is to study whether there are any benefits to using real disaggregate data.
Methods We use the term safety potential to describe how much safety would improve in Finland if the rate of a selected measure in Sweden existed in Finland as well. In our analyses we use population risk to compare safety as a main measure.
Results Comparison of the number of fatalities per population in 2009–2013 between Finland and Sweden showed that for Finland there is a safety potential of 99 yearly fatalities out of 248. The number of fatalities per vehicle kilometre in Finland is 30% higher than in Sweden and the number of motor vehicle kilometres per person 23% higher. The highest potential for fatality reduction is for cars, related mainly to head-on fatalities. Age groups 15–17 and 18–20 years were identified as having the greatest relative population risk in Finland: the safety potential among 15–17-year-olds is seven moped and motorcycle fatalities and among 18–20-year-olds 12 car fatalities annually. Finland having the Swedish fatality risk per person kilometre would prevent six bicycle and six pedestrian fatalities per year.
Conclusions The extensive network of middle-barrier roads introduced in Sweden would probably offer the most extensive safety benefit for Finland also. Advanced use of disaggregated data provides more options than programmes created for analysing aggregate data.

Keywords Road safety · Comparison · Method · Tools · Sweden · Finland

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1 Introduction

Road safety comparisons with relatively similar countries can be used to identify where there is potential for safety improvements [9, 25]. If another county has performed better in similar conditions, that would suggest potential for improvements. Earlier studies comparing the differences in safety between countries have concentrated mainly on factors explaining the differences and are based on aggregated accident data [e.g. 8, 9, 11, 24, 4].

A recent study [10] compared traffic safety and related factors in Finland with those in Sweden, the UK and the Netherlands. In contrast to traditional country-wise road safety comparisons, the study included other transport modes and modal split. The main results indicated that 77 road fatalities (out of 296) would have been prevented annually in Finland in 2006–2010, had the number of fatalities per capita been the same as in the best performing countries. A major identified contributing factor was distance travelled in road traffic per person, which was greatest in Finland overall, especially by passenger car. In the last 25 years, road traffic in Finland has increased far more than in Sweden, the UK and the Netherlands. Over the same time period, Finland has not been able to decrease the fatality rate as much as in Sweden, the UK and the Netherlands.

This study was initiated to further examine detailed road accident data in Finland and Sweden. Road, traffic and climate conditions in these two countries are relatively similar compared to those in the Netherlands and the UK. Additionally, we had access to disaggregated accident data that enables a more detailed analysis of accidents than would be possible with tools created for analysing accident data across Europe.

The main objective of this study is to identify factors behind Finland having a poorer road traffic accident record than Sweden. Another aim is to assess whether there are any benefits to using real disaggregate data compared to data that can only be used through special analysis tools like SAP Businessobjects when using the European Care/CADaS database.

2 Approach

Contrary to several other studies, our approach was to focus on accident data instead of factors affecting it. This means that our approach is much less comprehensive than that of studies that have examined the entire road traffic safety process. We use population risk or mortality rate (annual number of fatalities per capita) to compare safety as a main measure. The main sources of the identified safety potential as described in Formula 1 —(1) different amount of exposure to accidents (e.g. vehicle kilometres) and (2) difference in risk per exposure—are analysed as far as there is reliable data available.

$$\text{Number of killed persons/population} = \text{Risk exposure/population} * \text{Killed/Exposure} \quad (1)$$

In-depth analysis of accident-related data between Finland and Sweden was based on the availability of detailed disaggregate data. The data allowed us to perform the analyses combining hierarchically structured data, i.e. data from all three levels of accidents. For example, one can select accidents in urban areas involving a car driven by a novice driver and analyse whether the killed or injured persons are these drivers, persons in their vehicles or other road users (Fig. 1). Analyses were carried out using a net-based computer program created to enable versatile analysis of accident data without endangering personal data privacy.

Data from both countries is based on police reports of injury accidents. Finnish data was obtained from the database of the Finnish Transport Agency. The data was prepared by Statistics Finland, an organisation that publishes official Finnish road safety statistics [14]. Swedish data was collected from the national road traffic accident information system STRADA (Swedish Traffic Accident Data Acquisition) [15].

The study was limited to fatal accidents and fatalities, as there are no major differences between the two countries in their definitions of road fatalities. By contrast, definitions of injuries in traffic accidents are not as precise and injury accidents are under-reported, notably in regard to minor injuries and those incurred by bicyclists [5].

The recommended definition for a person killed in a road traffic accident is: Any person killed immediately or dying within 30 days as a result of an injury accident, excluding suicides [20]. Sweden has excluded suicides as suggested since 2010, but in Finland they are included in the official road accident statistics. Otherwise both countries record road fatalities according to the recommendation [14, 17].

Numbers of vehicle kilometres used in calculating fatality rates were obtained from national statistics [6, 18, 19].

Detailed comparisons were based primarily on national definitions, as the police adhere to these in their reports. However, accident type is defined in Finland by the involved traffic elements and police judgement of the accident, while in Sweden the judgement is based on registered involved traffic elements and their movements during the accident. Although the accident types did not match perfectly, the Swedish types could be modified into the Finnish equivalent. The modifications were based largely on the involvement of unprotected road users.

It is acknowledged that differences in the reporting systems of the two countries could be responsible for some of the obtained findings. Furthermore, no statistical tests of significance were performed. Consequently, only substantial differences and clear similarities with sufficient frequencies are discussed.

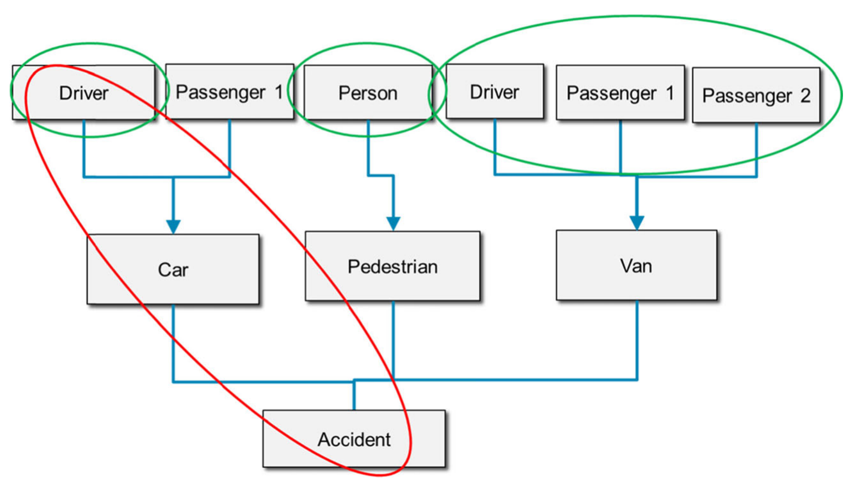

Fig. 1 Example of hierarchically structured accident data

3 Background statistics

Selected background statistics by country shown in Table 1 indicate that there are no major differences between Finland and Sweden, although the population density is somewhat higher in Sweden. On the other hand, the proportion of urban population is relatively similar.

4 Road safety comparisons

A road safety comparison between Finland and Sweden begins with an overview of road accidents and their consequences as well as risks (Section 4.1). Next, a comparison of major differences examines the potential for safety improvements (Section 4.2.1), followed by a more detailed accident comparison done separately for traffic units of special interest: fatalities in cars and goods vehicles (Section 4.2.2.), killed bicyclists and pedestrians (Section 4.2.3.), and fatalities on mopeds and motorcycles (Section 4.2.4.).

4.1 Overview of road safety

4.1.1 Accidents and consequences

The number of fatal accidents in 2009–2013 and their share by road type is compared in Fig. 2. The average yearly number of fatal accidents was 248 in Finland and 277 in Sweden. Even the distribution between public highways and other roads is of the same order; around three out of four fatalities have occurred on public highways. The type of road in the STRADA data is unknown for 3.9% of fatal accidents based purely on police reports [15]; in Finland this information is completed during the reporting process.

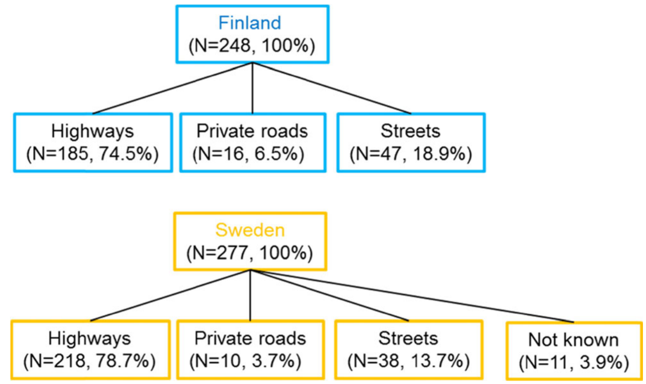

Fig. 2 Average yearly number and share (%) of fatal accidents by road type in Finland and Sweden in 2009–2013 [14, 15]

4.1.2 Fatality rates and vehicle kilometres

Fatality rates (fatalities per motor vehicle kilometre) on public highways and on streets were 0.44 and 0.17 in Sweden and higher in Finland, at 0.56 and 0.27, respectively [6, 14, 15, 18]. The fatality rates in Finland are 28.1% higher on public highways and 57.3% higher on streets. Another main factor behind the higher fatality figure in Finland is the higher number of vehicle kilometres per population. Specifically, the number of motor vehicle kilometres per person was 8480 km/year in Sweden and 23.3% higher in Finland, at 10460 km/year [16, 18]. Both differences are remarkable.

4.2 Safety potential for Finland

4.2.1 Defining safety gaps

We use analysis of the number of fatalities by traffic unit to demonstrate the idea of safety potential. In Table 2, the main safety figures for 10 traffic units are compared between

Table 1 Selected background statistics by country

Region[a]	Finland Northern Europe	Sweden Northern Europe
Population, thousand (2013) [b]	5439	9600
Area, thousand km^2 (2013) [b]	338	450
Population density, inhabitants per km^2 (2013) [b]	16	21
Urban population (2014) [a]	84.1%	85.7%
Population aged 65+ (2013)[b]	19.1%	19.3%
Life expectancy at birth, years (2013)[b]	81.1	82.0
Gross domestic product per capita (PPP), US$ (2013)[b]	40134	44,586
Motorways, km^2	810	2044
Other roads, km^2	106760	212836
Number of passenger cars per 1000 inhabitants (2013)[b]	571	468
Number of motorcycles per 1000 inhabitants (2013)[b]	46	30
Number of mopeds per 1000 inhabitants (2013)[b]	56	8

[a] [21] [b] [22]

Table 2 Number of fatalities, fatality rates per population and potential for fatality reductions [14, 15]

Traffic unit	Fatalities in 2009–2013/Y(a)		Fatalities per population(b)		Relative population risk in Finland(c)	Reduction if(d) Swe average in Fin
	Finland	Sweden	Finland	Sweden		
Passenger car	158	163	30.6	18.1	169	64
LGV(e)	9	8	1.8	0.9	200	5
HGV(e)	7	5	1.4	0.5	274	5
Pedestrian	34	44	6.5	4.9	134	9
Bicycle	21	21	4.0	2.3	175	9
Moped	8	8	1.6	0.9	179	4
Motorcycle	23	40	4.5	4.5	101	0
Bus	1	1	0.2	0.2	125	0
Tractor	3	2	0.5	0.2	253	2
Other vehicle	6	5	1.1	0.6	181	3
Total	270	298	52.3	33.0	158	99

[a] Yearly average of road fatalities in 2009–2013

[b] Road fatalities per million inhabitants, year (Fin = 5.16, Swe = 9.03 million people)

[c] Fatalities per population in Finland compared to Sweden (Index for Sweden = 100)

[d] Yearly reduction of fatalities in Finland, if No. of fatalities per population same as in Sweden

[e] *LGV* light goods vehicle (max 3500 kg), *HGV* heavy goods vehicle (over 3500 kg)

Finland and Sweden. Dividing the yearly fatality numbers (columns 2 & 3 in Table 2) by the population of the county gives the population risk (columns 4 & 5). The total population risk for Finland (52.3) is 58% higher than that for Sweden (33.0), as seen in column 6. The safety potential is defined as the number of yearly reduced fatalities if the population risk for Finland were the same as in Sweden. Population risks would be equal if the yearly number of fatalities in Finland were reduced by 99 fatalities. Evidently, the safety potential for Finland is greatest for people killed in cars, but considerable also for pedestrians and bicycles.

To ensure that demographic differences did not cause the safety gap, we calculated age and gender adjusted fatality rates. They showed that the effect of demographic differences was less than two fatalities yearly, actually reducing the safety gap between Sweden and Finland.

Calculations on safety potential revealed that two thirds of the potential is on public highways (69%) and one third (31%) on other roads. Most of the fatalities on other roads have occurred on streets in Finland (73%) as well as in Sweden (64%).

Figure 3 shows the number of fatalities per population by accident type in Finland and Sweden. Head-on and single

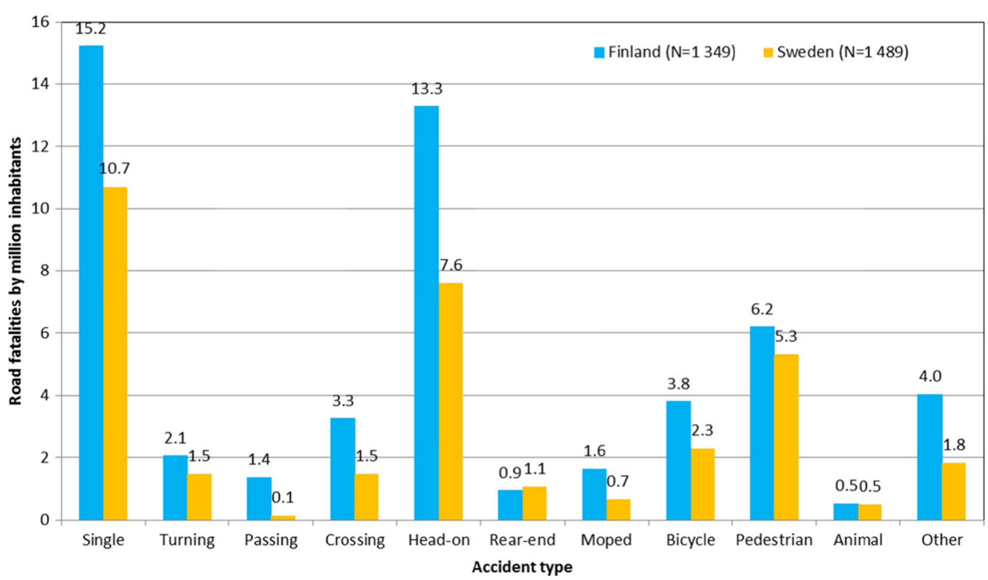

Fig. 3 Number of fatalities per population by accident type in Finland and Sweden in 2009–2013 [14, 15]

accidents are the two most dangerous accident types in both Finland and Sweden, causing more than half of all fatalities in each country (54.6% and 55.5%, respectively). Importantly, they are also the two accident types with the greatest safety potential for Finland. If their population risk were the same as in Sweden, 30 head-on fatalities and 23 single accident fatalities would be prevented in Finland.

Fatalities in age groups 15–17 and 18–20 years by traffic unit are compared in Fig. 4. The figure shows that the high population risks in Finland compared to Sweden for 15–17-year-olds are caused mainly by moped and motorcycle fatalities and for 18–20-year-olds mainly by car fatalities. In fact, the safety potential for 15–17-year-olds in Finland is four moped and three motorcycle fatalities yearly, and for 18–20-year-olds 12 car fatalities yearly.

In the following (Sections 4.2.2. through 4.2.4.), the safety potential is presented by traffic unit type.

4.2.2 Fatalities in cars and goods vehicles

Risk and kilometres driven For passenger cars and goods vehicles, estimates are available for total kilometres in Finland and Sweden [6, 18]. Using these exposure data, one can estimate fatality risks per vehicle kilometre by traffic unit (Table 3).

For Finland, having the same population risk as Sweden would mean 74 fewer car and goods vehicle fatalities per year. This figure derives from two sources: (1) having the Swedish fatality risk per vehicle kilometre would prevent 50 fatalities (Table 3), and (2) having the Swedish number of vehicle kilometres per person (8371 instead of 10,347) would prevent an additional 24 fatalities per year.

For Finland this would drop the number of fatalities per year in cars and goods vehicles from 174 to 100, suggesting a safety potential of 74. It should be noted that in Table 3, the total is not exactly equal to the sum of individual rows. This resulted from a different share of vehicle kilometres among traffic units. Vehicle kilometres per population are higher in Finland for cars and heavy goods vehicles but lower for light goods vehicles compared to Sweden.

Counterparts in fatalities Fatalities by traffic unit are presented above in Table 3. When a heavy goods vehicle is involved in a fatal accident, more than 90% of killed people are in opposite traffic units. For light goods vehicles this share is around 60% and for cars around 20%. These results suggest that fatalities in counterpart units should also be considered when analysing the meaning of cars and especially heavy goods vehicles for road safety.

Traditionally internal and external risks per number of involved vehicles are calculated for presenting how often some traffic unit is involved in an accident causing a fatal outcome in a counterpart or own unit. However, we calculated the safety potential for this purpose also. Safety potential is, again, calculated as how many fatalities would be saved if the number of fatalities per population in Finland were equal to that in Sweden. The safety potential for cars and goods vehicles by counterpart unit is shown in Table 4. The safety potential in Finland for fatalities in cars is highest in accidents with heavy goods vehicles (35 fatalities yearly), followed by single car accidents (16 fatalities) and accidents with other cars. The safety potential for light and heavy goods vehicles is substantially lower. The high number of fatalities in cars in accidents with heavy goods vehicles is partly related to suicides as head-on collisions [1]. Their number is not exactly known, but they do not explain the whole safety potential in cars in collisions with heavy vehicles.

In the following sections we analyse accidents and persons involved in all fatal accidents where at least one car or goods

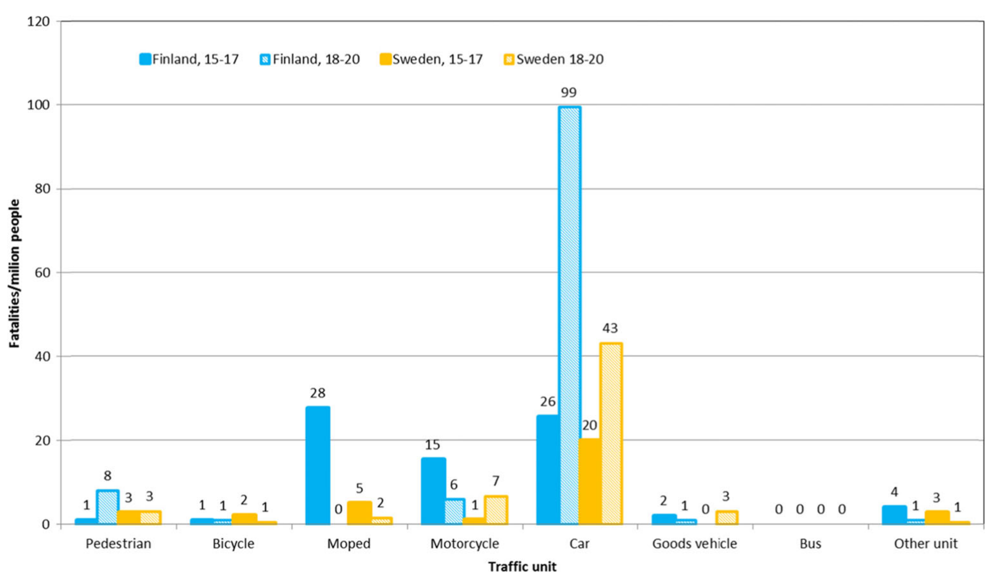

Fig. 4 Number of fatalities per population for Finnish highest-risk age groups by traffic unit in Finland and Sweden in 2009–2013 [14, 15]

Table 3 Number of fatalities, fatality rates per vehicle kilometre and potential for fatality reductions [14, 15]

Traffic unit	Fatalities in 2009–2013/y(a)		Fatalities per vehicle km (b)		Relative risk per kilometres in Finland(c)	Reduction if(d) Swe average in Fin
	Finland	Sweden	Finland	Sweden		
Passenger car	158	163	3.4	2.6	131	38
LGV(e)	9	8	2.4	1.0	232	5
HGV(e)	7	5	2.3	1.0	232	4
Total	174	176	3.3	2.3	140	50

a Yearly average of road fatalities in 2009–2013

b Road fatalities per 1000 million vehicle kilometres

c Fatalities per vehicle kilometre in Finland compared to Sweden (Index for Sweden = 100)

d Yearly reduction of fatalities in Finland, if No. of killed per kilometre same as in Sweden

e *LGV* light goods vehicle (max 3500 kg), *HGV* heavy goods vehicle (over 3500 kg)

vehicle is involved. In practice this means including fatal accidents in which cars and goods vehicles are counterpart units to those of the persons killed.

Fatal accident types involving a car or goods vehicle The number of fatalities per population in accidents involving a car is presented by accident type in Fig. 5. The graph suggests that Finland has a safety potential in fatal single, crossing-related as well as head-on and overtaking accidents involving a car. In fact, frequencies of fatal overtaking accidents are very small compared to head-on accidents. From all the fatal accidents including a car, only pedestrian and rear-end accidents are slightly more common per population in Sweden than in Finland.

The magnitude of the safety potential in Finland was calculated using the population risk differences (Fig. 5) and actual yearly fatality numbers in Finland. These safety potential figures for accidents involving cars or goods vehicles are presented in Table 5. Note that potentials are not directly additive, as several vehicles are related to one fatality; this is also why the figures under Car or GV are higher than the sum of columns Car, LGV and HGV in Table 2.

Table 4 Safety potential for yearly fatalities in Finland for car and goods vehicle fatalities by counterpart units if the number of fatalities per population were the same as in Sweden [14, 15]

Unit of the killed person	Other units involved in accident					Total
	None(a)	Car	LGV(b)	HGV(b)	Other	
Car	16	8	4	35	1	64
LGV(b)	1	1	0	2	1	5
HGV(b)	1	1	0	1	0	4
Total	18	10	5	38	2	74

1 Single accidents

2 *LGV* light goods vehicle (max 3500 kg), *HGV* heavy goods vehicle (over 3500 kg)

The results show that the most substantial safety potential is for accidents involving cars, followed by heavy goods vehicles. The most sizable potential is for head-on and overtaking accidents, followed by single vehicle accidents and intersection-related accidents.

Further analysis reveals that most of the safety potential (77.3%) is on public highways. We can reasonably assume that most of the difference is attributable to the extensive network of middle-barrier roads in Sweden, and probably offers the most extensive safety potential for Finland [8].

Drivers in fatal accidents It is common to analyse fatalities by gender and age to investigate driver characteristics, usually considering only the killed vehicle drivers [12, 20]. However, our analysis was extended to all the drivers involved in a fatal accident; the extension for car drivers is shown in Table 6. The results indicate that analyses considering only killed vehicle drivers underestimate the role of car drivers in accidents. In fact, in this case they would ignore 45% of the Finnish and 59% of the Swedish car drivers involved in fatal accidents (Table 6). Such underestimation would also lead to further bias from ignoring all accidents causing fatal injuries to counterpart persons, among them most collisions with pedestrians.

The safety potential figures for Finnish fatal accidents involving cars by gender of the driver are presented in Table 7. The results show that the safety potential for Finnish car drivers is much higher for men than for women. Further, the highest safety potential is related to head-on collisions and single accidents.

To analyse the safety potential of car drivers by age and gender, population risk for involvement as car drivers in fatal accidents is displayed by driver age and gender in Fig. 6. The results show that especially in the early ages of the car driving career, and especially so for Finland, male population risk appears to be higher than female. The risk of male drivers aged 70 years or older seems to be higher than for somewhat younger drivers in Finland but not in Sweden.

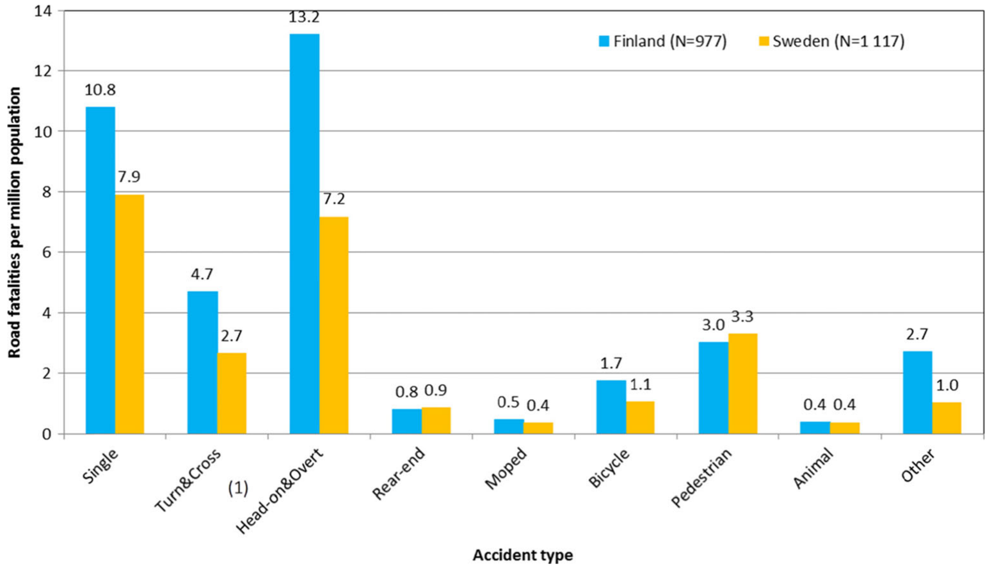

Fig. 5 Number of fatalities per population by accident type in accidents involving a car in Finland and Sweden in 2009–2013 [14, 15]. [1]Turn&Cross = turning and crossing. Head-on&Overt = head-on and overtaking

Based on the population risks in Fig. 6, a safety potential comparison of car drivers by age and gender is presented in Table 8. As suggested by the population risks, Finland has a safety potential especially for young (<=25 years) and elderly (>70 years) male car drivers. The potential is highest at the age of 18–19; in Finland yearly, 263 young men per million population were driving a car in a fatal outcome accident, while the respective figure for Sweden was 126. This is equivalent to a potential of nine fatalities yearly.

There is no data available on kilometres driven by age. However, some indication can be acquired by analysing the number of driving licences by number of population by age group (Fig. 7). The main results indicate that Swedish people aged 24 or less drive less than their counterparts in Finland. The opposite is true for people aged 65 or more. However, driving licences include licences for mopeds and motorcycles, which somewhat affects the results, although the proportion of car kilometres is dominant for people aged 18 or more.

Table 5 Safety potential for yearly fatalities in Finland by type of vehicle involved if the number of fatalities per population were the same as in Sweden [14, 15]

Accident type	Accidents involving			
	Car	LGV[(a)]	HGV[(b)]	Car or GV[(c)]
Single	15	1	1	17
Turning & crossing	10	3	9	12
Head-on & overtaking	31	6	31	36
Rear-end	0	-1	1	0
Moped	1	1	1	3
Bicycle	4	1	0	5
Pedestrian	-1	0	6	5
Animal	0	0	0	0
Other	9	2	4	10
Total	68	13	54	87

[a] *LGV* light goods vehicle (max 3500 kg)

[b] *HGV* heavy goods vehicle (over 3500 kg)

[c] Any car or goods vehicle

Speed limits on public highways Speed limit systems in Finland and Sweden are different, implying that a safety potential by speed limit cannot be analysed directly. For example, in Sweden different speed limit values are represented more often than in Finland. This is related to changes in the Swedish speed limit system over the past few years [24]. In addition, there was no specific information available from Sweden for speed limits by road type and many other aspects. However, the comparisons of fatal accidents showed that the most common speed limit in Finnish accidents is 80 km/h (54.1% of all fatalities) and 70 km/h in Sweden (34.5% of all fatalities). Average speed limits in Finland are somewhat higher than those in Sweden for fatal and injury accidents, e.g. 79.9 km/h in Finland and 78.9 km/h in Sweden for fatal accidents.

4.2.3 Fatalities among pedestrians and bicyclists

Risk and kilometres travelled The COST action travel survey [2] suggests that in Finland one person travels an average daily distance of 1.05 km on foot and 0.73 km on a bicycle. In Sweden, the respective figures are somewhat lower with 0.95 and 0.58 km per day per person.

The number of pedestrian and cyclist fatalities and their fatality rates per kilometre based on these estimates are given in Table 9. For Finland, having an equivalent population risk to Sweden would mean nine fewer bicycle and nine fewer pedestrian fatalities per year. These figures derive from two sources: (1) having the Swedish fatality risk per person kilometre would prevent six bicycle and six pedestrian fatalities (Table 9), and (2) having the Swedish number of

Table 6 Gender of car driver by role in fatal accidents in Finland and Sweden in 2009–2013 [14, 15]

Gender	Finland		Sweden	
	Got killed him/herself	Involved in fatal accident[(b)]	Got killed him/herself	Involved in fatal accident[(b, c)]
Male	484	837	461	1075
Female	96	223	118	332
Total	580	1060	579	1423

[a] Drivers who were themselves killed

[b] Drivers of cars involved in fatal accidents

[c] Gender of 16 drivers in fatal accidents in Sweden unknown

pedestrian and bicycle kilometres per person would prevent an additional three bicycle and three pedestrian fatalities per year. For Finland this would drop the number of fatalities per year for pedestrians and bicyclists from 55 to 37, meaning a safety potential of 18.

Further analysis reveals that most of the safety potential for Finnish pedestrian fatalities is outside public highways, mainly on streets (eight out of nine yearly fatalities). Also most of the potential for bicycle fatalities is outside public highways (six out of nine fatalities).

Counterparts in fatalities When a pedestrian or bicyclist is involved in a fatal accident, he or she represents 95% of the fatalities in this type of accident in both countries. The safety potential in Finland for pedestrian fatalities is highest in accidents with heavy goods vehicles (six fatalities yearly) and for bicyclists with cars (four fatalities). In fact, in Sweden cars are more often involved in pedestrian accidents than in Finland, causing for Sweden a safety potential of two killed pedestrians in collisions with cars. Overall, these figures are too low to draw any solid conclusions.

Table 7 Safety potential for yearly fatalities in Finland by gender of the car driver if the number of fatalities per population were the same as in Sweden [14, 15]. Note: population risk figures calculated using people aged at least 18 years by gender

Accident type	Gender of car driver		
	Male	Female	Total
Single	12	-2	10
Turning and Crossing	5	2	7
Head-on and overtaking	23	3	26
Rear-end	-1	0	-1
Moped	0	1	1
Bicycle	2	1	4
Pedestrian	-2	-1	-2
Animal	0	0	-1
Other	8	2	10
Total	46	6	52

Age and gender The number of fatalities per million people by gender for pedestrians and bicyclists in Finland and Sweden is shown in Table 10. Fatality rates per population are higher for males than for females. This is the case for both countries and for pedestrians and bicyclists. However, the gender differences are not as high as for car drivers (see Fig. 6).

The number of fatalities per million people by age group in Finland and Sweden for pedestrians and bicyclists is shown in Fig. 8. The difference between the curves shows that the safety potential for Finland is especially high among people aged 66 years or above. In fact, half of the potential of nine pedestrian and nine bicycle fatalities per year is in these age groups: the Swedish population risk in Finland would cut the yearly number of pedestrian fatalities at the age of 66 or above from 16 to 12. The corresponding drop for bicyclists would be from 10 to five.

4.2.4 Fatalities relating to mopeds and motorcycles

Risk and kilometres travelled Kilometres travelled have been estimated for mopeds and motorcycles only as a total [2], suggesting that moped and motorcycle kilometres in Finland are more than double those in Sweden (0.56 vs. 0.28 km per person per day).

We completed the figures with the assumption that the share of person kilometres on public highways equals the share of moped and motorcycle fatalities on public highways in Finland and Sweden together. The results based on this data are presented in Table 11. For Finland, having an equivalent population safety to Sweden would mean four fewer motorcycle and moped fatalities per year. This figure derives from two sources: (1) having the Swedish fatality risk per person kilometre would actually add 24 fatalities (Table 11) and (2) having the Swedish number of moped and motorcycle kilometres per person (0.28 km per day per person instead of 0.56 km) would prevent 28 of those fatalities yearly.

In Finland this would drop the number of fatalities per year for moped and motorcycle passengers from 32 to 28, meaning a safety potential of four yearly. The potential for moped fatalities is equally high on public highways and other roads,

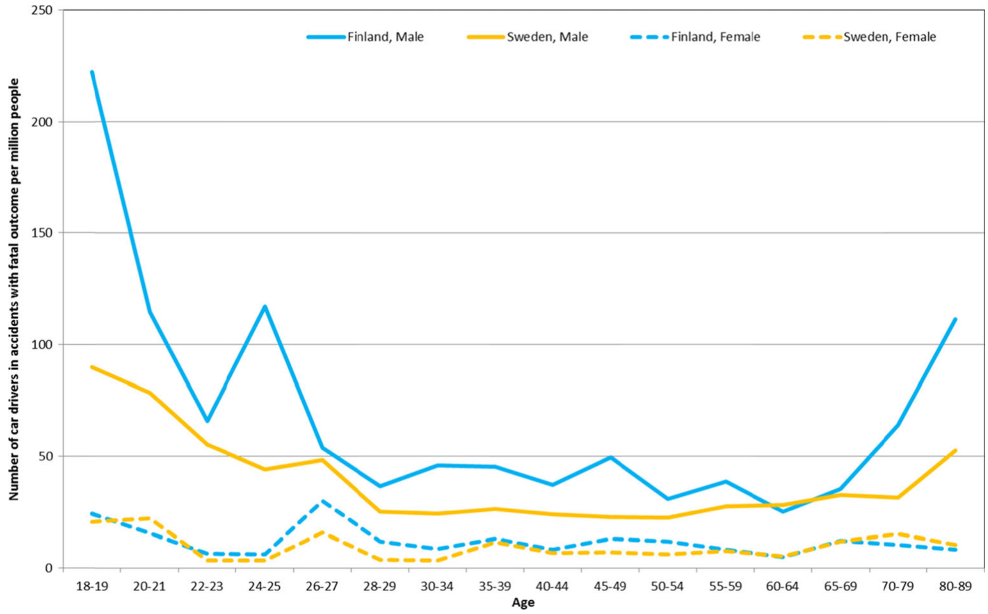

Fig. 6 Number of fatalities per population by age group of the involved car driver in Finland and Sweden in 2009–2013 [14, 15]

with two fatalities per year on each. There is no safety potential for Finland related to motorcycle fatalities in total.

Counterparts in fatalities When a motorcycle is involved in a fatal accident, the motorcycle's rider/passenger is killed in more than 97% of cases in both countries. Analogously, when a moped is involved in a fatal accident, the rider/passenger is often the killed party (in Finland 86% and in Sweden 93% of cases). In Finland, four pedestrians were killed in accidents involving a moped over a period of 5 years, whereas no such accidents occurred in Sweden.

The safety potential in Finland for three moped fatalities is evenly distributed among cars, heavy goods vehicles and other vehicles. The number of motorcycle fatalities per population is higher in Sweden in collisions with cars (three fatalities) but lower with other counterpart units. Overall, the figures are too low to result in any strong conclusions.

Table 8 Safety potential for yearly fatalities in Finland by gender and age of the car driver if the number of fatalities per population were the same as in Sweden [14, 15]. Note: population risk figures calculated using the number of people of that age group by gender

Age	Gender of car driver		
	Male	Female	Total
18–19	9	1	10
20–21	3	0	3
22–23	0	0	0
24–25	6	0	6
26–27	0	2	2
28–29	1	0	1
30–34	4	2	5
35–39	3	0	3
40–44	0	0	0
45–49	6	2	8
50–54	3	0	3
55–59	4	0	5
60–64	-1	1	0
65–69	-2	-1	-3
70–79	8	-1	7
80–89	4	0	4
Total	47	6	54

5 Discussion

The main objective of this study was to identify factors behind Finland having a poorer road traffic accident record than Sweden. In the following, the main results are discussed and our conclusions outlined. In addition, we share our experience on using an advanced tool designed for analysing disaggregate accident data, instead of general statistical tools typically used such as the European Care/CADaS database.

5.1 Road safety in Finland and Sweden

The results show that by comparison with Sweden, in Finland there is a safety potential of 99 yearly fatalities. Two thirds of the potential is on public highways and one third on other roads, mostly streets.

The results based on comparison of numbers of motor vehicle kilometres suggest that the number of fatalities per vehicle kilometre is 30% higher in Finland than in Sweden. In addition, the number of motor vehicle kilometres per person was 23% higher in Finland than in Sweden (10,460 km/year vs. 8480 km/year). We can conclude that Finland has a safety potential in

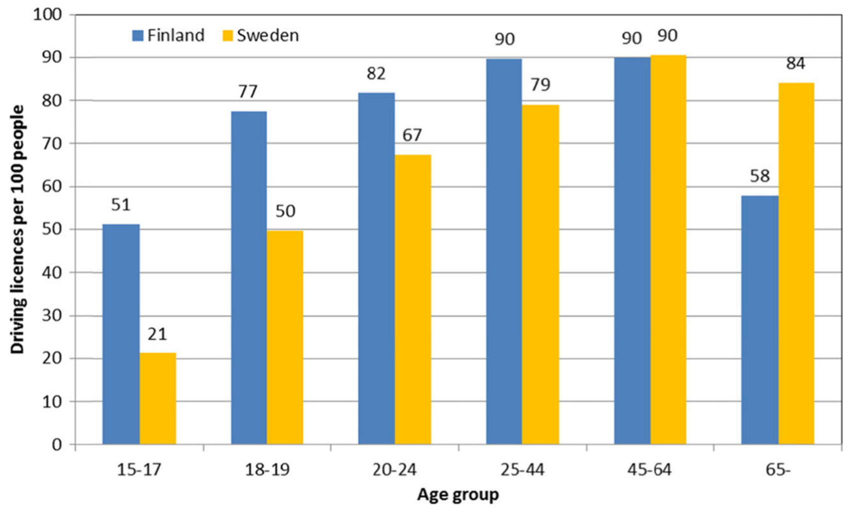

Fig. 7 Number of driving licences per 100 people by age group in Finland and Sweden in 2009–2013 [7, 16]

reducing the number of vehicle kilometres, as well as reducing their fatality risk. In Finland, more effective safety measures are therefore recommended to reduce the fatality risk. Good Swedish urban planning has probably led to a more limited need to use cars, contributing to a lower exposure to road accidents. However, advanced urban planning is a structural factor that is hard to achieve quickly [11]. Nonetheless, long-term development is recommended, and other related means are available as well, such as developing public transport and encouraging people to use it, alongside telecommuting, etc.

Comparison of the traffic units of killed persons suggests that compared to Sweden, Finland has the highest potential for fatality reduction (64 fatalities yearly) for cars. Also, Finland has an overrepresentation of travellers in heavy goods vehicles (population risk 2.7 times that in Sweden) and light goods vehicles (population risk 2.0 times that in Sweden) and on mopeds and bicycles (population risk 1.8 times that in Sweden).

The main conclusion from accident type comparisons was a huge potential for reducing head-on fatalities, as well as single vehicle fatalities, in Finland. Specifically, head-on and single accidents are the two most dangerous accident types in both Finland and Sweden, causing more than half of all fatalities in each country. Importantly, they are also the two accident types with the greatest safety potential for Finland. If their population risk were the same as in Sweden, 30 head-on fatalities and 23 single accident fatalities would be prevented in Finland. Furthermore, the safety potential for Finland for fatalities in cars is highest in accidents with heavy goods vehicles. We acknowledge that the results of this comparison might be slightly biased, since Finland does not omit suicides from its road accident statistics as Sweden has done since 2010. However, the safety potential for Finland, even considering head-on accidents alone (30 fatalities yearly), is substantially higher than the total number of fatalities excluded in Sweden as suicides (on average 21 in 2009–2013). Overall, we can reasonably assume that most of the difference is attributable to the extensive network of middle-barrier roads in Sweden. They would probably offer the most extensive safety benefit for Finland also. Another key factor is that the Swedish road safety policy does not allow high speed limits such as 100 km/h on main roads with no middle barrier. In Finland the speed of 100 km/h is used on many roads without middle barriers, especially from April to October when wintertime speed limits are not in force [13].

Table 9 Number of fatalities and fatality rates per person kilometre for pedestrians and bicyclists [2, 14, 15]

Traffic unit	Fatalities in 2009–2013/y[(a)]		Fatality risk per person km[(b)]		Relative risk per kilometre in Finland[(c)]	Reduction if[(d)] Swe average in Fin
	Finland	Sweden	Finland	Sweden		
Bicycle	21	21	15	11	139	6
Pedestrian	34	44	17	14	122	6
Total	55	65	16	13	127	11

[a] Yearly average of road fatalities in 2009–2013
[b] Road fatalities per 1000 million person kilometres
[c] Fatalities per kilometrage in Finland compared to that in Sweden (Index for Sweden = 100)
[d] Yearly reduction of fatalities in Finland, if No. of killed per kilometrage same as in Sweden

Table 10 Number of fatalities per million population for pedestrians and bicyclists by gender and country [14, 15]

Traffic unit	Male		Female		Total	
	Finland	Sweden	Finland	Sweden	Finland	Sweden
Pedestrian	7.1	5.7	5.6	3.9	6.3	4.8
Bicycle	4.9	2.8	2.9	1.6	3.9	2.2
Total	12.0	8.5	8.5	5.5	10.2	7.0

Age groups 15–17 and 18–20 years were identified as having the greatest relative population risk in Finland. Population risks for these ages were compared by traffic unit, and we conclude that in Finland the safety potential among 15–17-year-olds is four moped and three motorcycle fatalities and among 18–20-year-olds 12 car fatalities annually.

Our results suggest that in both countries, the population risk of a male being involved in a fatal accident as a car driver is much higher than for respective females. Comparing the age and gender of car drivers involved in fatal accidents revealed that Finland has a safety potential especially among young (<=25 years) and elderly (>70 years) male car drivers. The potential is highest for novice car drivers; achieving the same population safety as in Sweden would every year save nine fatalities in accidents involving an 18–19-year-old man as a car driver.

For pedestrians and bicyclists, the results showed that both the fatality risk and exposure per person are higher in Finland than in Sweden. Having the Swedish fatality risk per person kilometre, there is safety potential in Finland for six bicycle and six pedestrian fatalities per year. Correspondingly, having the Swedish number of pedestrian and bicycle kilometres per person with the current risk level would result in an additional three pedestrian and three bicycle fatalities. In total, there is a safety potential of 18 fatalities in Finland. Most of it is outside public highways, primarily on streets. Further research is suggested to compare pedestrian and bicyclist behaviour, path infrastructure etc. in Finland and Sweden in order to explain these differences and suggest specific safety measures.

Our results indicated that Finland has a safety potential of six yearly pedestrian fatalities in collisions with heavy goods vehicles. Respectively, in Sweden cars are involved in pedestrian accidents more often than in Finland, causing a safety potential for Sweden of two fatalities per year among pedestrians in collisions with cars.

Travel survey data suggests that in Finland the daily average number of kilometres travelled per person on mopeds and motorcycles is roughly double that in Sweden (0.56 vs. 0.28 km per person per day). These estimates suggest that for Finland, having the Swedish fatality risk per person kilometre would actually add 24 fatalities, but cutting the number of moped and motorcycle kilometres per person to the Swedish level would prevent 28 fatalities. This would drop the number of fatalities per year on mopeds or motorcycles in Finland from 32 to 28, meaning a safety potential of four moped riders every year. However, given the challenge of travel surveys in obtaining reliable data, these results should be viewed as potential trends.

The above comparisons focused on accidents. However, it is acknowledged that comparison of accidents cannot reveal all the meaningful differences, and the comprehensive road traffic comparison should include many other aspects as well, such as institutional management functions and behavioural indicators. For example, there is some information available on driver behaviour and vehicle factors in these countries that affect road safety. Dacota [3] showed that in Sweden the use of seatbelts in front seats is somewhat higher (96% vs. 90%) but lower in rear seats (80% vs. 87%). The corresponding comparisons for helmet use are: motorcyclists 95% vs. 99%,

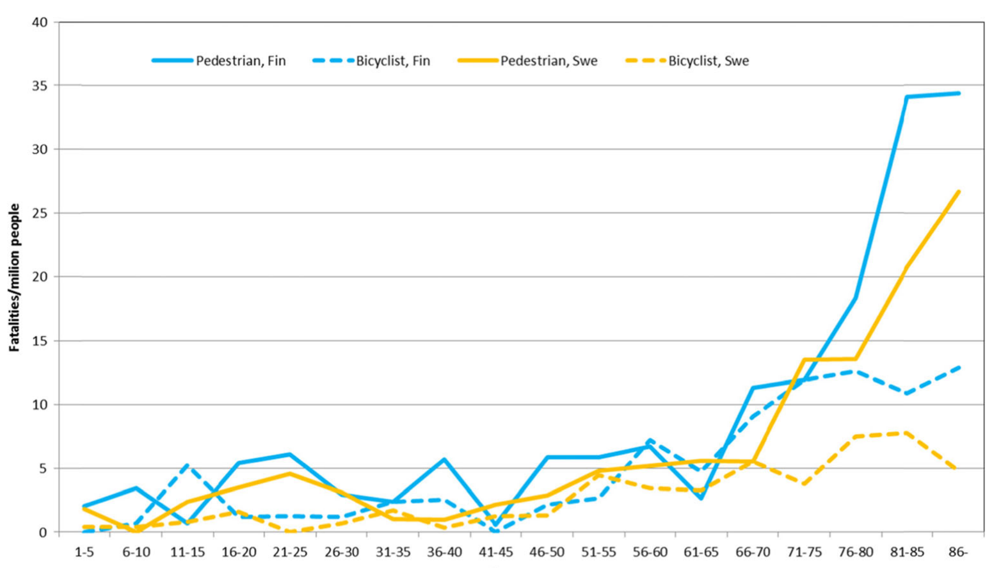

Fig. 8 Number of pedestrian and bicyclist fatalities per million population by age group [14, 15]

Table 11 Number of fatalities and fatality rates per person kilometre for moped and motorcycle passengers [2, 14, 15]

Road type	Fatalities in 2009–2013/y(a)		Fatality risks per person km(b)		Relative risk per kilometer in Finland(c)	Reduction if(d) Swe average in Fin
	Finland	Sweden	Finland	Sweden		
Public highways	22	38	33	66	50	-22
Non-highway ro ads	10	10	44	54	82	-2
Total	32	48	30	52	57	-24

[a] Yearly average of road fatalities in 2009–2013

[b] Road fatalities per 1000 million person kilometres

[c] Fatalities per kilometrage in Finland compared to that in Sweden (Index for Sweden = 100)

[d] Yearly reduction of fatalities in Finland, if No. of killed per kilometre the same as in Sweden

mopedists 90% vs. 99% and bicyclists 27% vs. 31%. Furthermore, Swedish drivers are less often intoxicated (0.8%) when stopped by the police than their Finnish counterparts (1.3%), although the legal limit is lower in Sweden than in Finland (0.02% vs. 0.05%). Finally, the age of passenger cars is much lower in Sweden than in Finland; for example the proportion of cars older than 10 years is 35% in Sweden and 47% in Finland. These results might go some way to explaining the above differences in fatality risk by country. For example, the higher fatality risk among Finnish car drivers and occupants is affected by more frequent drinking and driving, less frequent use of seatbelts in front seats, and older cars.

Several of the above results emphasize the importance of focusing road safety measures on large target groups in addition to identified risk groups. This was also one of the main conclusions of our earlier study [10].

Overall, our comparisons of road safety in Finland and Sweden show that a generally recognised safety difference in these countries can be analysed in detail, and that there are several specific areas of safety potential for Finland. Further comparisons between Sweden and Finland are recommended, and should include (1) road register data from Sweden in order to analyse differences by road environment, (2) comparison of severity of injuries and (3) comparison of road accidents and speed by speed limit.

5.2 Finnish and Swedish accident data

We compared police-reported accident data only, because in Finland there is no hospital data on road accidents available for the time period (2009–2013) included in the present analyses. However, this type of data is under preparation for 2014. Comparing detailed data between countries reveals the pros and cons in different datasets. Our main findings related to the compared datasets are as follows:

First, Finland should consider removing suicides from official road accident statistics, as Sweden has done since 2010 and is suggested by UNECE, ITF and Eurostat [23].

Second, Finland should complete the system to combine hospital data with police-reported accident data. The system should be developed to enable complementation and remedying of police-reported data on the consequences of accidents, especially (1) poorly recorded accidents like bicycle accidents and (2) severity of injuries using MAIS3+ criteria as suggested e.g. by OECD/ITF [12].

Third, information on driving under the influence of alcohol in the STRADA database (Sweden) is based on police reports only, and is not checked against official investigations. Doing so, as is currently the case in Finland, would be extremely useful as it is well known that a number of road accidents are alcohol related in all motorised countries.

Finally, Swedish data does not include any verified data on road conditions at the time of accident. Even the information on road type is based on police reports only and is lacking data. Additionally, some person-related data (e.g. driving licence) and vehicle-related data (e.g. age and weight of the vehicle) would be useful in Swedish data. Validated road data in both countries for the time of accident as well as additional person- and vehicle-related data would allow us to conduct several useful comparisons.

5.3 Benefits of using disaggregated data

One of our main conclusions is that advanced use of disaggregated data provides more options than programmes created for analysing e.g. European-wide accident data. Two specific examples of this are as follows:

When analysing the role of e.g. car drivers in accidents, one should focus on all fatalities resulting from accidents. Specifically, considering only the killed car drivers themselves underestimates the overall role of car drivers in accidents. Thus counterpart persons should be included in the analyses as well. For example, in our data 45% of the Finnish and 59% of the Swedish car drivers involved in fatal accidents would have been ignored if we had analysed killed car drivers only. Such underestimation would also have led to further bias from ignoring all accidents causing fatal injuries to counterpart persons, among them most collisions with pedestrians.

Using advanced analysis of disaggregated data allows for modification of data as has been done for Fig. 3. Although the accident types did not match perfectly, the Swedish types could be modified into their Finnish equivalent.

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References

1. Airaksinen N, Korpinen A, Parkkari I (2016) Tie - ja raideliikenteen itsemurhat. Esiselvitys. (Suicides in road and rail traffic. Feasibility study) Research reports of the Finnish Transport Agency 7/2016
2. COST (2015) Post-harmonised travel data collected in the Cost SHANTI Action
3. Dacota (2013) Road safety knowledge system. http://safetyknowsys.swov.nl/Safety_issues/Safety-issues.html. Accessed 16 November 2016
4. Delorme R, Lassarre S (2014) A new theory of complexity for safety research. The case of the long-lasting gap in road safety outcomes between France and great Britain. Saf Sci 70:488–503
5. Derriks HM, Mak PM (2007) Underreporting of road traffic casualties. IRTAD Special Report. OECD & International Transport Forum
6. Finnish Transport agency (2015) Finnish road statistics 2014. Statistics from the Finnish Transport agency 7/2015. http://www2.liikennevirasto.fi/julkaisut/pdf8/lti_2015-07_tietilasto_2014_web.pdf Accessed 9 November 2015
7. Finnish transport safety agency (2016) Voimassa olevat ajokortit iän mukaan (Valid driving licences by age). http://www.trafi.fi/tietopalvelut/tilastot/tieliikenne/ajokorttitilastot/voimassaolevat_ajokortit. Accessed 18 January 2016
8. Hytönen K, Peltola H (2016) Kustannustehokkaat keskikaideratkaisut (Cost-effective middle barrier solutions). Research reports of the Finnish Transport Agency 2/2016. http://www2.liikennevirasto.fi/julkaisut/pdf8/lts_2016-02_kustannustehokkaat_keskikaideratkaisut_web.pdf. Accessed 18 January 2016
9. Koornstra M, Lynam D, Nilsson G, Noordzij P, Pettersson H-E, Wegman F, Wouters P (2002) A comparative study of the development of road safety in Sweden, the United Kingdom, and the Netherlands. http://ec.europa.eu/transport/roadsafety_library/publications/sunflower_report.pdf. Accessed 9 November 2015
10. Luoma J, Peltola H, Salenius S (2013) Miksi tieliikenteen turvallisuus Suomessa ei ole parhaiden maiden joukossa? (Why is road safety in Finland not at the same level as in the best-performing countries?) Liikenneviraston tutkimuksia ja selvityksiä 44/2013. http://www2.liikennevirasto.fi/julkaisut/pdf3/lts_2013-44_miksi_tieliikenteen_web.pdf. Accessed 4 November 2015
11. Luoma J, Sivak M (2014) Why is road safety in the U.S. not on par with Sweden, the U.K., and the Netherlands? Lessons to be learned. Eur Transp Res Rev 6:295–302
12. OECD/ITF (2015) Road Safety Annual Report 2015, OECD Publishing, Paris. doi: 10.1787/irtad-2015-en
13. Peltola H (2015) Talviajan nopeusrajoitusten liikenneturvallisuusvaikutukset. Vuosien 2010–2014 onnettomuuksien tarkastelu. (Safety effects of lower speed limits during winter months. Analysis of accidents in 2010–2014.) Research reports of the Finnish Transport Agency 61/2015
14. Statistics Finland (2015) Statistics on road traffic accidents. http://tilastokeskus.fi/til/ton/index_en.html. Accessed 9 November 2015
15. Swedish Transport Agency (2015) STRADA – Swedish Traffic Accident Data Acquisition. http://www.transportstyrelsen.se/en/road/statistik-och-register/STRADA/. Accessed 9 November 2015
16. Swedish Transport Agency (2016) Statistik över körkortsinnehavare efter åldersgrupp (Statistics on owners of driving licences by age group). https://www.transportstyrelsen.se/sv/vagtrafik/statistik-och-register/Vag/Korkort/Statistik-over-korkortsinnehavare-efter-alder/. Accessed 18 January 2016
17. Trafikanalys (2014) Road traffic injuries 2013. Statistik 2014:8. http://trafa.se/globalassets/statistik/vagtrafik/vagtr?afikskador/vaegtrafikskador_2013.pdf. Accessed 9 November 2015
18. Trafikanalys (2015) Vehicles kilometres on Swedish roads. http://www.trafa.se/vagtrafik/trafikarbete/. Accessed 17 November 2015
19. Trafikverket (2015) Sveriges vägnät (Swedish road network). http://www.trafikverket.se/resa-och-trafik/vag/Sveriges-vagnat/. Accessed 23 November 2015
20. Toroyan T, Peden M (eds) (2007) http://whqlibdoc.who.int/publications/2007/9241595116_eng.pdf?ua=1. Accessed 19 July 2016 Youth and road safety. World Health Organization, Geneva
21. UN (United Nations) (2015) World statistics pocketbook 2015 (series V, no. 39). United Nations, New York
22. UNECE (United Nations Economic Commission for Europe) (2016) Statistical database. http://w3.unece.org/PXWeb2015/pxweb/en/STAT/?rxid=924049a0-b155-4cf0-9821-52cb8f2991ef. Accessed 19 July 2016
23. UNECE, ITF and Eurostat (2009) Glossary for Transport Statistics, 4th edition. http://www.unece.org/fileadmin/DAM/trans/main/wp6/pdfdocs/glossen4.pdf. Accessed 16 November 2016
24. Vadeby A, Forsman Å (2013) Speed management in Sweden: evaluation of a new speed limit system. 16th Road Safety on Four Continents Conference. Beijing, China 15–17 May 2013
25. Wegman F, Oppe S (2010) Benchmarking road safety performances of countries. Saf Sci 48:1203–1211