

## Road safety comparisons with international data on seriously injured

### Abstract

Reducing the number of fatalities is a key objective of road safety policy. As road safety improvements in Europe have decreased the number of fatalities, more focus has been directed to seriously injured. The aim of this study is to compare the different definitions of and international data on seriously injured, combine this data with fatality data and investigate the results and the conclusions for road safety policy. Particularly, a combined indicator of killed and seriously injured (KSI) is used in analysis. For comparing the amount of seriously injured in different countries, the definition recommended by the European Commission, the Maximum Abbreviated Injury Scale (MAIS) level 3+ was adapted. Based on the comparisons the use of a KSI indicator is recommended as it widens overall awareness of road safety performance. When analysing the amount of seriously injured and KSI, the results highlight bicycle, moped and motorcycle users compared to fatalities as an indicator. As sustainable mobility and urbanisation shape the future transport systems and increase the importance of cycling, adopting KSI indicator is increasingly important, but further research is needed to identify the best practices and define guidelines for gathering, reporting and analysing international data on seriously injured.

### Keywords

road safety, seriously injured, fatalities, KSI, comparison

### 1. Introduction

Road safety strategies typically emphasise reducing fatal accidents and fatalities. The number of road fatalities is the most important road safety performance indicator worldwide (European Commission, 2013; OECD, 2011). However non-fatal injuries, especially serious injuries, cause also considerable impacts on public health and economic costs for society (OECD, 2008; Bambach & Mitchell, 2015). Road safety policies have been traditionally developed to decrease fatalities, but more actions are required for effective prevention of serious injuries (Breen et al., 2017). There are typically some deficiencies in injury statistics, which presents a challenge for monitoring the situation and setting targets. The number of fatalities is usually the most reliable indicator concerning the severity of accidents (Elvik & Mysen, 1999; OECD, 2011). Recent recommendations on accident statistics, especially concerning serious injuries aim to create a more detailed understanding of the current road safety performance in different countries (European Commission, 2013; OECD, 2011).

The concepts of safe system, Vision Zero and Sustainable Safety aim at eliminating fatalities and serious injuries in road traffic (OECD, 2008; Tingvall & Haworth, 1999). These concepts have been widely adopted in national policies in e.g. Sweden, the Netherlands, Norway and Finland (OECD, 2016). As Vision Zero is a long-term vision, there is also a need for shorter-term targets and measures (OECD, 2008). E.g., European Union's (EU) goal to reduce road fatalities by 50% in ten years by 2020 is one step towards the road safety vision, but target for seriously injured is also called for (European Commission, 2010; European Commission, 2015a). In 2017, transport ministers of the EU member states undertook to set a target for seriously injured, i.e. halving serious injuries in the EU by 2030 from the 2020 baseline (Valletta Declaration on Road Safety, 2017).

The long term trend in the number of road fatalities in the EU is looking positive, but there has been a stagnation during 2013-2016 (CARE, 2018). The amount of serious injuries is still somewhat unclear because of statistics' heterogeneity (CARE, 2018; ETSC, 2016). European road safety stakeholders have had a common interest to develop serious injury data and its comparability (Papadimitriou & Yannis, 2014). In 2017, transport ministers of the EU member states undertook to report reliable and comparable data by using a common definition by 2018 (Valletta Declaration on Road Safety, 2017). Despite the comparability problems, the European Commission (2017) estimates that 135 000 people are seriously injured on EU roads.

Most studies on seriously injured in road traffic have focused on certain features of the accidents, e.g. age groups, pedestrians or roundabouts (De Brabander & Vereeck, 2007; Fredriksson et al., 2010; Newgard, 2008; Weiss et al., 2014). Most of the country comparisons concerning road safety performance discuss fatalities (e.g. Hermans et al., 2009; Page, 2001; Shen et al., 2012). Eksler (2010) stated that road safety performance should be described by the amount of killed or seriously injured, KSI, when the amount of fatalities is small. In recent years, the KSI indicator has increasingly been applied in road safety studies (Aarts & Houwing, 2015; Høy, 2016; Thompson et al., 2013; Nishimoto et al., 2017). Shen et al. (2014) and Kukic et al. (2016) used the KSI indicator to compare road safety performance in European countries and found changes in countries' rankings when the number of seriously injured was added up with fatalities. Tingvall et al. (2013) compared different definitions of seriously injured but did not consider KSI. By now, however, different definitions of seriously injured and their suitability from KSI point of view have not been analysed.

This study aims to compare the different definitions of and international data on seriously injured, combine this data with fatality data and investigate the results and the conclusions for road safety policy. In order to compare and combine the data, the following questions are analysed in three EU member states, i.e. in Sweden, the Netherlands and Finland:

- How and what data on seriously injured is reported?
- How is the data collection method affecting the results, i.e. how many seriously injured are there and in which road user groups?
- How is the outlook on road safety changing when the data on seriously injured is combined with data on fatalities to killed or seriously injured, KSI?

Sweden and the Netherlands are selected as countries for comparison as these are among the best performing countries in road safety and their injury statistics involving serious injuries are also advanced (Hermans et al., 2009; OECD, 2016). Compared to Sweden and the Netherlands, Finland is closer to the EU average in terms of road fatalities per population (OECD, 2016). Finland started its statistical procedure to published data on seriously injured late compared to many other EU countries and the first official annual data was released for year 2014. The three countries have dissimilar definitions for the official amount of seriously injured. From these points of view, it is interesting to see what can be learnt from the country comparisons.

The study is carried out by analysing accident data supported by a literature study. This paper compares the different definitions of seriously injured and their outcomes and describes the characteristics of seriously injured according to different definitions in the three analysed countries. Furthermore, the use of KSI indicator is presented and its additional value compared to using data solely on fatalities is discussed.

## **2. The value and use of data on seriously injured in road traffic**

Road fatalities enable only limited view to road safety situation. Underestimation and biased information of road safety problems are challenges when analysis cover solely fatalities (Shen et al., 2014). Scarcity of fatal accidents even emphasize these challenges. Eksler (2010) stated that in analysis at the local level the relative change in amount of fatalities needs to be enormous in order to achieve a statistically significant change. Therefore local and international road safety comparisons should include seriously injured as well as fatalities (Eksler, 2010; Shen et al., 2014). According to Shen et al. (2014) and Kukic et al. (2016) countries that were best-performing in the country comparison of fatalities had a lower ranking when fatalities and seriously injured were combined.

As a safety performance indicator killed or seriously injured (KSI) takes into account the two most severe accident outcomes, it enables analysing safety situation more precisely. KSI is used for instance in Norway at national level, in the United Kingdom at local level and in city of Stockholm, Sweden to guide road safety actions (Department for Transport, 2011; Institute of Transport Economics, 2014; Norwegian Public Roads Administration, 2014). As a consequence of Vision Zero adopted nationally, road safety target in Norway is to decrease the number of killed or seriously injured. The amount of KSI should be no more than 500 in 2024 (Norwegian Public Roads Administration, 2014). KSI as a target or an indicator proposes that a death and a serious injury are equivalent from the perspective of road safety. This can be reasoned by e.g. the slight difference between these severities - a serious injury could have turned fatal if some minor detail would have altered and vice versa. Because of the inconstancies between these severities, the indicators of road safety performance should include seriously injured as well as fatalities.

Another reason for developing indicators that include also injuries is the remarkable human suffering and public health impact resulting from injuries (WHO, 2015). Serious injuries also cause enormous costs for society (Methorst et al., 2016). For instance, lifelong injuries for young people affect long-term tax losses and treatment costs. In Finland, the costs of accidents with serious injuries (MAIS 3+) were 412 million euros while costs of fatal accidents were 634 million euros in 2014 (Tervonen, 2016). The costs of accidents with serious injuries are actually higher because the official injury statistics based on police records does not include all accidents where outcomes are serious. In the Netherlands, the costs from accidents with serious injuries (5.2 billion euros) were almost three times the cost of fatal accidents (1.9 billion euros) in 2011 (OECD, 2016). This is partly due to the fact that in the Netherlands the definition of serious injuries (MAIS 2+) includes a larger share of injuries compared to Finland.

## **3. Data and methods**

### **3.1 Definitions of road fatalities and seriously injured**

The definition of a road fatality, death as a consequence of and within 30 days after a crash, is widely used and enables comparability between different countries (OECD, 2011). However, in Sweden the official amount of fatalities excludes suicides since 2010 (Trafikanalys, 2016). For proper comparison in this study, suicides are included in the annual fatality numbers of Sweden. Unlike for fatalities, there is not a common definition for seriously injured even though recent policy actions aimed at adopting one (European Commission, 2013; OECD, 2011; Valletta Declaration on Road Safety, 2017).

There has been a vast range of definitions of injury severity in the EU countries. Criteria for severity has been based e.g. on length of hospitalisation, type and level of injury, the inability to work, the length of recovery or long-term disability caused by the accident (European Commission, 2015b). In

2012, the high level group on road safety proposed a common definition for serious injuries in EU member states in order to standardize procedures and to make data from different countries comparable. Based on the proposition European Commission recommended a definition of Maximum Abbreviated Injury Scale (MAIS) for commissioning in the member states. (European Commission, 2013.) Impairment of an injured person is given a score from one to six on Abbreviated Injury Scale (AIS) and in the case of multiple impairments, the most severe impairment determines the total severity of injury (OECD, 2011). Score of MAIS three or more (MAIS 3+) is classified as serious injury. The most recommended way to apply the new definition is to create a link between hospital and police data (European Commission, 2013). European Commission (2013) also proposed other possibilities to gather the amount of seriously injured including the use of coefficients in police data or to use only hospital data. These methods are not as advisable as linking police and hospital data but they can act as first steps towards a proper injury statistics strategy. There are some difficulties of using the common definition in some member states. Based on European Commission (2016) and European Transport Safety Council (ETSC, 2016), 12 European countries including Austria, Czech Republic, England, France, Germany, Italy, the Netherlands, Poland, Portugal, Spain, Sweden and Finland have published serious injury data on MAIS 3+.

### 3.2 Data

In this study, both fatality and serious injury data sets of Sweden, the Netherlands and Finland are used. The definitions and different data sets on road fatalities are described in Table 1. The definition of a road death is the same in Sweden, the Netherlands and Finland in this study. Here Swedish data also includes the suicidal cases. In order to calculate risks per population, population data for each country is based on the number of inhabitants of 1<sup>st</sup> of January each year reported by Eurostat (2017).

Table 1. Definitions and data sets of fatalities in road traffic in Sweden, the Netherlands and Finland.

Country	Definition of road fatality	Data sets on road fatalities in this study	Data on years
Sweden	Within 30 days after a crash	OECD, 2014; OECD 2016; OECD 2017	2010-2015
The Netherlands	Within 30 days after a crash	OECD, 2014; OECD 2015; OECD, 2016; OECD, 2017	2010-2015
Finland	Within 30 days after a crash	Statistics Finland, 2017	2010-2015

In most European countries utilizing MAIS, MAIS 3+ is the definition of a serious injury (ETSC, 2016). However, Finland is the only country of these three to use MAIS 3+ as an official definition. In the Finnish procedure of gathering the official statistics hospital data can only be accessed when police data is linked to it (Utriainen, 2016). Therefore the official amount of seriously injured include only the cases which police reports, but not the ones that are solely in hospital data. For making country comparisons with comparable data in this study, we use the term *comparable MAIS 3+* to clarify the difference to *official MAIS 3+* injured. The comparable MAIS 3+ injured in Finland refers to the figures that include also the seriously injured outside the official, police reported cases, but existing in hospital data.

Sweden and the Netherlands do not use MAIS 3+ as their definition for seriously injured in official statistics but both countries have the ability to report the amount of MAIS 3+ injured as well. In Sweden, official statistics on seriously injured is solely based on police data without any hospital data. (OECD, 2016.) In the Netherlands, MAIS 2+ is used as an official definition for seriously injured. Institute for road safety research (SWOV) estimates the total number of seriously injured by linking police and hospital data. The police register produces data of crash circumstances while injury severity and injury type are recorded in hospitals. (SWOV, 2016.) In this study, the comparable MAIS 3+ figures for Sweden and the Netherlands on seriously injured are produced similarly as for Finland,

i.e. these include the hospital data also in the cases where there is no linkage to police data, see Table 2.

Table 2. Definitions and data sets of seriously injured in road traffic in Sweden, the Netherlands and Finland.

Country	Official statistics on seriously injured	Data used in this study: Comparable MAIS 3+ injured	Data sets on seriously injured in this study	Data on years
Sweden	Police reported	Hospital data also in the cases where there is no linkage to police data	Trafikanalys, 2016	2010-2015
The Netherlands	MAIS 2+, based on linking police and hospital data and complemented with hospital data	Hospital data also in the cases where there is no linkage to police data	SWOV, 2016	2010-2015
Finland	MAIS 3+, based on police reported cases that link with hospital data	Hospital data also in the cases where there is no linkage to police data	Statistics Finland, 2017	2014-2015

To highlight differences between various definitions of seriously injured, also MAIS 2+ data is presented from Sweden and the Netherlands. For Finland, MAIS 2+ data is not available. In this study, the most important definition is comparable MAIS 3+ which allows fair country comparisons.

### 3.3 Method

The study compares and combines data on fatalities and seriously injured of three countries. The amount of fatalities and seriously injured by different definitions are presented in 2010-2015, but Finnish data on seriously injured is only available from years 2014 and 2015. The annual casualty numbers per 100 000 inhabitants are also analysed and compared. In addition to annual numbers, average annual numbers over the longer time period are calculated regarding the shares of casualties in different road user groups in each country. In the comparisons it is analysed how the total amount of casualties and road safety performance change when different definitions are used and how the different definitions reflect to road user groups. Performance in KSI presents the development of road safety more comprehensively as KSI indicates the sum of fatalities and seriously injured.

## 4. Fatalities and seriously injured in Sweden

Data on fatalities and seriously injured in Sweden are from six years (2010-2015), however data regarding the seriously injured in different road user groups was available only for 2010-2014. In Sweden, the official figures on seriously injured are based on assessment made by the police. To make the comparison possible with the Netherlands and Finland, we present the comparable figures based on MAIS 3+ and use this also for calculating the KSI indicator.

In Sweden, there were annually on average 302 fatalities and 1 088 MAIS 3+ injured in 2010-2015. The amount of fatalities was almost the same while the amount of seriously injured defined as MAIS 3+ decreased when comparing years 2010 and 2015. However, there was fluctuation in both numbers in the period 2010-2015. There was a decrease in KSI when comparing 2010 to 2015 (Table 3).

Table 3. Fatalities, police recorded seriously injured, MAIS 3+ injured and KSI (fatalities plus MAIS 3+ injured) in Sweden in 2010-2015 (OECD, 2014; OECD, 2016; OECD, 2017; Trafikanalys, 2016).

Year	Official statistics (police reported)				Comparable figures on seriously injured and KSI		
	Fatalities (including suicides)	Fatalities /100 000 inhabitants	Seriously injured	Seriously injured /100 000 inhabitants	MAIS 3+ injured	MAIS 3+ injured /100 000 inhabitants	KSI (fatalities + MAIS 3+ injured)
2010	283	3.0	2 888	30.9	1 217	13.0	1 500
2011	342	3.6	3 127	33.2	1 096	11.6	1 438
2012	321	3.4	2 976	31.4	1 027	10.8	1 348
2013	288	3.0	2 721	28.5	1 091	11.4	1 379
2014	295	3.1	2 395	24.8	1 192	12.4	1 487
2015	282	2.9	2 445	25.1	906	9,3	1 188
Average	302	3.2	2 759	28.9	1 088	11.4	1 390

In Sweden, the official amount of fatalities excludes suicidal cases. In road user groups presented next, the fatalities are based on these official figures. Half (51%) of the fatalities were in the road user group of passenger car occupants in 2010-2014. The share of seriously injured cyclists (32%) defined by MAIS 3+ was the same as passenger car occupants' share (32%) in 2010-2014 (Fig. 1). KSI (deaths and MAIS 3+ injured) mainly consists of seriously injured because the amount of MAIS 3+ injured is four times greater than the amount of fatalities.

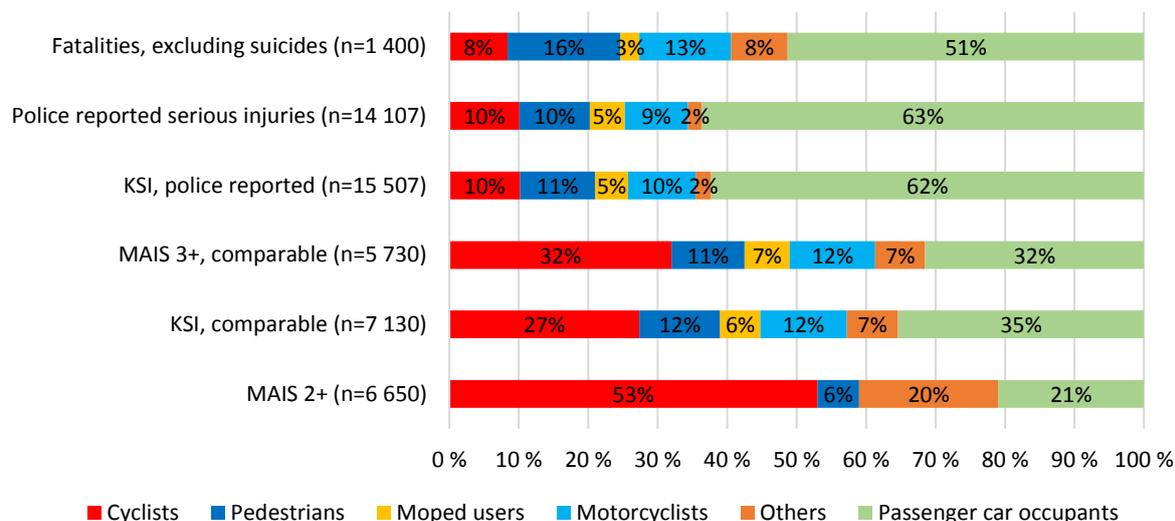


Fig. 1. The share of road user groups in fatalities excluding suicides, police reported seriously injured, KSI (fatalities plus police reported seriously injured), MAIS 3+, KSI (fatalities plus MAIS 3+ injured) and MAIS 2+ injured in Sweden. The data is for years 2010-2014 except of MAIS 2+ injured only for 2012. (OECD, 2014; OECD, 2016; Peltola, 2017; Tingvall et al., 2013; Trafikanalys, 2016).

In MAIS 2+ injured, the share of cyclists was considerably larger than by other definitions. Conversely, in seriously injured recorded by the police the share of cyclists was the lowest and the share of passenger car occupants was the largest, which may reflect the difference between police and hospital data. Police reported seriously injured is the sole definition when hospital data is not used.

## 5. Fatalities and seriously injured in the Netherlands

Data on fatalities and seriously injured in the Netherlands is from six years (2010-2015). The official definition of seriously injured is MAIS 2+ in the Netherlands. In this study, MAIS 3+ data is also presented for comparison. In the Netherlands, there were annually on average 619 fatalities and 6 667 seriously injured (MAIS 3+) in 2010-2015 (Table 4). The number of fatalities decreased 3% from 2010 to 2015. Yet, the number of KSI increased 33% at the same period because the number of MAIS 3+ injured increased 37%. The number of MAIS 2+ injured increased 12%.

Table 4. Fatalities, MAIS 2+ injured, MAIS 3+ injured and KSI (fatalities plus MAIS 3+ injured) in the Netherlands in 2010-2015 (OECD, 2014; OECD, 2015; OECD, 2016; OECD 2017; SWOV, 2016).

Year	Official statistics				Comparable figures on seriously injured and KSI		
	Fatalities	Fatalities /100 000 inhabitants	MAIS 2+ injured	MAIS 2+ injured /100 000 inhabitants	MAIS 3+ injured	MAIS 3+ injured /100 000 inhabitants	KSI (fatalities + MAIS 3+ injured)
2010	640	3.9	19 100	115.2	5 700	34.4	6 340
2011	661	4.0	19 700	118.3	6 100	36.6	6 761
2012	650	3.9	19 500	116.6	6 400	38.3	7 050
2013	570	3.4	18 800	112.0	6 500	38.7	7 070
2014	570	3.4	20 700	123.0	7 500	44.6	8 070
2015	621	3.7	21 300	126.0	7 800	46.2	8 421
Average	619	3.7	19 850	118.5	6 667	39,8	7 285

According to the MAIS 2+ definition, 60% of seriously injured were cyclists, 19% moped users or motorcyclists, and 11% were passenger car occupants in the Netherlands in 2010-2015 (Fig. 2). In fatalities, the share of passenger car occupants (35%) was greater than the share of cyclists (30%). In the Netherlands, road user groups of MAIS 3+ injured are not available. The amount of MAIS 2+ represent 97% of KSI (fatalities plus MAIS 2+ injured) and therefore KSI and MAIS 2+ figures are basically is the same.

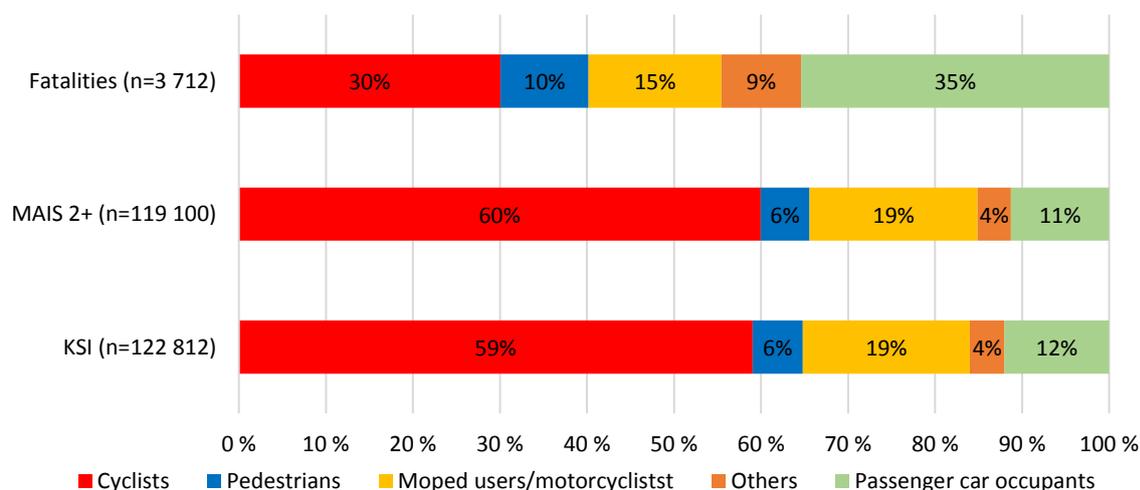


Fig. 2. Fatalities, MAIS 2+ injured and KSI (fatalities plus MAIS 2+ injured) by road user groups in the Netherlands in 2010-2015 (OECD, 2014; OECD, 2016; OECD, 2017; SWOV, 2016). Data for presenting the distribution of road users is not available with MAIS 3+ definition.

## 6. Fatalities and seriously injured in Finland

In Finland, there were annually on average 270 road fatalities in 2010-2015. Compared to Sweden and the Netherlands, there is less data available on seriously injured as Finnish data has only been published since 2014. In official statistics, MAIS 3+ injured are solely recorded when hospital data links to police data. In 2014 and 2015, the official amount of MAIS 3+ injured was on average 498, while there were on average 915 seriously injured altogether, when also the cases are included where there is only hospital data. This data is called comparable MAIS 3+ to indicate the difference to official MAIS 3+. To calculate the KSI, fatalities and comparable MAIS 3+ are summed together. Of the sum KSI, on average 79% was the share of comparable MAIS 3+ injured in 2014-2015 (Table 5).

Table 5. Fatalities in 2010-2015, seriously injured defined as official MAIS 3+ and comparable MAIS 3+ and KSI (fatalities plus comparable MAIS 3+ injured) in 2014-2015 in Finland (Kokkonen, 2017; Statistics Finland, 2017).

Year	Official statistics (police reported) *hospital data is used when it links to police data				Comparable figures on seriously injured and KSI (seriously injured include also the cases where there is only hospital data)		
	Fatalities	Fatalities /100 000 inhabitants	MAIS 3+ injured *	MAIS 3+ injured * /100 000 inhabitants	MAIS 3+ injured	MAIS 3+ injured /100 000 inhabitants	KSI (fatalities + comparable MAIS 3+ injured)
2010	272	5.1	-	-	-	-	-
2011	292	5.4	-	-	-	-	-
2012	255	4.7	-	-	-	-	-
2013	258	4.8	-	-	-	-	-
2014	229	4.2	519	9.5	953	17.5	1 182
2015	270	4.9	477	8.7	876	16.0	1 146
<b>Average</b>	<b>263</b>	<b>4.9</b>	<b>498</b>	<b>9.1</b>	<b>915</b>	<b>16.7</b>	<b>1 164</b>

Analysis based on the data in Table 5 are twofold. In 2014, the amount of fatalities was low compared to previous years. In 2015, the number of deaths increased 18%. However, KSI decreased 3% in 2015 because the number of seriously injured was 8% lower in 2015 than in 2014.

The largest road user group in fatalities (56%) was passenger car occupants in 2014-2015 (Fig. 3). In comparable MAIS 3+ injured, the share of passenger car occupants (32 %) and cyclists (31 %) was almost the same. The share of cyclists and moped riders and motorcyclists were notably greater in seriously injured compared to fatalities. Conversely, in fatalities, the share of pedestrians and passenger car occupants were greater than in seriously injured. Therefore, cyclists and moped riders and motorcyclists stand out in KSI compared to data on fatalities.

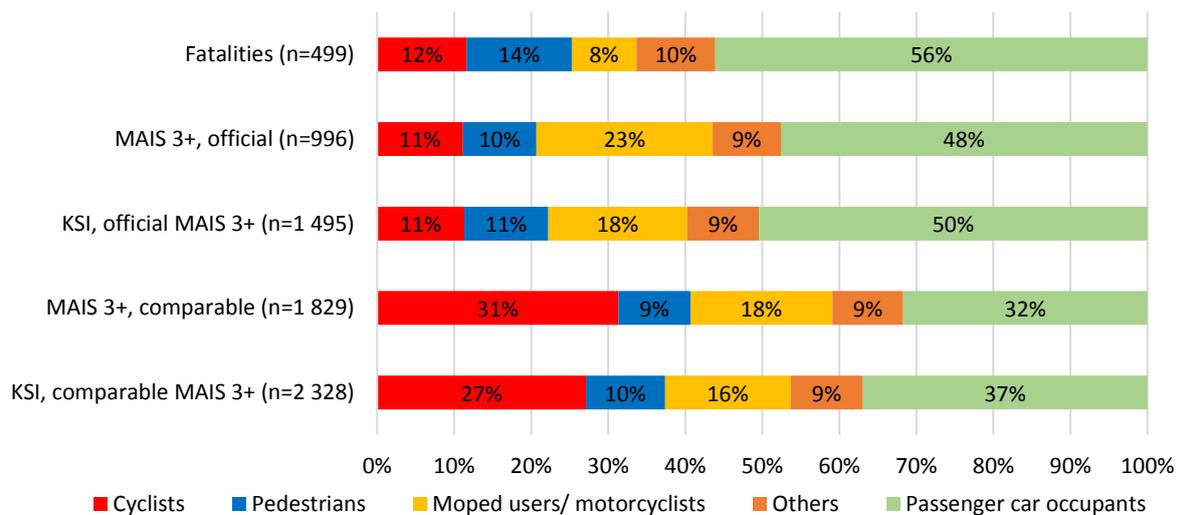


Fig. 3. Fatalities, official MAIS 3+ (i.e. police reported) and comparable MAIS 3+ injured and KSI based on fatalities plus official MAIS 3+ figures and fatalities plus comparable MAIS 3+ figures by road user groups in Finland in 2014-2015 (Kokkonen, 2017; Statistics Finland, 2017).

Distribution of road user groups in serious injuries differ when considering official figures (police reported MAIS 3+ injured) and comparable MAIS 3+ injured. The main differences are seen in the share of cyclists and passenger car occupants. The official figures, where hospital data is only partly used, emphasise injuries of passenger car occupants whereas comparable MAIS 3+ injured emphasise cyclists.

## 7. Comparison of road safety performance and data

Road safety in Sweden and the Netherlands is at a better level than in Finland when considering fatalities per 100 000 inhabitants in 2010-2015 depicted in tables 3, 4 and 5. In comparable MAIS 3+ injured per population, Sweden (11.4 seriously injured/100 000 inhabitants) performs better than Finland (16.7) and the Netherlands (39.8). Road safety performance in the Netherlands changed remarkably when seriously injured and fatalities were combined and compared solely to fatalities. In KSI, divided by 100 000 inhabitants, Sweden (14.6) was the safest and Finland (21.6) was before the Netherlands (43.5). It can be stated that currently international comparisons of seriously injured are not as reliable as comparisons of road fatalities due to the differences in statistical procedures. There can be seen notable changes in safety rankings when adding seriously injured to fatalities. This is also recognised in other studies by e.g. Shen et al. (2014) and Kukic et al. (2016).

Reliable comparison demands similar definitions and methods for acquiring and analysing the data. Similarly produced seriously injured data was available from all these countries, even though comparable MAIS 3+ injured were not the official figures in any of these countries. According to official figures in these countries, the amount of seriously injured per 100 000 inhabitants was 28.9 in Sweden (police reported), 118.5 in the Netherlands (MAIS 2+) and 9.1 in Finland (MAIS 3+, including only the cases where police records links to hospital data). Comparison between countries is not possible when different definitions are used. Furthermore, road safety performance in these countries is on a completely different level when comparing with the official and a preferred method where the figures are based on comparable MAIS 3+ injured.

There were many similarities in these three countries when comparing road user groups. The comparable MAIS 3+ figures in Sweden and Finland and the MAIS 2+ figures in the Netherlands

showed that seriously injured cyclists were considerably more common than cyclists' fatalities. Conversely, passenger car occupants' share of fatalities was greater than the share of seriously injured in every country, excluding solely police reported seriously injured in Sweden. In Sweden and Finland the shares of seriously injured in different road user groups were almost the same in comparable MAIS 3+ figures and thus road safety challenges and necessary actions to promote road safety could be quite similar in these two countries. MAIS 3+ figures on the distribution of road user groups is not available in the Netherlands. According to the fatality and MAIS 2+ injured data, cyclists' safety demands even more attention in the Netherlands than in Sweden or Finland. Cycling is far more popular transport mode in the Netherlands than in Sweden or Finland (e.g. Pucher & Buehler 2012) which reflects also to the safety of biking.

Uncertainty towards existing definitions of seriously injured reflects to observations concerning road user groups. Especially in Sweden, distributions in road user groups varied considerably when using different definitions and data sources. As depicted in Fig. 1, the share of seriously injured cyclists varied from 10% (police recorded) to 53% (MAIS 2+). The same variation with passenger car occupants was from 21% (MAIS 2+) to 63% (police recorded). Considering the variation, road safety measures are likely to be directed differently when following different definitions and their outcomes.

Examples from Sweden and Finland indicate that underreporting issues may affect the outlook of road safety performance. In Sweden, police recorded 50 % of the actual number of MAIS 3+ injuries in 2010-2014 (Peltola, 2017). Without additional hospital data, only half of the seriously injured would have been in statistics. Likewise, in Finland police recorded 54% of the MAIS 3+ injured that came into hospital records in 2014-2015. Use of sole police data underestimates the share of cyclists and overestimates the shares of seriously injured passenger car occupants, moped riders and motorcyclists compared to comparable MAIS 3+ figures which includes also the hospital data. In many countries, bicycle accidents in particular have been poorly included in official statistics based on police records (Wegman et al., 2012). Poor data has been recognized to reflect to underreporting of cyclist accidents and gaps in available data have led to accident risks of cycling being poorly understood (Short & Caulfield, 2014).

Police data provably differs from hospital data but there are also variation between different definitions when police and hospital data are linked. For instance, when using the hospital data the share of cyclists was considerably higher in MAIS 2+ injured (53%) than in comparable MAIS 3+ injured (32%) in Sweden as presented in Fig. 1. In addition, in the Netherlands the share of seriously injured cyclists' by MAIS 2+ definition was 60% in 2010-2015 as presented in Fig. 2 and by MAIS 3+ definition the share was on average 37% in 2000-2014 as European Commission (2016) presented. Even though comparison years were not comparable in the Netherlands as a whole, there is a clear difference between MAIS 3+ and MAIS 2+ injured in road user groups. In the Netherlands, the share of seriously injured passenger car occupants was higher in MAIS 3+ (40%) in 2000-2014 (European Commission, 2016) than in MAIS 2+ (11%) in 2010-2015 as presented in Fig. 2.

## **8. Discussion**

To reach the aims of this study three questions were posed. Firstly, *how and what data on seriously injured is reported*. In this study, many definitions for seriously injured and data based on both police and hospital records are discussed. This might cause confusion regarding the actual amount of seriously injured. In the Netherlands, the amount of MAIS 3+ injured was annually on average 6 667 while the official amount (MAIS 2+) was 19 850 in 2010-2015 as presented in Table 4. In Sweden, the annual average amount in 2010-2015 also varied a lot as police recorded 2 759 serious injuries (i.e.

the official statistics) and hospital recorded 1 088 seriously injured (i.e. comparable MAIS 3+ figures) as presented in Table 3. If the limit of seriously injured would be lower than MAIS 3+, like in case of MAIS 2+, the amount of seriously injured would be greater and road safety could receive more attention. Nevertheless, MAIS 2+ is not as suitable in the KSI as MAIS 3+ definition. It cannot be concluded unambiguously which definition is the most applicable. Even though MAIS 3+ is the most preferred, other definitions are also worth to be used beside MAIS 3+. In international comparisons, the comparability of the amount of seriously injured between countries is essential for proper results.

*The second question posed was how the data collection method is affecting the results, i.e. how many seriously injured are there and in which road user groups.* The study showed that when hospital data is comprehensively utilised in statistical procedures, seriously injured cyclists are emphasized compared to fatalities. Furthermore, as less severe injuries happen more to cyclist than to passenger car occupants, MAIS 2+ as a definition for seriously injured highlights cyclists whereas MAIS 3+ definition draws more attention to passenger car occupants' injuries. Understandably, the share of seriously injured cyclists is large in the Netherlands, where cycling is a very popular mode of transport. Seriously injured cyclists are also the largest group together with passenger car occupants in Sweden and Finland, which is not that expectable. The climate and transport system of Sweden and Finland are rather similar which can be the reason for the similar proportion of MAIS 3+ injured in different road user groups in these two countries. The process to link police and hospital data is important for road safety actions and comparability. By combining hospital and police data, underreporting can be decreased which can affect e.g. the shares of road user groups in the accident data analysis.

The third question was *how the outlook on road safety changes when the data on seriously injured is combined with data on fatalities to killed or seriously injured, KSI.* As reducing the amount of seriously injured is an integral part of many road safety visions, the number of killed or seriously injured describes safety problems more widely because KSI as an indicator includes more casualties than the number of fatalities. KSI indicator highlights bicycle, moped and motorcycle users compared to fatalities as an indicator. On the other hand, passenger car occupants' share of the KSI is lower than when using fatalities.

Because of statistical fluctuation, the annual number of road fatalities can vary remarkably, particularly in local road safety analysis. Applying KSI as an indicator the statistical fluctuation is likely to be relatively smaller. However, it is justified to ask, why seriously injured should be "merged" with fatalities in the KSI indicator. Death is permanent and there is no possibility to recover to previous health condition like it may be possible in the case of a serious injury. However, in the most serious road accidents it is not always clear why the consequence of an accident is death or serious impairment. There may be a fine line between a fatal injury and a serious injury in certain accidents. If focusing only on fatalities, an integral part of road safety performance awareness can be lost.

It was found out that the KSI is a usable indicator if the amount of seriously injured and fatalities are of somewhat similar magnitude. For instance, in the Netherlands KSI is practically useless as an indicator when MAIS 2+ injured are considered as they outnumber the fatalities 30 times and therefore KSI is basically the same as the seriously injured. Shen et al. (2014) used weight restrictions to compensate a lower share of fatalities in KSI. Weighting is a possible solution when serious injuries and fatalities are not in balance but it is not clear how much the amount of fatalities should be emphasized compared to seriously injured. The amount of MAIS 3+ injured and fatalities in Sweden and Finland are more balanced and therefore KSI is beneficial without weighting. In addition

to Sweden and Finland, also in Spain, Portugal, Poland, Austria and Italy, the amount of seriously injured (MAIS 3+) is also approximately four times the number of fatalities (ETSC, 2016). The estimate is based on ETSC's data 2010-2014, but annual data for the whole period was not available in all countries. When considering KSI, MAIS 3+ is a more applicable definition of seriously injured than the other definitions in this study. When using the other definitions, KSI would consist almost entirely of seriously injured.

## **9. Conclusions**

Road safety has traditionally been analysed based on the number of fatalities. As e.g. Vision Zero includes also a target zero for seriously injured, these should be taken into account similarly as fatalities. While international comparisons of road safety based on fatalities have a long tradition and established practices, international comparisons of seriously injured are difficult to make because of varying definitions for seriously injured between and also within different countries.

This paper aimed to compare the different definitions of and international data on seriously injured, combine this data with fatality data and investigate the results and the conclusions for road safety policy. The results emphasise that the definition of a serious injury has a major influence on the amount of seriously injured and the shares of casualties in different road user groups. As the (MAIS) level 3+ is recommended by the European Commission and widely in use, it is currently the best definition for international comparisons. However, it is also advisable to maintain other definitions beside MAIS 3+ as the amount of seriously injured vary when different definitions are used and keeping to only one definition results in incomplete view of seriously injured. Road safety concerns change when for instance MAIS 2+ is used instead of MAIS 3+ leading to different focus of road safety policy.

Data on seriously injured highlights other road user groups compared to fatality data. Especially the share of seriously injured cyclists was more than the share of cyclists' fatalities in all three countries. This reflects also to KSI indicator as it highlights different road user groups than mere fatalities. As KSI indicator includes a higher number of casualties compared to fatalities and seriously injured separately, KSI has less statistical fluctuation and therefore KSI is a recommended key indicator for road safety performance.

The results of the study represent especially the findings from Swedish, Netherlandish and Finnish definitions and data on seriously injured. The data on seriously injured from other countries could highlight other aspects of road safety. In addition to varying definitions, there are also different methods in gathering data. As the analysis of the three studied countries presented, there are many possibilities in defining seriously injured and collecting the data on these. Studying other countries, also outside Europe, would probably depict even a larger set of definitions and ways of collecting the data on seriously injured, which could help in defining the most common and most recommended way, especially from the international comparison point of view. From this point of view, future research is called for also outside EU countries, and when comparable data on all EU countries will be available considering year 2018.

For international comparison, there is great potential in developing the process of gathering and publishing data on seriously injured. Overall, this study recognises the differences in definitions and data, and by acknowledging this correctly, supports seriously injured and KSI to be key indicators of road safety performance in future, also in international comparisons.

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