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Thematic Report

PROVISION FOR VULNERABLE ROAD USERS (PEDESTRIANS AND CYCLISTS) AND ASSESSMENT OF THE POTENTIAL FOR DEDICATED INFRASTRUCTURE PROVISION AND POLICY ATTITUDES TOWARDS DEDICATED PROVISIONS FOR VRUS IN THE DANUBE REGION

RADAR – Risk Assessment on Danube Area Roads

https://www.interreg-danube.eu/radar

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2.65	05.06.2020.	Report consolidated and finalised based on the analysis of inputs provided by experts. Final conclusions and recommendations are also included.	Marko Ševrović, EIRA Bojan Jovanović, FPZ Sanja Leš, FPZ

Abbreviation list

AIS	Abbreviated Injury Scale
DSS	Decision Support System
EU	European Union
RAP	Road Assessment Programme
RSEG	Road Safety Expert Group
SRS	Star Rating Score
VRU	Vulnerable Road User
WHO	World Health Organization

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1. Introduction

This report gives overview of the leading causes and the main types of fatal and serious road traffic accidents involving pedestrians and bicyclists and provides the information about existing methodologies which are currently used in the selected EU and Danube region countries for identifying the high-risk locations for Vulnerable Road Users (VRUs) on the road network as well as for defining and implementing the appropriate countermeasures in order to reduce the number of pedestrian and bicyclist casualties across the observed road network.

The report also gives insight into key results and conclusions drawn from the relevant Case Studies and Projects, primarily related to the safety of vulnerable road users (pedestrians and bicycles), which were recently performed or are currently underway in the EU countries, gives the information about relevant EU legislative framework and defines the best ways for improving the road safety for pedestrians and bicyclists.

Finally, the informations obtained based on the analysis of relevant methodologies, Studies and Projects are used to select the appropriate methodologies for assessing the road safety and define appropriate countermeasures for vulnerable road users, which can be used in order to provide the implementation-ready road layout concept plans and designs that will effectively reduce road risks for pedestrians and bicyclists on the Danube road network. In this sense, this report provides the key inputs for the drafting and adoption of the Danube Infrastructure Road Safety Improvement Strategy (DIRSIS) and Danube Infrastructure Road Safety Improvement Action Plans (DIRSIAP). Implementation of Safety Improvement Strategy (DIRSIS), complemented with higher knowledge and the common use of best practice methodologies and tools in the different countries, will result in reduced deaths and serious injuries for all road users.

Thematic Area 2 Report: Provision for vulnerable road users (VRUs) primarily focuses on locations where successful countermeasures for VRUs have been implemented and locations where the best opportunities exist to implement future countermeasures, i.e. locations where there is pedestrian or cycling activity but no footway or cycle provision and where pedestrian crossing facilities are absent or of poor quality.

RADAR project aims to increase the road safety in the Danube region by contributing to the establishment of safer transport network which enables safe transport accessibility and mobility for all road traffic participants, both in urban and rural areas. One of the main goals of the RADAR project is to promote active mobility for all, making cities and human settlements inclusive, safe, resilient and sustainable, by improving road safety especially for vulnerable road users and consequently increasing the trips done on foot and by bicycle where before was not possible. In order to reach this goal, it is, among other things, necessary to tackle the problem of high rates of casualties among vulnerable road users, particularly on the regional and tertiary road network where high pedestrian and bicycle activity is present. This can be done by enhancing transnational cooperation and exchange of best practice among Project Partners in the Danube region.

Results obtained in the relevant road safety assessment projects clearly show that risk of fatal and serious traffic accident occurrence is unacceptably high on a large pats of Danube road network. The number of killed and seriously injured persons in road traffic accidents on the most of Danube region countries is significantly higher than the EU average. This is particularly true for vulnerable road users, which are on large parts of observed road network directly exposed to motorised traffic due to the lack of adequate pedestrian and bicyclist infrastructure. For

example, the results of the SENSoR project showed that 93% of the roads with speed limit of 40 km/h or more do not have footways, regardless of the fact that high pedestrian activity was observed along the road. It was also determined that 97% of roads where significant number of bicyclists was observed had no dedicated provision for cyclists. Besides that, many locations within Danube region do not have sufficient provision for pedestrians on their way to school. The provision for pedestrians and bicyclists is often of poor quality or absent. Many lives can be saved by implementing the appropriate countermeasures primarily on roads that pass through urban areas or villages where vehicles travel at high speed, but pedestrian/cyclist infrastructure is lacking or of poor quality or there is no appropriate segregation between motorised and non-motorised traffic.

High rates of casualties among vulnerable road users on Danube roads are mainly the result of the fact that most of the countries within Danube region lack professional capacity and knowledge in using appropriate road risk assessment methodologies in the process of defining, selecting, prioritizing and implementing the appropriate countermeasures on the critical parts of the road network. It is therefore necessary to transfer this knowledge to the responsible road safety organisations in the Danube area, so that they can identify and systematically reduce the risks on their road networks. Based on their participation in the project activities, the Danube region road safety experts will be obtain additional knowledge and experience necessary to better identify the critical road network sections for vulnerable road users as well as to develop optimal investment plans which, if implemented, will ensure the maximum reductions in the number of vulnerable road users fatalities and serious injuries in their own Countries.

2. Vulnerable road users accidents characteristics

2.1. Pedestrian Accidents: Overall Figures

Each year, road traffic accidents take over 1.35 million lives over the world [1], whereby pedestrians, depending on country, typically constitute from 22% to 33% of all road deaths. The proportion of pedestrians killed in relation to other road users varies significantly over the main geographic regions in the world. For example, in the African Region 39% of all road fatalities include pedestrians, while in South-East Asia Region pedestrians constitute about 13% of all road traffic accident fatalities. From the geographic distribution of pedestrian mortality, it is evident that, with the exception of Eastern Mediterranean and Western Pacific Regions, there is a much greater proportion of pedestrian fatalities in low and middle-income countries than in high income countries. This statistics become even more alarming, considering the fact that in many countries over the world road accidents involving pedestrians are poorly reported, so the actual number of pedestrian fatalities is probably even higher than numbers shown in official statistics.

The road accident data available in the CARE database show that pedestrian fatalities in EU28 constitute approximately 22% of all road deaths (Figure 1.)[1]. The pedestrian fatalities have second largest proportion in total number of road traffic accidents just after passenger car occupants (45%) and motorcyclists categories (18%). Among European countries, only Romania, Latvia, Slovenia and Poland have significantly higher proportions off pedestrian deaths in the overall fatalities (38%, 37.5%, 34% and 34%, respectively).

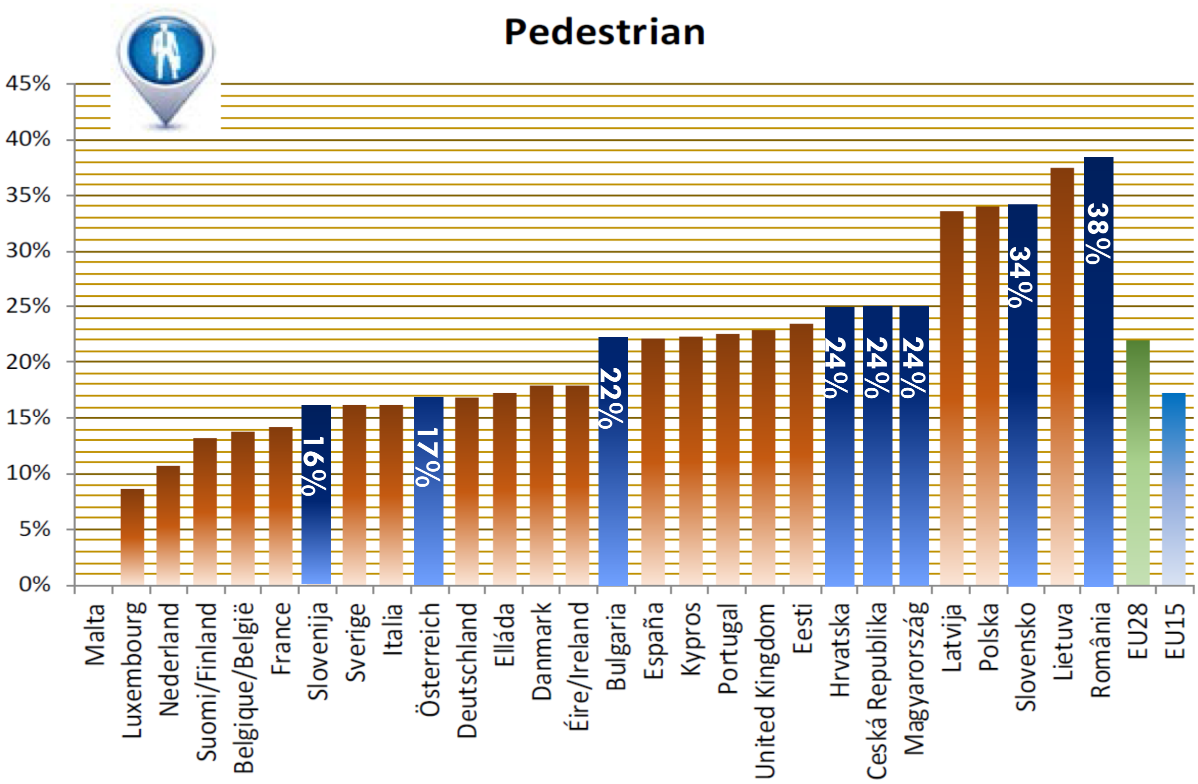

Figure 1.: Proportion of pedestrian fatalities in European countries. Source: edited by authors based on [2]

[1] Danube area countries, for which data is available, are marked with blue colour on graph.

According to the European Commission factsheet Traffic Safety Basic Facts 2018 for pedestrians: "*During the decade 2007-2016, in the European Union, pedestrian fatalities were reduced by 36%, while the total number of fatalities was reduced by almost 41%. Figure 2 shows the trend of the number of pedestrian fatalities over the period 2007-2016 in comparison with the respective trend of total road fatalities over the same period.*"

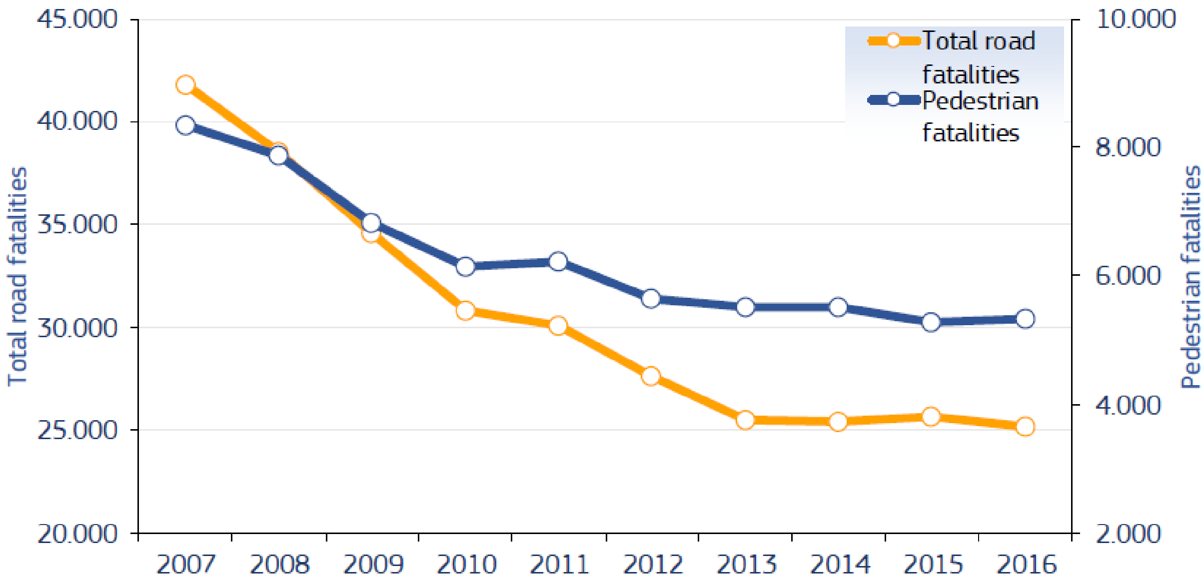

Figure 2: Number of pedestrian fatalities and all road fatalities, EU, 2007-2016. Source: [3], European Commission, retrieved from CARE database, data available in May 2018

"While the percentage of pedestrian fatalities in the EU decreased over the decade 2007-2016, the respective percentage of all road fatalities had a slightly increasing trend, as shown in Figure 3. The rate of pedestrian fatalities per million population is highest in Eastern European countries" (Figure 4.).

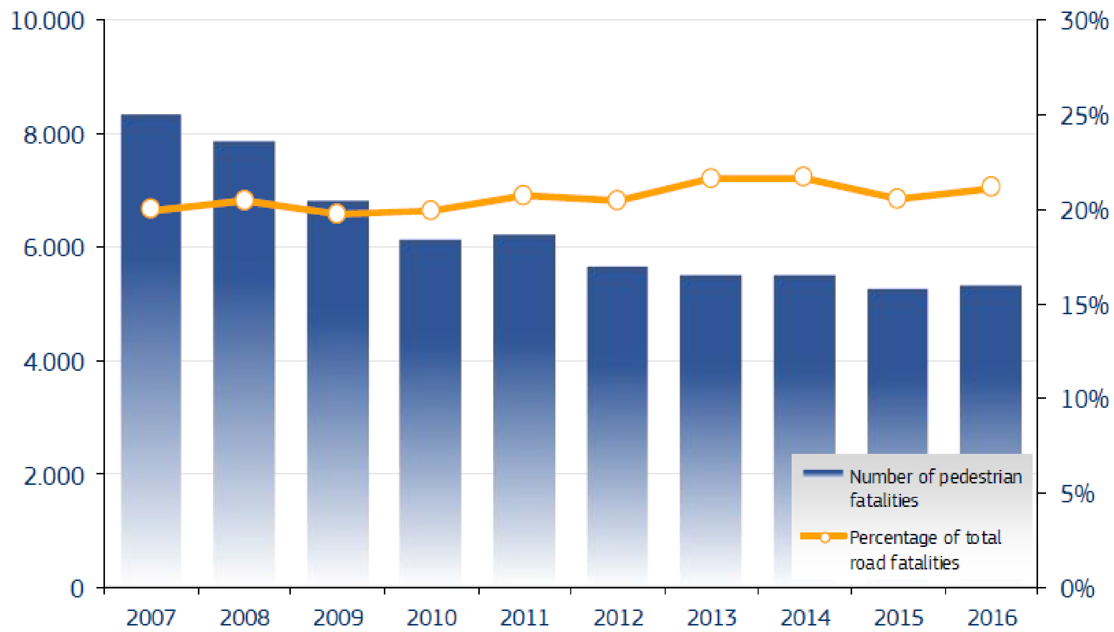

Figure 3: Number of pedestrian fatalities and percentage of all road fatalities, EU, 2007-2016. Source: [3] European Commission, retrieved from CARE database, data available in May 2018

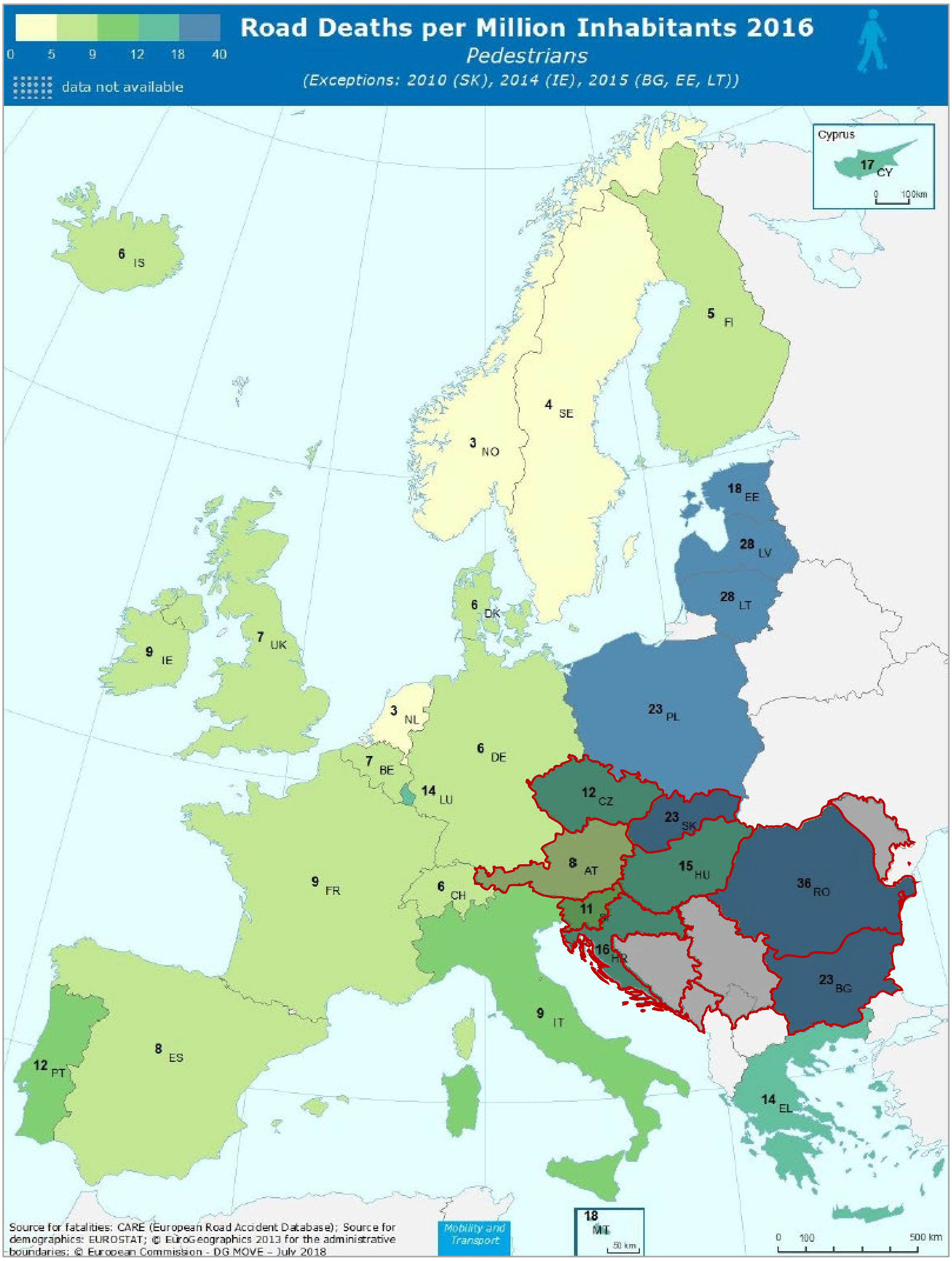

Figure 4: Pedestrian fatality rates per million population by country[2]. Source: edited by authors based on [3]

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[2] Borders of Danube area countries involved in RADAR project are marked with red colour on the map.

2.2. Cyclists Accidents: Overall Figures

The average proportion of cyclists fatalities in the overall number of fatal road traffic accidents in the world is about 4%. The geographic distribution of cyclist fatalities shows similar characteristics almost in all main regions across the world, with the exception of Western Pacific Region, which has somewhat higher proportion of cyclist deaths (7%). The road accident data available in the CARE database show that cyclist fatalities in EU28 constitute approximately 8% of all road deaths (Figure 5.)[3]. The Nederland, Denmark and Slovenia have highest rate of cyclist fatalities among the European Union countries (respectively 24%, 17% and 13% of the total road fatalities).

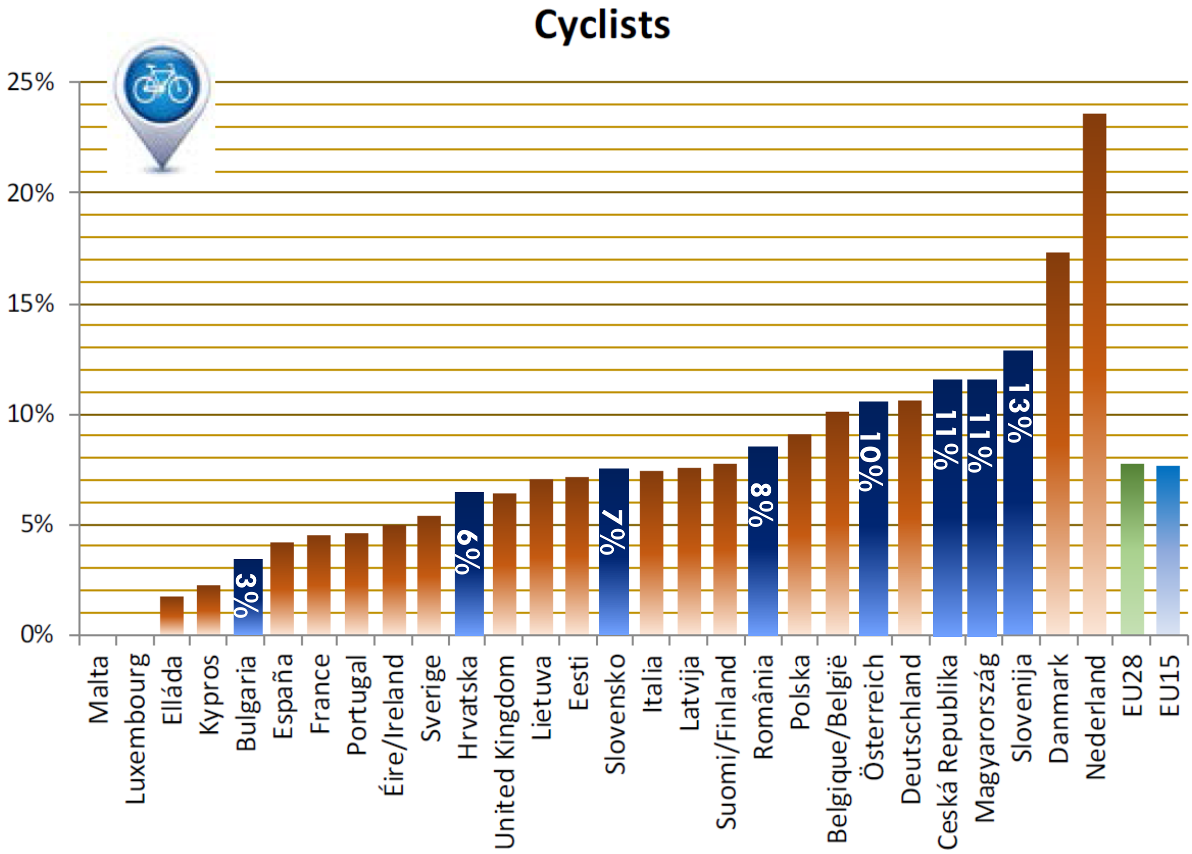

Figure 5: Proportion of Bicyclist fatalities according to European countries. Source: edited by authors based on [4]

Figure 6 shows both the number of cyclist fatalities and the number of all road fatalities in the EU between 2007 and 2016. According to the European Commission factsheet Traffic Safety Basic Facts 2018 for cyclists: "*In this period the decrease of bicycle fatalities was 24%. Figure 7 shows the number of cyclist fatalities and the percentage of all road fatalities in the EU between 2007 and 2016. In this period there was a decrease of 24% in the number of cyclist fatalities. The percentage of cyclist fatalities of all road fatalities increased from 6% in 2007 to 8% in 2016. Romania, Lithuania and Hungary had the highest cyclist fatality rates per million population in the EU 2016. Estonia, Cyprus and Spain had the lowest cyclist fatality rates per million population in the EU 2016 (Figure 8.).*"

[3] Danube area countries, for which data is available, are marked with blue colour on graph.

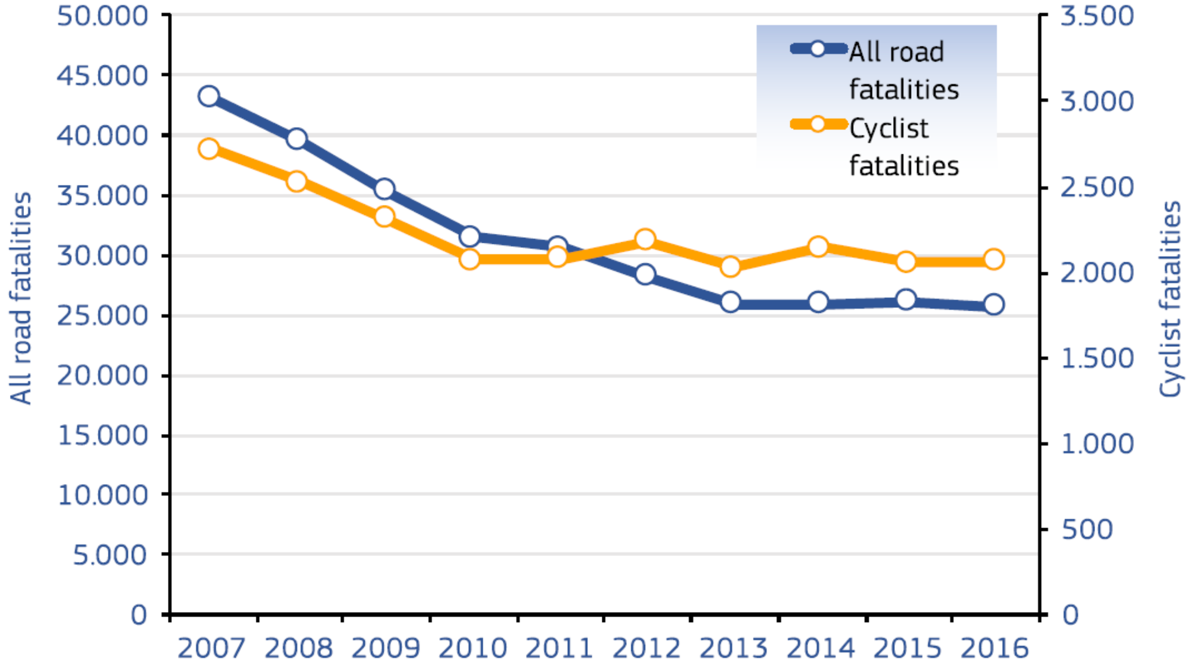

Figure 6: Number of cyclist fatalities and all road fatalities, EU, 2007-2016. Source: [5], European Commission, retrieved from CARE database, data available in May 2018

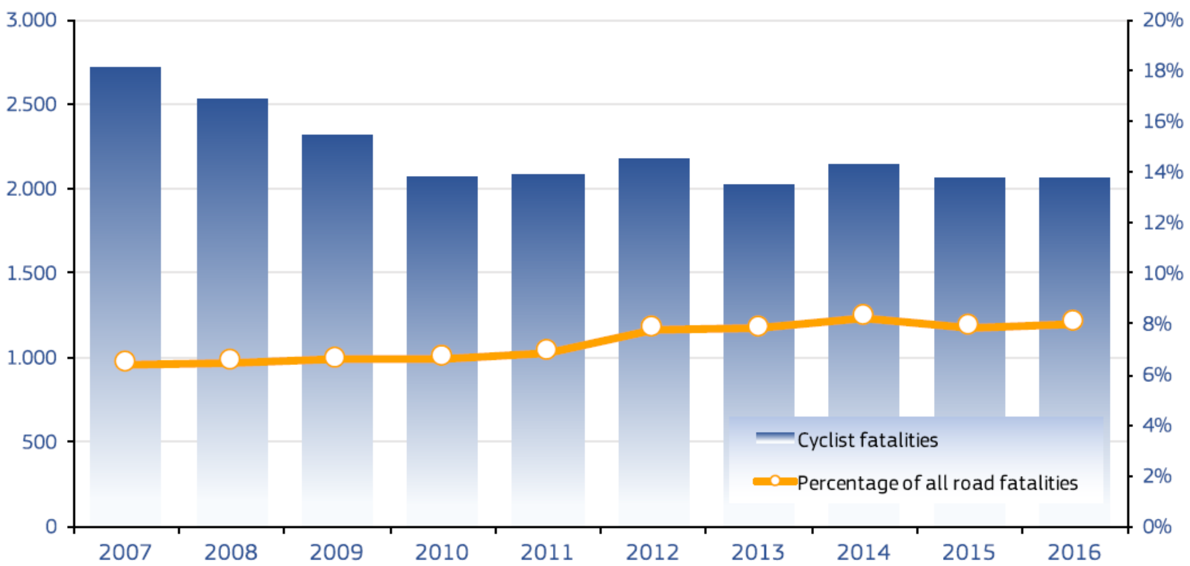

Figure 7: Number of cyclist fatalities and percentage of all road fatalities, EU, 2007-2016 or latest available year. Source: [5], European Commission, retrieved from CARE database, data available in May 2018

Figure 8: Cyclist fatality rates per million population by country[4]. Source: edited by authors based on [5]

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[4] Borders of Danube area countries involved in RADAR project are marked with red colour on the map.

2.3. Characteristics of vulnerable road users crashes in EU countries

According to the European Commission document SafetyNet Pedestrians & Cyclists: "*The trends for the number of fatalities among pedestrians and cyclists in Europe show that since 1980 both numbers have decreased by about 65 and 55% respectively. However, of all traffic fatalities, the proportion of pedestrian fatalities is still about 17%, and the proportion of cyclist fatalities is about 6%. Age groups that have the highest percentage of pedestrian fatalities are children younger than 10 years of age and adults aged 65 years or older. Cyclist fatalities have the highest share among children between 6 and 14 years of age. The percentages o9f fatalities for these age groups are about twice as high as the average percentages for all age groups.*

Looking at the reductions since 1980 for each country separately, it turns out that the reductions in the number of pedestrian fatalities varied between 35 and 75%, the smallest reduction having taken place in Greece and the largest in Germany, France, the Netherlands, and Austria. National trends in the number of cyclist fatalities were much more unstable. Some trends even showed a temporary increase in the number of fatalities among cyclists (Austria, Denmark, Hungary, Ireland, Norway, and Spain). Nevertheless, in most countries the number of cyclist fatalities eventually decreased gradually. Reductions varied between 15 and 75%, the smallest reduction having taken place in Hungary and Spain and the largest in France, Ireland, and the Netherlands."

Figure 9 shows index figures (1980=100) indicating the extent to which the mean number of fatalities in 16 European countries decreased and the extent to which the mean number of car kilometres travelled in 9 of those countries increased since 1980.

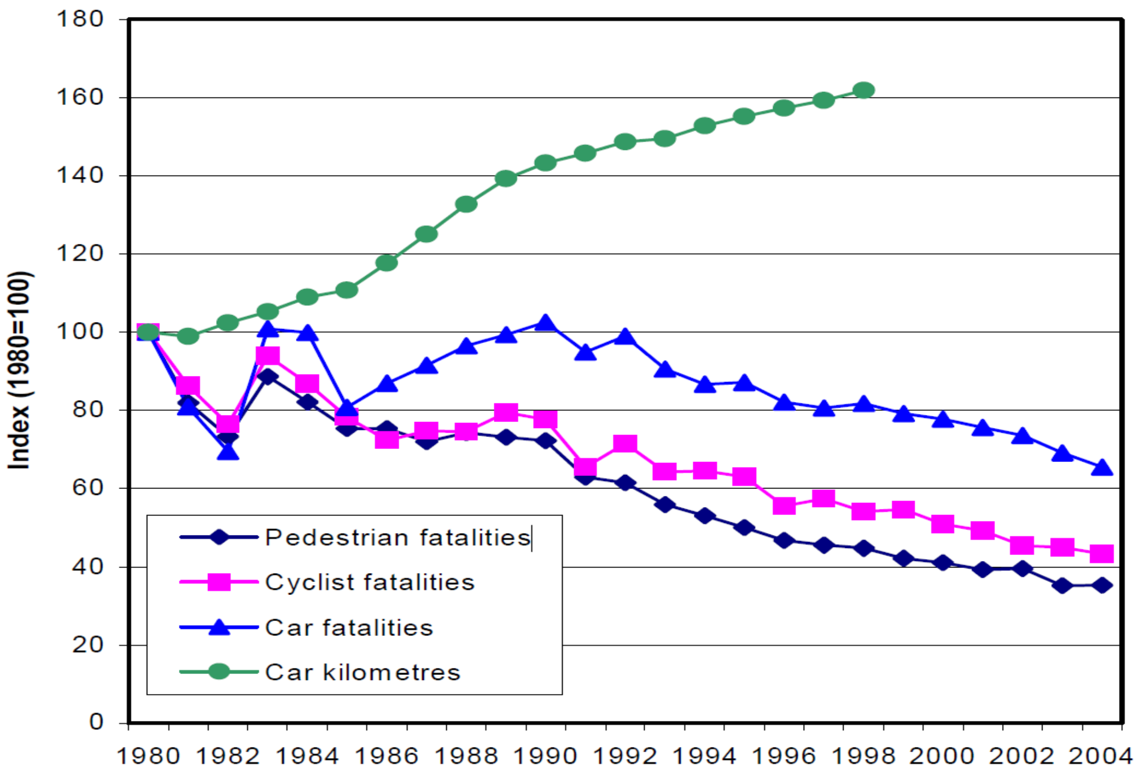

Figure 9. Index numbers of average number of pedestrian, cyclist and car fatalities in 16 European Countries and index numbers for average number of car kilometres in 9 of those countries. Source: European Commission, SafetyNet (2009) Pedestrians & Cyclists, IRTAD data, retrieved 28.08.2019

European Commission document SafetyNet Pedestrians & Cyclists and Traffic Safety Basic Facts 2018 pedestrian and cyclist factsheets also provides the following basic facts related to vulnerable road users in EU countries [3], [5]:

- *"Of all journeys in EU countries, 20-40% are travelled by cycle or on foot. Walking is particularly important for children below the age of 12 and adults aged 75 and above. The bicycle is used most frequently by adolescents (12-17 years of age);*
- *12-30% of all trips is made by walking. For short trips under 5 km, the share of walking is higher, with a maximum of 45%. The average length of walking trips varies from just under 1 km to 2.8 km;*
- *About 15-30% of all person kilometres walked is for shopping purposes. Home-leisure trips cover about 30-55% of the person kilometres;*
- *3-28% of all trips are made by cycling. For short trips under 5 km, the share of cycling varies from 12% to 39%. The average trip length for cycling is around 3 km in most European countries;*
- *The bicycle is used for short trips to shops and for leisure purposes. Between about 30 and 40% of the person kilometres by bicycle is travelled on home-work trips. Home-leisure trips cover about 20-45% of the person kilometres;*
- *Most fatalities, severe and slight injuries to pedestrians and cyclists occur in urban areas. However, in rural areas, the percentage of fatalities is larger than the percentage of slight injuries [8].*
- *Motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians and cyclists [6][7]. More than average crash opponents are: cars for young pedestrians, and heavy vehicles (vans and lorries) for young cyclists.*
- *Almost one third of the severely injured cyclist casualties occur in the well-known crash scenario where the cyclist is in the blind spot of a lorry turning right.*
- *Crashes involving pedestrians and cyclists occur frequently at facilities designed for pedestrians and cyclists such as pedestrian crossings, cycle tracks, and cycle lanes. This means that these facilities are not necessarily good enough to prevent crashes. However, pedestrian crossings might also be the location at which roads are most often crossed.*
- *The change in the number of pedestrian fatalities from 2007 to 2016 by age group is presented in Figure 10. Age groups that have the highest percentage of pedestrian fatalities are children younger than 10 years of age and adults aged 65 and above. About 35 to 40% of the fatalities in these age groups were pedestrian fatalities; twice as much as the average percentage for all age groups. Cyclist fatalities have the highest share among children between 6 and 14 years of age. About 14% of the fatalities in this age group were cyclist fatalities; twice as much as the average percentage for all age groups. Children between 10 and 14 years of age also have the highest percentage of cyclist casualties: 30% of the casualties in this age group were cyclist casualties.*
- *Figure 11 indicates that over the period 2007-2016, there has been a marked reduction in cyclist fatality numbers across almost all ages in the EU countries. The least reduction occurred for cyclists aged over 75, the most visible one refers to cyclists aged between 12 and 17 and between 65 to 70 years.*
- *Pedestrian crashes occur most often whilst crossing the roadway, especially for older pedestrians. Of the elderly, 75% of pedestrian fatalities died as a result of a crash whilst crossing the road. Of these, 38% were crossing the road at a pedestrian crossing Pedestrian crashes often occur when people are trying to cross the street on links outside pedestrian crossings or where no pedestrian crossings exist. One of the causes is the driver's difficulty in perceiving pedestrians because of darkness and/or parked cars.*

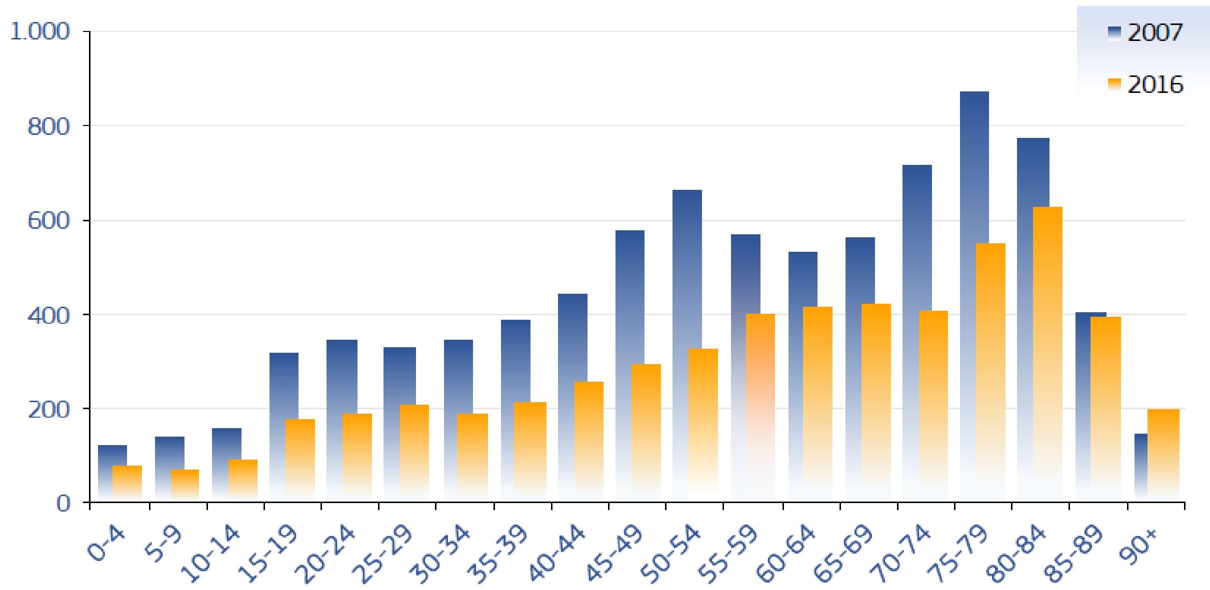

Figure 10: Number of pedestrian fatalities by age group, EU, 2007 and 2016 or latest available year. Source: European Commission, retrieved from the CARE database, data available in May 2018

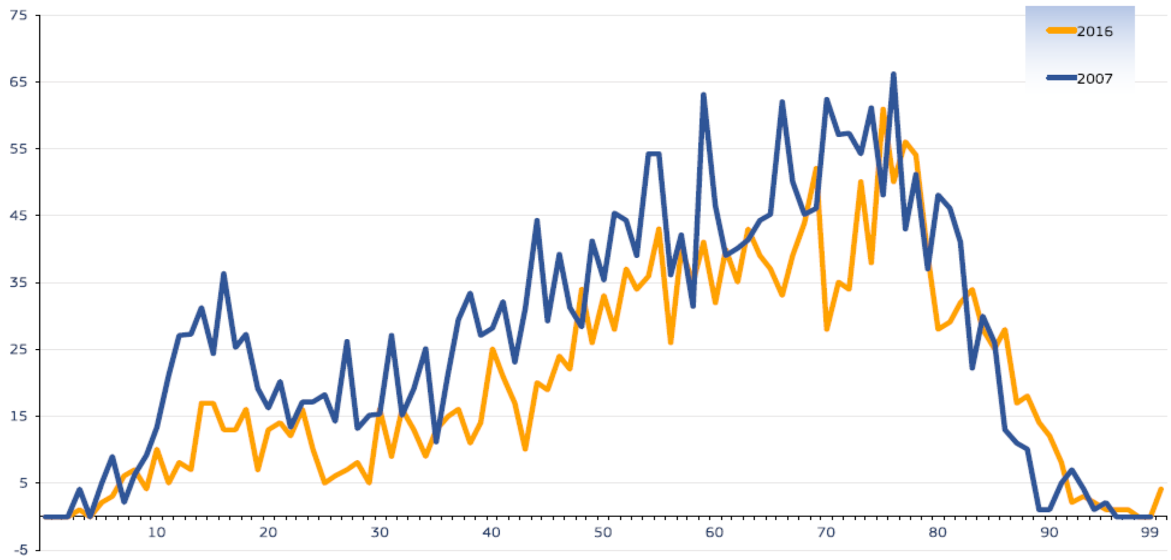

Figure 11: Number of cyclist fatalities by age, EU, 2007 and 2016. Source: European Commission, retrieved from the CARE database, data available in May 2018

- *Inverse relationship exists for the number of pedestrians or cyclists crossing at intersections. Summersgill et al. [9] have shown that for pedestrians crossing at intersections, increasing pedestrian flows result in lower crash rates per crossing pedestrian [10][11].*

Certain types of crashes are underreported

Pedestrian and cyclist crashes are heavily and disproportionally underreported in the police crash statistics compared to what hospital records and other studies show [8][6]. "*Data from EU countries clearly show that the amount of under-representation becomes larger as the victim's transport mode changes from passenger car to cyclist. The level of under-representation also increases as injury severity decreases. For all severities, casualties among cyclists are far less reported in comparison with casualties among other road users.*"

2.4. Characteristics of vulnerable road users crashes obtained in SafetyCube project

SafetyCube (Safety CaUsation, Benefits and Efficiency) *was a research project funded by the European Commission under the Horizons 2020, the EU Framework Programme for Research and Innovation, in the domain of Road Safety. The project started on May 1st, 2015 and ran for a period of three years. The primary objective of the SafetyCube project was to develop an innovative road safety Decision Support System (DSS) that will enable policy-makers and stakeholders to select and implement the most appropriate strategies, measures and cost-effective approaches to reduce casualties of all road user types and all severities in Europe and worldwide.*

Safetycube Scenarios: Pedestrian accidents

Pedestrian Accident is one of the seven main scenarios defined in the SafetyCube project. This scenario contains all injury accidents involving at least one pedestrian. Based on the in-depth analysis of the VOIESUR[5] database performed in SafetyCube project, it was determined that almost 2/3 of pedestrian fatalities occur when pedestrian is hit by passenger car (62%), 15% of pedestrian fatalities occur when pedestrians are hit by heavy vehicles, 11% when pedestrians are hit by light commercial vehicles and the remaining 12% of pedestrian fatalities are caused by motorcycles and other road users. Pedestrian serious injuries are mainly caused by passenger cars (69%) and motorcycles (18%). The Figure 12. shows the proportions of fatal, serious and slight pedestrian accidents in the overall number of road traffic accidents considered in the seven main SafetyCube project scenarios.

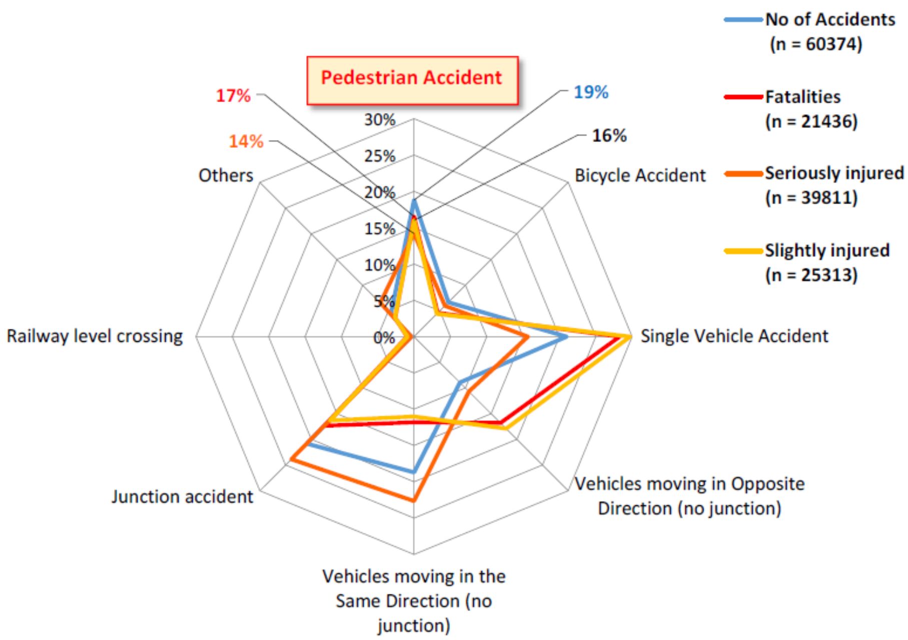

Figure 12. The proportions of fatal, serious and slight pedestrian accidents in the overall number of road traffic accidents considered in the seven main SafetyCube project scenarios. Source: [2], SafetyCube project, VOIESUR database, France 2011

[5] The figures related to road traffic accidents involving pedestrians and bicyclists are based on the VOIESUR database and concern injury accidents occurring in France during the year 2011. This database is based on an in-depth analysis of police reports. The sample is composed of all fatal accidents and 1/20 of non fatal accidents. To make this database representative at national level, weighting coefficients have been introduced. This weighting process does not take into account under-reporting by the police.

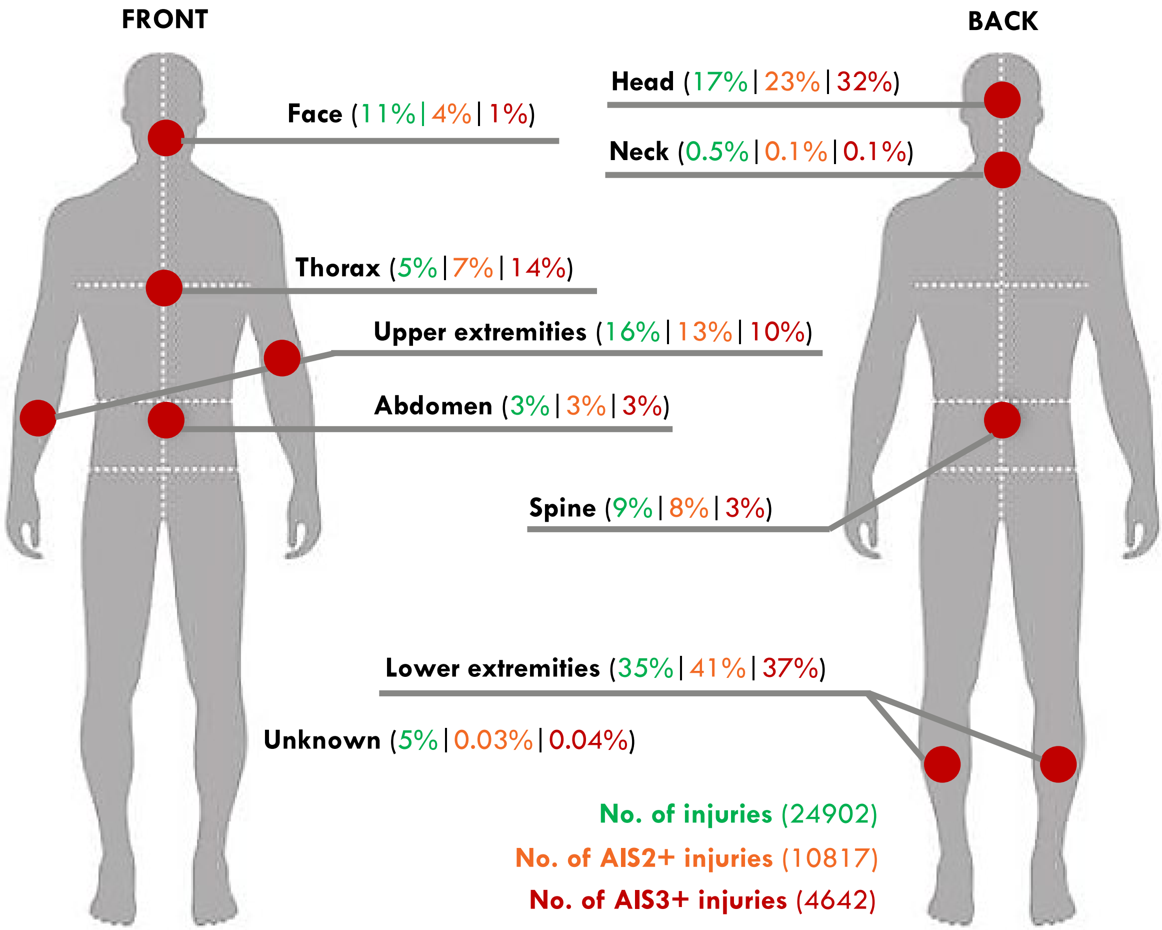

Figure 13. Relative frequency distribution of AIS[6] injuries across different body regions caused in pedestrian accidents. Source: edited by authors based on the data available in [2], SafetyCube project, VOIESUR database, France 2011

Most of the pedestrian serious injuries (injury type AIS3+) are related to lower extremities (37%), the head (32%) and the thorax (14%). For moderate pedestrian injuries (injury type AIS2+), the top three injured body regions include lower extremities (41%), the head (23%) and upper extremities (13%). Figure 13. shows relative frequency distribution of serious and moderate injuries across different body regions caused in pedestrian accidents.

Safetycube Scenarios: Cyclist accidents

Cyclist Accident is one of the seven main scenarios defined in the SafetyCube project. This scenario contains all injury accidents involving at least one cyclist. Based on the in-depth analysis of the VOIESUR database performed in SafetyCube project, it was determined that 2/3 (66%) of cyclists fatalities are caused by passenger car, 21% are caused by truck and the remaining 13% of cyclists fatalities are caused by other road users. Cyclist injuries are predominantly caused by passenger car (75%) and motorcycles (13%). The Figure 14. shows the proportions of fatal, serious and slight bicycle accidents in the overall number of road traffic accidents considered in the seven main SafetyCube project scenarios.

[6] The Abbreviated Injury Scale (AIS) is an anatomical-based coding system created by the Association for the Advancement of Automotive Medicine to classify and describe the severity of injuries. It represents the threat to life associated with the injury rather than the comprehensive assessment of the severity of the injury. AIS2+ and AIS3+ are the codes for moderate and serious injuries, respectively.

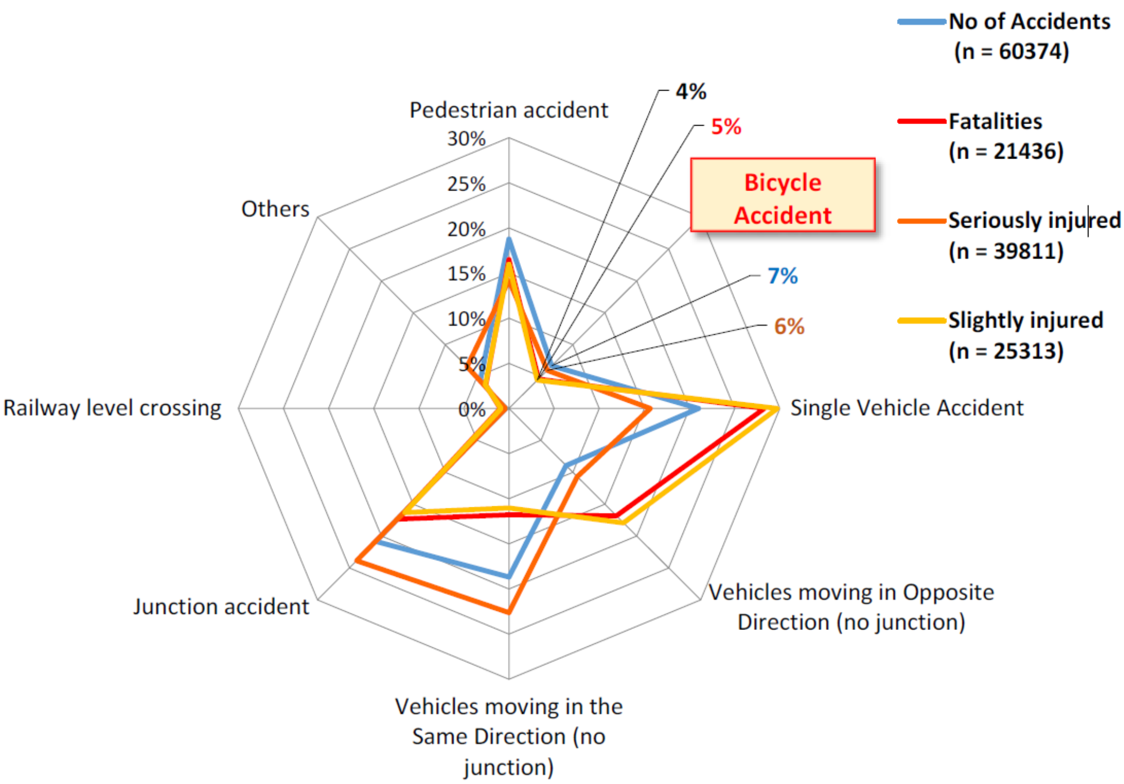

Figure 14. The proportions of fatal, serious and slight bicycle accidents in the overall number of road traffic accidents considered in the seven main SafetyCube project scenarios. Source: [4], SafetyCube project, VOIESUR database, France 2011

Most of the cyclist serious injuries (injury type AIS3+) are related to the head (30%), lower extremities (26%), and the thorax (21%). For moderate cyclist injuries (injury type AIS2+), the top three injured body regions include lower extremities (26%), upper extremities (23%) and the head (21%). Figure 15. shows relative frequency distribution of serious and moderate injuries across different body regions caused in cyclist accidents.

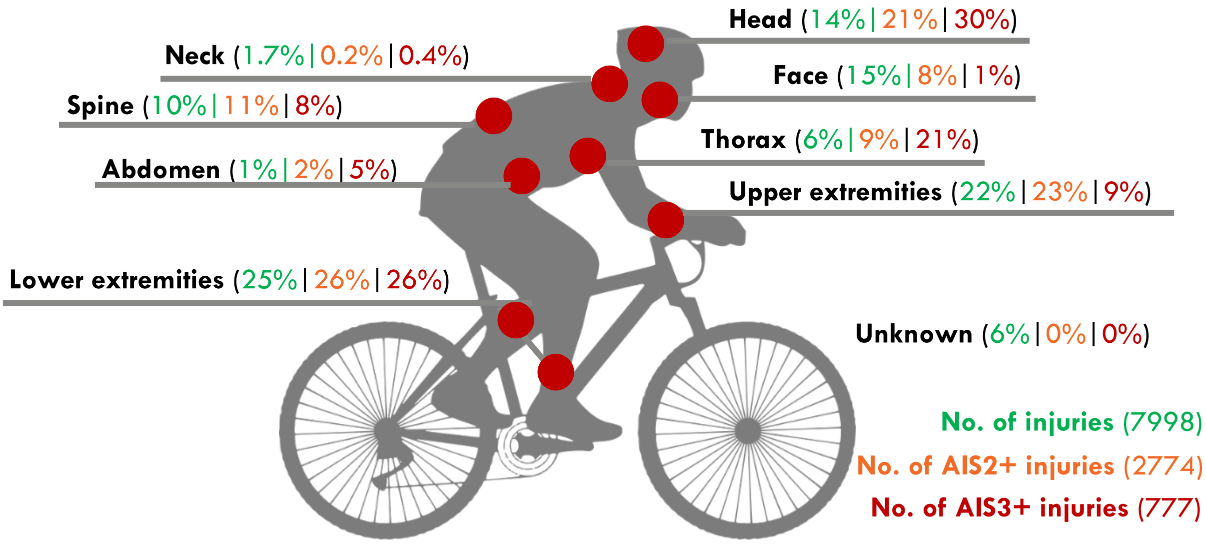

Figure 15. Relative frequency distribution of AIS injuries across different body regions caused in cyclist accidents. Source: edited by authors based on the data available in [4], SafetyCube project, VOIESUR database, France 2011

2.5. State of the art in Danube countries: Vulnerable road users accidents characteristics

Annual number of pedestrian fatalities varies significantly between countries in Danube region. Average annual pedestrian fatality rate varies from 8.2 to 16.8 per million inhabitants, with average rate of 17.9. Based on the analysis of the available data it can be concluded that during the last decade the annual number of pedestrian fatalities has reduced in most of the Danube-area countries, with the exception of Hungary which had slight growth in the number of pedestrian fatalities in the last couple of years. The reduction of pedestrian fatalities in the last decade varies between 17% and 50%, depending on the country, with average reduction of 21%.

Average number of cyclist fatalities also varies significantly among countries, with average bicyclist fatality rates ranging from 2.9 and 8.4 per million inhabitants. The overall average of annual number of cyclists killed in traffic accidents on Danube roads is 5.5 cyclists per million inhabitants per year. During the last decade the achieved reduction in the average annual number of cyclist fatalities, depending on the country, ranges between 3 to 47%, with the average reduction being 18%. The number of seriously injured pedestrians, in the countries for which data was available, is on average 8.2 times larger than the number of pedestrian fatalities. The ratio between cyclist serious injuries and cyclist fatalities is higher, i.e. 11.4 serious injuries per fatality.

Average proportion of pedestrian fatalities in the total number of road traffic accident fatalities in Danube-area countries is 27% on average, and it ranges between 16% and 38%, depending on the country. On the other hand, average proportion of cyclist fatalities is somewhat lower, i.e. 10% on average, with range from 4% to 23%. In the countries for which data was provided, with the exception of Bosnia and Herzegovina, the majority of road traffic accidents involving vulnerable road users occurs in urban areas.

The vulnerable road users age groups that are most involved in traffic accidents include children between 11 and 18 years of age and elderly aged 64 and above.

None of the countries have provided the estimates of the number of underreported pedestrian and cyclist accidents. However, the countries are aware that the underreporting issue is significantly larger for accidents involving cyclists, especially for single vehicle accidents with cyclists which are often found in the hospital data, and very seldom in the police traffic accident database. The level of underreporting significantly depends on the severity of the road traffic accident. Some of the countries recognise the need for linking the police and hospital database in order to obtain more precise data on cyclist accidents.

Most of the countries do not have the data on percentage of journeys travelled by foot and bicycle and the data on exact numbers of annual distance travelled by pedestrians and cyclists, as well as the data on their average travel time. Due to that fact, based on the available data, these countries cannot calculate the exact values of pedestrian and cyclist exposure rates expressed in the number of pedestrian and cyclists accidents per million kilometres travelled. Since this parameter gives a much clearer understanding of the risks related to vulnerable road users, and its value can be easily compared between countries, and due to the fact that it would provide additional information based on which it would be possible to improve the countermeasure selection, prioritisation and implementation process, it is important that all countries in the Danube region ensure that the data on annual distance travelled by pedestrians and cyclists as well as their travel times are periodically collected.

2.6. Road safety performance of the word's roads for vulnerable road users

The following charts present the road safety performance of the world's roads for vulnerable road users, along with the road features that elevate risk, to show the basic safety features missing from the world's roads. The presented results are based on the iRAP's Big Data Tool, Vaccines for Roads IV which includes the Star Rating Scores obtained by iRAP SRS methodology performed on the 358,000 km of roads across 54 countries in the world.

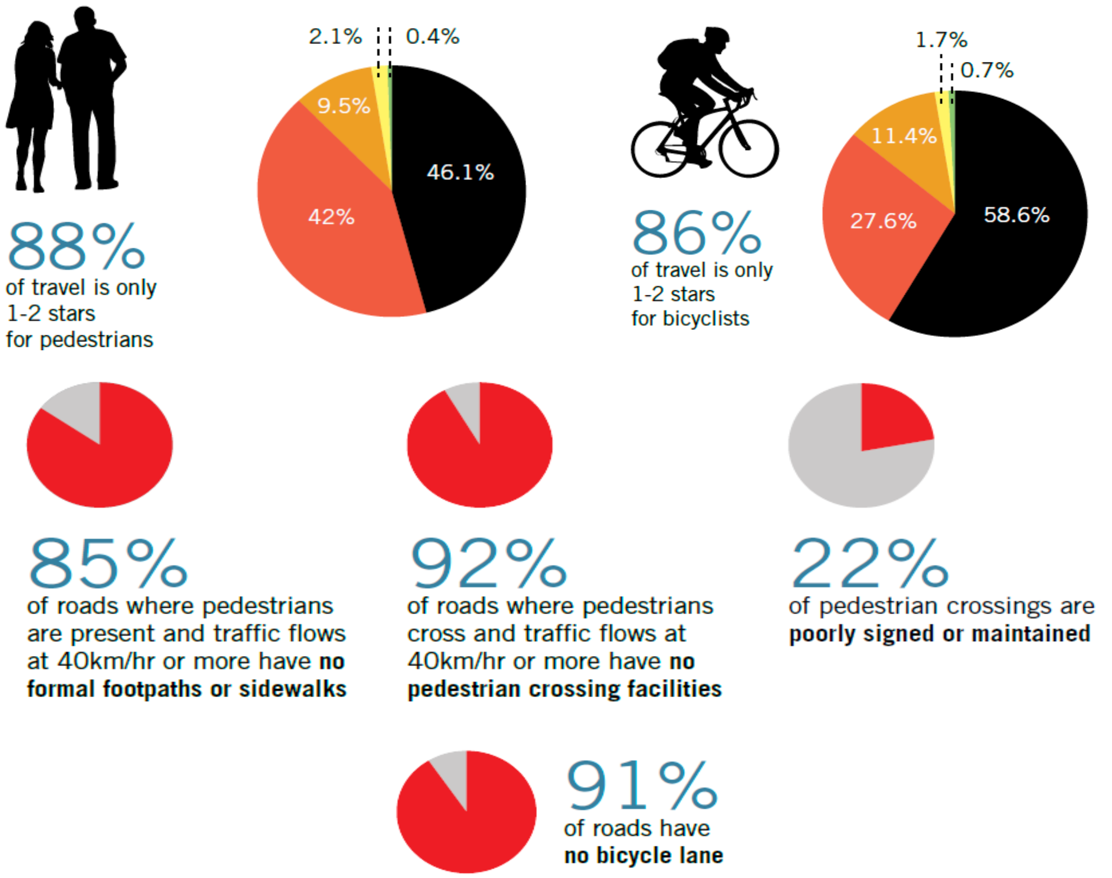

Figure 16: Road safety performance of the word's roads for vulnerable road users. Source: iRAP Vaccines for Roads IV Data Tool, year 2014

Results presented on the charts (Figure 16.) clearly show that in the pedestrian and bicyclist category, the largest part of observed road network is rated with 1 or 2 stars (88% and 86%, respectively), which indicates that most of the observed road network lack of proper provisions for vulnerable road users. The unacceptably high risks of pedestrian fatalities are primarily caused by the facts that: (1) 85% of roads where pedestrians are present and the speed of traffic flow is equal or greater than 40 km/h have no formal foothpaths or sidewalks; (2) 92% of roads where pedestrians are present and the speed of traffic flow is equal or greater than 40 km/h have no pedestrian crossing facilities[7] and (3) 22% of existing pedestrian crossings are poorly signed or maintained. The risks of cyclists fatalities are even higher since more than half of the observed road network (58.6%) belongs to the one-star very-high risk category. This is mainly caused by the fact that only 9% of the roads have adequate bicycle facilities.

[7] According to the iRAP SRS methodology, the presence of pedestrian crossing facilities is coded on all 100-meter road segments which have one or more pedestrian crossings.

2.7. State of the art in Danube countries: Road safety performance of the Danube region roads for vulnerable road users

Most of the Danube area countries do not have the precise information on the total length of their existing pedestrian and bicyclist network. Pedestrian and cyclist infrastructure is mostly build only in urban areas. Based on the results of previously performed road safety assessments and additional data delivered by some of the countries it is determined that close to 90% of the Danube roads where pedestrians are present and operating speed of vehicles in traffic flow is 40 km/h or greater, do not have formal footpaths along road. Situation is even worse for cyclists, since more than 95% of existing roads do not have appropriate provisions for cyclists. On average, each third existing pedestrian crossing on the Danube road network is poorly signed or maintained. The existing vertical traffic signage and horizontal signalisation is often missing or of poor quality. Many road sections where pedestrians often need to cross the road and operating speed of traffic flow is 40 km/h or more, do not have appropriate pedestrian crossings, so pedestrians are crossing the road on dangerous and unmarked locations. The results of previously performed iRAP SRS analysis show that pedestrians and cyclists are exposed to very high risks on about 58% and 61% of Danube roads, respectively.

Detailed data related to relevant pedestrian and bicycle infrastructure characteristics, including the: (1) total length of pedestrian and cyclist network in each country, the percentage of road network covered by pedestrian and cyclist facilities; (2) the locations, (3) types and (4) quality of existing and planned pedestrian and cyclist facilities/crossings are very important inputs, necessary for accurate identification of potential dangerous locations for vulnerable road users on the road network, calculation of individual road sections risk rates, as well as selection, prioritisation and implementation of appropriate countermeasures. Based on the delivered data, it can be concluded that majority of countries in the Danube area still lack the datasets which would provide data on relevant pedestrian and bicycle infrastructure characteristic. Therefore, this countries should develop new and/or restructure existing datasets on road network so that this information can be easily retrieved and used in future road safety assessment, studies and researches. This datasets should be periodically updated in order to provide the data necessary for performing detailed and accurate performance tracking and traffic forecasts in future periods. Relevant data contained in the road network database of each individual country should be freely available to all countries in Danube-area in order to enable simple knowledge-transfer among the countries.

The collected data as well as results and conclusions obtained based on performed projects, studies and researches related to the safety of vulnerable road users should also be freely exchanged among countries.

3. EU Legislation related to vulnerable road users

Pedestrians and cyclists are both subject to the traffic rules defined in the Vienna Convention of 1968. In some countries, additional regulations have been defined. These relate to supplementary regulations regarding mandatory equipment to ensure cyclists' visibility (e.g., pedal reflectors, spoke reflectors), standards for children's bicycle seats (e.g., seat attachment, footrests), minimum age for cycling on public roads, and helmet legislation. Special regulations for vulnerable road users are provided in the following two EU regulations:

- EU regulation 78/2009 – vehicle approval / protection of vulnerable road users
- EU regulation 631/2009 – implementing vehicle approval to protect vulnerable road users

3.1. Traffic rules and regulations for pedestrians

In addition to the rules which normally apply to all public highway users, according to the Vienna Convention, pedestrians are subject to the following specific rules defined in their national legislation in order to ensure that they can travel safely and easily [12]:

- *"If, at the side of the carriageway, there are pavements (sidewalks) or suitable verges for pedestrians, pedestrians shall use them. Nevertheless, if they take the necessary precautions: (a) Pedestrians pushing or carrying bulky objects may use the carriageway if they would severely inconvenience other pedestrians by walking on the pavement (sidewalk) or verge; (b) Groups of pedestrians led by a person in charge or forming a procession may walk on the carriageway.*
- *If it is not possible to use pavements (sidewalks) or verges, or if none is provided, pedestrians may walk on the carriageway; where there is a cycle track and the density of traffic so permits, they may walk on the cycle track, but shall not obstruct cycle and moped traffic in doing so.*
- *Pedestrians walking on the carriageway shall keep as close as possible to the edge of the carriageway.*
- *Pedestrians walking on the carriageway shall keep to the side opposite to that appropriate to the direction of traffic except where to do so places them in danger. However, persons pushing a cycle, a moped or a motor cycle, and groups of pedestrians led by a person in charge or forming a procession shall in all cases keep to the side of the carriageway appropriate to the direction of traffic. Unless they form a procession, pedestrians walking on the carriageway shall, by night or when visibility is poor and, by day, if the density of vehicular traffic so requires, walk in single file wherever possible."*
- *"Pedestrians wishing to cross a carriageway: (a) Shall not step on to it without exercising care; they shall use a pedestrian crossing whenever there is one nearby. (b) In order to cross the carriageway at a pedestrian crossing signposted as such or indicated by markings on the carriageway: (i) If the crossing is equipped with light signals for pedestrians, the latter shall obey the instructions given by such lights; (ii) If the crossing is not equipped with such lights, but vehicular traffic is regulated by traffic light signals or by an authorized official, pedestrians shall not step onto the carriageway while the traffic light signal or the signal given by the*

authorized official indicates that vehicles may proceed along it; (iii) At other pedestrian crossings, pedestrians shall not step on to the carriageway without taking the distance and speed of approaching vehicles into account. (c) In order to cross the carriageway elsewhere than at a pedestrian crossing signposted as such or indicated by markings on the carriageway, pedestrians shall not step on to the carriageway without first making sure that they can do so without impeding vehicular traffic. (d) Once they have started to cross a carriageway, pedestrians shall not take an unnecessarily long route, and shall not linger or stop on the carriageway unnecessarily."

3.2. Traffic rules and regulations for cyclists

The traffic-related rules and regulations that are applicable to cyclists can be divided into vehicle regulations, regulations regarding the use of cycle helmets, and traffic rules. According to the Vienna Convention, a cycle is a vehicle with at least two wheels that is propelled solely by the muscular energy of the person riding on that vehicle, in particular by means of pedals or hand-cranks. Furthermore, the Convention states that a cycle shall [12]:

- *"have an efficient brake, b) be equipped with a bell capable of being heard at a sufficient distance, and carry no other audible warning device, and c) be equipped with a red reflecting device at the rear, and devices ensuring that the bicycle can show a white or yellow light at the front and a red light at the rear."*

In addition to the abovementioned "conditions for the admission of cycles to international traffic", some countries such as Germany and the Netherlands have supplementary regulations regarding mandatory equipment to ensure cyclists' visibility. Examples are:

- *"One white reflecting device visible from the front. Orange pedal reflectors visible from the front and rear. Two wheel-mounted orange spoke reflectors on each wheel, arranged at an angle of 180° and visible from the side, or continuous white circular retro-reflector strips on the tyres or on the spokes of the front and rear wheels. One additional red large-surface reflector on the rear. Mudguards to prevent mud from reducing the visibility of lights and reflectors."*

In some countries, standards for accessories such as children's bicycle seats have been drawn up. These standards include requirements and recommendations regarding seat attachment, dimensions, footrests, and protection against feet coming into contact with the spokes [13].

Bicycle helmet legislation

According to data provided by European Commission: "*In some European countries, cycle helmets have become mandatory in the last few years. In Malta, cycle helmets became mandatory for all cyclists in April 2004. In Sweden, cycle helmets became mandatory for children up to 15 years of age on January 1st 2005. The same group of cyclists has to wear helmets in Slovenia and the Czech Republic. In Austria, bicycle helmets became obligatory for children up to 12 years in 2011. In Spain, cyclists have to wear a helmet outside urban areas except when going uphill [14]. The definition of precise standards without which the effectiveness of helmets cannot be guaranteed, is a prerequisite for any regulations on the wearing of helmets. Some countries have already set up such norms. The European Directive No. 89/686/EC on personal protective equipment lays down the standards which could be adopted for cyclists' helmets. The provisions for children's helmets, however, still have to be settled [13]."*

Traffic rules for cyclists

In addition to the rules which normally apply to all public highway users and in accordance with the Vienna Convention, cyclists are subject to the following specific rules defined in their national legislation in order to ensure that they can travel safely and easily [12]:

- *"Cyclists must not ride without holding the handlebars with at least one hand, must not allow themselves to be towed by another vehicle, and must not carry, tow, or push objects which hamper their cycling or endanger other road users.*
- *They must keep to the right of the carriageway (to the left in drive-on left countries) and give an appropriate arm signal when they wish to turn.*
- *In principle, cyclists may not ride more than one abreast. Some countries however introduced exceptions to this rule; for instance, cyclists may ride two abreast where the carriageway is wide enough, where cycle traffic is heavy, on cycle tracks, etc.*
- *They are required to use cycle lanes and tracks. They may not, however, use motorways and similar roads."*

"When walking and pushing their bicycles on foot, cyclists are classified as pedestrians and may therefore use the pavement [13]. The Vienna Convention prohibits the transport of passengers on bicycles, but enables the Contracting Parties to authorise exceptions. In some countries, the transport of a passenger is allowed only if he is under a statutory age limit and if the cyclist himself has a minimum age [13]. Germany has recently added new elements to its traffic code for cyclists. Since then, cyclists are allowed to ride contraflow in selected one-way streets, and in so-called bicycle streets cyclists may make use of the whole street whereas cars have to stay behind the cyclists.

Some national legislations provide that cyclists can only ride on a road after a certain age. In Switzerland, a cyclist must have at least the legal age to go to school before he can ride on a road. In Denmark, children under the age of 6 are not allowed to go by bicycle unless they are escorted by a person who is 15 years old or older. In Germany, children must be at least 8 years old with the same provisions as in Denmark. In Poland, children over 10 years must have passed a test to be allowed on a road [13]."

3.3. State of the art in Danube countries: Vulnerable road users legislation

Danube area countries which are members states of the European Union have implemented the relevant EU laws and regulations related to vulnerable road users into the framework of their national legislation. The most important regulations and directives related to vulnerable rad users, adopted by EU member states include: (1) 2008/96 EC Directive on road infrastructure safety management; (2) EU regulation 78/2009 on vehicle approval and protection of vulnerable road users; (3) EU regulation 631/2009 on implementing vehicle approval to protect vulnerable road users and (4) 1968 Vienna Convention on Road Traffic.
In addition to the relevant EU laws and regulations, individual countries in Danube region have different national laws and local regulations which precisely define the rights, obligations, rules and responsibilities of pedestrians and cyclists in road traffic, specific requirements related to design of pedestrian and cyclist facilities, safety requirements of bicycles, as well as obligations of the road safety auditors during road safety inspections and road safety impact assessments. For example, in Hungary, according to the existing laws and regulations, the road safety auditors must give a priority to safety of vulnerable road users while doing a road safety audit, a road safety inspection or a road safety impact assessment. At the design phase a special attention should be payed to the safety of pedestrians and cyclists and the location of pedestrian crossings. Children, elderly people and disabled persons should be also protected intensively.
The national legislation in the Danube-area countries is established in a manner that the involved parties in road traffic system, including the road designers, road operators, manufacturers of equipment and vehicles, as well as all road users have shared responsibilities. Additional specific requirements for vulnerable road users are usually defined in sub-normative acts of the competent ministries such as the Ministry of the Interior, the Ministry of Regional Development and Public Works and Ministry of Education and Science, as well as in ordinances of local government units (competent municipalities).
Some countries have also developed their own guidelines for road design, construction, maintenance and supervision, which include specific additional requirements related to design of facilities and crossings for vulnerable road users. Several countries have defined specific obligations on the wearing of cycle helmets and retro-reflective vests in order to ensure that cyclist are adequately protected and visible during the night-time and periods of reduced visibility, while others have additional regulations that consider specific measures, related to the design of infrastructure for pedestrians and cyclists in urban areas. For example, in Austria, existing laws and regulations now define new types of bicycle facilities, including bicycle streets, encounter streets and bicycle lanes without obligatory use.
Some countries have reported that they still struggle with various legal and political barriers which prevent and slow down the road safety improvement and that the implementation of the relevant regulations related to vulnerable road users is still weak and inefficient.
Existing regulatory documents for road signs and traffic management in many Danube area countries have either not well defined or excessively strict requirements for counterflow cycling, cycle lanes, bicycle streets, traffic calming measures and wayfinding for cyclists.

4. Types of crashes involving pedestrians and cyclists

Walking and cycling are transport modes where unprotected road users interact with traffic of high speed and mass. This makes pedestrians and cyclists vulnerable. They suffer the most severe consequences in collisions with other road users because they cannot protect themselves against the speed and mass of the other party.

4.1. Pedestrian crashes

Pedestrians are much more vulnerable to accidents than other road users. In many countries, collisions with pedestrians are a leading cause of death and injury. In some countries, over half of all road deaths are caused by collisions between vehicles and pedestrians. About 21% of all traffic fatalities in the EU are pedestrians. Collisions between pedestrians and vehicles typically occur in a number of situations, including:

- Walking in to the path of a vehicle, especially while trying to cross the road
- Walking along the roadside, or on the road
- Playing or working on the road
- On driveways or footpaths
- While boarding or leaving public transport vehicles.

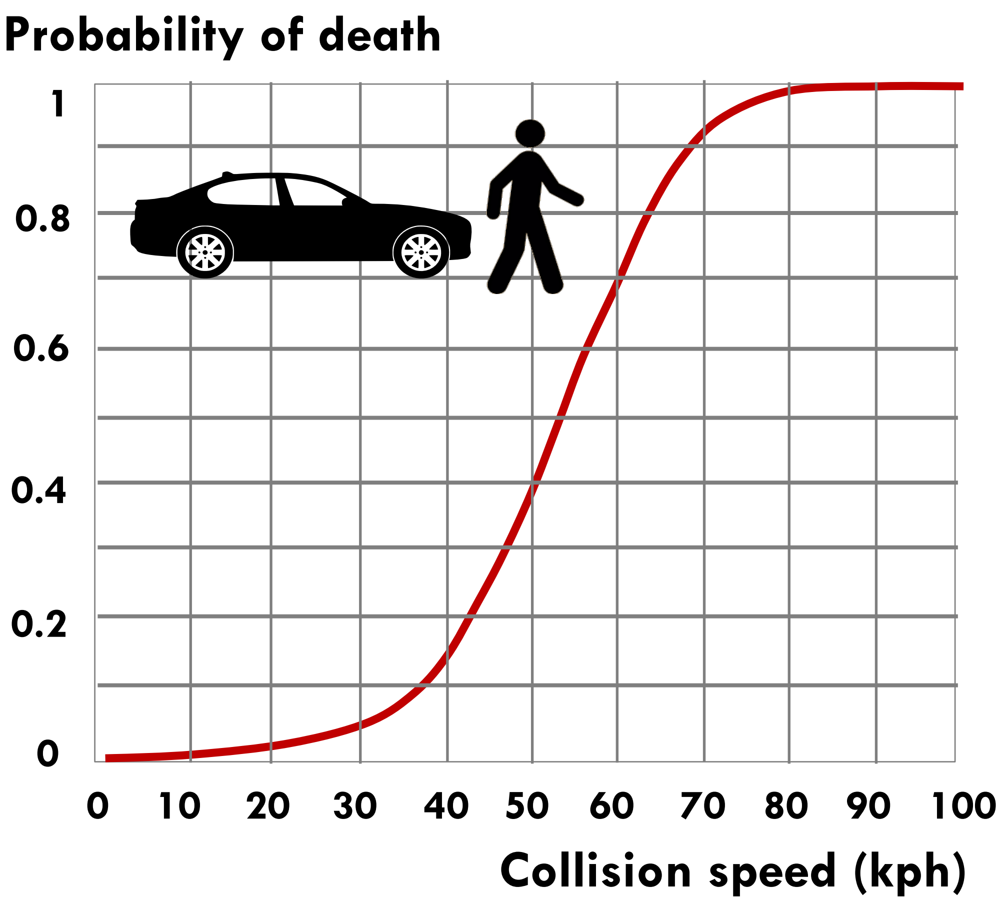

Figure 17. Probability of pedestrian survival upon an impact with a motorised vehicle. Source: edited by authors based on [15].

The severity of pedestrian crashes is strongly dependent on the speed of traffic. Research shows that the chances of a pedestrian surviving an impact with a motorised vehicle reduces

dramatically above 30 km/h (Figure 17.), and even at lower speeds than this, serious harm can be caused, especially to elderly or child pedestrians. The risk of pedestrian injuries is increased by a number factors that relate to the road environment, including:

- High speed of traffic;
- Inadequate crossing facilities;
- Lack of pedestrian crossing opportunities (gaps in passing traffic);
- Number of lanes to cross;
- Complexity and unpredictability of traffic movements at intersection;
- Lack of pedestrians infrastructure along the road;
- Inadequate separation from traffic;
- Poor crossing sight distance.

4.2. Cyclists crashes

Bicycling is a sustainable and affordable method of transport. Bicycles require less to be spent on road infrastructure than heavier, larger vehicles. In higher income countries cycling is recognised as an environmentally friendly and healthy activity. However, cyclists are amongst the most vulnerable of all road users. In some countries where bicycles are a primary mode of transport, cyclist death and injury can form a significant component of all casualties. The severity of cyclist crashes is often much higher than passenger or heavy vehicle crashes in similar situations, due to lack of physical protection. The level of risk experienced by cyclists is related to the following contributory factors:

- Interaction with larger vehicles (cars, trucks and buses);
- Road surface issues (such as roughness, potholes or debris on the road);
- Speed environment - both for cyclists and other vehicles;
- Road design and traffic management;
- Lack of cyclist infrastructure along the road;
- Inadequate physical separation from traffic;
- Other obstructions on the road.

The severity of cyclist crashes is strongly dependent on the speed of traffic. Research shows that the chances of a cyclist surviving an impact with a motorised vehicle reduces dramatically above 30 km/h, and even at lower speeds than this, serious harm can be caused, especially to elderly or child cyclists.

4.3. Vulnerable road users crash types considered by iRAP methodology

Acording to the iRAP SRS methodology, the risk of fatal and serious road traffic accidents occurrence is separately calculated for four road user categories: (1) Vehicle occupants, (2) Motorcyclists, (3) Bicyclists and (4) Pedestrians. Since the SRS scores are calculated separately for each of these four road user types, it is possible to ensure that the Safer Road Investment Plans (SRIPs) include specific groups of countermeasures that will save most lives of all road users types in the most cost-effective way. The Star Rating model includes five crash types related to vulnerable road users. The bicyclists Star Rating Score is calculated based on three crash types that account for a large proportion of bicycle deaths and serious injuries, i.e. crashes that occur while travelling along road, crashes on intersections and run-off road crashes. For pedestrians, the Star Rating model considers two crash types that cause the majority of pedestrian fatalities and serious injuries, i.e. the crashes involving pedestrians walking along road and pedestrians

that cross the inspected or side road. The iRAP risk assessment model considers a series of 'crash initiation modes' or ways in which a crash can begin for each crash type. The Figures 18. and 19. show examples of main crash types involving vulnerable road users that are considered by the Star Rating model.

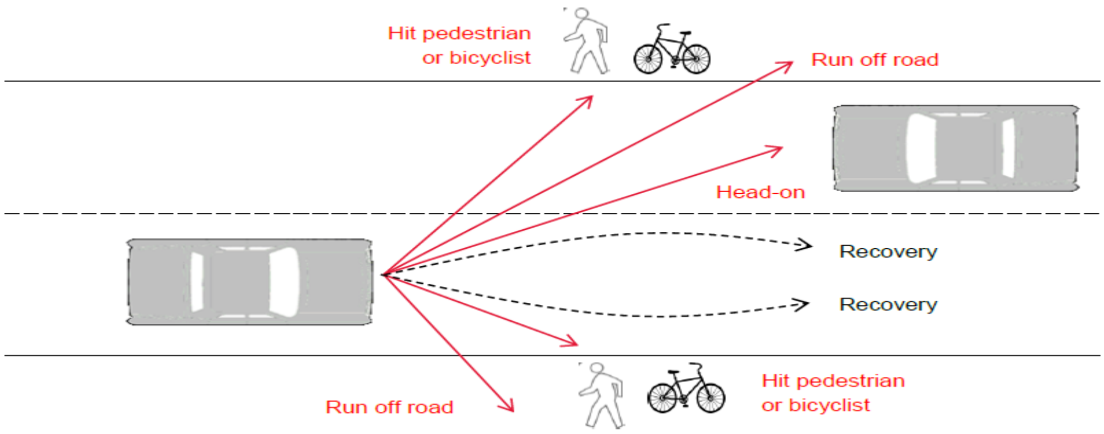

Figure 18. A vehicle occupant or motorcyclist departs from the lane (loss of control or overtaking) and hits pedestrian or bicyclist along the road. Source: [16], iRAP model factsheet 4, Crash types.

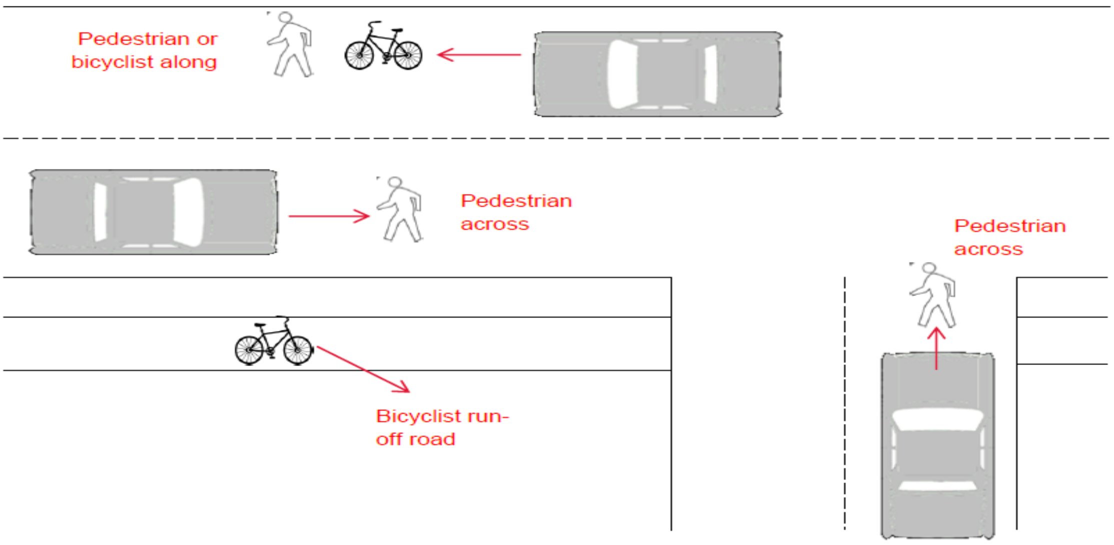

Figure 19. Pedestrian or bicyclist hit while moving along or across the road. Source: [16], iRAP model factsheet 4, Crash types.

4.4. Vulnerable road users crash types considered by SafetyCube project methodology

4.4.1. Pedestrian accident scenario

The SafetyCube Pedestrian accident scenario is subdivided into nine sub-scenarios in order to consider various pre-accident configurations, i.e. to determine detailed relative frequency distributions of fatal, serious and slight pedestrian accidents for different types of road crashes involving pedestrians. Therefore, the pedestrian accident scenario includes the following nine sub-scenarios of pre-accident configurations: (1) Pedestrian crossing road out of crossing path; (2) Pedestrian crossing road on crossing path at straight stretch; (3) Pedestrian crossing road in front of junction; (4) Pedestrian crossing road behind junction; (5) Pedestrian moving along the road; (6) Vehicle reversing; (7) Pedestrian sitting or lying on the ground; (8) Pedestrian – changing mode (e.g. driver getting off the car) and (9) other pedestrian configuration.

The pedestrian accident sub-categories defined in the SafetyCube project do not take into account risk factors that have contributed to the road traffic accident occurrence, but rather they rely on road traffic configuration that was present on the road just before the accident occurrence. Distribution of fatal, serious and slight pedestrian accidents for nine sub-scenarios of pre-accident configurations defined in the SafetyCube project is shown on Figure 20.

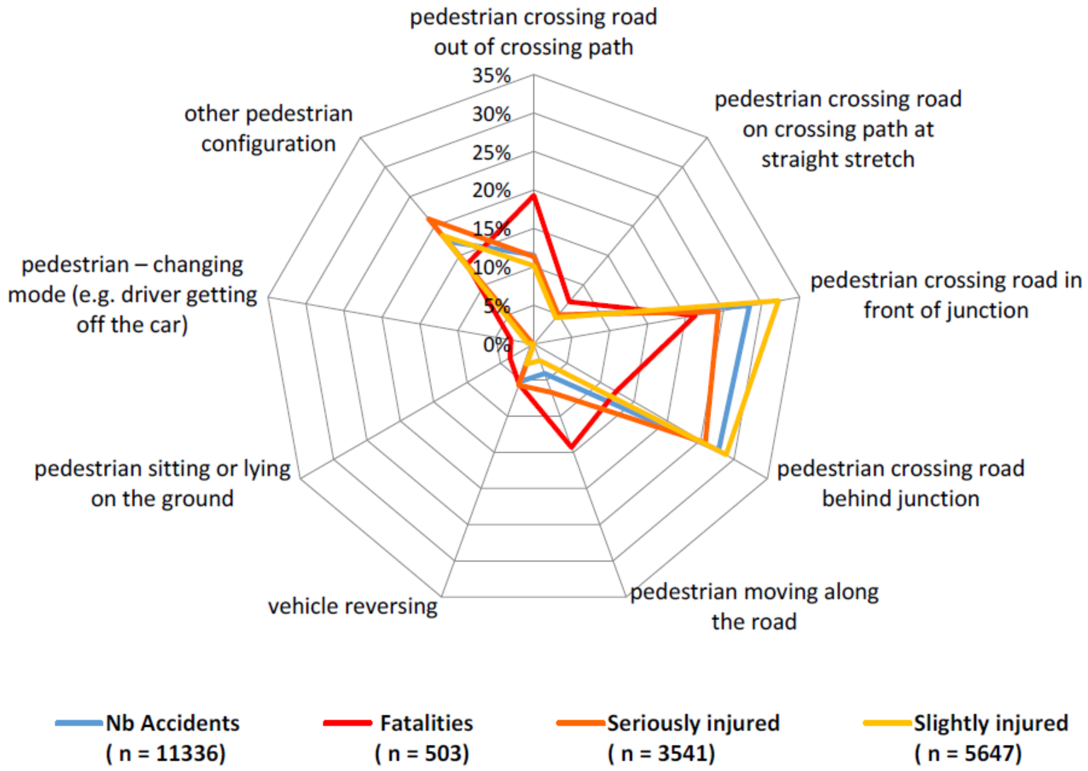

Figure 20. The proportions of fatal, serious and slight pedestrian injuries in nine sub-scenarios of pre-accident configurations, considered in SafetyCube project. Source: [2], SafetyCube project, VOIESUR database, France 2011

The most frequent pre-accident scenarios, besides category "others", include ''pedestrians crossing road in front of junction'' (28.4%), ''pedestrian crossing road behind junction'' (27.7%) and ''pedestrian crossing road out of crossing path'' (12%). The largest proportions of pedestrian fatalities are related to traffic accidents that occurred while pedestrians were crossing road in front of junction (21%), followed by accidents in which pedestrians were crossing road out of crossing path (19%) and accidents where pedestrians were walking along the road (14%). The most serious pedestrian injuries, besides category ''others'' occur in accidents where pedestrians are crossing the road behind or in front of junction, followed by accidents in which pedestrians are crossing the road out of crossing path.

4.4.2. Cyclist accident scenario

The SafetyCube Cyclist accident scenario is further into 13[8] sub-scenarios in order to consider various pre-accident configurations, i.e. to determine detailed relative frequency distributions of fatal, serious and slight cyclist accidents for different types of road crashes involving cyclists.

[8] The cyclists sub-scenarios of pre-accident configurations used in SafetyCube project are originally defined in CATS (Cyclist-AEB Testing System) project.

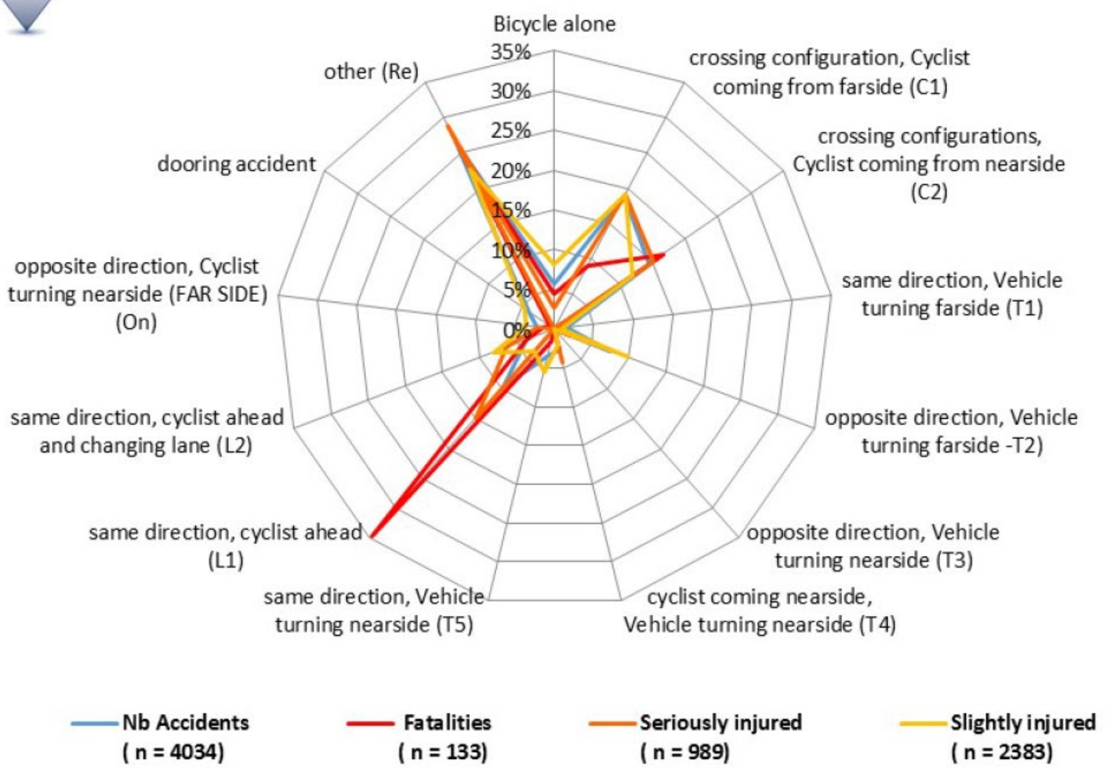

Figure 21. The proportions of fatal, serious and slight cyclist injuries in 13 sub-scenarios of pre-accident configurations, considered in SafetyCube project. Source: [4], SafetyCube project, VOIESUR database, France 2011

Therefore, the cyclist accident scenario includes the following 13 sub-scenarios of pre-accident configurations: (1) Bicycle alone; (2) Crossing configuration – cyclist coming from farside; (3) Crossing configuration – cyclist coming from nearside; (4) Same direction – vehicle turning farside; (5) Opposite direction – vehicle turning farside; (6) Opposite direction – vehicle turning nearside; (7) Cyclist coming (nearside) farside – vehicle turning (nearside) farside; (8) Same direction – vehicle turning nearside; (9) Same direction – cyclist ahead; (10) Same direction – cyclist ahead and changing lane; (11) Opposite direction - cyclist turning nearside; (12) Dooring accident and (13) Other types of accidents.

The most frequently occurring cyclist accident sub-scenarios (Figure 21.), besides category “others”, include “Crossing configuration, Cyclist coming from farside” (20%), “Crossing configurations, Cyclist coming from nearside” (15%) and “Same direction, cyclist ahead” (10%). The largest proportions of pedestrian fatalities are related to traffic accidents that occurred in the same direction with cyclist ahead (36%), followed by accidents in which cyclists are hit while crossing the road from nearside (17%) and farside (9%), respectively. The most severe cyclist injuries are caused in accidents that occur when the cyclist is ahead and moves forward or tries to change the lane in front of the vehicle and in accidents in which cyclist is coming from either side of the intersection and crosses over the trajectory of vehicle that turns right or left.

4.5. State of the art in Danube countries: Types of crashes involving pedestrians and cyclists

In Danube area Countries for which detailed data on distribution of the absolute and relative number of fatal and serious pedestrian/cyclist injuries by main types of crashes is provided, it is clear that most of the fatal and serious road traffic accidents, involving pedestrians, occur on intersections and straight road sections where pedestrians are crossing the road. Based on the available data, provided for some countries, it is estimated that about 60% of pedestrians are killed or seriously injured on straight road sections while crossing the road on unmarked locations, about 10% while walking across the road on dedicated pedestrian crossing and about 15% pedestrians are killed or seriously injured while walking on dedicated pedestrian crossings at intersections. Most of the fatal and serious collisions involving cyclists also occur at straight road sections and intersections (60% and 35% on average, respectively). Generally speaking, it is estimated that 20-30% of fatal accident involving pedestrians and 25-35% of fatal accident involving cyclist occur at intersections. High number of pedestrian fatalities happen during the dark part of the day. Some countries report that most of the road traffic accidents involving pedestrians occur in urban areas between intersections, while pedestrians are trying to cross the carriageway. On the other hand, fatal and serious accidents involving pedestrians in rural areas occur most often on primary state roads, near roadside restaurants and shopping areas while pedestrians cross the road on unmarked locations or walk along the road without appropriate pedestrian provisions. From the available data it is estimated that 30-40% of the total number of road traffic accidents, involving pedestrians occur on pedestrian facilities or crossings.

Based on the data obtained from individual countries it can be concluded that some of the countries in the Danube area recognise that existing road traffic accident databases do not contain precise information on the frequency and spatial distribution of road traffic accidents involving road users, primarily due to the issue of significant underreporting, and therefore the statistical analysis of this types of road traffic accidents cannot produce very precise and reliable results.

The risk factors that contribute to the probability of vulnerable road users accidents occurrence the Danube area countries include: speeding, drunk driving, drivers distraction and inattention, low traffic culture (usage of mobile phone while driving, not giving priority, irregular turning, overtaking or lane changing, lack of respect for other road users, vehicle parking on bicycle lanes), poor visibility (clearance along the road), pedestrian irregularities (pedestrians disobeying traffic regulations, careless and disturbing behaviour while crossing the road, red light running, etc.), cyclist irregularities (non-usage of appropriate reflective and protective equipment, not using protective helmet), lack of road lighting and lack of appropriate pedestrian and bicycle infrastructure, especially in rural areas (lack of sidewalks, lack of dedicated bicycle lanes and paths along the road, inappropriate segregation of motorised traffic and vulnerable road users, absence or poor quality of existing crossing facilities, i.e. lack of visible pavement markings, lack of signalised pedestrian crossings and/or pedestrian refugee islands where necessary), lack of infrastructure maintenance (damaged and unmaintained pedestrian and cyclist facilities) and lack of road users education. Additional problem arises from the fact that in urban areas there is often limited space for building appropriate pedestrian and cyclist infrastructure. Some countries have reported that they do not have appropriate speed management and traffic calming elements (speed humps, video cameras) at many locations where they are needed.

5. Review of methods for assessing the risks for vulnerable road users

The risks for vulnerable road users can be assessed with various risk assessment methodologies which include implementation of different analytical-statistical or GIS based techniques in order to identify main VRU traffic accidents risk factors, determine their impact on the probability of road traffic accidents occurrence and distribution of fatal and serious VRU accidents and select specific countermeasures which will ensure the most cost-effective improvement of road traffic safety for pedestrians and cyclists. The main risk rating methodologies used by different countries across the world in order to assess the risks for vulnerable road users include:

- iRAP/EuroRAP SRS methodology for assessing the in-built safety of road infrastructure;
- Pedestrian and cyclists "hot spot" analysis;
- Methods for indentification of clusters and risk factors of fatal and serious injuries in crashes involving pedestrians and cyclists;
- Regression analysis between risk factors, the number and the severity of road traffic accidents involving pedestrians and cyclists;
- Other methods for determining the risks of vulnerable road users.

Based on the implementation of these methodologies it is possible to identify which locations and road sections on the observed road network are most dangerous for vulnerable road users. Determined "hot-spots" can then be used in order to select appropriate countermeasures and prioritise their implementation, i.e. to develop optimal investment plans which will ensure that available funds are allocated in the best possible way.

5.1. Main contributary risk factors in the causation of pedestrian and cyclist crashes

According to the European Commission document SafetyNet Pedestrians & Cyclists: "*Factors that have been identified as contributory factors in the causation of pedestrian and cyclist crashes and injuries include:*

- *Speed of motorised vehicles;*
- *Weight and design of motor vehicles;*
- *Lack of visibility of vulnerable road users;*
- *Lack of protection of pedestrians and cyclists*
- *The influence of technical defects and;*
- *Alcohol consumption.*

5.2. *Road safety risk factors for vulnerable road users considered by iRAP methodology*

According to the iRAP SRS methodology, the relative risk of death and serious injuries for vulnerable road users are expressed by pedestrian and bicyclist Star Rating Scores (SRS) which are calculated by multiplying crash type scores determined based on five sets of risk factors related to likelihood of road traffic accidents occurrence, severity of crash, operating speeds of vehicles in traffic flow, external flow influences and median traversability. Pedestrian star rating score is calculated based on the coded values of 22 attribute groups. Total pedestrian star rating score is calculated by summing the crash scores determined for three main types of road traffic accidents that involve pedestrians, i.e. along score, crossing score on inspected road and crossing score on side road. The crash scores are calculated by multiplying likelihood, severity, operating speed and external flow influence factors whose values are determined based on the coded attribute values in relevant attribute groups. The Figure 22. shows the graphical representation of pedestrian SRS equation.

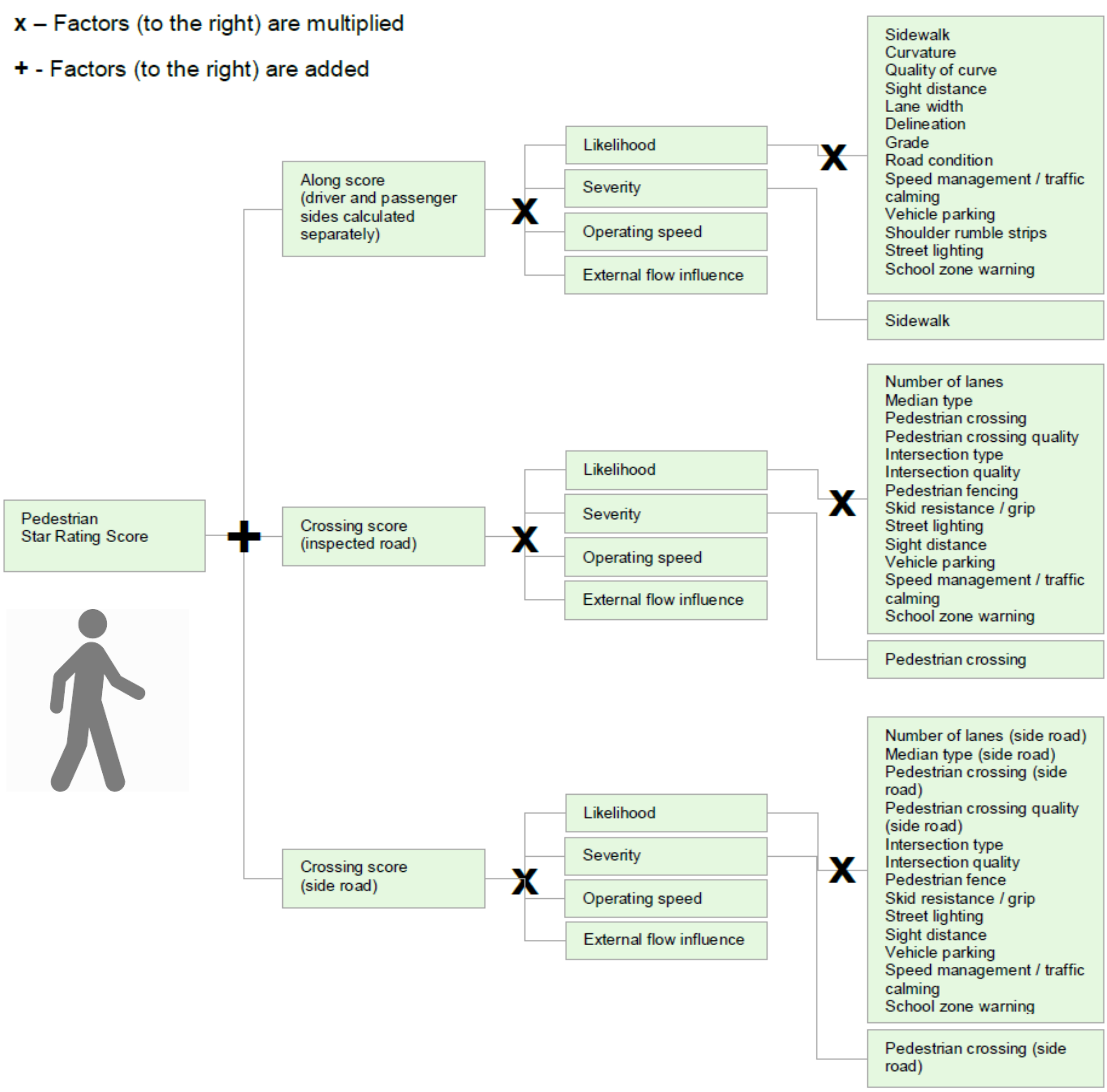

Figure 22. Graphical representation of pedestrian SRS equation used in iRAP SRS methodology to calculate Pedestrian Star Rating Score. Source: [17], iRAP model factsheet 6, Star Rating Score Equaltions).

Bicyclist star rating score is calculated based on the coded values of 22 attribute groups. Total bicyclist star rating score is calculated by summing the crash scores determined for three main types of road traffic accidents that involve bicyclists, i.e. run-off score, along score and intersection score. The crash scores are calculated by multiplying likelihood, severity, operating speed and external flow influence factors whose values are determined based on the coded attribute values in relevant attribute groups. The Figure 23. shows the graphical representation of bicyclist SRS equation.

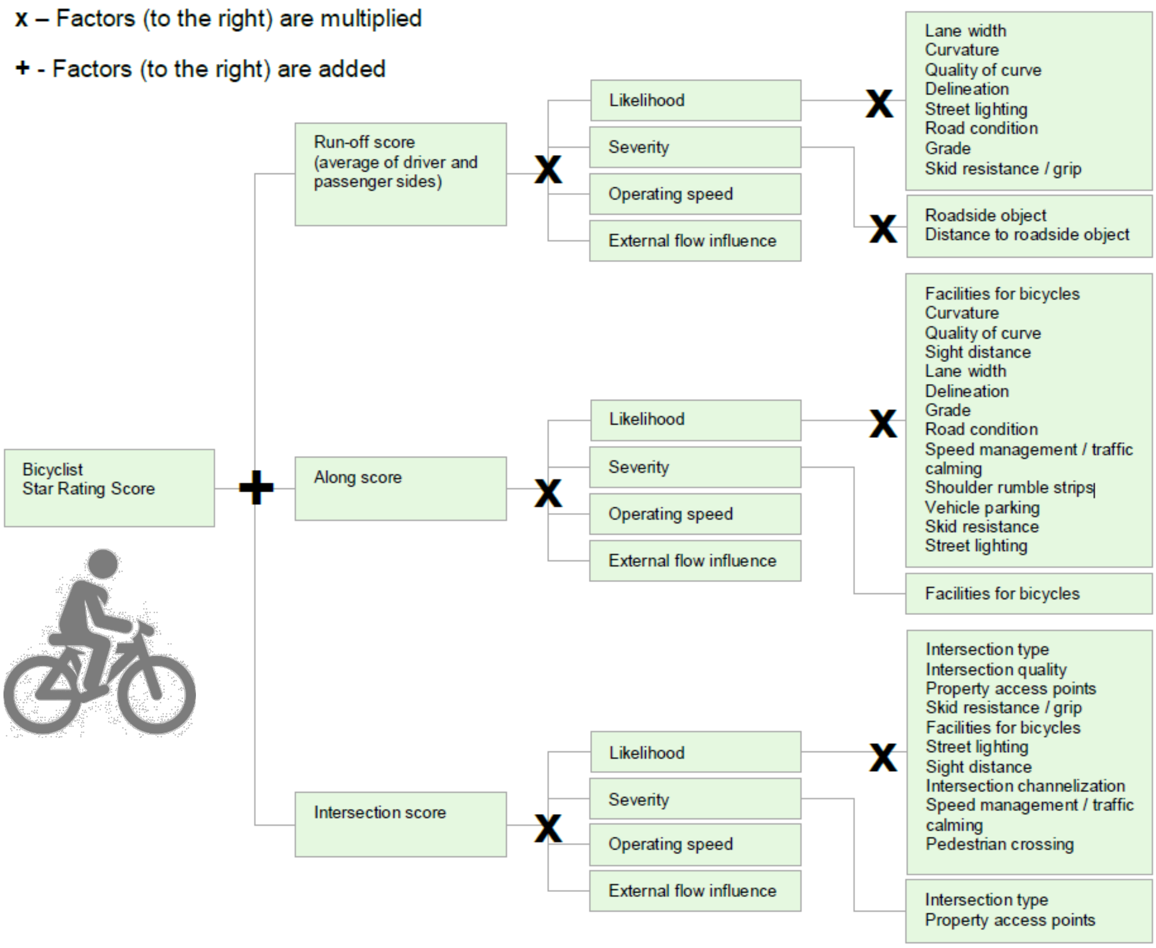

Figure 23. Graphical representation of bicyclist SRS equation used in iRAP SRS methodology to calculate Bicyclist Star Rating Score. Source: [17], iRAP model factsheet 6, Star Rating Score Equaltions).

5.3. Road safety risk factors for vulnerable road users considered by SafetyCube project

SafetyCube Project considers eight main road traffic accident scenarios, including (1) Pedestrian accidents, (2) Bicyclist accidents, (3) Single vehicle accidents, (4) Head-on collisions/On-coming traffic, (5) Rear-end collisions/Same direction traffic, (6) Junction accidents (no turning), (7) Junction accidents (turning) and (8) Railway crossing accidents. The main risk factors that contribute to the probability of fatal and serious traffic accidents occurrence and corresponding countermeasures that can be implemented in order to reduce these risks are determined separately for each of the eight main road traffic accident scenarios.

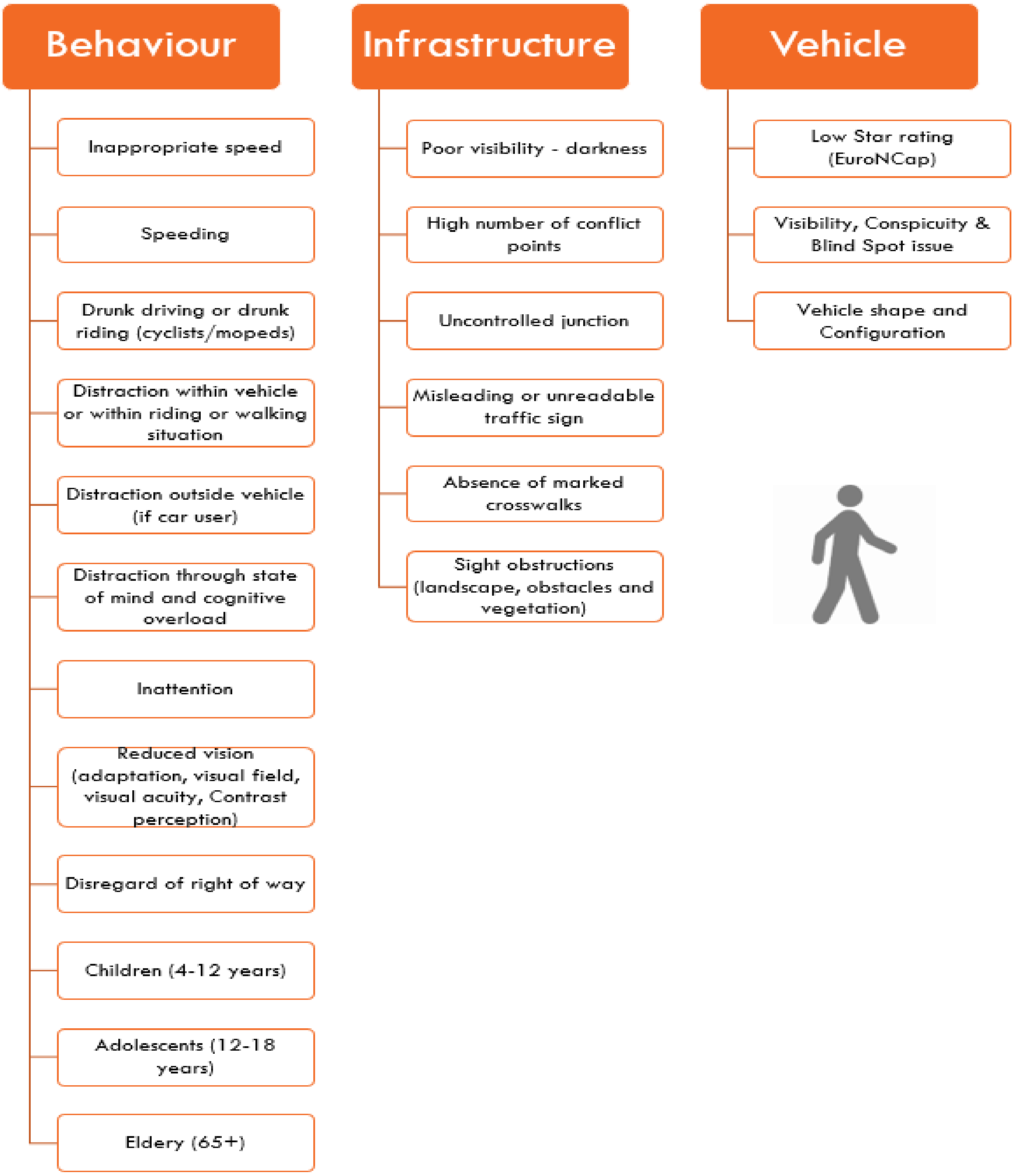

Figure 24. Pedestrian accidents risk factors considered in SafetyCube Project. Source: edited by authors based on the data available on SafetyCube DSS webpage: www.roadsafety-dss.eu.

In SafetyCube Project, Main Risk Factors which contribute to vulnerable road users accidents and countermeasures which can be implemented in order to reduce these risks are divided into three main categories, related to road users behaviour, road infrastructure and vehicle characteristics. Pedestrian and cyclist accidents risk factors are shown on Figure 24. and 25., respectively. While iRAP methodology mainly considers the risk, factor associated with road infrastructure elements and road environment characteristics, the risk assessment methodology used in SafetyCube project considers greater variety of risk factors related to the behaviour of road users and relevant vehicle characteristics.

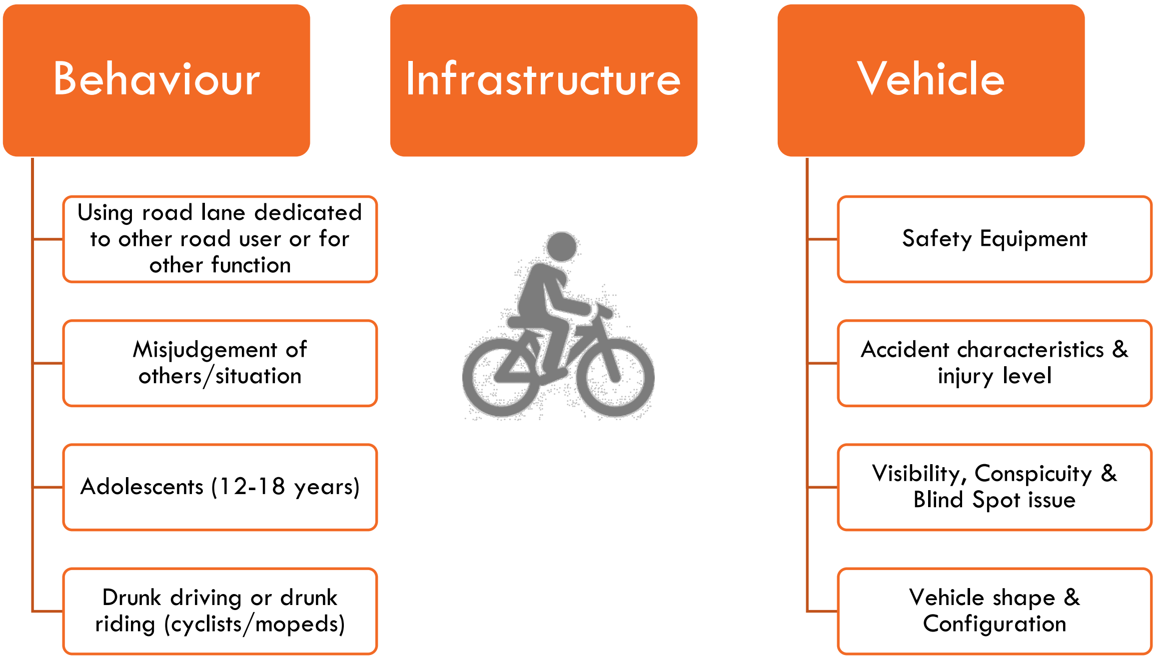

Figure 25. Bicycle risk factors considered in SafetyCube Project. Source: edited by authors based on the data available on SafetyCube DSS webpage: www.roadsafety-dss.eu.

5.4. State of the art in Danube countries: Review of methods for assessing the risks for vulnerable road users

The methods which are most commonly used in Danube-area countries in order to assess the risks of vulnerable road users include: (1) visual identification of high-risk areas based on road safety audits (RSA) and road safety inspections (RSI) procedures; (2) Black Spot Management (BSM) procedures and (3) EuroRAP Star Rating procedures. Some countries have reported that they do not have specific methodology that is applied in order to determine the risks for vulnerable road users.

The risk of road traffic accident occurrence, involving vulnerable road users is mostly calculated/assessed on the basis of number and rate of road accidents in which pedestrians and/or cyclist are killed or seriously injured. In order to calculate the risks, most of the countries analyse both absolute and relative frequencies of different types of road traffic accidents involving vulnerable road users. The other most commonly used method involves calculation of vulnerable road users accident densities, i.e. the number of pedestrian and cyclist accidents per kilometre of observed road network. However, Countries for which data was provided, do not measure the risks for vulnerable road users separately. The risks of traffic accidents occurrence is instead calculated based on the all fatal and serious injuries contained in the road traffic accident database.

Most of the Danube-area Countries do not have precise exposure data in terms of the number of walked and cycled kilometres, based on which it would be possible to determine the risk of vulnerable road user accident occurrence per kilometres travelled. Many countries do not distinguish between different types of risk factors when calculating the probability of VRUs traffic accident occurrence. Instead, all potential risk factors are considered in analysis of relevant characteristics of each individual road traffic accident recorded in the database.

In Countries for which data was provided, data on pedestrian/cyclist peak-hour flow volume is not directly used for assessing the vulnerable road users risks. However, in some countries this volume is used at design stage for selecting the type and determining the capacity of pedestrian/cyclist facilities and crossings. For example, in Slovenia, pedestrian crossing arrangements (marked crossing, signalised crossing or off-level crossing) are selected based on the pedestrian and vehicle peak-hour flow volumes.

Based on the available data, it can be concluded that majority of countries in the Danube area still lack the datasets which would provide precise data on all relevant characteristic of road traffic accidents involving pedestrians and bicyclists. Many countries recognise the issue of significant underreporting of road traffic accidents involving vulnerable road users. The effect of underreporting is larger for slight injury accidents, since road users, in the case of slight injuries, usually do not call the police.

The database on road traffic accidents involving vulnerable road users is usually managed by the Ministry of Interior. In Countries for which data was provided, the database on road traffic accidents is accessible for the road safety stakeholders via internet. Standard road traffic accident statistics is usually available on the Ministry of Interior and National Statistic Institute websites, while additional specific information can be obtained throughout official request. Some Countries have developed their own analytical software which can be used for road traffic accidents data analysis and reporting.

Since existing methodologies used in different Danube-area countries for assessing the risks for vulnerable road users consider different parameters in order to identify most dangerous road sections on the observed road network, the results obtained by this methodologies can vary significantly and often cannot be easily compared between countries. This indicates the

need for a development of a new unified protocol for assessment of the risks of vulnerable road users, which should be used in all countries in order to obtain comparable results. A good example of a unified safety assessment approach is the methodology that has been used in order to assess the safety on 19.000 km of the EuroVelo, the European Cycle Route Network, which considers 60 different parameters, including route component type, traffic volume, traffic speed, surface material, surface quality, width and obstacles along cycle routes, whose values are recorded on every kilometre of the observed network in order to produce the safety scores for individual cycle route sections.

6. Selection of road sections to be reconstructed/upgraded

Based on determined pedestrian and cyclist high-risk locations and critical road sections on the observed road network it is possible to select appropriate countermeasures and prioritise their implementation. The selection of road network sections that will be included in the countermeasure implementation process can be performed by various methods, which typically consider the following indicators:

- Number of fatal, serious and slight road traffic accidents involving vulnerable road users;
- Distribution of vulnerable road users crash types;
- Pedestrian and cyclist peak hour flow volumes;
- Determined risk levels for pedestrians and cyclists;

This process of selection of road sections which need to be reconstructed/upgraded involves assessing locations where pedestrian or cycling activity is relatively high but where provision of pedestrian and/or cycling facilities is low or poorly maintained and crashes will likely occur. For pedestrians, it is important to consider the relation between adjacent land-use and pedestrian peak-hour flow in order to estimate likely pedestrian activity, i.e. the demand characteristics on pedestrian footways and crossings and to assess the condition of existing pedestrian facilities. (Facilities often lack visibility for drivers, are badly worn or there is poor enforcement of nearby parking.) In addition to that, it is also important to consider desire lines for pedestrians between different generators of activity, compare the warrants for provision of facilities, assess what must be done to raise the standard of provision for pedestrians to a generally accepted safe standard and determine what group of countermeasures can be potentially implemented in order to achieve this goals.

For cyclists, it is necessary to estimate cycling activity and desire lines within settlements, the need for implementation of dedicated cycle lanes on existing roads, separate paths, green wave, dedicated traffic lights or similar facilities, and perform other similar assessments as those described for pedestrians.

6.1. State of the art in Danube countries: Selection of road sections to be reconstructed/upgraded

Among Danube-area Countries which have provided all relevant input data, most of them, with exception of Hungary, have reported that they do not have official database which includes the data about existing/planned pedestrian and cyclist infrastructure. In Hungary, data on existing pedestrian and cyclist network is collected and stored in two separate official databases which can be accessed via internet: National Road Database and "KENYI" database. However, the quality of this databases is affected by the fact that data service from individual municipalities is voluntary. There are also databases about the planned cyclist infrastructure at ministerial and investorial level, but usually they are not accessible to road safety auditors and non-governmental stakeholders.

In most of the Danube-area Countries, for which data were provided, road safety key performance indicators (KPIs) are not used as a method for selection and prioritisation of road sections on which pedestrian/cyclist infrastructure should be built, reconstructed or upgraded. Most of the Danube-area Countries have reported that they use standard road safety indicators in order to select locations on which countermeasures for vulnerable road users will be implemented, including the number of road traffic accidents and/or fatalities and serious injuries per kilometre, the number of road traffic accidents and/or fatalities and serious injuries per million vehicle-kilometres travelled and road traffic accidents unit costs per kilometre of observed road network. The additional problem arises from the fact that in some Countries, individual municipalities which operate the pedestrian/cyclist facilities at local level decide what specific indicators will be taken into account for safety assessment of pedestrian/cyclist infrastructure.

Generally speaking, the road safety KPIs are very rarely used in countermeasure selection, prioritisation and implementation process. During recent years, some Danube-area countries have been involved in various EU-funded projects in which road safety for pedestrians and cyclists have been considered. In scope of this projects, detailed road safety audits of existing pedestrian/cyclist infrastructure on selected parts of road network have been performed.

7. Selection and prioritisation of countermeasures for vulnerable road users

7.1. Main measures to reduce crash numbers and injury severity

According to the European Commission document SafetyNet Pedestrians & Cyclists: "*Measures that can be taken to reduce the future number of crashes involving pedestrians and cyclists, and/or to decrease the severity of resulting injuries, relate to:*

- *Long-term planning, which is needed to create the fundamental changes that will improve the safety and mobility of vulnerable road users. Concepts like Sustainably Safe Traffic and Zero Vision provide the framework that long-term planning requires.*
- *Education and training: Education should, be primarily directed at children, but also and at other types of road users, such as motorists. Two central themes for an instruction programme are recommended in this respect: adaptation of speed, and learning to understand other road users and to 'communicate' with them [60].*
- *Land use planning: Pedestrian safety measures that are the most comprehensive and most closely associated with urban planning and policy philosophies are: Area-wide speed reduction or traffic calming schemes, and Provision of an integrated walking network- These are two complementary measures, which can be implemented together without conflicting.*
- *Protective devices – helmets: Some countries have legislation on helmet wearing, whereas others are against governmental promotion of helmet use. To prevent helmets having a negative effect on the use of bicycles, the best approach might be to leave the promotion to the manufacturers and shopkeepers.*
- *Visibility – lighting and reflecting devices;*
- *Vehicle design of crash opponents: Injuries to cyclists and pedestrians can be reduced by better design of cars and heavy vehicles. Design measures include crash-friendly car fronts, and side-underrun protection on lorries [60].*
- *Road design: Road design measures that assure a pedestrian-friendly and cyclist-friendly infrastructure, which relate to: (1) Area-wide speed reduction; (2) Cycling networks and (3) Crossing facilities.*

7.2. Countermeasures for vulnerable road users considered in iRAP project

Primary Countermeasures related to vulnerable road users that are considered by iRAP model can be divided into following groups:

- *Delineation improvements;*
- *Pedestrian crossing improvements;*
- *Use of formal crossing points – unsignalized pedestrian crossings;*
- *Use of signalised pedestrian crossings (Pedestrian crossing signalization);*
- *Constructing pedestrian Refuge islands;*
- *Pedestrian fencing;*
- *Sight distance improvements;*
- *Implementation of traffic calming measures and*
- *Sidewalk improvements.*

7.3. Countermeasures for vulnerable road users considered in SafetyCube project

Similarly to accident risk factors, countermeasures for pedestrian and cyclists accident scenarios defined in the SafetyCube project are divided into three main categories related to road user behaviour, road infrastructure and vehicle characteristics. Figures 26. and 27. show countermeasures considered for pedestrian and cyclist road users categories, respectively.

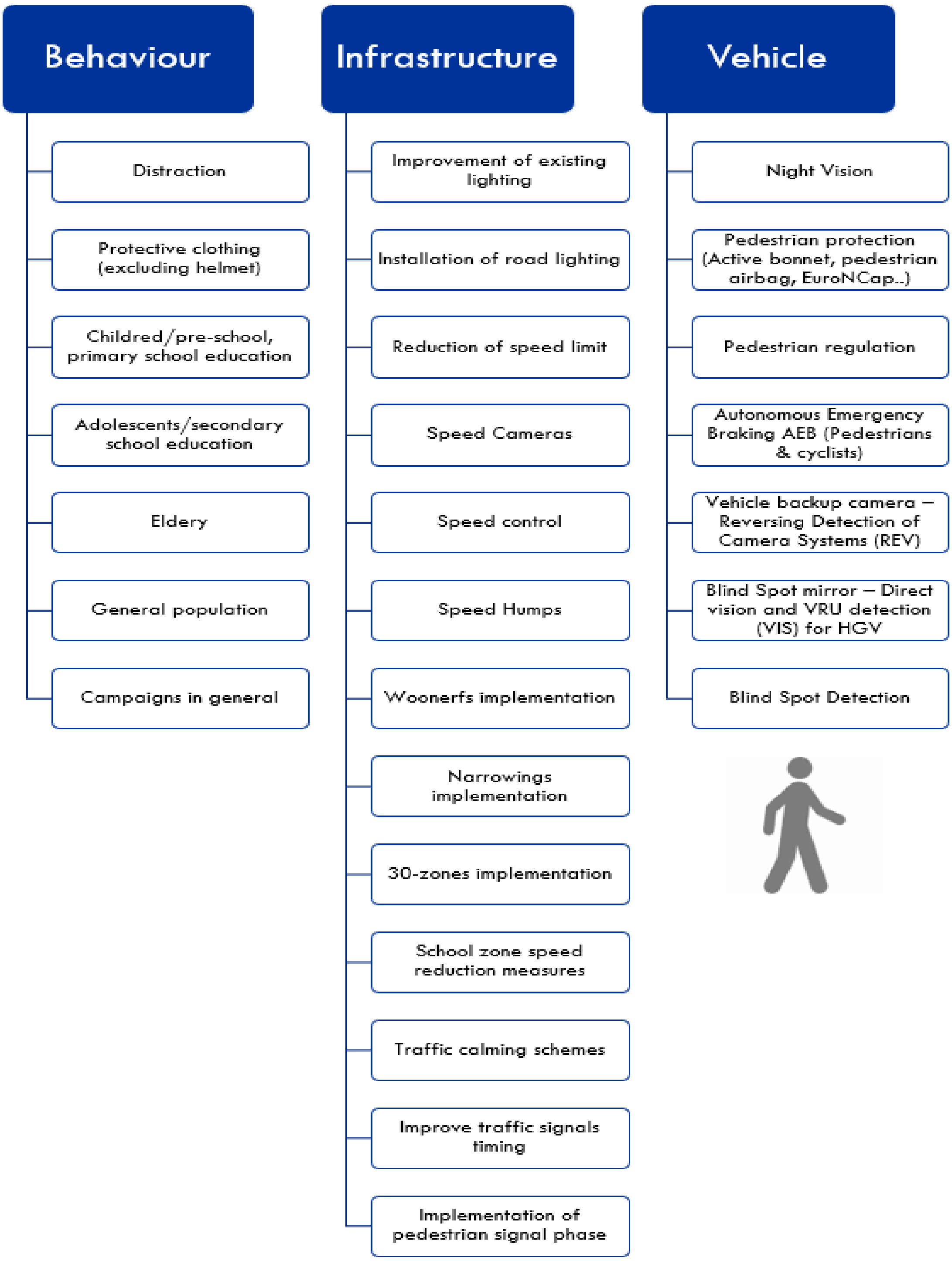

Figure 26. Pedestrian countermeasures considered in SafetyCube Project. Source: edited by authors based on the data available on SafetyCube DSS webpage: www.roadsafety-dss.eu.

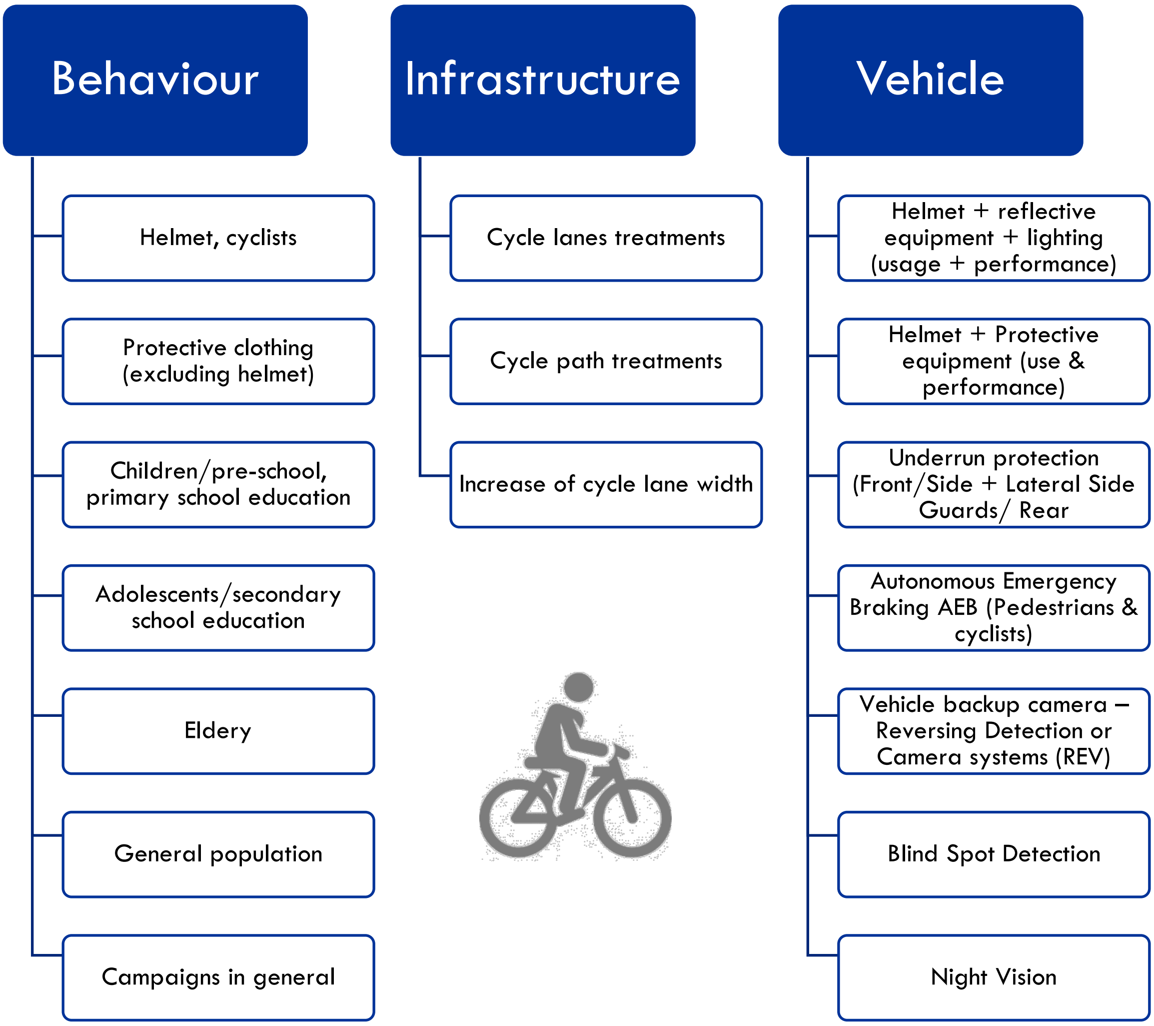

Figure 27. Cyclist countermeasures considered in SafetyCube Project. Source: edited by authors based on the data available on SafetyCube DSS webpage: www.roadsafety-dss.eu.

7.4. State of the art in Danube countries: Selection and prioritisation of countermeasures for vulnerable road users

In order to select appropriate countermeasures for vulnerable road users, some of the Danube area countries, for which data was provided, use the data collected by road survey team during field visit of the critical locations on the road network. In most of the cases road safety auditor is also member of this team. Based on the performed field investigations team members propose countermeasures which will be considered for implementation. Some countries have also developed their own guidelines for pedestrian and cyclist infrastructure planning, which are also used in countermeasure selection, prioritisation and implementation process. Other Countries in the Danube-area, for which data was provided, report that they often select countermeasures based on the subjective criteria. In most of the times, countermeasures for vulnerable road users are selected and implemented based on the results of statistical analysis of relevant road traffic accidents characteristics and decision of the road owner. Proposals from other stakeholders are also considered before making the final decision. Each dangerous location is usually examined independently in order to determine specific countermeasures that may differ from one location to another.

Among Danube-area Countries for which relevant input data was provided, the countermeasures that are typically proposed and implemented in order to increase the safety for vulnerable road users can be generally be classified into three main groups: (1) Countermeasures aiming to change road users behaviour (trainings for children in kindergartens and schools, National campaigns and conferences for vulnerable road users, as well as targeted impact through media in order to raise traffic culture and public awareness of the risks to which VRUs are exposed in road traffic, raise the awareness of the importance and benefits of using reflective objects and wearing light clothing for better visibility at night or in periods of reduced visibility while walking on the road, importance and benefits of usage of safety equipment such as cycle helmets and retro-reflective vests, etc.); (2) Countermeasures related to pedestrian and bicyclist infrastructure improvements (delineation/pavement markings improvements, vertical traffic signage improvements, retroreflective horizontal signalisation and reflectors, building/reconstructing sidewalks for pedestrians and dedicated lanes or paths for bicyclists, improving the pedestrian/cyclist facilities surface, ensuring the continuity of cycle path surfacing and colour, segregation of vulnerable road users from motorised traffic, improving the quality of exiting pedestrian crossings, building pedestrian/cyclist crossing facilities, constructing kerb ramps on pedestrian/cyclist crossings in order to ensure the accessibility for cyclists and disabled persons, pedestrian fencing, street lighting improvements, obstacle treatments, etc.); (3) Speed calming countermeasures (speed humps, speed bumps or speed cushions before and on pedestrian crossings, installation of speed cameras, radars and vehicle activated speed limit signs to control vehicle speed, carriageway narrowing and/or building pedestrian refuge islands depending on road width, raised pedestrian crossings, signalising pedestrian crossings, horizontal and vertical road deflection, police control, etc.).

Practices from various Danube-area countries show that safety of pedestrians and cyclists can be improved to some measure, by taking simple protective actions which primarily include: (1) Education of vulnerable road users throughout road safety education programs

in preschool and school institutions and general public raise awareness campaigns in order to increase their awareness of the risks in road traffic so that they understand the importance and feel the need to comply with traffic regulations; (2) Developing new or improving existing technical specifications for pedestrian and cyclist infrastructure; (3) Developing and implementing new policy for vulnerable road users. In urban areas safety for vulnerable road users can be significantly improved by lowering the speeds and traffic volumes of motorised vehicles and giving priority to vulnerable road users in densely populated areas with high intensity of pedestrian and cyclist traffic flows. During the countermeasure selection, prioritisation and implementation process it is also important to consider the influences that the proposed/implemented countermeasures will have on overall quality of public space, changes in modal distribution, air quality and level of traffic noise. The main focus should be on implementing low-cost, high-impact countermeasures by considering the concepts of tactical urbanism and space-wise planning. Good practice examples include car-free city centers/low emission zones and implementation of congestion charging schemes.

In order to rise awareness of all road users of the: (1) importance and benefits of obeying traffic rules and regulations; (2) the risks to which vulnerable road users are exposed in road traffic; (3) importance and benefits of wearing reflective objects, light clothing, cycle helmets and retroreflective vests, relevant information can be disseminated to the public by various media sources, including television, radio, web-pages, newsletter, journals, leaflets and posters. For example, in Slovenia, leaflets and posters with recommendations for pedestrians that they should use reflective objects or light clothing for better visibility at night or in the dark while walking on the road were issued in order to rise their awareness of the risks they are exposed in road traffic and therefore improve traffic culture.

Pedestrian and cyclists should be physically separated from motorised and heavy traffic in all areas where operating speed of traffic flow, and traffic flow volumes exceed the defined safety threshold values. All road sections where operating speed of traffic flow is greater than 40 km/h and AADT volume greater than 2500 veh/day cannot provide safe and comfortable mixed traffic, therefore in this cases vulnerable road users should be properly segregated from motorised traffic.

None of the Countries, for which data was provided has an official methodology for determining the costs of implementing the countermeasures for vulnerable road users. The data on typical unit costs for implementing these countermeasures is also not available. The country-specific costs of road traffic accidents involving vulnerable road users is not known in most of the cases. Only some countries estimate the average unit costs of fatal injury road accidents. Cost-benefit analysis is usually performed only in a scope of large projects. In this cases, potential benefits which can be achieved if proposed countermeasures are implemented are estimated by considering all positive and negative impacts of proposed countermeasures (e.g. lower risks of road traffic accident occurrence, health benefits generated by reduced emissions, traffic noise, etc.).

8. Vulnerable road users case study examples

iRAP for safer cities

The Road traffic accidents are the biggest killer of people worldwide, especially young ones and they are recognised as a global safety crisis by the United Nations. It is estimated that by 2030, about 500 million people will be injured and 15 million people will be killed on the roads over the world.

Results of the recently performed iRAP Case studies [18] show that very large number of pedestrians and bicycles fatalities and serious injuries occur in urban areas across the world. The average percentage of pedestrian fatalities in cities typically varies between 18% in high income countries to 45% in low and middle-income countries. This becomes even more alarming, considering the fact that today more than 50% of world's population lives in cities.

Based on the iRAP SRS analysis conducted within urban areas across the world it was determined that unacceptably high percentage of roads where pedestrians are present and speeds are over 40 km/h do not have provisions for vulnerable road users. Specifically, it was determined that about 89% of such roads have no pedestrian crossings, 70% of roads have no sidewalks and even 94% of roads within urban areas have no bicycle facilities.

In order to properly address the urban road safety issues, the iRAP organisation aims to achieve two United Nations Sustainable Development goals, i.e. Goal 3.6 related to good health and well-being: "to halve the number of global death injuries from road traffic accidents" and Goal 11.2 related to sustainable cities and communities: "to establish safe, affordable, accessible and sustainable transport systems for all". An especially important step towards achieving this goals is to ensure that roads are safe for pedestrians and bicyclists.

In order to further increase road safety levels on roads in urban areas, many cities around the world are joining the Vision Zero movement. The concept behind Vision Zero movement aims to change the way in which the safety of road users is addressed in planning, design, construction and operation stages of urban road network. The final goal of Vision zero is to completely eliminate fatal and serious injuries caused by road traffic accidents and to ensure safe, healthy and equitable mobility for all traffic participants. The iRAP supports the Vision zero by providing tools which enable the cities to track their progress towards achieving 5-star target for bicycling and walking, as well as for other road users. Currently, the iRAP organisation is helping the World Bank to increase the safety of urban road network in 10 cities and 5 countries worldwide. In order to achieve sustainable transport, increase the safety of mass transit systems and reduce the risk of traffic accident occurrence on urban road network, the iRAP accredited suppliers perform risk assessment of existing streets, street designs and street upgrades within selected cities across the world.

9. Recommendations

9.1. State of the art in Danube countries: Ideas and recommendations

Danube-area Countries, for which data was provided, mention the need for development of traffic culture as a one of most important issues that needs to be solved in order to increase the safety for vulnerable road users. In one hand, drivers often do not respect pedestrian crossings, while on the other pedestrian and cyclists also do not obey existing traffic rules and regulations, i.e. they have tendency to expose themselves to unnecessary risks. Therefore, some countries emphasise that the attitudes of drivers and vulnerable road users both need to change in order to increase the safety in road traffic systems. They also recognise that speed calming measures can significantly reduce the risks to which pedestrians and cyclists are exposed in urban areas, but still a lot of them state that education of the whole society would be the most effective measure.

Data provided by most of the Danube-area countries, gives an impression that there is still lack of proper understanding of the importance and benefits of implementing various infrastructure-related countermeasures. Many Countries still look on primarily on the behaviour of road users as a main influential factor which contributes to the risk of road traffic accident occurrence. Some of the Countries, do however to some extent, recognise the need for safer infrastructure, but there is a sense that the overall significance and benefits of implementing such countermeasures is still not fully recognised.

Therefore, is important to stress out that optimal improvement of road safety for vulnerable road users can only be achieved by multilateral Safe System approach, i.e. by simultaneously improving education of road users, upgrading/reconstruction of pedestrian and cyclist infrastructure and performing law enforcement where necessary. In the Safe System approach, it is accepted that human beings will always make errors. The engineering of the road and vehicle, when combined with education and enforcement, aims to contain drivers within a "normal driving" envelope.

To conclude, Based on the analysis of the inputs provided by road safety experts from Danube area countries, and the identified road safety issues, specifically related to vulnerable road users on Danube roads, it is recommended that:

- Danube-area Countries should incorporate the principles and concepts of Safe System approach in relevant legislation (laws, regulations, ordinances, etc.) related to vulnerable road users and ensure that this concepts are considered and implemented in all phases of road planning, design, construction and maintenance processes, as well as in all road safety audits, inspections and generally in any kind of road safety assessments which will be performed in future studies, projects and road safety researches. The criteria based on which countermeasures for vulnerable road users are selected, prioritised and implemented should in all cases also be aligned with Safe System approach principles and concepts;
- National laws and regulations related to safety of vulnerable road users and specific requirements for VRUs which are usually defined in sub-normative acts of the in-country competent ministries such as the Ministry of the Interior, the Ministry of Regional Development and Public Works and Ministry of Education and Science, and similar, as well as in ordinances of local government units (competent municipalities)

should be aligned between all Danube area Countries in order to remove legal barriers which prevent and slow down the road safety improvements;

- Specifically, all countries should amend existing regulatory documents for road signs and traffic management in a way that they include clear definitions and reasonable requirements for counterflow cycling, cycle lanes, bicycle streets, traffic calming measures and wayfinding for cyclists;
- Since existing methodologies used in different Danube-area countries for assessing the risks for vulnerable road users consider different, and in some cases only subjective parameters in order to identify most dangerous road sections on the observed road network, the results obtained by this methodologies can vary significantly and often cannot be easily compared between countries. This indicates the need for a development of a new unified protocol for assessment of the risks of vulnerable road users, which should be used in all countries in order to obtain results which are clearly understood and comparable between countries. A good example of a unified safety assessment approach is the methodology that has been used in order to assess the safety on 19.000 km of the EuroVelo, the European Cycle Route Network;
- The countermeasures selection, prioritisation and implementation process should not in any case be performed only based on subjective criteria but primarily based on objective methodology which considers all relevant road safety indicators. Therefore, the critical road sections on which countermeasures for vulnerable road users will be implemented should be selected/filtered based on at least the following key road safety indicators: (1) AADT traffic flow volumes on the observed road sections; (2) Pedestrian peak-hour flows along and across the observed road sections; (3) Operating speed of motorised traffic on the observed road sections; (4) The number of fatal and serious road traffic accidents involving vulnerable road users; (5) The density of fatal and serious road traffic accidents involving vulnerable road users; (6) The risk rate of vulnerable road users traffic accidents occurrence per kilometres travelled; (7) The main crash types involving vulnerable road users; (8) Relevant road design and pedestrian/bicyclist infrastructure characteristics including, road category, road width, the types of existing intersections, the position and quality of existing sidewalks, bicycle lanes/paths, pedestrian and bicyclist crossings, as well as existing road sight distance characteristics;
- All Countries should use supporting data on AADT values, traffic flow operating speeds and pedestrian peak-hour flow along and across the road together with information on the relevant characteristics of existing pedestrian and cyclist infrastructure on the road network (total length of pedestrian and cyclist network, the percentage of road network covered by pedestrian and cyclist facilities, the locations, type and quality of pedestrian and cyclist crossings, etc.) in order to select the critical road network sections which will be included in the countermeasure implementation process;
- Aforementioned relevant supporting data should be periodically collected on characteristic locations on the road network on a mandatory basis and updated in relevant databases. It is also important to ensure that this data is freely available at all times to road safety planners, engineers, auditors and all other stakeholders (accessible via internet);
- In addition to the primary selection criteria based on aforementioned key road safety indicators it is also important to ensure that: (1) Pedestrian and cyclists are physically separated from motorised and heavy traffic in all areas where operating speed of

traffic flow, and traffic flow volumes exceed the defined safety threshold values. All road sections where operating speed of traffic flow is greater than 40 km/h and AADT volume greater than 2500 veh/day cannot provide safe and comfortable mixed traffic, therefore in this cases vulnerable road users should be properly segregated from motorised traffic; (2) Types of pedestrian/cyclist facilities and crossing arrangements (marked crossing, signalised crossing or off-level crossing) should selected based on the pedestrian and vehicle peak-hour flow volumes;

- After identification of critical road sections on the observed road network, appropriate countermeasures should be selected based on Cost-Benefit analysis in which benefits of each proposed countermeasure, expressed in terms of estimated reductions in the number of vulnerable road users fatalities and serious injuries should be compared with the costs of its implementation. Priorities of implementation for selected countermeasures should be determined in a way that available funds are primarily invested in countermeasures which will ensure the maximal number of lives saved in future periods. Road safety planners, engineers and auditors should also consult all other relevant stakeholders before making final decision on which countermeasures will be implemented;
- During the countermeasure selection, prioritisation and implementation process it is also important to consider the influences that the proposed/implemented countermeasures will have on overall quality of public space, changes in modal distribution, air quality and level of traffic noise. The primarily focus should be on implementing low-cost, high-impact countermeasures by considering the concepts of tactical urbanism and space-wise planning. Good practice examples include car-free city centres/low emission zones and implementation of congestion charging schemes;
- All countries should periodically perform analysis of effectiveness and efficiency of countermeasures for vulnerable road users, after they are implemented in order to determine actual benefits over time in terms of the real achieved reductions in the number of vulnerable road users fatalities and serious injuries on observed parts of the road network. The results obtained by this analysis should be used to calibrate the expected BCR ratios of individual VRUs countermeasures. In that way precision of Cost-Benefit estimates can be improved over time;
- Individual municipalities which operate the pedestrian/cyclist facilities at local level should not be allowed to solely decide what indicators will be taken into account for safety assessment of pedestrian/cyclist infrastructure. They should instead be obligated to use standard road safety indicators defined at National and International level. Therefore, all countries should amend their legislation in a way that will ensure that results obtained by road safety assessments performed in individual municipalities at local level are standardised and comparable between different municipalities. This will ensure that data and knowledge collected during individual road safety assessments can be simply transferred and used as standardised input that can be fed into various national and international network-wide road safety assessments, as well as other relevant road safety studies, projects and researches that will be performed in future periods. In that way performance tracking and countermeasure selection, prioritisation and implementation processes both on national and international level can be significantly simplified and improved;
- All countries in the Danube region should ensure that the data on annual distance travelled by pedestrians and cyclists as well as their travel times are periodically collected in order to enable the calculation of the exact values of pedestrian and

cyclist exposure rates expressed in the number of pedestrian and cyclists accidents per kilometres travelled;

- Danube area countries should restructure road traffic accident databases in a way that they contain precise information on the frequency, types, spatial distribution, causes and consequences of road traffic accidents involving vulnerable road users. This data needs to be stored in databases in such a way that it can be easily filtered, extracted and compared, i.e. used as a basis for performing precise and reliable statistical analysis;
- The police database on road traffic accidents should be linked with hospital data in order to minimise the vulnerable road users accidents under-reporting issue;
- Danube area countries should develop new and/or restructure existing datasets on road network so that information on relevant pedestrian and bicycle infrastructure characteristic can be easily retrieved and used in future road safety assessments, studies, projects and researches. The road network database of each Country should include at least the following data on VRUs infrastructure: (1) total length of pedestrian and cyclist network; (2) the locations of existing/planned pedestrian and cyclist facilities; (3) the types of existing/planned pedestrian and cyclist facilities and (4) the quality of existing/planned pedestrian and cyclist facilities. This data is necessary for accurate identification of potential dangerous locations for vulnerable road users on the road network, calculation of individual road sections risk rates, as well as selection, prioritisation and implementation of appropriate countermeasures so it should be included in each road network database;
- Road traffic accidents and road network databases should be periodically updated in order to provide the data necessary for performing detailed and accurate performance tracking and traffic forecasts in future periods. Relevant data contained in the road traffic accidents and road network databases of each individual country should be freely available to all countries in Danube-area in order to enable simple knowledge-transfer among the countries;
- All countries should aim to develop their own analytical software which can be used for road traffic accidents and road network data analysis and reporting;
- The collected data as well as results and conclusions obtained based on performed projects, studies and researches related to the safety of vulnerable road users should also be freely exchanged among countries;
- In order to rise awareness of all road users of the: (1) importance and benefits of obeying traffic rules and regulations; (2) the risks to which vulnerable road users are exposed in road traffic; (3) importance and benefits of wearing reflective objects, light clothing, cycle helmets and retroreflective vests, relevant information can be disseminated to the public by various media sources, including television, radio, web-pages, newsletter, journals, leaflets and posters.

RADAR project Thematic Area 2 (TA2): Provision for vulnerable road users and assessment of the potential for dedicated infrastructure provision and policy attitudes towards dedicated provisions for VRUs in the Danube region

RECOMMENDATIONS SHEET

Recommendations for state governments/ministries/agencies:

- *To incorporate the principles and concepts of Safe System approach in relevant legislation and VRUs countermeasures selection criteria;*
- *To develop/incorporate a unified protocol for assessment of the risks of VRUs, which will ensure that results are understood and comparable between countries;*
- *The countermeasures selection, prioritization and implementation process for VRUs should not in any case be performed only based on subjective criteria but primarily based on official, standardized, objective methodology which considers all relevant road safety indicators (AADT, peak-hour pedestrian/cyclist flows, operating speed, traffic accidents characteristics);*
- *To define a national minimal standard threshold values of relevant road safety indicators based on which high-risk road sections for VRUs will be identified;*
- *To ensure that available funds are primarily invested in low-cost, high-impact countermeasures, by considering the concepts of tactical urbanism and space-wise planning;*
- *To develop/restructure and link datasets on road traffic accidents and road network in order to increase their precision and provide free and easy access to all stakeholders;*
- *To link the police database on road traffic accidents with hospital data in order to minimize the VRUs accidents under-reporting issue;*
- *To change traffic culture and public awareness by disseminating relevant information to the public by various media sources;*
- *To make knowledge transfer with demonstrations of good practices and approaches for road authorities and to regional/local governments.*

Recommendations for local governments:

- *To ensure that results obtained by road safety assessments performed in individual municipalities at local level are standardized and comparable between different municipalities and on the National level;*
- *To start systematic, high-quality road safety data collection and analysis to plan interventions/investments on most critical locations.*

Recommendations for road authorities:

- *To use the official, standardized, objective methodology for selecting most critical locations for VRUs with highest potential savings;*

- *To ensure that types of pedestrian/cyclist facilities and crossing arrangements are selected based on the operating speed of traffic flow and pedestrian, cyclists and vehicle peak-hour flow volumes;*
- *To periodically collect relevant supporting data on characteristic locations on the road network on a mandatory basis and update relevant databases;*
- *To periodically perform analysis of effectiveness and efficiency of implemented countermeasures for VRUs;*
- *To engage all stakeholders in the process of the road design (engineers need to collaborate with different stakeholders and NGOs).*

Your Road Safety is on our RADAR.

References

[1] World Health Organization, Global status report on road safety 2018. World Health Organization, 2018.

[2] Hermitte, T, Safetycube Scenarios Pedestrian accident, European Road Safety Decision Support System, developed by the H2020 project SafetyCube, 2017., Retrieved from www.roadsafety-dss.eu on 20.08.2019.

[3] European Commission: Traffic Safety Basic Facts 2018 – Pedestrians, European Road Safety Observatory Documentation. Traffic Safety Basic Facts. European Commission, Brussels, 2018.

[4] Hermitte, T, Safetycube Scenarios Cyclist accident, European Road Safety Decision Support System, developed by the H2020 project SafetyCube, 2017., Retrieved from www.roadsafety-dss.eu on 20.08.2019.

[5] European Commission: Traffic Safety Basic Facts 2018 – Cyclists, European Road Safety Observatory Documentation. Traffic Safety Basic Facts. European Commission, Brussels, 2018.

[6] ETSC Safety of pedestrians and cyclists in urban areas. European Transport Safety Council ETSC, Brussels,1999.

[7] Lynam, D., Nilsson, G., Morsink, P., Sexton, B., Twisk, D.A.M., Goldenbeld, C. & Wegman, F.C.M., An extended study of the development of road safety in Sweden, United Kingdom, and the Netherlands. Leidschendam, SWOV Institute for Road Safety Research / Crowthorne, Berkshire, Transport Research Laboratory TRL / Linköping, Swedish National Road and Transport Research Institute VTI, 2005.

[8] Organisation for Economic Co-operation and Development (OECD), Safety of vulnerable road users. Organisation for Economic Co-operation and Development OECD, Paris, 1998.

[9] Summersgill, I. Kennedy, J.V. & Baynes, D., Accidents at three-arm priority junctions on urban single-carriageway roads. TRL Report PR184. Transport Research Laboratory TRL, Crowthorne, 1996.

[10] Wittink, Promotion of mobility and safety of vulnerable road users: final report of the European research project PROMISING (Promotion of Measures for Vulnerable Road Users). D-2001-3. SWOV Institute for Road Safety Research, Leidschendam, 2001.

[11] PROMISING, Cost-benefit analysis of measures for vulnerable road users. Final report of Workpackage 5 of the European research project PROMISING (Promotion of Measures for Vulnerable Road Users), Deliverable D5. Transport Research Laboratory TRL, Crowthorne, Berkshire, 2001.

[12] UNECE, Convention on Road Traffic of 8 November 1968, incorporating the amendments to the Convention which entered into force on 3 September 1993. Inland Transport Committee of the United Nations Economic Commission for Europe UNECE, Geneva, 1993.

[13] ECMT, Safety in road traffic for vulnerable users Organisation for Economic Co-operation and Development OECD, Paris, 2000.

[14] ETSC, The safety of vulnerable road users in the Southern, Eastern, and Central European countries (The "SEC Belt"). European Transport Safety Council ETSC, Brussels, 2005.

[15] Pasanen, E., Driving speeds and pedestrian safety. Teknillinen korkeakoulu, Liikennetekniikka, Espoo, 1991.

[16] International Road Assessment Programme, iRAP Methodology Fact Sheet 4 – Crash types, 2013.

[17] International Road Assessment Programme, iRAP model factsheet 6, Star Rating Score Equaltions, 2013.
[18] International Road Assessment Programme, iRAP for Safer Cities Case Study: 5-Star Cities for all road users, 2019.
[19] https://ec.europa.eu/transport/road_safety/users/pedestrians_en
[20] https://ec.europa.eu/transport/road_safety/users/cyclists_en
[21] http://www.pedbikesafe.org/bikesafe/guide_background.cfm
[22] https://ec.europa.eu/transport/road_safety/specialist/statistics/map-viewer/
[23] https://www.safetycube-project.eu/
[24] https://www.roadsafety-dss.eu/#/knowledge
[25] https://www.vaccinesforroads.org/irap-big-data-tool/
[26] http://toolkit.irap.org/
[27] https://www.irap.org/methodology/