The Consequences of Adopting a MAIS 3 Injury Target for Road Safety in the EU: a Comparison with Targets Based on Fatalities and Long-term Consequences

Claes Tingvall, Jan Ifver, Maria Krafft, Anders Kullgren, Anders Lie, Matteo Rizzi, Simon Sternlund, Helena Stigson and Johan Strandroth

Abstract It has been proposed in the European Union (EU) to adopt a Maximum Abbreviated Injury Scale (MAIS) of 3 or greater as the basis for a road safety target. To have a common definition of serious injury across the EU is in itself very positive. In this study, fatalities, MAIS 3+, MAIS 2+ and injuries leading to permanent medical impairment (PMI) were used to identify problem scenarios.
A national data set of injuries reported to Swedish hospitals from 2007 to 2012 (STRADA) was used. Police-reported injuries were also taken into account.

The results showed that, depending on the data source and injury rating method, problem scenarios differed substantially. While fatalities were dominated by vehicle occupants in high-speed environments, vulnerable road users in urban areas were in greater focus as a result of lowered thresholds for injury or impairment levels. Bicyclists in particular have many injuries at less severe, yet significant, levels.

There is a particular need to consider certain diagnoses which lead, relatively often, to long-term consequences at the AIS 1 level. To achieve a better injury and consequence scenario, data from the medical system are an essential prerequisite.

Keywords Injury classification, long term consequences, safety management

I. INTRODUCTION

Modern philosophies in traffic safety management [1-3] consider target setting an essential part of road traffic safety strategies. Targets should be defined both in terms of long-term final outcomes (visionary), medium term (quantitative and set in time) and intermediate targets (such as seat belt use, infrastructure safety, etc.). Intermediate targets, often called safety performance indicators or safety performance factors, should be linked to the final outcome in such a way that improvements of the intermediate factors lead to improvement of the final outcome [4]. Defining the final outcome and the ambitiousness of the target of the final outcome have, therefore, a direct link to how countermeasures are prioritized and which results are consequently reached. This is also the approach used in safety management standards such as ISO 39001 [5].

The European Union (EU) as well as many nations outside the EU have had medium term targets addressing fatalities for many years [2]. The most recent target period for the EU was 2001-2010 where the aim was to reduce deaths by at least 50% [6]. The aim was nearly achieved with an overall reduction of 43%, although many nations reached a 50% reduction [7]. As a result, aspirational

C. Tingvall, Dr Med Sc, is Director of Traffic Safety, Swedish Transport Administration and Adj Professor, Chalmers University of Technology (phone +46 10 123 6549, email claes.tingvall@trafikverket.se). J. Ifver is Analyst, Swedish Transport Agency. M. Krafft, Dr Med, is Director of Traffic Safety and Environment, Folksam, and Assoc Professor, Umeå University. A. Kullgren, Dr Med, is Director of Traffic Safety Research, Folksam and Adj Professor, Chalmers University of Technology. A. Lie, Dr Med, is Traffic Safety Specialist, Swedish Transport Administration and affiliated with Chalmers University of Technology. M. Rizzi is Road Safety Researcher, Folksam and PhD student, Chalmers University of Technology. S. Sternlund is Road Safety Analyst, Swedish Transport Administration and PhD student, Chalmers University of Technology. H. Stigson, Dr Med, is Road Safety Researcher, Folksam and affiliated with Karolinska Institute. J. Strandroth, Lic tech, is Road Safety Analyst, Swedish Transport Administration and PhD student, Chalmers University of Technology.

medium term targets have been reset for a further 50% reduction for 2011-2020. The long-term final outcome target for deaths on European roads by 2050 has been set at “close to zero” [8].

The EU has also considered a target for reducing injuries, in particular serious injuries, to encourage effective actions [9]. Implicitly, this could be seen as a way to prioritize serious injury, but also to ensure that if serious injuries are not addressed by the same actions as those leading to a reduction in deaths, different actions to reduce serious injuries will now be considered as a better way. The use of injury scales and severity levels offer a variety of options that in turn have different implications and may possibly present a different picture of the road traffic safety problem [10]. The immediate outcome of an event might differ from the long-term outcome, and the health and quality-of-life dimension might present different pictures as well. Vision Zero, sometimes called Safe System Approach, has defined a serious injury as an injury with a long-term consequence [11]. ISO 39001 includes a similar definition as follows: *Serious injury – injury with a long term health impact or non-minor harm caused to a person’s body or its functions arising from a road traffic crash*.

The definition of a target to be attained in terms of a reduction in the number of injuries and injury severities is fundamental to the final outcome. The ISO definition is directed towards the health consequences of injury. Even if the ISO definition is not directly applicable in an operational way, it indicates a direction towards the health consequences of injury. Other injury definitions are directed more towards the immediate outcome of a crash in terms of injury severity judged by the police or the AIS, which is mainly but not exclusively a threat to life scale [10].

The definition of a final target is not the only issue when deciding the most valid priorities. Quality of data, both in terms of reliability as well as coverage, is an important aspect. For example, if underreporting is skewed towards certain types of road users, injuries or crash situations, the traffic safety picture will be distorted [12].

In this paper, several classifications of injury were used to study whether priorities would differ for different road user categories. Police-reported injuries were compared to hospital data over the study period.

II. METHODS

The data were analysed using three injury classification methods. First, the samples were classified according to the UNECE definition of injury and its subdivisions (fatal, severe and minor injury) [10]. Fatalities are defined as persons killed immediately or dying within 30 days as a result of an injury accident. A severely injured person according to this definition is anyone injured and hospitalised for a period of more than 24 hours. Minor injuries are defined as any person injured but not seriously. Assessment of injury severity is made by the police, normally at the accident scene. Second, a classification was made according to the Abbreviated Injury Scale (AIS 2005 scale) classification of injuries. In Sweden, this is carried out at emergency hospitals by medically trained personnel. Finally, individuals’ risks of permanent medical impairment (RPMI) were established using the method described by Malm et al [13-14]. This method is based on the AIS classification of injuries.

The RPMI matrix is based on approximately 35 000 diagnoses from 20 000 injured car occupants who reported an injury to an insurance company. The injured car occupants were followed for at least 5 years to assess the risk of permanent medical impairment for different body regions and AIS severity levels (Tables I and II). By multiplying the immediate injury outcome with the RPMI matrix a prediction of the number of impaired persons can be made. Medical impairment is considered permanent when no further improvement in physical and/or mental function is expected with additional treatment [15]. The assessed impairment degree is independent of cause and without regard to occupation, hobbies or other special circumstances of the injured person. The principles of grading medical impairment have been developed since the beginning of the 20th century in Sweden and established in consensus with physicians. The injury is assigned a degree of medical impairment between 1% and 99%, where a level from approximately 10% results in persistent symptoms affecting activities of daily living.

In the present study emergency hospital data were applied on the risk matrices (Tables I and II) to obtain risk values for each injury. The combined RPMI for each patient was calculated based on a product of the risks of not being injured, described by Gustavsson et al [16], see Eq. 1, where n is the number of injured body regions sustained by each patient. Only the highest scored AIS coded injury per body region is included in the calculation.

$$RPMI = 1 - (1 - risk_1) \times (1 - risk_2) \times (1 - risk_3) \times \ldots \times (1 - risk_n) \tag{1}$$

TABLE I

RISK OF PERMANENT MEDICAL IMPAIRMENT (RPMI) ON 1%+ LEVEL (I.E. 1-99%). NUMBERS IN PERCENT. (FROM MALM ET AL. [13])

RPMI 1%	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	8.0	15	50	80	100
Cervical Spine	16.7	61	80	100	100
Face	5.8	28	80	80	n.a.
Upper Extremity	17.4	35	85	100	n.a.
Lower Extremity and Pelvis	17.6	50	60	60	100
Thorax	2.6	4.0	4	30	30
Thoracic Spine	4.9	45	90	100	100
Abdomen	0.0	2.4	10	20	20
Lumbar Spine	5.7	55	70	100	100
External (Skin)*	1.7	20	50	50	100

TABLE II

RISK OF PERMANENT MEDICAL IMPAIRMENT (RPMI) ON 10%+ LEVEL (I.E. 10-99%). NUMBERS IN PERCENT. (FROM MALM ET AL. [13])

RPMI 10%	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	2.5	8	35	75	100
Cervical Spine	2.5	10	30	100	100
Face	0.4	6	60	60	n.a.
Upper Extremity	0.3	3	15	100	n.a.
Lower Extremity and Pelvis	0.0	3	10	40	100
Thorax	0.0	0	0	15	15
Thoracic Spine	0.0	7	20	100	100
Abdomen	0.0	0.0	5	5	5
Lumbar Spine	0.1	6	6	100	100
External (Skin)*	0.03	0.03	50	50	100

*AIS 1 injuries from body regions such as abrasion, contusion, minor laceration and thermal injuries.

The AIS is a non-linear scale mainly but not exclusively related to threat to life, while RPMI is a health consequence scale predicting the risk of permanent impairment at different levels of loss of bodily function. It is assumed that the calculated RPMI values are points on a quotient scale.

III. MATERIAL

The injury data for this study originated from STRADA between 2007 and 2012. STRADA is the Swedish national system for road traffic injury data collection, containing police-reported injuries and injury data from hospitals. The injury section of STRADA gathers information from emergency hospitals in Sweden (all but one, since 2011). The information in the hospital section is limited to the road user category, geographical information, age/sex and injuries. Injuries are coded both according to ICD as well as AIS by trained coders at the hospital. While there might be underreporting as well as misclassification of the hospital data, the extent of these issues is not known. The hospital data are, where possible, matched with the injury crashes reported by the police where more information about involved vehicles, infrastructure (e.g. speed limits) and individuals can be obtained. For the present study, information from hospitals was the main source as they comprise, in essence, the entire population of significant injuries.

IV. RESULTS

Figures 1 to 7 illustrate the number of injured using different classification methods. The proportion of injured road user categories reported by the police presented a very different picture from those reported by hospitals. This is mainly due to considerable underreporting of some road user groups, particularly bicyclists with lower injury levels. The group “Other” contains heavy goods vehicles, buses, powered two-wheelers and “unknown”.

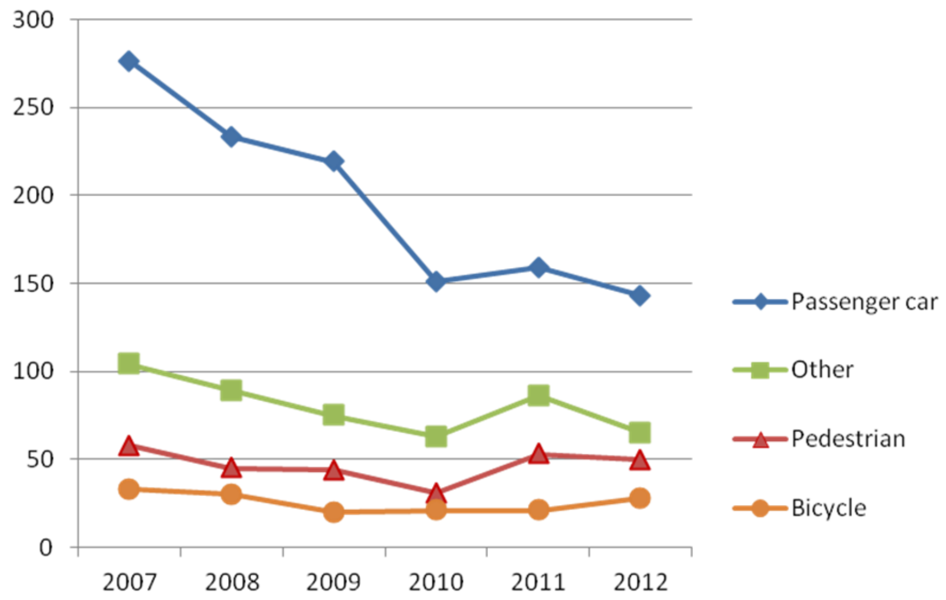

Fig. 1. Number of fatalities in Sweden divided by road user category based on police reports.

Road traffic fatalities are dominated by car occupants, although during 2007-2012 the number of killed car occupants dropped by 45% (Figure 1). The second largest road user category, considering fatalities, consists of pedestrians followed by motorcyclists and, lastly, by bicyclists. Bicyclists constituted about 10% of the deaths.

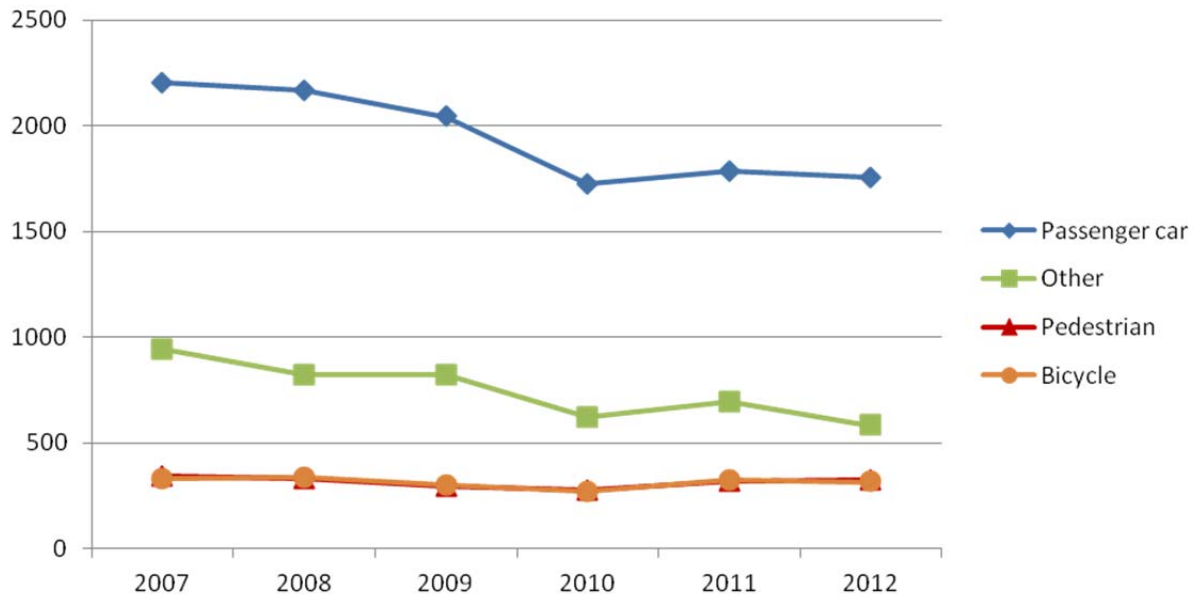

Fig. 2. Number of seriously injured in Sweden, as reported by the police and according to UNECE definition, divided by road user category 2007-2012 (note that the pedestrian and bicyclist lines overlap).

Seriously injured road users, as reported by the police, are dominated by car occupants, while bicyclists represent only 7% of this injury category. The number of seriously injured car occupants decreased by 20% during 2007-2012, a much smaller reduction than for fatalities.

The reductions of injured road users reported by hospitals, but classified differently, presented a picture similar to the police data. Yet the proportions between different road user categories and development over time differed. For MAIS 2+ injuries (Figure 3), bicyclists were the dominating road user group, which differs from the MAIS 3+ classification (Figure 4). Bicyclists constituted almost 55% of the total number of MAIS 2+ injured in 2012. The number of MAIS 2+ car occupants dropped by 35% from 2007 to 2012.

For road users with MAIS 3+ injuries, the picture is quite different from those with MAIS 2+ injuries. The proportion of bicyclists and car occupants are similar, about 35% for both 2011 and 2012. The number of MAIS 3+ injured car occupants fell by 44%, close to the reduction for fatalities. Also, the number of injured bicyclists fell during the same period by 25%, while there was no reduction of MAIS 2+ injured bicyclists for the same period.

The total number of injured differ substantially between the sources depending on the injury classification used.

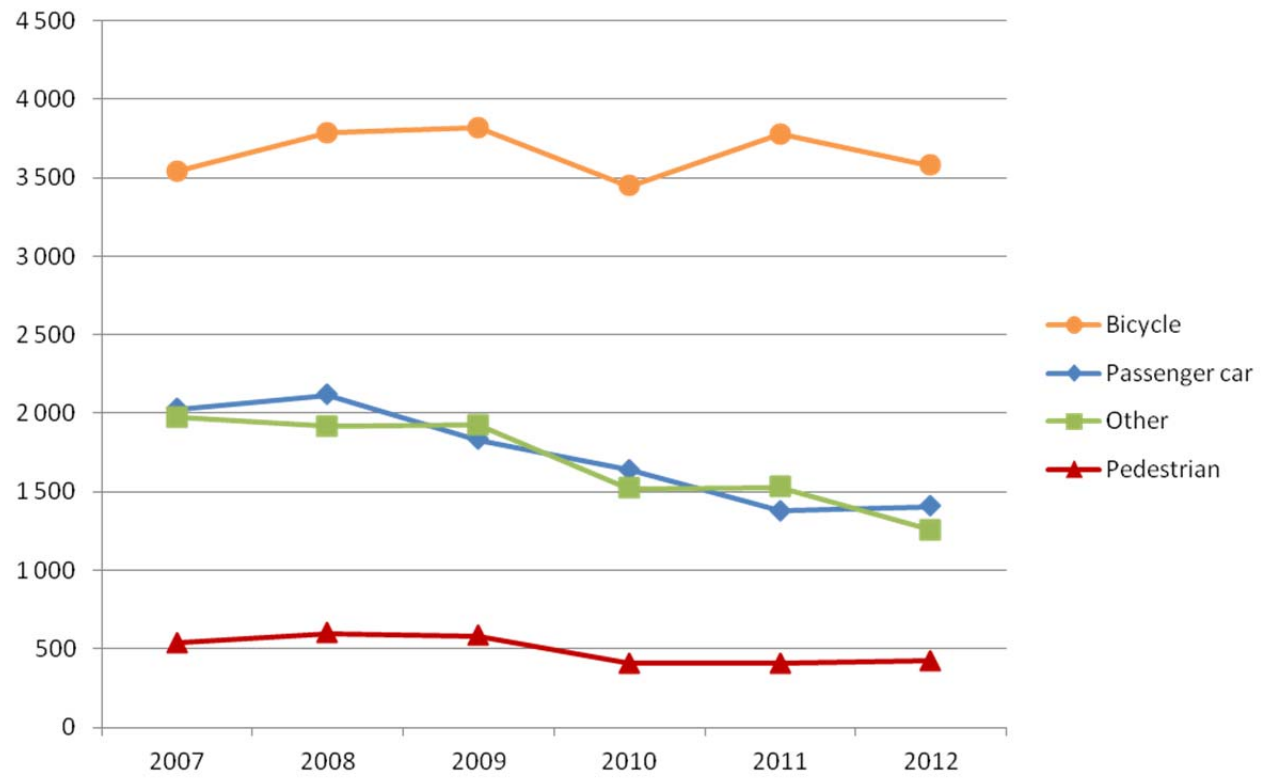

Fig. 3. Number of occupants with MAIS 2+ injuries in Sweden, as reported by hospitals, divided by road user category

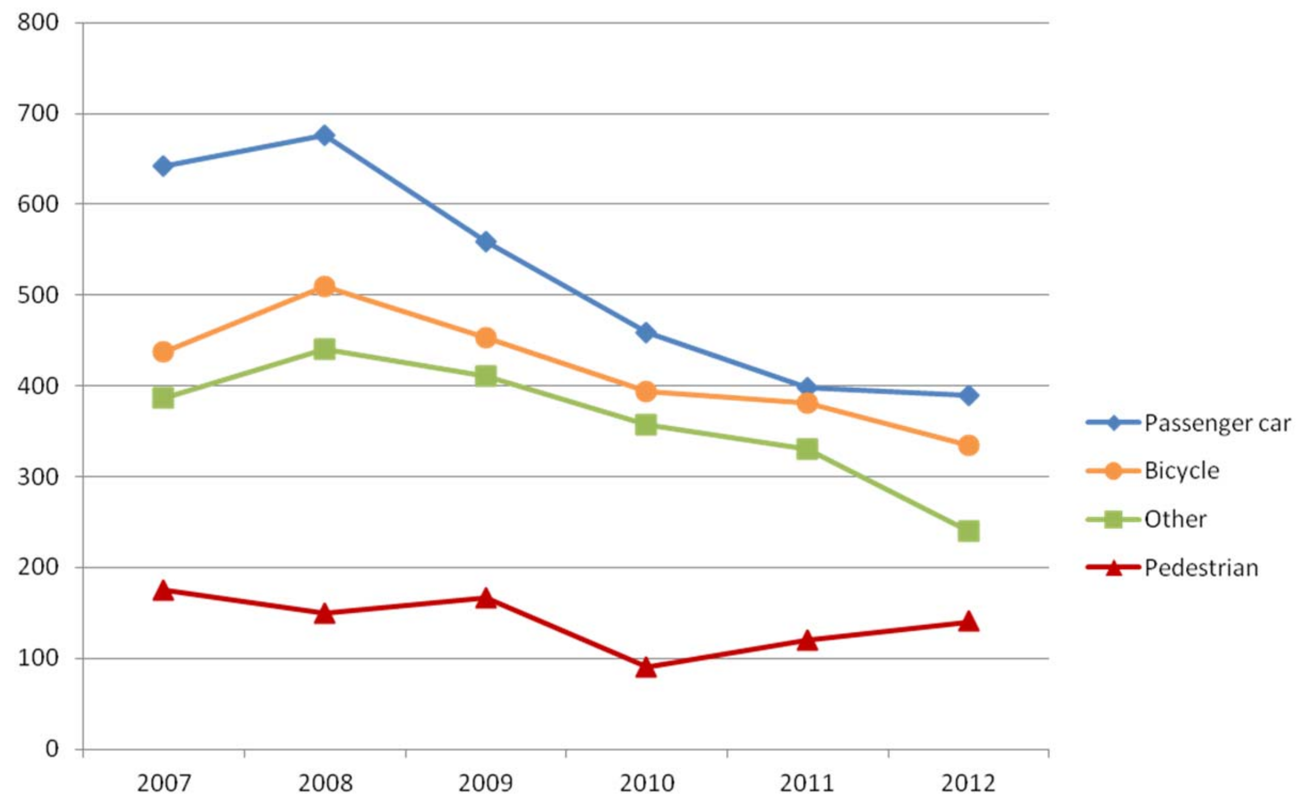

Fig. 4. Number of occupants with MAIS 3+ injuries in Sweden, as reported by hospitals, divided by road user category

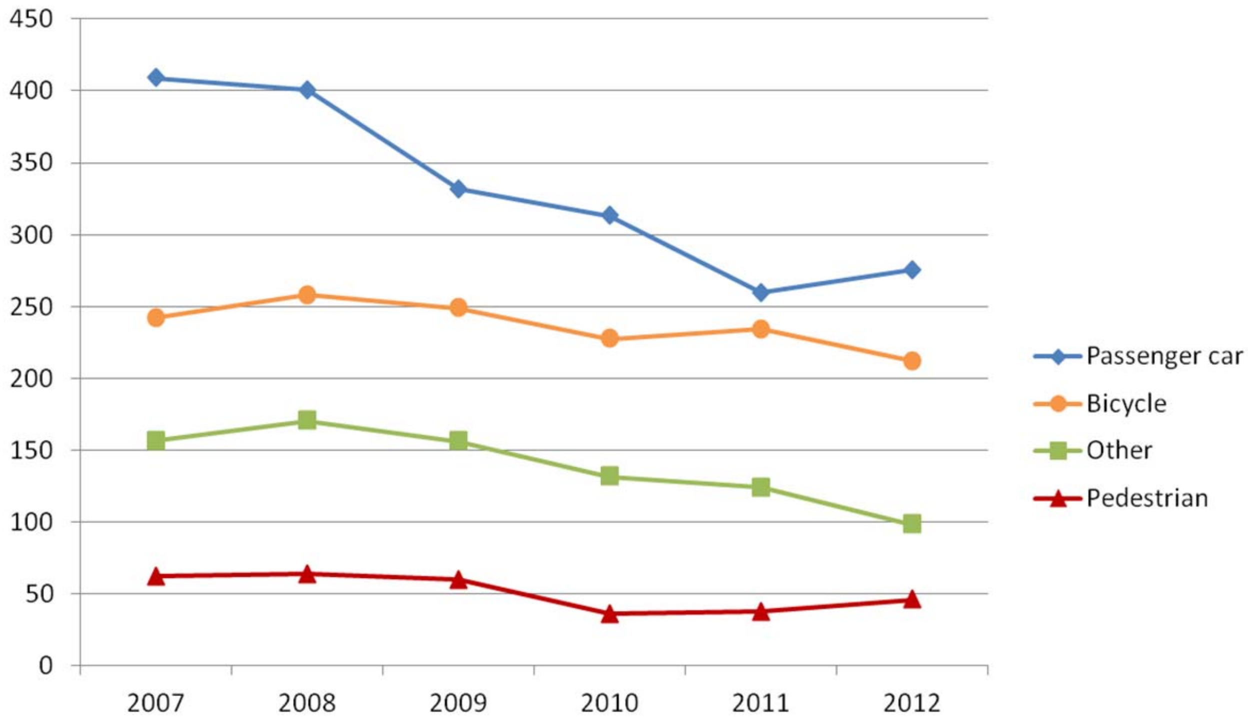

Fig. 5. Number of seriously impaired road users (PMI 10+) in Sweden divided by road user category

The analysis of injured road users with serious long term consequences (Fig. 5) showed that bicyclists accounted for 34% of cases, while car occupants, 42%. There was a 50% reduction of seriously impaired car occupants between 2007 and 2012, while seriously impaired bicyclists dropped by only 15% in the same period.

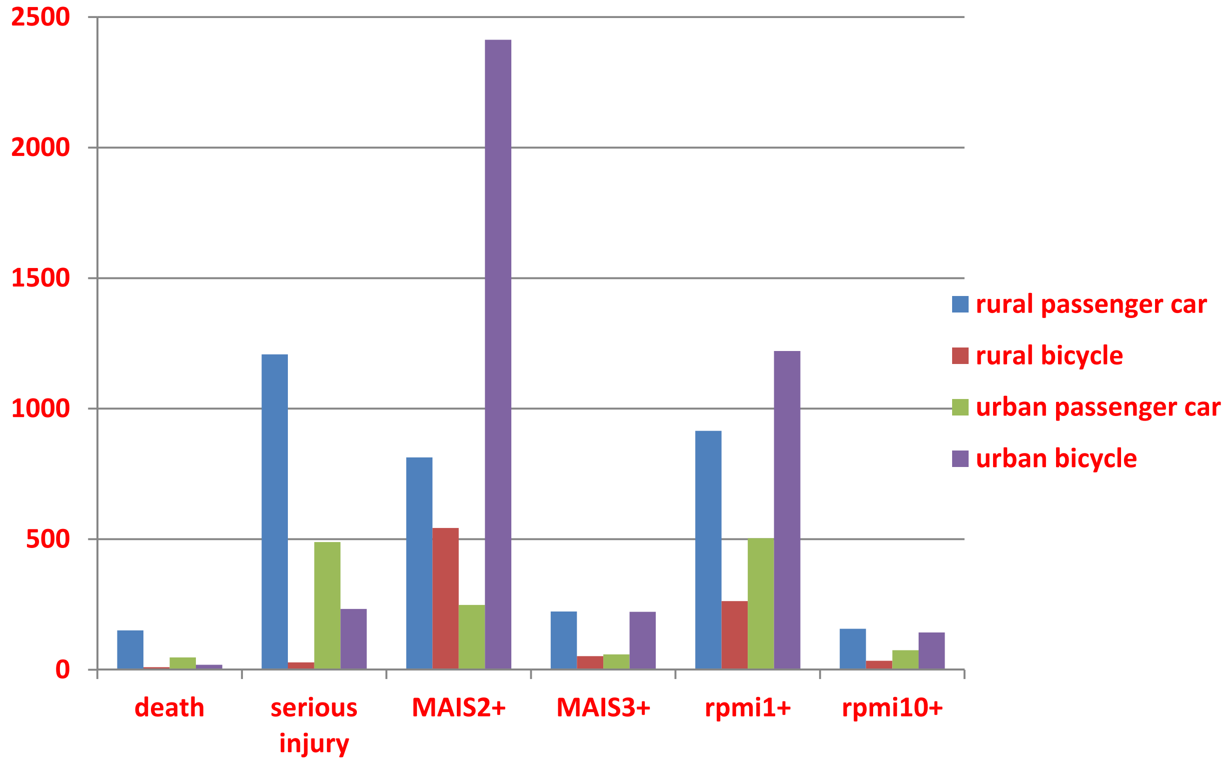

Fig. 6. Number of injured in Sweden in 2012 divided by car occupants and bicyclists, rural/urban location and injury classification (preliminary data)

In Figure 6, the numbers of injured car occupants and bicyclists divided by injury classification and by rural and urban location are shown. The distribution differed substantially depending on injury classification. Based on police-reported serious injuries car occupants in rural areas were indicated as the most critical category, while bicyclists in rural areas made up a very small group of those seriously injured. On the contrary, bicyclists injured in urban areas completely dominated the MAIS 2+ injury classification. For both PMI 1+ and 10+, bicyclists injured in urban areas also comprised a large group. The urban environment as a whole was noted as a problem area for both MAIS 2+ and injuries leading to PMI.

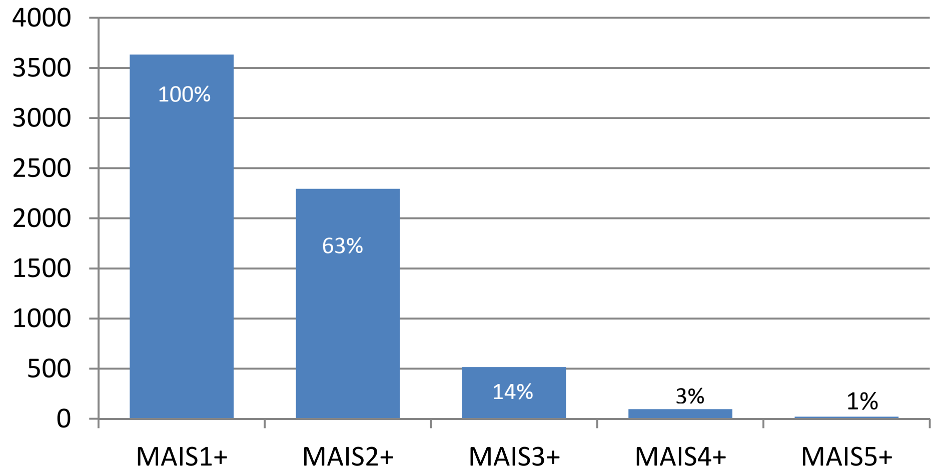

Fig. 7. Number of injured by MAIS and the associated proportion impaired at PMI 1+ for each MAIS level, for year 2012

Figure 7 shows that MAIS 3+ injuries only identified 14% of all cases leading to long term consequences (PMI1+). When MAIS 2+ was used, this proportion increased to 63%. This shows that it was critical to choose a specific injury severity level in order to pick up long term consequences of injury. Thirty seven per cent of the injuries leading to long term consequences were only at the AIS 1 level. The picture would of course change if PMI 10+ was the chosen impairment level.

V. DISCUSSION

A systematic approach is needed to meet the challenge of improving road safety [5]. Such an approach should include a link between targets and actions. Actions are expected to be planned and executed so that goals can be reached. This currently appears acceptable [2, 5, 17-18].

It can be assumed that traffic safety measures will be directed to areas with clearly identified major traffic safety problems. This study shows that the problem scenario will vary significantly depending on the injury measure used for follow-up. The problem scenario will guide priorities towards road user groups and locations, such as from urban to rural. The problem scenario will also guide selections of road traffic safety performance factors.

Targets have been set for fatalities for many years and results have been promising with a substantial reduction of fatalities [7]. There has been a systematic reduction in those road user groups and crashes posing risks for death. The EU Commission has now proposed a target for MAIS 3+ injuries along with a proposal on how data can be obtained to monitor the progress of anticipated injury reduction across all EU member states [9].

In a simple situation, targets and actions to reduce and eliminate deaths in road traffic crashes would also address injuries classified as targets for reduction and elimination. This seems, however, to be only partly true. The predictive validity to reduce deaths and serious injuries or long-term consequences are, for some road user groups, in fact quite limited, possibly resulting in significant injuries not gaining the attention they deserve.

Another important issue is how injuries are classified in terms of severity and outcome. It is well known that different classification systems lead to different priorities. The AIS scale and its derivatives are mainly based on a threat-to-life approach, while other systems such as RPMI [13] are linked to long-term consequences. In this study, both classification and level of severity were analysed on a national data set with the aim of seeing the consequences of a nation expressing its targets differently.

Target setting based on long-term consequences requires a predictive measurement to evaluate injury outcome in the same time frame as diagnoses become known. There are several ways of measuring long-term injury outcome, for example, the Functional Capacity Index (FCI) based on AIS diagnoses or societal cost-related scales such as the Injury Cost Scale (ICS). RPMI, which has been used in this study, is based on a national system where pain and physical and/or mental dysfunction are assessed by medical specialists in the absence of internationally accepted measurements. However, there is a need for a validated, predictive, long-term consequence measurement.

The results showed that, depending on scaling methods, the picture varied to such an extent that completely different strategies for prevention would be anticipated. The results also showed that the conclusions drawn from historical trends would differ substantially.

No doubt, concentration on deaths, meaning that car occupants are prioritised, has produced results. There has been an almost 50% reduction of such deaths in Sweden over a short period (2007-2012). This is an indicator that targeting and choosing priorities is meaningful and successful. Using the police definition of "serious injury" to monitor the progress of car occupants presented a different picture with a proportionally smaller reduction than for deaths.

Injury reports based on hospital data, particularly those concerning MAIS 3+ injuries as well as those with a high severity of impairment (PMI 10+), revealed a quite different picture than injuries reported by the police. In hospital data the number of injured car occupants dropped by 44% (MAIS 3+) and 50% (PMI 10%), respectively. These Swedish results, indicating that MAIS 3+ injuries were reduced by the same magnitude as fatalities between 2007 and 2012, makes it less logical to set a lower injury target than the fatality target. As high injury levels are often life threatening, it is not surprising to find similarities. What is effective in fatal injuries is highly likely to be so even for life-threatening injuries. Thus, a rational conclusion is that injuries to car occupants are already well addressed. The use of MAIS 3+ injuries and fatalities as the only instrument to guide actions would result in a potential risk for neglecting problems that might lead to impairments. MAIS 3+ injuries only address a small portion (14%) of predicted impairments. MAIS 2+ injuries would, on the other hand, cover over 60% of all long-term consequences. However, strain injuries to the spine (AIS 1) that relatively often lead to loss of health [19-20] would not be prioritized; and they obviously include a significant proportion of the long-term consequences. Long-term consequences arise from injuries at an AIS 1 level in 37% of the cases.

Insurance claims represent a higher amount of at least AIS 1 injuries, especially cervical strain injuries, compared to hospital data. Approximately half of all injuries in car collisions are reported as cervical strain injuries compared to a quarter of injured car occupants attending hospital [13-14]. This implies that the results of this study are probably underestimated when comparing the number of AIS 1 and AIS 2 injuries leading to long-term consequences with the more severe levels of AIS. The resulting impairment from an injury reported to the insurance system could however differ from an injury resulting in a hospital admission.

What seems to be a serious effect of the current concentration on deaths and the poor data coverage of some crash types is the low priority given to bicyclists, particularly in urban areas. While this road user group is seldom fatally injured, bicyclists in fact dominate the category of less severe injuries (MAIS 2+) reported to hospitals in Sweden. No doubt bicyclists make up the road user group most common in terms of injuries. Their injuries often occur in urban areas, but are also common outside urban areas. It is important for this group that data beyond fatalities as reported by the police are used to guide systematic and effective traffic safety actions. It is also essential to retain high quality injury data from the medical system to identify priorities for all road user groups as is demonstrated here for bicyclists. No doubt the relative magnitude of injured bicyclists would vary across nations, but the difference between police-reported serious injuries to bicyclists and the hospital data is striking.

The selection of a target is guided by the injury measure chosen. There is a tendency in modern traffic safety work to use fatalities and long-term health losses as outcome measures. A decision to change focus is an ethical question and best based on firm knowledge of the potential effects of the change. A reasonable standpoint is to use the AIS as this coding could be used for both a threat-to-life approach as well as for forming the basis of impairment scaling.

VI. CONCLUSIONS

In conclusion, the use of detailed injury data, particularly if the data source is hospital admissions or emergency room visits, would add a dimension not covered if only fatalities are used. Bicyclists in particular would be highlighted. To have a common definition of serious injury across the EU is positive. However, the cut off at the relatively high injury level identified by MAIS 3+ might lead to some frequent injuries that are the cause of long-term consequences to be either neglected or given less attention. A strong recommendation is to consider all injuries from AIS 2 or higher. This will no doubt incorporate injuries that are a threat to life as well as a threat to health in a long-term perspective. As a complement to AIS 2+, some diagnoses on the AIS 1 level that often lead to long-term consequences should also be considered in setting targets and priorities, and in monitoring changes. While target setting is a complex issue in itself, there is no obvious reason to have a lower ambition when setting a target for MAIS 3+ injuries than for fatalities.

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