About pedestrian safety in Europe

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***Abstract*— The objective of this research is to create an overall picture of pedestrians' road safety in European countries, to identify factors associated with increased pedestrian fatality risk, and to propose countermeasures for the improvement of pedestrians road safety in Europe. In particular, data on pedestrians' fatalities for the period 1997-2006 from 19 EU countries, extracted from the EU CARE database, are associated with basic road safety factors like pedestrian's age and gender (with particular focus on children and the elderly), lighting conditions, area type (inside / outside urban area) as well as seasonality. Both overall trends and countries comparisons are examined, whereas pedestrians' accident risk rates (fatalities per population) are also estimated. The results suggest that, although pedestrian fatalities in Europe present a decreasing trend, pedestrian fatality rates are still increased in Southern European countries, as well as in the new Member States. Moreover, pedestrian fatalities are increased inside urban areas, at night-time and during the winter, whereas children and the elderly remain the most vulnerable groups. These results are further discussed in relation to pedestrians risk exposure. Finally, a review of various road safety measures from the international experience is carried out and specific areas of action are proposed in the light of these results.**

***Index Terms*—pedestrians, risk factors, road safety, Europe.**

I. Introduction

Pedestrians are the most vulnerable users of road transport networks, and their increased vulnerability may be attributed on the one hand on the lack of speed, mass and protection, compared to other road users [1] and on the other hand on their particular characteristics (e.g. flexibility, ample space requirements, diversity of attention etc.) and behaviour [2-3] affecting the nature of their interaction with motorized traffic [4]. Moreover, pedestrian safety needs are not always adequately considered in road infrastructure design and traffic management [5].

Despite the fact that pedestrian road casualties in Europe presented a constantly decreasing trend during the last two decades, the number of pedestrians involved in road accidents in several countries and as a whole is still unacceptable [6] and illustrates the need for even greater efforts with respect to pedestrian safety. Most importantly, it is observed that the peak or abnormal situations remain practically unchanged over this period, suggesting a persistence of the basic pedestrian risk factors. In particular, pedestrians appear to be at increased road accident risk outside urban areas, during night-time and at adverse weather conditions, whereas children and the elderly are the most vulnerable pedestrians [7].

Within this framework, the objective of this paper is to provide an overview of pedestrians road safety in European countries, to identify factors associated with increased pedestrian fatality risk, and to propose countermeasures for the improvement of pedestrians road safety in Europe.

For this purpose, disaggregate data on pedestrians' road accidents from the EU-CARE database, as well as data from other international data sources (Eurostat etc.) are analyzed. In particular, data on pedestrians' road fatalities for the period 1997-2006 from 19 EU countries are associated with basic road safety factors like the pedestrian's age and gender (with particular focus on children and the elderly), the lighting conditions, the area type, as well as the month. Both overall trends and countries comparisons are examined, whereas pedestrians' accident risk rates (fatalities per population) are also estimated.

The data used are the latest data available, i.e. year 2006 for all countries except LU (2002), IE and NL (2003), IT (2004), PL (2005) and UK (2006 for GB, 2005 for NI). The data from CZ, EE, HU, MT and PL are not considered.

Moreover, pedestrian safety measures are examined on the basis of the international experience, in order to propose specific measures for addressing the pedestrians' road safety problem in Europe.

II. Analysis of Pedestrian Road Safety in Europe

A. Overall trends

In 2006, 3.547 pedestrians were killed in road traffic accidents in the EU-14. This is 14.4% of all fatalities in 2006. In the last decade, pedestrian fatalities have reduced by 36.6%, while the total number of fatalities has reduced by nearly 30% [7]. Figure 1 shows the total number of fatalities for the examined period (the line is dashed for years where data up to 2006 are not available for all countries). It is noted that the slight rise of pedestrian fatalities in 2002 results from an important increase in Italy on that particular year.

It can be seen that the proportion of pedestrian fatalities follows the general decrease of road fatalities between 1997 and 2004, but shows a slight increase since 2005. This suggests that, road safety measures implemented in the last decade have had a less considerably effect on pedestrian fatalities, compared to other road users' fatalities.

B. Country comparisons

In order to compare pedestrian fatalities of different countries, the respective population has been taken into account, as in Figure 2. The rate ranges from 5.9 pedestrian fatalities per million inhabitants in the Netherlands to 47.6 pedestrian fatalities by million inhabitants in Estonia, a rate

which is about 8 times higher, while the EU-19 average is equal to 15.8.

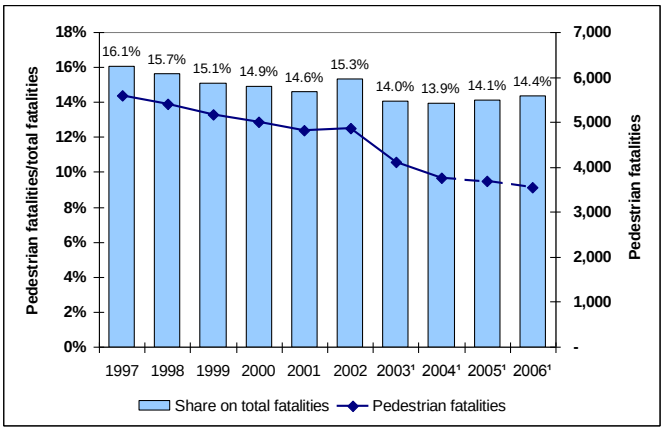

Fig. 1 - Number of pedestrian fatalities and proportion on total fatalities in EU-14, 1997-2006

Pedestrian fatality rates are also increased in Poland, Hungary and the Czech Republic, as well as in Greece and Portugal. An interesting pattern is identified, according to which pedestrian fatality rates are increased in Southern European countries, as well as in the new Member States. In the first case, this may be attributed to increased exposure of pedestrians, as a result of favorable climate, whereas in the second case it is more likely associated with increased exposure of pedestrians due to low motorization levels [8].

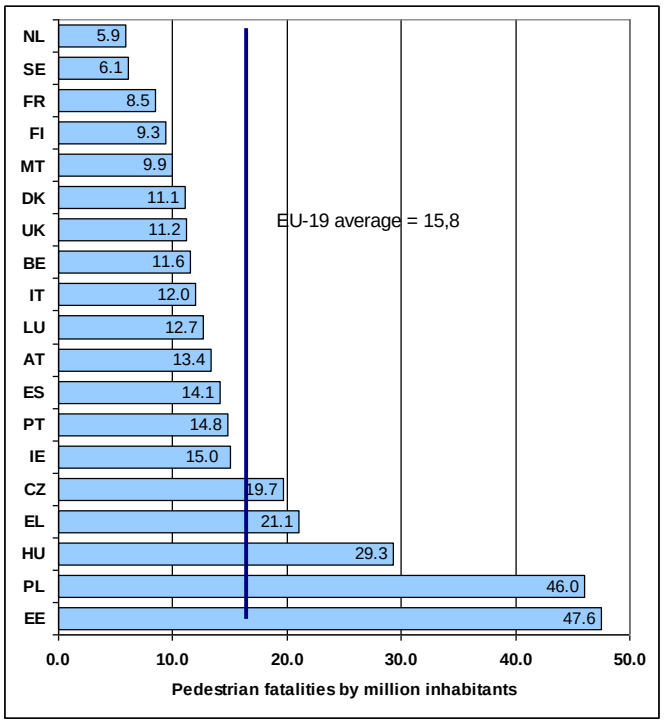

Fig. 2 - Pedestrian fatalities per million inhabitants by country, 2006

C. Effects of age and gender

The proportion of fatalities who are pedestrians is considerably high for children (i.e. age <15 years) as well as for the elderly (i.e. age >65 years). A reason for this could be the even more increased physical vulnerability, together with a lower level of motorization in these age groups, the latter reflecting an exposure pattern [9]. Figure 3 shows that around 30% of children's road fatalities are pedestrians. Additionally, more than 30% of persons killed in the age groups >65 years are pedestrians, a value that reaches 54% in the age groups > 85 years.

When examining country effects, it can be found that in Greece, Italy and France more than half of all pedestrian fatalities are the elderly, whereas the EU-19 average is 49%. On the other hand, the proportion of children pedestrian fatalities varies widely among the EU-19 countries, from 18% in the Netherlands to 2% in Finland. These differences among counties in children and elderly pedestrians' accident involvement may be attributed to differences in exposure of these particular groups, partly affected by weather conditions, as well as by other factors such as the country's residential and traffic infrastructure and the typical national habits (e.g. adults accompanying children to school etc) [10]-[11].

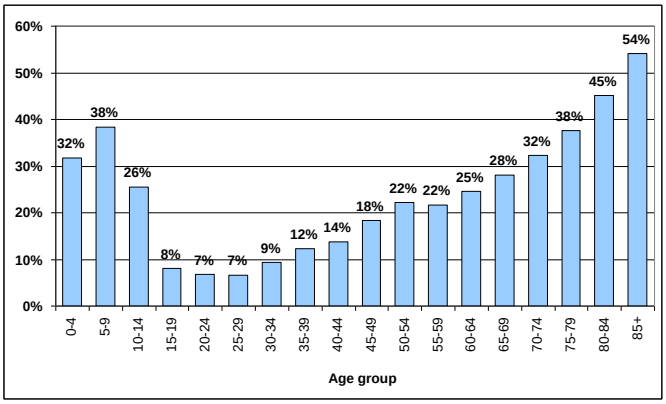

Fig. 3 - Pedestrian fatalities as a percentage of total fatalities by age group in EU-19, 2006

Nevertheless, as shown in Figure 4, although children have a high proportion on pedestrian fatalities, they have a lower fatality rate than the average population (15.8 pedestrian fatalities by million inhabitants). On the other hand, the pedestrian fatality rate of the elderly is much higher than the average, increasing up from the age of 70. In particular, the fatality risk of pedestrians of 70-74 years is twice the average, whereas the fatality risk of pedestrians of >85 years is about four times the average. Moreover, the risk rates of elderly pedestrians are up to ten times higher than those of children.

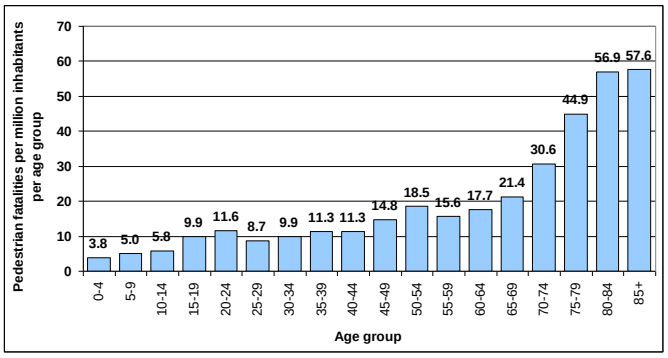

Fig. 4 - Pedestrian fatalities per million inhabitants by age, 2006, EU-19

As regards the effect of gender on pedestrian road safety in Europe, in all European countries male pedestrian fatalities are more than female pedestrian fatalities, ranging from 60% in Finland to 70% in Poland. It is likely that this is a result of differences in behaviours of males compared to females [12]-[13].

However, females are over-represented in pedestrian fatalities, compared to total fatalities. More specifically, as shown in Figure 5, the proportion of females in total fatalities in EU-19 is equal to 23%, whereas the proportion of females in total pedestrian fatalities in EU-19 is equal to 34%. It appears therefore that females are quite more vulnerable as pedestrians, compared to their overall road safety level. This may be partly due to increased exposure of females as pedestrians [14].

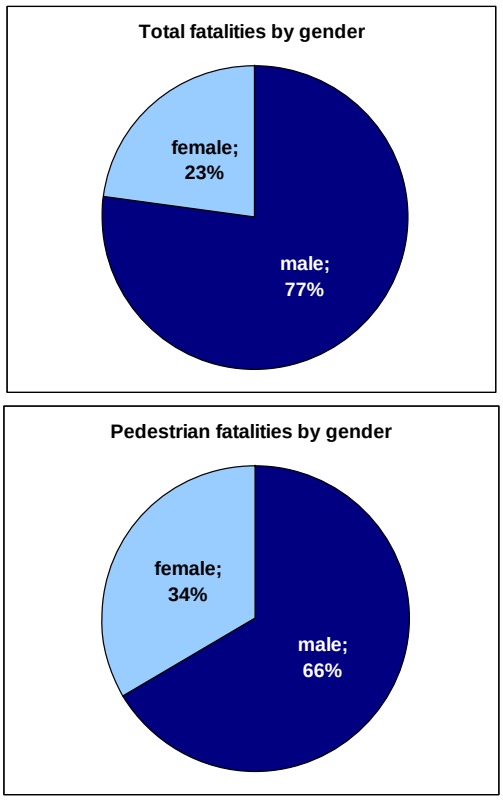

Fig. 5 - Share of gender for pedestrians and for total fatalities in EU-19, 2006

D. Effect of area type

Although most of all fatalities occur outside urban areas (around 65%), the majority of pedestrian fatalities occur inside urban areas (more than 60%), obviously due to the fact that most pedestrian trips take place inside urban areas [7].

On the other hand, pedestrian fatality risk outside urban areas is increased compared to fatality risk inside urban areas, due to the increased speed of motorized vehicles outside urban areas, resulting in increased impact speeds suffered by the pedestrians.

E. Effect of lighting conditions

The distribution of fatalities by lighting conditions (see Figure 6) shows that pedestrians have increased fatalities during night-time with an average of 45.9% of pedestrian fatalities. This varies significantly between the respective countries, from 59% in Poland to 35% in The Netherlands. When examining country effects, Southern European countries present relatively low proportions of pedestrian fatalities at night-time.

It is noted Luxemburg and Italy are excluded from this analysis due to a high proportion of fatalities with unknown light conditions. Moreover, the results concerning Malta are not discussed here, given that they are based on a very low sample of pedestrian fatalities during night-time.

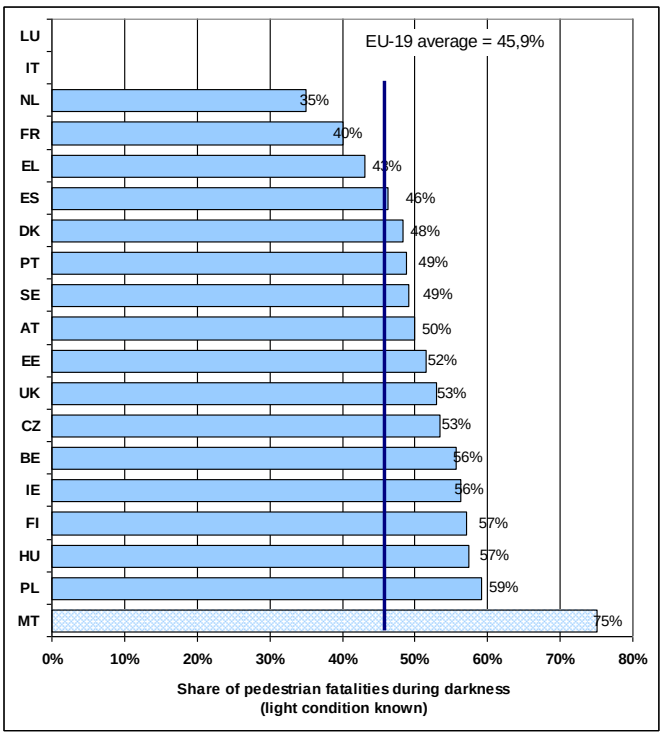

Fig. 6 - Pedestrian fatalities during darkness as a proportion of all pedestrian fatalities by country 2006

F. Seasonality

Generally pedestrian fatalities are most frequent from October to December and least frequent from April to June, although pedestrians exposure are generally expected to increase during spring and summer. The proportion of the

months October to December is especially high in northern countries like Finland and Sweden. Only The Netherlands have less than a fifth of their pedestrian fatalities occurring between October and December [7].

It is interesting to note that pedestrian fatalities show large differences in their seasonality compared to total fatalities (see Figure 7). They increase in autumn and decrease in spring with highest fatality numbers from November to January, while the peak season for total fatalities is in summer. The increased pedestrian fatalities during the winter compared to other seasons, are probably caused by a higher risk for pedestrians in darkness. The time of darkness/twilight is longer than in other seasons, weather conditions are more adverse and consequently pedestrians are much less visible. The months with the lowest numbers of killed pedestrians are April and May.

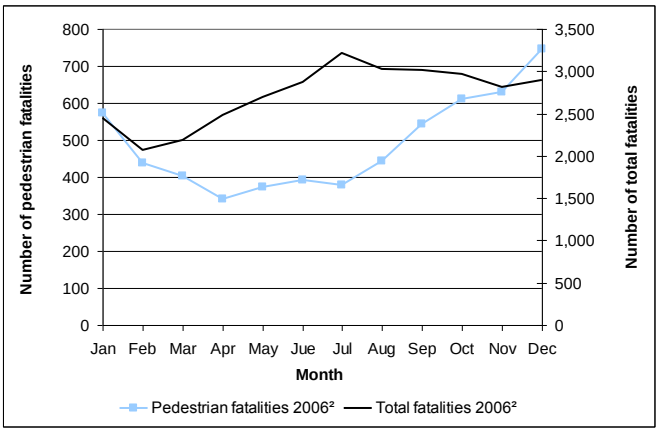

Fig. 7 - Pedestrian fatalities and total fatalities by month in EU-19, 2006

III. PEDESTRIAN SAFETY MEASURES

The above results on pedestrian fatalities in the European countries confirm previous findings with respect to pedestrian risk factors in Europe. The most updated comparable data at European level reveal a persistence of the basic risk factors for pedestrians and a need for intensification of efforts to address these risk factors. They suggest that, although pedestrian fatalities in Europe present a decreasing trend, pedestrian fatality rates are still increased in Southern European countries, as well as in the new Member States. Moreover, pedestrian fatalities are increased inside urban areas, at night-time and during the winter, whereas children and the elderly remain the most vulnerable groups.

Consequently, pedestrian safety measures should aim to address these specific risk factors. In this section, a review of pedestrian safety measures is carried out, and specific measures, among the most effective ones, are eventually proposed in view of the risk factors identified above.In general, the measures that can be envisaged to improve pedestrian safety may be classified in the following eight categories according to what they primarily do [5]:

(i)Reduce excessive speeds of motor vehicles on roads likely to be crossed (or shared) by pedestrians, in order to reduce stopping distances and minimize accident consequences.

(ii) Reduce conflicts between pedestrian flows and motorized traffic, and thus reduce exposure [16].

(iii) Facilitate and protect pedestrian crossings [17-18].

(iv) Improve visibility of pedestrians to drivers (and of vehicles to pedestrians).

(v) Improve readability of the road environment for all road users.

(vi) Improve vehicle design, so as to prevent pedestrian accidents or reduce their severity.

(vii) Solve problems of special pedestrian groups, such as children, elderly and handicapped people by providing acceptable levels of service to those road users.

(viii)Improvement of road user behavior through education, enforcement or social measures.

Therefore, a combination of measures and actions may efficiently address the basic pedestrian risk factors in each case [15]. As regards the specific measures available, four basic areas can be defined, corresponding to the broad fields of application of the safety measure, namely management of vehicle traffic, provision or improvement of pedestrian infrastructure, improving road user perception and education / enforcement. Each area can be subdivided into actions, which refer to specific objectives of design and planning / policy to address specific risk factors, and each action can be materialized through a number of distinct measures. Specific measures from each area can be summarized as follows [5], [17]:

(i) **Management of Vehicle Traffic**, aiming to reduce vehicle traffic and speeds, and vehicle / pedestrian conflict situations, as well as to reduce accident consequences**:** Reducing vehicle traffic (e.g. traffic restrictions, Ring road / bypass, Lorry ban, Closure of side streets, One-way streets), lowering vehicle speeds (e.g. speed limits, Roundabouts, Rumble strips), area-wide speed-reduction or traffic calming schemes (e.g. Narrowed carriageway, Advance warning for speed reduction, speed humps, Raised junctions, Planting / landscaping), reducing vehicle skidding (e.g. anti-skid surfacing, ABS) and introducing vehicle softening impacts (e.g. "Friendly" vehicle fronts, Side protection screen on lorries and other vehicles).

(ii) **Provision or Improvement of Pedestrian Infrastructure**, aiming to re-allocate urban space in favour of pedestrians and offer pedestrians a more integrated, safer and comfortable walking environment**:** provision of sidewalks, provision of an integrated walking network (e.g. Pedestrian zone / streets, Zebra crossings, Push-button signalized crossings, Yellow flashing light at crossings, Stop-line before pedestrian crossings), shared use of road surface by vehicles and pedestrians (e.g. Woonerf), channelising crossings, grade separation of crossings (e.g. pedestrian bridge / overpass, Pedestrian tunnel / underpass, shortening (especially uncontrolled) crossings (e.g. refuge, Median opening), avoidance of abrupt level changes (e.g. raised crossing, Low kerbs and mild gradients for pedestrians, Ramps for wheelchairs / mobility-handicapped, Kerb cut), automated demand-responsive crossings, pedestrian-friendly walking surfaces, reducing walking distances for the handicapped etc.

(iii) **Improving Road User Perception**, in order to improve visibility and facilitate timely action both for drivers and pedestrians, especially as regards children and the elderly**:** making pedestrians more visible (e.g. fluorescent / retro-reflective clothing, street lighting, removal of visual obstacles), improving overall visibility for drivers (e.g. better lateral visibility for lorries and other vehicles, elimination of glare sources, avoidance of accumulated signs, telematics driver aids), making vehicles more visible / noticeable (e.g. daytime running lights, reduction of noise level from indoor sources), making signing / marking more visible / comprehensible etc.

(iv) **Education and Enforcement**, aiming to improve road user behaviour and raise awareness on the importance of safe behaviour**:** educating road users in general (e.g. general traffic education, advertising campaigns), educating drivers (e.g. driver training, rewarding safe drivers, changing behavior of younger traffic participants towards the elderly), educating pedestrians, educating special groups of pedestrians (e.g. guidelines / training for the blind / ill-sighted, elderly pedestrians, mentally handicapped people, education, training and publicity for children), enforcement (e.g. Police control / enforcement, Provisions in legislation and regulations, Highway code), special protection for children / the elderly (e.g. provision of crossing patrols, physical protection of crossing patrols, supervision of children in vicinity of busy roads).

However, a particular objective may correspond to different types of measures, indicating that, very often, a combination of measures is required to bring about the desired solution to a pedestrian safety problem.

Taking into account appropriate criteria such as the cost-effectiveness of a measure (i.e. low cost and high safety effect), the promotion of technical measures and the non-restrictiveness of a measure (in terms of pedestrian mobility), the most promising road safety measures for pedestrians have been identified in recent research [15],[18],[19],[20], following exhaustive review and evaluation of the safety effects and the cost-effectiveness of the measures in different countries and settings. In particular, traffic calming, integrated walking networks, roundabouts and other junction treatments (e.g. channelization, median openings) are cost-effective measures that can contribute to the improvement of pedestrian mobility and safety in urban areas. Road lighting improvements and daytime running lights should be more extensively implemented for addressing the nighttime / visibility risk factors for pedestrians. Special measures for the elderly / disabled pedestrians, mainly through related infrastructure treatments, as well as education, are considered to be particularly cost-effective road safety measures for vulnerable groups of pedestrians.

IV. Discussion

On the basis of these results, and keeping in mind the risk factors identified through the analysis of the most recent data at European level, it is recommended to put particular emphasis on measures aiming both to reduce vehicle speeds / vehicle traffic and at the same time upgrade the infrastructure for pedestrians. The promotion of such road safety policies should be a priority at national and European level [6]. The implementation of more case-specific measures to address particular or local pedestrian safety problems is equally important [15].

However, with responsibilities in road safety shared between national and local authorities in most European countries, intersectional co-ordination at the highest level is not sufficient [21]. Some co-ordination and links must also exist between the national and the local decision-making structures. On the one hand, national policies need to be relayed at the local level in order to become effective. On the other, effects of local policies need to be assessed and taken into account when formulating new policies at the national level.

Finally, it is underlined that thorough analysis is always necessary in order to optimize the effects of road safety policies or specific measures in different countries or areas [15], by taking into account the extent of the problem, the specific risk factors, and the specific national or local requirements.

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