Assessment of pedestrian safety measures in Europe

George Yannis [1]	***George Kanellaidis***	***John Dimitropoulos***	***Nicole Mulhrad***
Assistant Professor	*Professor*	*Transportation Engineer*	*Research Director*
National Technical University of Athens *5, Iroon Polytechniou street, GR-157 73 Athens, Greece* *geyannis@central.ntua.gr*			*INRETS* *2, av. Gen. Malleret Joinville,F-94114* *Paris, France*

[1] Address for correspondence:
Dr. George Yannis
Department of Transportation Planning and Engineering,
National Technical University of Athens
5, Iroon Polytechniou str., GR-15773 Athens Greece
phone +30.210.7721326, fax +30.210.7721454, e-mail: geyannis@central.ntua.gr

Assessment of pedestrian safety measures in Europe

Abstract

This research aims to synthesize and assess various pedestrian safety measures in Europe, in terms of their effectiveness and to propose a set of interventions with positive impact on pedestrian safety, with emphasis on technical non-restrictive measures. An extensive hierarchical inventory of pedestrian safety measures took place, classifying them according to the functions served and the main safety problems addressed. The evaluation of the effectiveness, the restrictiveness and the implications of each measure led to the proposal of a set of "most promising" measures. This comprehensive synthesis showed that mechanisms should be ensured for converting policy into practice at the level of "street design" and guaranteeing coordination between actors of different responsibilities and disciplinary backgrounds.

Key-words: road safety, safety measures, pedestrian safety, traffic, measures assessment

INTRODUCTION

The definition of a pedestrian includes persons traveling on foot as well as those using some appliance or objects to help them fulfill that action or to accompany them in fulfilling it; this definition includes pushing a pram, wheelchair, bicycle or moped (however, not riding the bicycle or moped). In some countries, the definition is extended to cover people traveling by skis, skates or similar means (OECD, 1997).

Pedestrians are a fairly heterogeneous group: "everybody" is a pedestrian. Speeds as well as movement patterns vary for different pedestrian types. Particularly vulnerable groups include children, the elderly and the disabled (ETSC, 2005). However, the following general characteristics apply to all pedestrians (Vermeulen, 1998).

- vulnerability,
- flexibility / maneuverability,
- ample space requirements
- diversity of attention,
- non-traffic-related safety / security concerns,
- negative attitude towards regulations,
- tendency to move straight

Overall, the pedestrian's logic differs from the driver's logic - and is often not in line with the designer's logic (Nee, Hallenbeck, 2003). Taking the pedestrian's logic into account is an important prerequisite for judging pedestrian safety measures from the viewpoint of their main intended beneficiaries.

Urban transport planning theory and practice in recent years tends to promote more environmental-friendly travel modes, such as walking (and cycling) (ETSC, 1999). Safety is among the most important quality aspects of walking, in particular given the vulnerability of pedestrians (both in terms of accident probability and expected severity), and is a crucial factor not only in providing for the needs of existing walkers but also in attracting a portion of car users to walking (Behrensdorff, 1998).

Road accidents involving pedestrians is a relatively frequent road accident type due to the nature of the interaction between pedestrian and traffic (Fontaine, 1995). Furthermore, occurrence of pedestrian casualties is highest for the over-55 and under-12 years age groups in all European countries (SafetyNet Fact Sheets, 2005, Federation of European Pedestrian Association, 1993). The majority of pedestrian accidents take place inside urban areas whereas pedestrian accident severity is higher outside urban areas (ITE Task Force, 2001). The percentage of pedestrians killed on the total number of fatalities varies considerably between the European countries (Table 1) (European Commission, 2006).

*** Insert Table 1 here ***

Compared to most other road accident types, the severity of pedestrian accidents is considerably high, due to the vulnerability of pedestrians vis-à-vis the vehicles (City of Helsinki, 1997). Pedestrians have the highest ratio of deaths to injuries among all categories of people injured by motor vehicles: about twice as much as motorcyclists, and over four times as much as for motor vehicle occupants (Choueiri et al., 1993).).

A number of countermeasures have been implemented during the last decades focusing on safer pedestrian participation in traffic. These measures for pedestrian safety comprise special measures (information campaigns, school education, etc.) and equipment (clothing, etc.) for pedestrians, special road infrastructure (arrangements of roadway layout and pedestrian crossings and over-/underpasses, signing, street lighting, etc.) (Kamyab et al., 2003, Kothari, 2002, King et al., 2003, Esse et al., 1995, Retting et al., 1996), vehicle design (carfront design, etc.) and special measures for driver behavior (zone-30, etc.) (Huang and Cynecki, 2000). **These measures can be of a restrictive or non-restrictive and a technical or non-technical nature**. The efficiency of these measures is something rarely quantified and research in this field is under way (Elvik, 2000).

Measures to improve pedestrian safety, especially when they are non-restrictive for pedestrians, are often complex, as they usually associate different kinds of actions (on infrastructure, traffic, road-users), and they introduce important changes in traffic and transport patterns (Breen, 1998). **Their implementation therefore requires the participation of several actors** and they need to be integrated in wider policies of transport management or of safety for other categories of road users (Wouters, 1997).

OBJECTIVES AND METHODOLOGY

Within the above described framework, **the objective of this research was to assess the extent to which pedestrian safety measures affect the interaction between pedestrians and the traffic**, and to propose a set of interventions with a net positive impact to pedestrian safety, with emphasis on technical non restrictive measures.

On the basis of existing experience in Europe (six representative countries were examined in detail, Austria, France, Greece, Italy, The Netherlands and United Kingdom), the pedestrian safety problem was analyzed in detail allowing for the identification of measures aiming to face each type of problem. More precisely, about one hundred measures were identified and classified in a three-tier hierarchy, having a direct correspondence to the pedestrian safety problems addressed. These measures concerned the different vehicle and pedestrian traffic patterns (urban-rural, day-night, northern-southern European countries, etc.) as well as the particular pedestrian needs.

The assessment of the various pedestrian safety measures comprised an evaluation of the effectiveness, of the restrictiveness as well as of the implementation implications of each measure, allowing thus to propose not only a set of general conclusions but also a set of the "most promising" measures (PROMISING, 1998).

FROM PROBLEMS TO MEASURES

The term "safety measure", used in a broad sense, includes all physical items, settings and procedures intended to reduce the probability and/or severity of accidents, for one or more accident types and for one or more road user categories. Such a comprehensive definition is bound to include diverse types of measures. To facilitate their presentation and subsequent analysis and evaluation, it was necessary to categorize them. The categorization made was based on the functions served by pedestrian safety measures, which in turn relate to the main safety problems addressed (Muhlrad, 1995). The measures that can be envisaged to reduce the problems have been classified in the following eight categories according to what they primarily do:

(A) **Reduce excessive speeds of motor vehicles** on roads likely to be crossed (or shared) by pedestrians, in order to reduce stopping distances and, if a pedestrian accident does happen, to minimize its consequences (Martincigh et al., 1998).

(B) **Reduce conflicts between pedestrian flows and motorized traffic,** and thus reduce exposure, through the segregation of parts of the pedestrian network (Tira, Ventura, 1998).

(C) **Facilitate and protect crossing a stream of vehicular traffic,** as a majority of pedestrian accidents involve pedestrians crossing at "random" locations (Rennesson, Lourdaux, 1998).

(D) **Improve visibility of pedestrians to drivers (and of vehicles to pedestrians),** to avoid masking the pedestrians and improve communication between pedestrians and drivers.

(E) **Improve readability of the road environment for all road users** to facilitate anticipation of changes in the driving situation and avoid wrong expectations.

(F) **Improve vehicle design,** so as to prevent pedestrian accidents or reduce their severity (Edwards, 1998).

(G) **Solve problems of special pedestrian groups, such as children, elderly and handicapped people** by providing acceptable levels of service to those road users over the pedestrian network, and more specifically in areas which they particularly frequent or with high pedestrian concentration (Oxley, 2005).

(H) **Improvement of road user behavior** through education, enforcement or social measures, considered as indispensable elements of traffic safety policies complementing technical measures (Weber, Schausberger, 1998).

Following this categorization of pedestrian safety measures according to the safety problem addressed, a three-tier functional hierarchy of pedestrian safety measures was established:

- At the *top level*, four basic **Areas** were defined, corresponding to the broad fields of application of the safety measure. These Areas are denoted as follows:
    (i) Management of vehicle traffic
    (ii) Provision or improvement of pedestrian infrastructure
    (iii) Improving road user perception
    (iv) Education and enforcement

- At the *middle level*, each Area was subdivided into **Actions**, which refer to specific objectives of urban design and planning / policy. In total, twenty-six Actions were defined.

- At the *bottom level*, each Action is materialized through a number of distinct **Measures**, concerning street design items, regulations and initiatives.

The above hierarchy illustrates the linkage between specific measures and the objectives they (are intended to) fulfill. The full inventory of pedestrian safety measures, following the above three-tier hierarchy, is presented in the following Section. Some Measures could fit into more than one Actions - or even into different Areas. In those cases, classification was made according to the function considered to be predominant.

Table 2 features a matrix linking the Actions to the first-step categorization (types of measures) (PROMISING, 1998). Commonly, Actions 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.

*** Insert Table 2 here ***

AREAS, ACTIONS AND MEASURES OF PEDESTRIAN SAFETY

The five areas, the twenty-six actions and the ninety-seven measures identified in the framework of this research are presented below. More precisely, the aim and general characteristics of each action are presented, followed by the respective measures (in parenthesis). A detailed description of these measures, including design sketches is contained in the related final report of the PROMISING project (PROMISING, 1998).

Area (i) Management of Vehicle Traffic

Action 1. Reducing vehicle traffic

The aim of this action is, generally, to solve conflicting functions of an area in which too much traffic is disturbing or very dangerous. This applies to areas where living, recreation, schooling or shopping are dominant functions, which do not tolerate too much fast traffic. The measures taken should generally be considered in an area-wide perspective and be expressed in a traffic management scheme. What measure is most appropriate in each situation depends on the overall environment, its dominant function(s), layout, characteristics of groups using the environment, total space available, available means, and support of local users.

(Traffic restrictions / restraint, Ring road / bypass, Lorry ban, Cul-de-sac, Closure of side streets, One-way street, Location of parking at border of protected area).

Action 2. Lowering vehicle speeds, generally (esp. along main roads)

The aim of this action is, generally, to offer a better chance for road users to avoid a collision, and at least to reduce the consequences of an incident. Lowering vehicle speeds offers better conditions for looking out, for avoidance actions and for communication between different road users. This may result in more equality and a lower aggression level, in more efficient use of the road, thereby improving road capacity, and in easier planning of other measures, such as crossing measures. Speed limiting measures should be functional, in relationship to environmental or road characteristics..

(Overall speed limit for urban areas, Roundabout, Local speed limit sign, Feedback device, Rumble strips, Transverse / lateral marking, "Jiggle bars", Speed limiter in vehicles, Urban boulevard),

Action 3. Area-wide speed-reduction or traffic calming schemes

This action puts together the ideas of the previous two, namely vehicle traffic reduction and speed reduction. The general aim is to achieve that through traffic has a subordinate function in a certain area. One commonly-applied approach is the 30-km/h zones in residential areas.

(Gate-effect / threshold, Narrowed carriageway, Advance warning for speed reduction, Alignment change, Round-top hump / speed cushion, Flat-top hump, Raised junction, Planting / landscaping) (See Figure 1)

*** Insert Figure 1 here ***

Action 4. Reducing vehicle skidding

The aim of this action is to reduce the braking distance of cars; for instance, reduction of road slipperiness by 20% may result in shorter braking distances by 2.5 to 5.0 metres (depending on original extent of slipperiness). However, drivers may compensate by speeding, thereby undermining the effect of this measure.

(Anti-skid surfacing, Anti-locking brakes (ABS))

Action 5. Softening impacts

Because pedestrians are very vulnerable, a collision with a solid vehicle can have very severe consequences. It turns out that sharp and blunt vehicle parts, like mirrors or windscreens, as well as unprotected moving parts (including the overall front part) are hazardous. The aim of softening impacts is to reduce the consequences of a collision. However, it is again possible for compensation on the part of the driver (speeding, less attention) to cancel effects of measures intended to reduce severity of the impact.

("Friendly" (soft) vehicle fronts, Side protection screen on lorries and other vehicles)

Area (ii) Provision or Improvement of Pedestrian Infrastructure

Action 6. Provision of sidewalks

Sidewalks are areas reserved to pedestrians. However, they generally combine several

purposes. For instance, sidewalks are also used to place bicycles, terraces, pickets, road signs, waste baskets, stops, verge, lighting, information, etc. This often means that net space for pedestrians is rather limited. Sometimes sidewalks have to be shared with bicyclists; this should not be recommended. Well-designed and well-kept sidewalks are badly needed, as many pedestrian accidents happen on sidewalks.

(Proper physical design, Protection against unwanted usage) (See Figure 2)

*** Insert Figure 2 here ***

Action 7. Provision of an integrated walking network

The term "walking network" refers to the design of pedestrian routes across an urban area, linking all types of neighborhoods and facilities frequented by pedestrians (residential areas, city centre, commercial centers, leisure areas, schools, administrative buildings, etc.). The aim of pedestrian networks is to offer short and direct, but also pleasant, protected, comfortable, safe and secure routes between important destinations. Basic provisions like shelters, stops, benches, waste baskets, crossings, call boxes, letter boxes, special lighting, pedestrian finger posts and maps, etc. have to be integrated.

(Pedestrian zone / streets, Zebra crossings, Push-button signalized crossings, Yellow flashing light at crossings, Stop-line before pedestrian crossings)

Action 8. Shared use of road surface by vehicles and pedestrians

The aim of this action is to achieve equal right of use of space for all traffic participants. It may however also be used to save expensive space for building or for parking cars. Space

sharing has to meet strict criteria for construction, in order to warrant the equality of different users with different activities. Especially low vehicle intensity [Area (i), Action 1] and low vehicle speed [Area (i), Action 2] are important conditions.

(Woonerf / mixed traffic in residential area, Mixed traffic in central / busy area)

Action 9 Channelising crossings

The aim of this action is to concentrate the meeting of pedestrians and vehicles to certain spots. Generally these spots are determined by the needs and characteristics of vehicle traffic. Crossing mostly is channelised on wide traffic arterials with high intensities of pedestrians and vehicles, or near special spots like schools etc.

(Barriers against crossing)

Action 10. Grade separation of crossings

Grade separation generally aims at safe and uninterrupted proceeding of vehicles, and prevention of pedestrians crossing on unwanted spots. It may improve safety of pedestrians, if they are not avoiding the crossing, which may however easily be the case. Grade-separated crossing should be well planned and offer a minimum resistance for pedestrians: low level bridging, no detour and no fear for assaults.

(Pedestrian bridge / overpass, Pedestrian tunnel / underpass, Grade-separated crossing where the vehicular traffic (not the pedestrians) has to change levels (bridge or tunnel))

Action 11. Shortening (especially uncontrolled) crossings

Shortening crossings is a way to reduce pedestrian exposure, because it aims at minimizing meeting time between pedestrian and vehicle. Moreover it can result in better sight, in simplification of the crossing task, in shorter waiting times, and thereby in less risk-taking. The action is recommended on traffic arterials, with moderate intensities and speeds of vehicle traffic.

(Refuge, Median opening, Strip / short section of median, Sidewalk extension

Diagonal crossing)

*** Insert Figure 3 here ***

Action 12. Avoidance of abrupt level changes

Abrupt level changes mostly appear as a separation of pedestrian and vehicle space, forcing pedestrians to bridge level differences. Especially for bad walkers and handicapped people, but also for people carrying things, these are real obstacles, impairing mobility and evoking hazards (stumbling and falling over kerbs). Therefore, avoiding abrupt level changes aiming at improving proceeding for large groups of pedestrians can be welcomed. It should however safeguard against unintended use of pavements by cars or two-wheeled vehicles. It also should maintain a clear difference between sidewalk and carriageway, especially for children.

(Raised crossing, Low kerbs and mild gradients for pedestrians, Ramp for wheelchairs / mobility-handicapped, Kerb cut)

Action 13. Automated demand-responsive crossings

Demand-responsive signals are common for regulation of motorized vehicle traffic, because

they improve capacity of crossings and reduce waiting times. When implemented on pedestrian crossings, they should be able to adapt the green signal time to the walking speed of pedestrians, extending green for slow walkers. A criterion for maximum pedestrian waiting times should be built-in; it should result in fewer pedestrians having to wait. Finally, crossing should be made without a possible conflict with turning vehicle traffic.

(Electronically-sensed signalized crossing, Detector for pedestrians waiting, Detector for pedestrians crossing)

Action 14. Differentiated / alternative crossing designs to better suit special groups

"Design for all" aims at serving all groups in society, regardless of age, strength or physical health. Certain planning measures may be applied to enable special user groups to participate safely and comfortably in traffic.

(Adjustment of signal timing, assuming lower walking speed, Use of pedestrian traffic light at beginning of crossing, Auditory indicator for the blind / ill-sighted, Color contrast for the ill-sighted, Tactile indicator for the blind / ill-sighted, Signal push-button at convenient height for wheelchairs)

Action 15. Pedestrian-friendly walking surfaces

Bad construction or of the infrastructure may cause injuries to pedestrians (bumping, slipping, tripping, spraining or falling). A pedestrian-friendly walking surface implies evenness, roughness, smooth gradient, obstacle-free space, and absence of dirt, pits, holes, snow and ice.

(Differentiated paving / contrasted surfaces, Anti-slippery surface of walking path (sidewalk

or crossing), Obstacle removal from sidewalks or footpaths, Durable walking surfaces, Ice tracks for pedestrians)

Action 16. Reducing walking distances for the handicapped

People with walking problems or endurance problems have trouble to cover great distances when walking and need nearby provisions. Planning of special provisions aims at contributing to their special needs.

(Provision of reserved parking spaces for the handicapped)

Area (iii) Improving Road User Perception

Action 17. Making pedestrians more visible

Pedestrians may be masked during foggy or dark weather, by obstacles and objects such as parked cars, or by objects distracting attention (heavily lighted cars). Improving pedestrian visibility aims at reducing pedestrian unsafety, by facilitating the possibility of timely action, warning or preventive, on the part of the driver or the pedestrian. However, two unwanted effects should be warned against: first, if drivers can detect better, they may compensate by driving faster; second, some groups of pedestrians may feel insecure if they know that they are easily seen (for instance women or older people in quiet environments).

(Fluorescent / retro-reflective clothing, Lay-by (inlet) for car parking or for bus stop, Provision of adequate street lighting, general, Provision of special lighting / improved lighting quality near intersections, zebras and other crossings, Removal of visual obstacles)

Action 18. Improving overall visibility for drivers / Assistance to driving task

Driving is a complex task, highly dependent on visual input. Visual stimuli must correctly be detected and interpreted. Improving visibility or providing assistance to drivers may aim at better selection of relevant stimuli, thereby enhancing drivers' decision-making. It should not however result in masking other relevant stimuli, or in an overestimated feeling of safety.
(Better lateral visibility for lorries and other vehicles, Elimination of glare sources, Anti-glare surface, Elimination / avoidance of accumulated signs, advertisements and other excessive visual inputs, Telematics driver aids)

Action 19. Making vehicles more visible / noticeable

This action aims at better preventive action on the part of the pedestrians. It therefore puts the burden on the shoulder of pedestrians and may result in less care of drivers, and higher speeds.
(Daytime running lights, Noticeability of electric and other "silent" vehicles, Reduction of noise level from indoor sources)

Action 20. Making signing / marking more visible / comprehensible

Traffic participants have to select information when moving; road signs and road markings often are overlooked, especially when they are not expected or when they are badly situated. Better visible / comprehensible signing or marking for pedestrians aims at giving the right information at the right spot (or in the right time) and in a striking manner (Chu, 2005). Application of such measures is more limited in urban areas than in rural ones, especially for

signing (which has significant space requirements).

(Location, size and reflectivity of signs / markings, Legibility and messages of signs / markings, Coloring of road surface / markings at "zebra" crossings)

Area (iv) Education and Enforcement

Action 21. Educating road users in general

People have to understand the language of roads and road users, as well as traffic rules (formal and informal ones), and have to be aware of the importance of safe behavior (for themselves as well as others). Traffic education largely aims at improving behavior by providing information.

(Provisions in general traffic education, Provisions in advertising campaigns)

Action 22. Educating drivers

It is important to teach drivers to reckon with pedestrians and their characteristics and not expect from all pedestrians to understand the rules and situations or to be able to make the right decision. Moreover, drivers should realize that very dangerous situations for pedestrians can easily be created. Driver education should aim at appropriate communication and behavior towards pedestrians.

(Appropriate driver training, Rewarding safe drivers, Changing behavior of younger traffic participants towards the elderly)

Action 23. Educating pedestrians

Pedestrian education, starting in families and at school, often teaches defensive strategies and stressing avoidance actions. It should also aim at self-assured behavior, including clear decision-making and direct, outspoken communication with drivers.

(Education of pedestrians)

Action 24. Educating special groups of pedestrians

As pedestrians involve so many groups, those with special needs should be specially addressed. This action should aim at improving special groups' mobility by teaching adequate strategies, without curtailing their freedom of movement.

(Guidelines / training for the blind / ill-sighted, Education for elderly pedestrians, Education for mentally handicapped people, Education, training and publicity for children)

Action 25. Enforcement

Enforcement aims at improving behavior of road users e.g. behavior control, prevention of inappropriate behavior, learning from mistakes. Enforcement of pedestrian behavior, or behavior towards pedestrians, is rather rare.

(Police control / enforcement, Provisions in legislation and regulations, Highway code)

Action 26. Special protection for children / the elderly

Children and older people are very vulnerable and special measures for these groups aim at improvement of their subordinate position. However, taking special measures for these

groups also stresses their weakness and should therefore be limited.

(Provision of crossing patrols, Physical protection of crossing patrols ("Endlich-arm"), Supervision of children in vicinity of busy roads)

"MOST PROMISING" SAFETY MEASURES FOR PEDESTRIANS

The last step of the assessment methodology comprised the identification of the "most promising" pedestrian safety measures, based on the analysis of the measures presented at the previous section. This assessment was based on a set of criteria, namely:

- being technical,
- non-restrictiveness (by nature or conditionally),
- high (or at least moderate) effectiveness, coupled with low cost.

Table 3 presents a comparative assessment of Areas and actions of pedestrian safety measures (presented in Table 2) on the basis of these criteria. This assessment of actions refers to most of the measures of each action, as in most actions there are certainly measures with different characteristics (technical/non-technical, restrictive/non-restrictive). Results show that two actions related to Area (i), namely traffic calming and softening impacts and two actions of Area (iii), namely improving visibility / providing assistance to drivers and improving marking and signing for pedestrians, fulfill the whole set of criteria. Five actions of Area (iii), all related to relatively low-cost infrastructure improvements, were also proved to combine all the required characteristics.

*** Insert Table 3 here ***

It is noted that the final assessment was carried out at the bottom level of the functional hierarchy i.e. at the level of each distinct measure; however, for practical reasons the detailed Table can not be presented in this paper. As a result of this process, the "most promising" measures for pedestrian safety are summarized in Table 4.

*** Insert Table 4 here ***

DISCUSSION

Within this research, a comprehensive relationship between pedestrian safety functions (and related problems) and pedestrian safety measures is proposed, allowing not only for the identification of a set of "promising" measures but also for the modalities of their efficient implementation. From an extensive list of ninety seven pedestrian safety measures, categorized by the various pedestrian functions and the related safety problems they address, nineteen are proposed, as those presenting the highest effectiveness. Through the proposed relationship between problems and measures it was demonstrated that pedestrians' safety cannot be improved without some impact (trade-off) on travel conditions and mobility (Zegeer et al., 2002). Given the current disadvantageous position of pedestrians (especially the most vulnerable of them) among traffic participants, safety improvements will inevitably involve assertion of pedestrians' rights, and thus controversy - and it will be necessary to attain consensus, coordination and "cooperative planning".

Pedestrian safety measures are best to be implemented if they result from a consistent and comprehensive policy, rather than being "piecemeal", isolated improvements. Such a policy

should be aimed at achieving an optimum balance, both "internally" (i.e. targeted at all four Areas, "i" through "iv") and "externally" (i.e. taking into account the impact on other road users, in particular car traffic). Not only the effectiveness but even the characterization of restrictiveness and cost-effectiveness of several measures depends on their implementation policy.

Furthermore, mechanisms should be ensured for converting policy into practice at the level of "street design" in an effective and efficient manner. These go beyond the evident need for coordination among different levels of responsibility and scientific disciplines; it is very important to also improve knowledge of the effectiveness of (sets of) safety measures, through follow-up of actual applications as well as a synthesis of existing research findings. Quantitative information, if available, can lead to the incorporation of the acquired knowledge into a rational decision-making framework, in a systematic and convincing way.

Implementation of modern pedestrian safety policies and measures requires actions at the local (also regional), national and international levels. Coordination is required not only among those levels but also within each one of them, especially between actors of different disciplinary backgrounds. Local authorities, which will usually be responsible for applying street-level measures, may need incentives (regarding financing and/or transfer of know-how) in order to adhere to policies formulated at higher levels.

Therefore, future research could concentrate on the following main areas, where there are a number of open questions:

- Linkage of pedestrians' attitudes / needs, behavior and safety vis-à-vis specific (sets of) safety measures

- Evaluation of alternative combinations of pedestrian safety measures (or alternative pedestrian safety policies)
- Case studies of pedestrian safety policies and their institutional / organizational backgrounds
- Advanced comparative analysis (e.g. meta-analysis) of pedestrian safety data (accidents / countermeasures) at a European level, thus allowing transport and urban planners as well as decision makers to choose the most suitable set of solutions to their specific problems.

ACKNOWLEDGEMENT

This paper is based on the work carried out in the PROMISING research project (PROMISING, 1998), partly financed by the European Commission, Directorate-General for Transport.

REFERENCES

1. Behrensdorff, I. et al. ADONIS project – How to substitute short car trips by cycling and walking. Copenhagen, Danish Council of Road Safety Research, 1998.

2. Breen, J. "The value of low-cost measures, safety audit and safety impact assessment: an international view". European Seminar on cost effectiveness of road safety work and measures, European Commission, Prévention Routière Internationale, Luxembourg, 1998.

3. Chu, X. - "Pedestrian Safety at mid-block locations". FDOT - Florida Department of Transportation, 2006.

4. City of Helsinki. WALCYNG – Safety problems of pedestrians and cyclists. Helsinki, 1997.

5. Edwards, G. PROMISING - Promotion of measures for vulnerable road users - Pedestrian protection. Crowthorne, Transport Research Laboratory, 1998.

6. Elvik, R.. "Which are the relevant costs and benefits of road safety measures designed for pedestrians and cyclists?". Accident Analysis and Prevention, Vol. 32, No 1 (January 2000): 37-45.

7. Esse, T., Zegeer, C., Zegeer, C. "European Practices and Innovations for Pedestrian Crossings". ITE Journal, November 1995.

8. 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.

9. European Commission, 2006. CARE database accident statistics. http://www.europa.eu.int/comm/transport/care/statistics/most_recent/detailed_breakdown/index_en.htm.

10. Federation of European Pedestrian Association. Elderly Europeans on foot - Report on the position of the elderly pedestrians in Europe. Hague, 1993.

11. Fontaine, H. "A typological analysis of pedestrian accidents". Seventh ICTCT Workshop, Paris, 1995.

12. Huang, H., Cynecki, M. "Effects of traffic calming measures on pedestrian and motorist behavior". Transportation Research Record 1705, 2000: 26-31.

13. ITE task Force. ITE Pedestrian and bike task force survey results summary. ITE Journal, 2001: 50pp.

14. Kamyab, A., Andrle, S., Kroeger, D., Heyer, DS. "Methods to reduce traffic speed in high-pedestrian rural areas". Transportation Research Record No: 1828, 2003.

15. King, MR., Carnegie, JA., Ewing, R.. "Pedestrian safety through a raised median and redesigned intersections". Transportation Research Record No 1828, 2003.

16. Kothari, AM. "Evaluation of lighted crosswalks - Are they really effective?" ITE 2002 Annual Meeting and Exhibit. Institute of Transportation Engineers, Philadelphia, 2002.

17. Martincigh, L. et al. PROMISING - Promoting of Measures for Vulnerable Road Users. Universita degli Studi Roma Tre, Roma, 1998.

18. Muhlrad, N. "Pedestrians' problems and safety: an ICTCT paper". International Conference on Strategic Highway Research Programme and Traffic safety, Prague, September 1995, the Czech Republic, 1995.

19. Nee, J., Hallenbeck, M. A motorist and pedestrian behavioral analysis relating to pedestrian safety improvements, Final Report. Research Project T1803, Task 16, Washington State Transportation Commission, USDOT- Federal Highway Administration, Washington, 2003.

20. ETSC. Safety of pedestrians and cyclists in urban areas. ETSC, Brussels, Belgium, 1999.

21. OECD. Safety of vulnerable road users. OECD, Paris, France, 1997.

22. Oxley, J., Corben, B., Fildes, B., O'Hare, M. & Rothengatter, T. - "Older vulnerable road users: measures to reduce crash and injury risk". MUARC Report No. 218. Accident Research Centre MUARC, Monash University, Clayton, Victoria, 2005.

23. SafetyNet. Traffic Safety Basic Facts, 2005

http://www.erso.eu/data/content/traffic_safety_basic_facts_2005.htm.

24. PROMISING. PROMISING project final report - Pedestrian safety problems and countermeasures. National Technical University of Athens, Athens, Greece, 1998.

25. Rennesson, C., Lourdaux, H. PROMISING - Pedestrian safety measures - Infrastructure. Centre d' Etudes sur les Réseaux, les Transports l' Urbanisme et les Constructions, Lyon, 1998.

26. Retting, R.A., Van Houten, R., Malenfant, J.E.L., Van Houten, J., Farmer, C.M. "Special signs and pavement markings improve pedestrian safety", ITE Journal, 1996, 66: 28-35.

27. Tira, M., Ventura, V. PROMISING - Elaboration of pedestrian safety measures: an infrastructure viewpoint. University of Brescia, Brescia, 1998.

28. Vermeulen, W. PROMISING - Review of measures promoting safety of pedestrians. De Voetgangers Vereniging, Hague, 1998.

29. Weber, K, Schausberger, B. PROMISING - Elaboration of pedestrian safety measures – driver. Kuratorium für Verkehrssicherheit, Wien, 1998.

30. Wouters, P. Urban Safety Management in Europe, an overview of current practice in nine countries in the context of the DUMAS project. SWOV, Leidschendam, the Netehrlands, 1997.

31. Zegeer, CV., Seiderman, C., Lagerwey, P., Cynecki, M., Ronkin, M., Schneider, B. Pedestrian Facilities Users Guide - Providing Safety and Mobility. Publication No. FHWA-RD-01-102, FHWA, Washington, 2002.

Table 1. Percentage of pedestrians killed on the total number of fatalities in the EU countries (1991-2004).

	Austria	Belgium	Denmark	Germany	Spain	Finland	France	Greece	Ireland*	Italy	Luxemburg**	Nederlands*	Portugal	Sweden	Un.Kingdom	EU 15
Inside urban area	39%	24%	32%	32%	41%	34%	25%	31%	46%	26%	35%	19%	32%	31%	49%	32%
Outside urban area	8%	6%	9%	12%	11%	10%	6%	12%	16%	6%	3%	6%	14%	7%	11%	8%
All areas	16%	11%	17%	20%	16%	16%	12%	20%	25%	14%	15%	10%	22%	14%	27%	16%

** 2003 Data, ** 2002 Data*

Table 2. Areas, actions and types of pedestrian safety measures.

Area		Action	Types of measures							
			A	B	C	D	E	F	G	H
			Motor vehicle speeds	Conflicts between peds & motor	Problems or lack of level crossings	Deficient visibility	Read-ability of road environ-ment	Vehicle design	Special groups	Road user behaviour
(i)		**Management of vehicle traffic**								
	1.	Reducing vehicle traffic		●						
	2.	Lowering vehicle speeds, generally (esp. along main roads)	●				●	●		
	3.	Area-wide speed-reduction or traffic calming schemes	●				●			
	4.	Reducing vehicle skidding	●							
	5.	Softening impacts					●	●		
(ii)		**Provision or improvement of pedestrian infrastructure**								
	6.	Provision of sidewalks		●						
	7.	Provision of an integrated walking network		●	●		●			
	8.	Shared use of road surface by vehicles and pedestrians	●				●			
	9.	Channelising crossings		●			●			
	10.	Grade separation of crossings		●						
	11.	Shortening (esp. uncontrolled) crossings			●					
	12.	Avoidance of abrupt level changes			●				●	
	13.	Automated demand-responsive crossings			●					
	14.	Differentiated/alternative crossing designs to better suit special groups			●				●	
	15.	Pedestrian-friendly walking surfaces			●					
	16.	Reducing walking distances for the handicapped							●	
(iii)		**Improving road user perception**								
	17.	Making pedestrians more visible				●				
	18.	Improving overall visibility for drivers / Assistance to driving task				●		●		
	19.	Making vehicles more visible / noticeable				●	●	●		
	20.	Making signing / marking more visible / comprehensible			●	●	●			
(iv)		**Education and Enforcement**								
	21.	Educating road users in general								●
	22.	Educating drivers								●
	23.	Educating pedestrians								●
	24.	Educating special groups of pedestrians							●	
	25.	Enforcement								●
	26.	Special protection for children / the elderly							●	

Table 3. Assessment of Areas and Actions of pedestrian safety measures

Area		Action	Criteria			
			Technical	Non-restrictive	High effectiveness	Low cost
(i)		**Management of vehicle traffic**				
	1.	Reducing vehicle traffic				●
	2.	Lowering vehicle speeds, generally (esp. along main roads)			●	●
	3.	Area-wide speed-reduction or traffic calming schemes	●	●	●	●
	4.	Reducing vehicle skidding	●	●		
	5.	Softening impacts	●	●	●	●
(ii)		**Provision or improvement of pedestrian infrastructure**				
	6.	Provision of sidewalks	●	●		●
	7.	Provision of an integrated walking network	●	●	●	●
	8.	Shared use of road surface by vehicles and pedestrians		●		●
	9.	Channelising crossings	●			●
	10.	Grade separation of crossings	●	●	●	
	11.	Shortening (esp. uncontrolled) crossings	●	●	●	●
	12.	Avoidance of abrupt level changes	●	●	●	●
	13.	Automated demand-responsive crossings	●	●		
	14.	Differentiated/alternative crossing designs to better suit special groups	●	●	●	●
	15.	Pedestrian-friendly walking surfaces	●	●	●	●
	16.	Reducing walking distances for the handicapped	●	●		
(iii)		**Improving road user perception**				
	17.	Making pedestrians more visible	●	●		●
	18.	Improving overall visibility for drivers / Assistance to driving task	●	●	●	●
	19.	Making vehicles more visible / noticeable	●	●		●
	20.	Making signing / marking more visible / comprehensible	●	●	●	●
(iv)		**Education and Enforcement**				
	21.	Educating road users in general		●		
	22.	Educating drivers		●		
	23.	Educating pedestrians		●		
	24.	Educating special groups of pedestrians		●		
	25.	Enforcement			●	
	26.	Special protection for children / the elderly		●		

Table 4. List of "most promising" technical non-restrictive pedestrian safety measures

1)	Protection of sidewalk against unwanted usage
2)	Refuge
3)	Median opening
4)	Signal push-button at convenient height for wheelchairs
5)	Anti-slippery surface of walking path (sidewalk or crossing)
6)	Strip / short section of median
7)	Ice tracks for pedestrians
8)	Kerb cut
9)	Color contrast for the ill-sighted
10)	Tactile indicator for the blind / ill-sighted
11)	Round-top hump / speed cushion
12)	Side protection screen on lorries and other vehicles
13)	Zebra crossings
14)	Yellow flashing light at crossings
15)	Diagonal crossing
16)	Ramp for wheelchairs / mobility-handicapped
17)	Adjustment of signal timing, assuming lower walking speed
18)	Better lateral visibility for lorries and other vehicles
19)	Legibility and messages of signs / markings

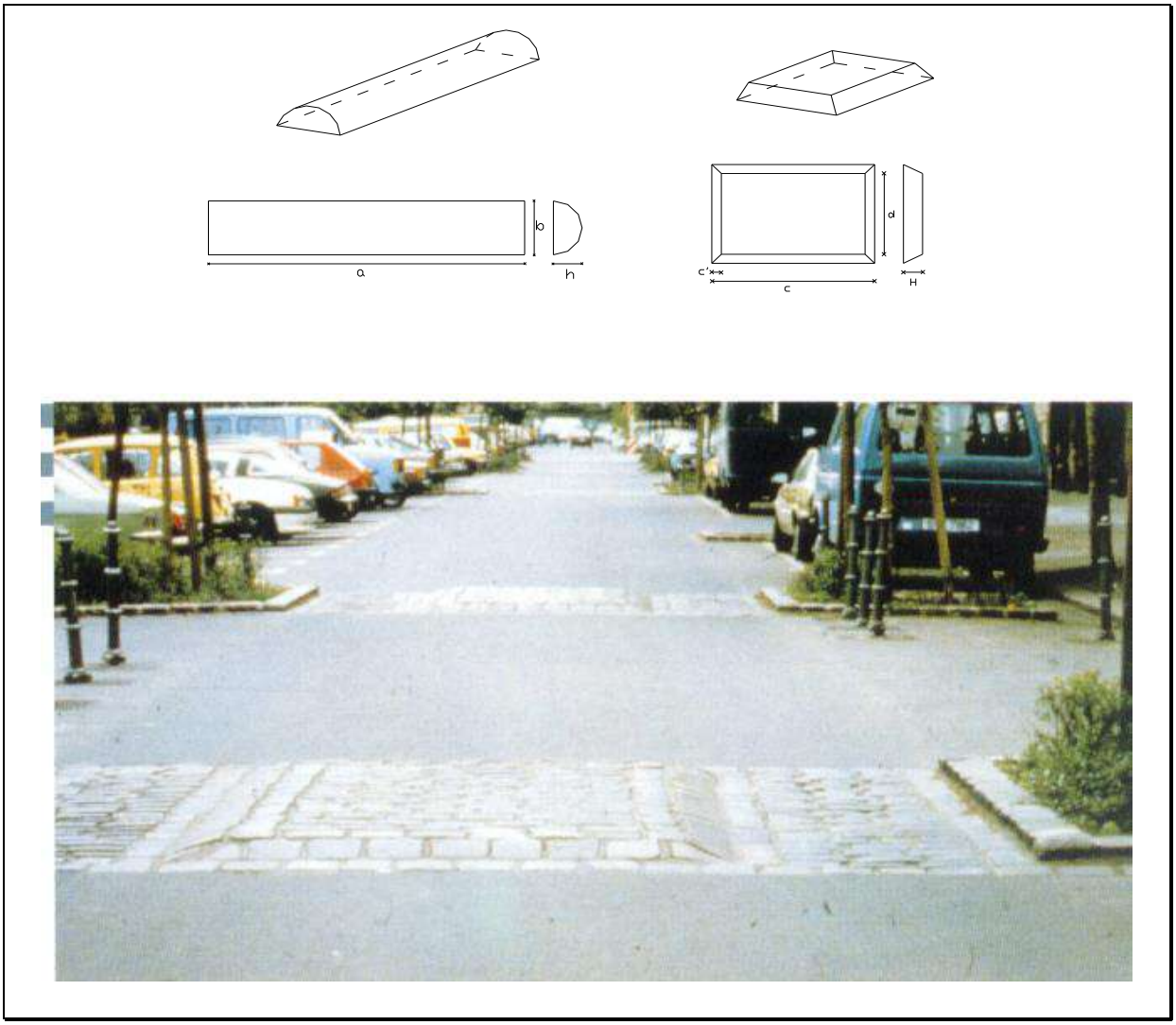

Figure 1. Hump

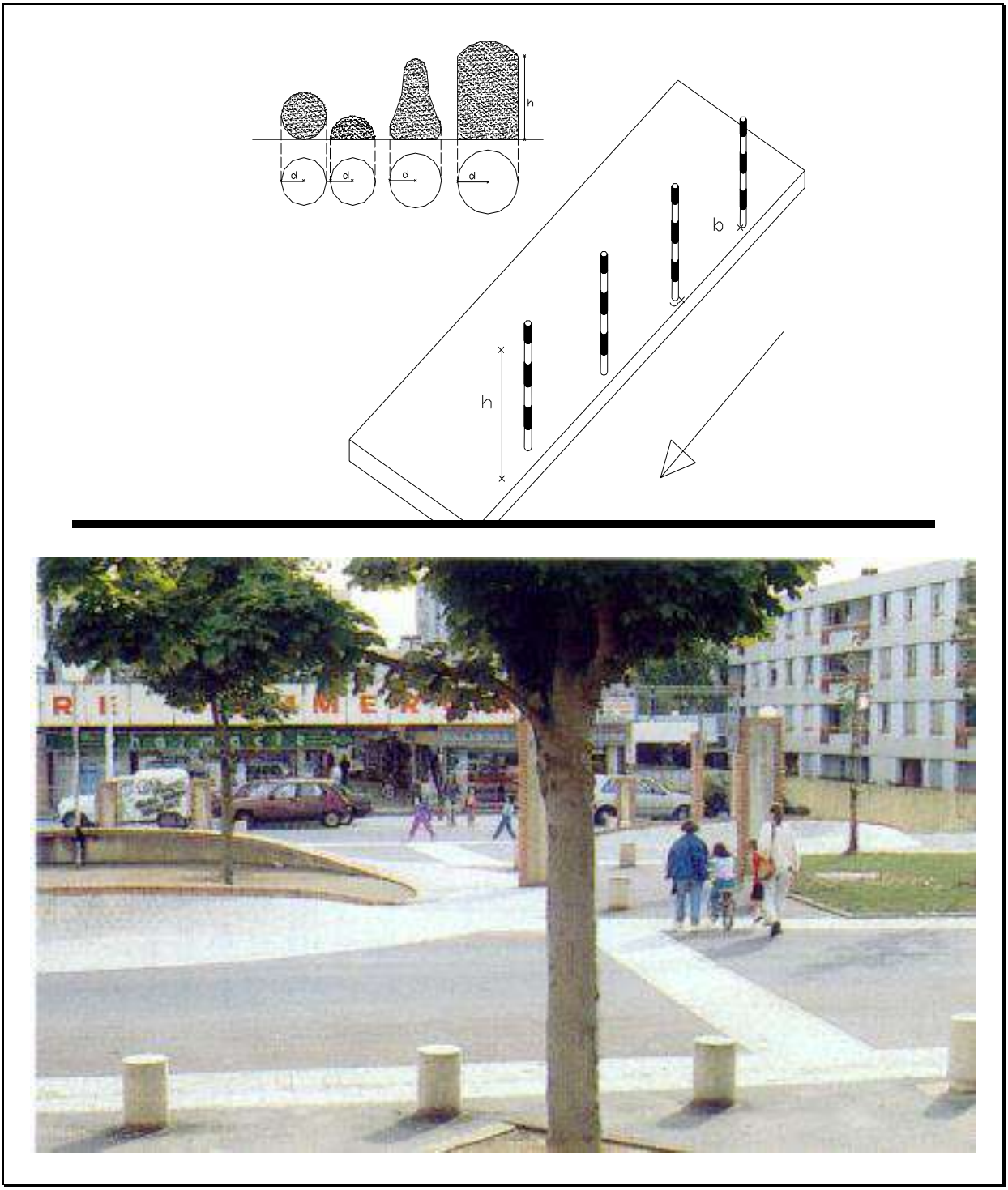

Figure 2. Protection of sidewalk