State of the art on urban road safety

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Abstract

Purpose: The objective of this study is to provide a comprehensive picture of the current situation on urban road safety and of the future challenges with focus on urban safety and mobility in Europe, especially of the vulnerable road users. Results: Although urban road fatalities are constantly decreasing in the EU, during the last years, their share on total fatalities remains significant and increasing. In addition, trends in road fatalities vary considerably among the different European regions. Evidence based road safety decision making is a key component for the improvement of road safety in urban areas. However, several challenges related to data and knowledge need to be dealt with, including the various technical, political and international cooperation barriers preventing the assessment of road safety measures and their prioritisation. Conclusions: In the complex urban environment, a number of difficult road safety choices persist in order to balance conflicting social needs and economical restraints, especially during the economic crisis period. Urban road safety should be integrated into urban mobility plans, equally with environment, energy and mobility concerns, within a long term and sustainable vision. Both authorities and citizens should be supported by reliable scientific evidence and make the necessary brave choices with focus on slower traffic and car traffic restriction.

Key-words: road safety, urban mobility, road safety measures

1. Introduction

Urban growth is linked to road network expansion and mobility is dominated for decades by the increased use of private cars and their traffic, environment, energy and safety implications. Initial functions of transport networks such as the regulated and channeled interactions or accessibility became gradually complex with a direct consequence an unacceptable number of road accident casualties. The continuous increase of traffic in urban areas and the multiplication of several different lighter (pedestrians, cyclists, motorcyclists) and heavier (passenger cars, busses, vans and trucks) road users leads to numerous unmanageable and serious conflicts and potential accidents (Millot, 2004).

Programs aimed at reducing road accident frequency and severity in urban areas, have traditionally been reactive in that they mainly examine problems on existing networks. Ideally, an estimation of the anticipated number of road accidents should be made before a road project is built or upgraded so that potentially hazardous elements can be identified and corrected accordingly, before the road is delivered to traffic. Planning analysis conducted in view of the construction or the improvement of a transportation project, is usually concerned with impacts on travel time, air pollution and fuel consumption while road safety is less possible to be taken into consideration (Lord & Persaud, 2004). During the last years, benefits gained from incorporating safety planning into the design process of transportation projects become more and more

perceivable (Wang et al, 2013). The review of the latest comprehensive transportation plans in 35 metropolitan areas, worldwide, revealed the incorporation of safety considerations as an essential element of these plans (Peng and Wang, 2011).

Efforts to minimize the frequency and severity of road accidents in complex urban environments require an understanding of the design and operation of urban road networks as well as of the equipment used for traffic control. The review of motor vehicle collision patterns is a key tool on this direction. Road accidents in urban areas are often concentrated at specific locations and occur in patterns that can be mitigated through appropriate engineering countermeasures. In addition to developing countermeasures for individual intersections based on specific collision patterns, it is important to consider implementing safety-related operational and design changes along entire stretches of urban arterials (Retting et al, 2001).

In residential areas of large cities, accident rates are often increased and accidents tend to be scattered throughout the road network. Planned transport functions of the streets are not always maintained as traffic volumes may be higher than foreseen in the design and some residential streets may have through traffic, especially during the rush hours. In such cases, an area wide approach for the prevention of road accidents is needed. During the last 40 years, area wide traffic calming schemes, have been implemented in residential areas, in major cities, in many motorised countries (Elvik, 2001).

The problem of road accidents in urban areas has been examined in several studies worldwide. Indicative subjects on which such studies focus are fatal risks inside and outside urban areas (Valent et al., 2002), (Vorko-Jovic et al, 2006), the effects of area-wide urban traffic calming schemes (Elvik, 2001) or specific measures on road safety (Hyden & Varhelyi, 2000) and the economic impact of road accidents (Hijar et al, 2004).

The objective of this study is to provide a comprehensive picture of the current situation on urban road safety and of the future challenges with focus on urban safety and mobility in Europe, especially of the vulnerable road users. At first, the basic facts on urban road safety in Europe are analysed, followed by a comprehensive analysis of current and future data and knowledge challenges for evidence based road safety decision making, including the road safety measures assessment and the related barriers to overcome. Subsequently, a comprehensive road safety research priorities list is established, followed by the discussion of the fundamental contemporary urban mobility and safety choices and the related directions to follow.

In fact, this study aims to address answers to several key open questions concerning urban road safety such as:

- Which are the current and future urban road safety problems?
- Are they the same across Europe?
- How critical are data and evidence based decision making?
- How much transferable are successful urban road safety solutions?
- How to integrate road safety into urban mobility plans?
- Can road safety compete environmental, energy and mobility concerns?
- Are Citizens and Authorities ready for the necessary choices?
- Which are the future challenges of urban road safety?

2. Basic facts on urban road safety in Europe

In the European Union (EU), during the period 2000-2010, urban road fatalities are constantly decreasing. However, their share on total fatalities remains significant and it is increasing (Figure 2.1). Furthermore, the trends in road fatalities vary considerably among the different European regions.

For the purposes of this study three groups of European countries are broadly defined: North-Western countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, United Kingdom), Southern countries (Cyprus, Greece, Italy, Malta, Portugal, Spain) and Eastern countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia). The highest road fatalities decrease in urban areas is recorded in North-Western European countries. In Southern countries the decrease is slightly lower while in Eastern countries it is less than half of that in North-Western ones. A decrease in road fatalities is also recorded outside urban areas, in all European countries. In North-Western and in Eastern countries, the decrease in road fatalities is higher outside than inside urban areas. The opposite is observed in Southern countries where road fatalities have decreased more inside urban areas than outside (Table 2.1).

Table 2.1: Road fatalities change in EU, 2001 – 2010 (source: CARE)

	Urban Areas	
	Inside	**Outside**
North – Western countries	-48.4%	-50,0%
Southern countries	-47,7%	-42,4%
Eastern countries	-22,6%	-24,3%

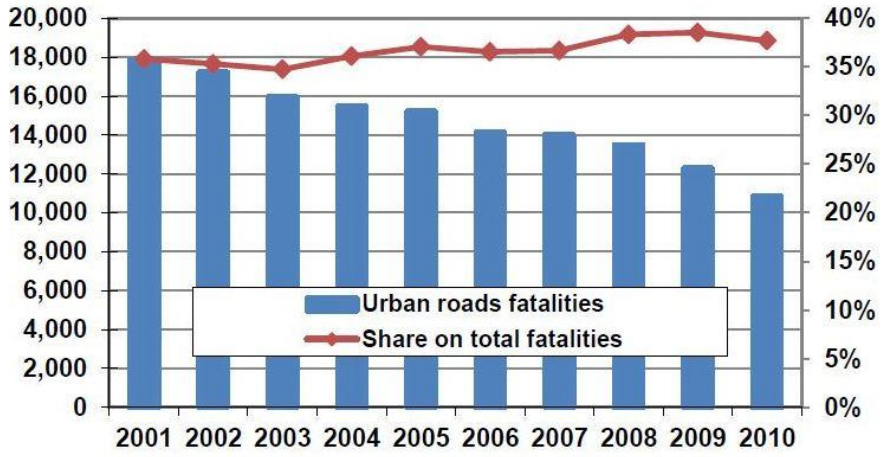

Figure 2.1: Urban Road fatalities 2001 – 2010 (source: CARE)

Urban road safety in the European Union is far from uniform across countries. The number of urban road fatalities by million inhabitants in 2010 shows a great variation

among European countries ranging from over 80 in Romania to almost 10 in Sweden (Figure 2.2).

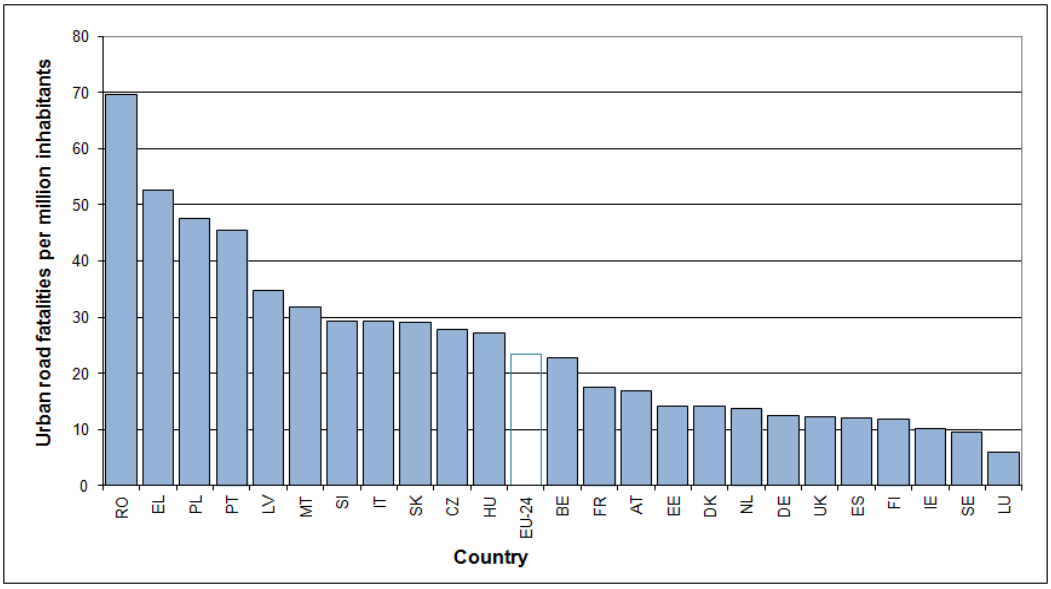

Figure 2.2: Urban road fatalities by million inhabitants EU 2010 (source: CARE)

The analysis of urban traffic fatalities per user type reveals different urban safety patterns in different groups of countries (Table 2.2). In all groups of European countries, pedestrians represent high percentages of urban fatalities, followed by power two wheelers and cyclists, with the exception of Southern countries where power two wheeler fatalities are more than pedestrian fatalities. It appears that power two wheeler safety is a more important problem of the South, cyclist safety a more important problem of North and West and pedestrian safety is a more important problem of the East.

Table 2.2: Road fatalities in the EU, 2010 (source: CARE)

Power Two Wheelers	Urban	Total	%
North-Western countries	848	3.776	22%
Southern countries	1.091	3.399	32%
Eastern countries	434	4.183	10%

Cyclists	Urban	Total	%
North-Western countries	472	3.776	13%
Southern countries	203	3.399	6%
Eastern countries	400	4.183	10%

Pedestrians	Urban	Total	%
North-Western countries	1.249	3.776	33%
Southern countries	1.066	3.399	31%
Eastern countries	1.888	4.183	45%

The distribution of road fatalities per user type (car driver, car passenger, pedestrian) in urban areas, in EU countries is shown in Figure 2.3. High percentages of pedestrians' fatalities are again depicted, especially in Eastern countries.

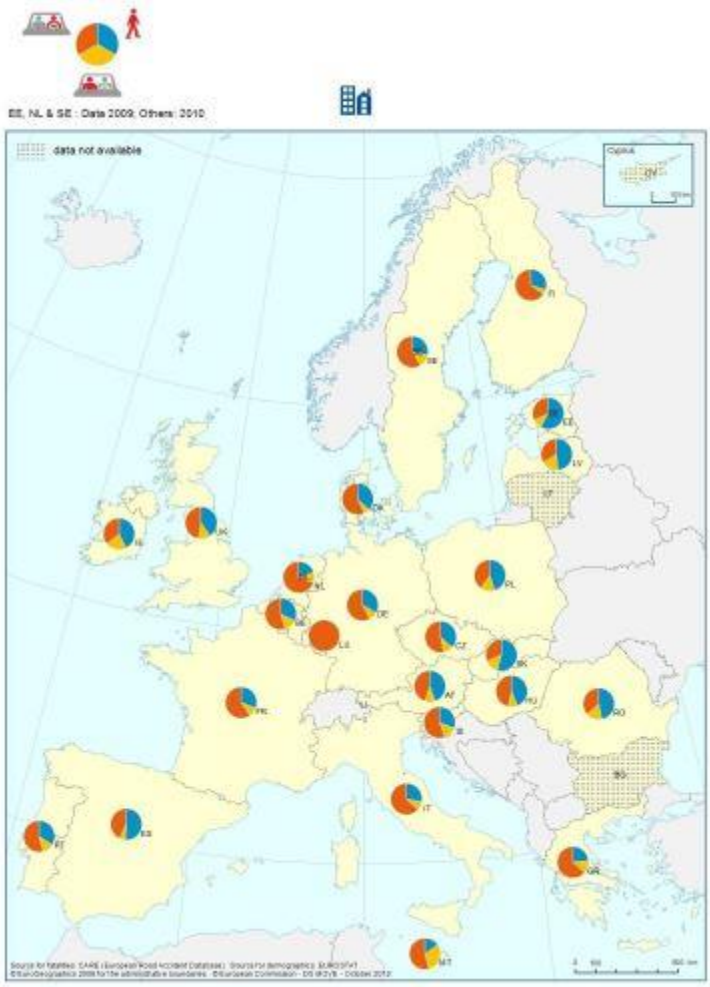

Figure 2.3: Urban road fatalities by user type, EU 2010 (source: CARE)

In summary in the European Union, road fatalities is a more important problem outside urban areas, whereas road injuries is a more important problem inside urban areas. The increasing number of power-two wheelers in the North-Western EU countries as well as the increasing number of cyclists in the Southern EU countries is resulting in a) power-two wheelers' safety problems of the South migrating to the North and West and b) Cyclists' safety problems of the North migrating at to the South. Finally, the economic recession has a direct impact to road fatalities decrease, however traffic fatalities trends after the recession cannot be easily predicted.

3. The need for evidence based road safety decision making

Road safety is a classic field for dedicating significant resources with potentially few or no results. Several road safety interventions are often very costly, especially those related to developing and maintaining road infrastructure and to vehicle technologies.

The impact of the implemented road safety measures is often limited and sometimes even negative. In addition, road traffic and driver behavior tend to adapt quickly to the new situation and new safety investments often bring new safety problems.

Therefore, there is an essential need for well designed road safety measures through evidence based decision making. The identification of the most suitable measures for specific road safety problems is a key challenge, possible only through the application of scientific and impartial methodologies. The social and economic benefits from a rigorous application of measures efficiency assessment can be very high. Road safety research and international cooperation are the keys to support evidence based decision making.

Positive and negative aspects of each solution, in the short and long term, should be demonstrated allowing all road safety actors (society, stakeholders, decision makers) to realise the positive and negative consequences of their choices. On that purpose, there is a clear need for publicly available high quality and impartial data and knowledge, with focus on the effectiveness assessment of road safety alternative solutions. However, there are several challenges related to data and knowledge that need to be dealt with.

Challenges for the necessary data supporting road safety analysis and the related decision making are numerous. Road accident data are not fully available (especially those for injuries) and not always reliable. Risk exposure data (vehicle/passenger kilometres/trips/time spent in traffic) are neither systematic nor sufficiently detailed, especially for the vulnerable road users (power two wheelers, cyclists, pedestrians). Performance indicators (speeding, drink and drive, seat belt/helmet use, etc.) are scarcely available and certainly not for all road users. Accident and injury causation indicators cannot have easily a general applicability and require more intensive data collection and analysis. Road user behaviour and attitude data not only are rare but also require considerable processing and analysis before being used to support decision making. Results of measures effectiveness are rare, piecemeal and not easily transferable from one case to the other. Studies and related results on road accident social cost remain poor.

Following the SUNFlower footprint (Wegman et al, 2005), road safety knowledge challenges can be listed in five distinct levels (Figure 3.1). At the first level, challenges related to the road safety structure and culture in each city, region and country should be addressed through long term and consistent road safety policies and organisational provisions. At the second level, concrete programmes and measures should be properly designed, implemented and monitored, exploring adequate analysis results and available good practice. At the third level safety performance indicators should be closely and systematically monitored to identify the effectiveness of policies, programmes and measures. At the fourth level thorough monitoring and analysis of the final safety outcomes expressed in terms of road casualties is necessary to support any further decision making. Finally, at the fifth level, the total social cost of road accidents and casualties should calculated and demonstrated, putting road safety high in the contemporary social problems agenda.

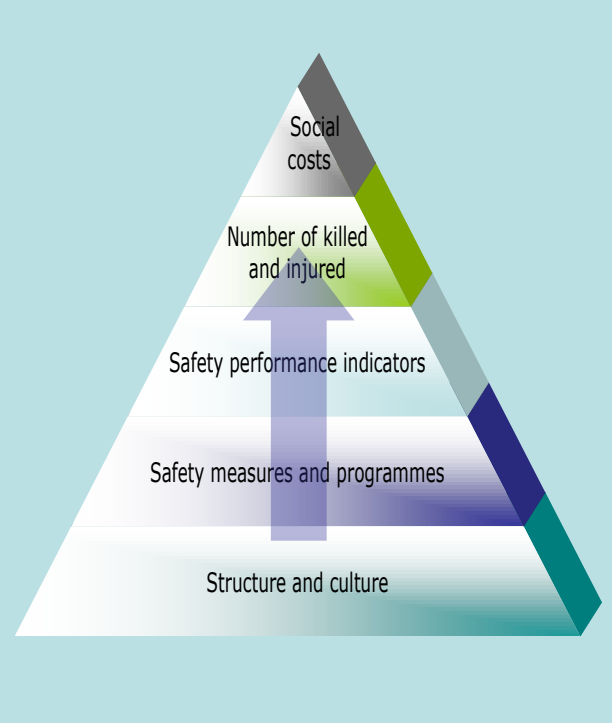

Figure 3.1. The SUNflower road safety system structure (Wegman et al, 2005)

Successful road safety decision making requires appropriate support for the measures to implement. However, the necessary assessment and prioritisation of potential road safety measures has to overcome several technical, political and international cooperation barriers.

Technical barriers for road safety measures assessment concern the difficulties in isolating the safety effect of a specific measure and in aggregating information and data due to high diversification of the measures. An additional technical barrier is the difficulty to compare information and data among cities, regions and countries, comprising of differences in road traffic environments, in the actual investment costs among the countries and in methodologies of safety effect calculation.

Political barriers for road safety measures assessment include mainly the fear of authorities and other stakeholders may have that ex-post evaluation of measures may prove that important road safety investments had little or limited impact. Furthermore, the comparison of measures' effectiveness among cities and among regions may reveal high discrepancies not only in the unit cost of the measures but also in the implementation effort.

Lastly, several barriers for exchange of road safety good experiences through international cooperation persist today. Transferability is not easy, because not all successful measures are suitable for all different road traffic environments; it is very much possible that the same interventions may lead to significantly different results in two different traffic environments. Furthermore, the scientists' competition and quest for the "excellent" methodology, together with the inherent difficulties of measures' efficiency assessment, puts in question any initiative. In addition, sometimes measures'

assessment invited by the authorities tend to use faster and less rigorous methodologies, favoring prevailing opinions and decisions already taken, creating thus a wide variety of non-converging efficiency results.

Few international initiatives exist so far in Europe for the exchange of the appropriate road safety data and knowledge to support decision making (OECD/ITF, UN-ECE, WHO). The European Road Safety Observatory (www.erso.eu) is a serious initiative of the European Commission providing data (annual statistical report, basic fact sheets, statistical tables, recent trends, geographical distribution) and knowledge (syntheses on road safety key issues, country profiles, policy, legislation, research results) which are necessary for the assessment of road safety measures and the support of appropriate road safety policies (Thomas et al., 2005).

4. Road safety research priorities

Road safety is a constantly changing phenomenon and scientific research is necessary to identify the causes of road accidents and the respective countermeasures as they evolve through time, especially in the complex traffic environment of the European cities. A series of road safety research priorities have been identified and organised into five basic categories (road user behavior, road infrastructure, vehicle technology, road safety management and research tools.) within the Dacota project (Thomas et. al 2013) and summarised here-after.

Concerning driver behaviour, research priorities in high need of more effort are vulnerable users, fitness to drive and behaviour changes. As far as vulnerable road users are concerned, focus should be given to young drivers which are still at highest risk among road users, followed by older drivers as the ageing drivers' population is constantly increasing. Furthermore, research on emerging safety problems of pedestrians, cyclists and power-two wheeler traffic should be intensified and gradually reach the levels of research effort concerning passenger car traffic.

In addition, special attention should be given to fitness to drive as all drivers are potentially concerned. Focus should be given to to driving under the influence of substances (alcohol, medicines, etc.), driver distraction and fatigue, with emphasis to definitions, measurements, causes and effects. Finally in view of improving road user behaviour towards safer practices it is necessary to further work on enforcement, campaigns and education with a focus on the five “killers” namely speeding, alcohol, non use if seat belt, non use of helmet and use of cell phones.

Road safety research priorities in relation to road infrastructure concern the creation of a smart infrastructure and the application of new road safety infrastructure management techniques. Moreover, design and construction of self-explaining roads and of forgiving infrastructure, which will also include roadside treatment is vital. It is also necessary that road infrastructure is becoming gradually more uniform across Europe and the not negligible road safety investments are better substantiated with the exchange of good practices.

Road safety should be integrated into all new transport, traffic and urban plans and appropriate scientific effort should be dedicated to this. Moreover, arrangements for the new generation of pedestrian and cyclist traffic should be explored, as well as special infrastructure and traffic arrangements for PTW's. Finally, the special requirements of the elderly, the vulnerable and other users with specific needs should be further investigated in the design of any urban infrastructure.

Research in the technological advances for active and passive safety of all vehicles should be intensified. The gradual inclusion in all vehicles of advanced driver assistance systems (ADAS) with focus on safety should be intensively explored. In addition, the safe design of the Human Machine Interface (HMI) and of the Human Vehicle Interface (HVI) should be further investigated and improved, together with the respective Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication and cooperative systems. A better understanding and support of the pre-crash phase is necessary for the reduction of road accidents while improved systems for the detection of pedestrians and two-wheelers could support accident avoidance. Research for special systems for the protection of motorcyclists and cyclists is also necessary. Lastly, the safety of new types of vehicles such as hybrid and electric should be further investigated at all stages of their development and putting in traffic.

As far as road safety management is concerned, research priorities in Europe should focus to the development of road safety culture, targeted strategies, integrated policies and efficient programs and measures. Other important steps that need to be explored include linking road safety management with road safety performance, monitoring implementation and effectiveness of road safety management and implement efficiency assessment and cost-benefit analysis with the use of crash modification factors, standardization and transferability.

Finally, there is need to improve the necessary tools to support research and evidence based decision making. Firstly, there is need for full operation of road safety knowledge centers (including the EU Road Safety Observatory) with reliable and high quality data and knowledge. Furthermore, the is need for exposure surveys (veh-kms, person-kms) for all road users (incl. PTW, cyclists, pedestrians), surveys for driver behaviour, attitudes, perceptions and road safety performance indicators and data harmonization and database interconnections (police, traffic, hospitals). Special emphasis should be given to multilevel and time series analysis and forecasting and to understanding road user behaviour and accident causes through large scale experiments for all road users through large scale in-depth accident investigations, naturalistic driving studies and driving simulator experiments.

5. Basic urban road safety choices

The high complexity of the urban environment makes road safety choices a very difficult task, attempting to balance conflicting social needs and economical restraints, especially during the economic crisis. Two of the most fundamental and not easy urban road safety choices that the decision makers and the citizens have to make concern: a) traffic efficiency (speed) versus traffic safety, b) vehicles versus vulnerable road users.

Speed is probably the most important cause of accidents and of the related casualty severity (Aarts et al., 2006). Therefore, the choice between speed and safety is a key issue in the development and operation of the road transport infrastructure. A road environment (road, sidewalks, adjacent uses) that is built to accommodate fast traffic of every kind, inevitably leads to increased number of traffic accidents, deaths and injuries. On the contrary, in a road environment where high speeds are not allowed, transport safety is increased and the frequency and the severity of traffic accidents and deaths is lower.

In modern societies, the right choice between speed and safety is that priority is given to safety. The respect of life is the number one priority and cannot be ignored in favour of faster transport. In order to achieve faster transport, other alternatives should be examined such as the channelling of faster traffic to peripheral ring roads outside or near cities and the development and support of more and better public transport which are also a safe way of transport.

The traffic of pedestrians, cyclists and power two wheelers - highly over-represented in road accidents - is a basic component of the quality of life offered in a modern city. Their interaction with vehicle traffic is a complicated issue concerning comfort as well as safety of travelling (OECD, 2001). Therefore, the choice between vehicles and vulnerable road users also constitutes a key concern in the development and the function of the city with a major safety component.

In the complex transport systems of the modern cities the choice among the groups of road users must be clear: priority must be given to calmer transport means and to public transport, with as clear as possible separation of the different types of traffic (pedestrian paths, bicycle routes, bus lanes etc.) in addition to the clear definition and the application of priority rules for every different road user category. Vulnerable users, meaning pedestrians, motorcyclists, young and older drivers, must be taken into account as fundamental design requirements during the development of road infrastructure and in traffic management.

In order to accommodate the various conflicting road user needs, urban road safety choices should follow the fundamental modern urban mobility directions. Safety should be integrated not only into the development of Urban Mobility Plans but also into proposed Urban Mobility Audits and Guidelines and be reflected in common targets. Additionally, plans should adopt a clear hierarchy of transport users, with public transport users, cyclists and pedestrians at the top of the hierarchy. The fact that the core public transport modes (bus and rail) are the safest modes of transport should always be taken into consideration. Finally, real and perceived safety can have a profound effect on modal choice especially in terms of the most sustainable modes of travel - walking and cycling ability to access public transport.

6. Conclusion

Urban road safety is a major and complex modern societal problem affecting quality of life in the cities worldwide. Within this study an attempt was made to provide a comprehensive picture of the current and future challenges of urban safety and mobility

in Europe, especially of the vulnerable road users. Basic urban road safety facts were followed by a comprehensive analysis of data and knowledge challenges for evidence based road safety decision making and the respective research priorities, with special mention to the fundamental contemporary urban mobility and safety choices.

Urban road safety should be integrated into urban mobility plans, equally with environment, energy and mobility concerns, within a long term and sustainable vision. Both authorities and citizens should realise the choices that need to be made with focus on car traffic restriction and work together and sincerely to implement them. The necessary knowledge for the support of decision making could only be acquired through targeted and systematic research.

Urban road safety challenges will continue to evolve. Future urban road safety challenges involve a serious effort for scientific research and evidence (data and knowledge) based policy making with emphasis on international cooperation. Focus should be given to improving driver behaviour and the overall safety culture, as well as more efficient solutions for smart and safe road infrastructure and vehicle active and passive safety, with special focus to the safety of power two wheelers, cyclists and pedestrians. If only scientific evidence is reliable and available to all, the appropriate brave urban road safety choices can be made.

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