Implementation of the SUNflower Methodology for the analysis of Powered Two-Wheelers Road Safety In Greece

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Abstract

Most studies on powered two-wheelers safety focus on the identification of risk factors related to the road infrastructure, the vehicles or the riders. This research aims to analyse the powered two-wheelers road safety level in Greece, by implementing and evaluating the 'Sunflower' methodology. The SUNflower methodology is based on a holistic approach, according to which the road safety 'footprint' of a country at a specific point in time can be described on the basis of a pyramid that includes a target hierarchy of five levels of distinct yet interrelated road safety components: the structural and cultural characteristics, the implemented road safety programmes and measures, the road safety performance indicators, the final outcomes in terms of road casualties and finally the social cost of road accidents. For the implementation of the methodology on powered two-wheelers road safety level in Greece, all available data for all layers of the pyramid were explored and analysed. The results of the analyses suggest that the increased ownership and use of powered two-wheelers, as well as the improper attitude and behavior of the powered two-wheeler users regarding active and passive safety, together with inefficient enforcement of traffic laws, are the main reasons for the increased risk of this specific group in Greece.

Key words : powered two-wheelers; SUNflower methodology; road accidents.

Introduction

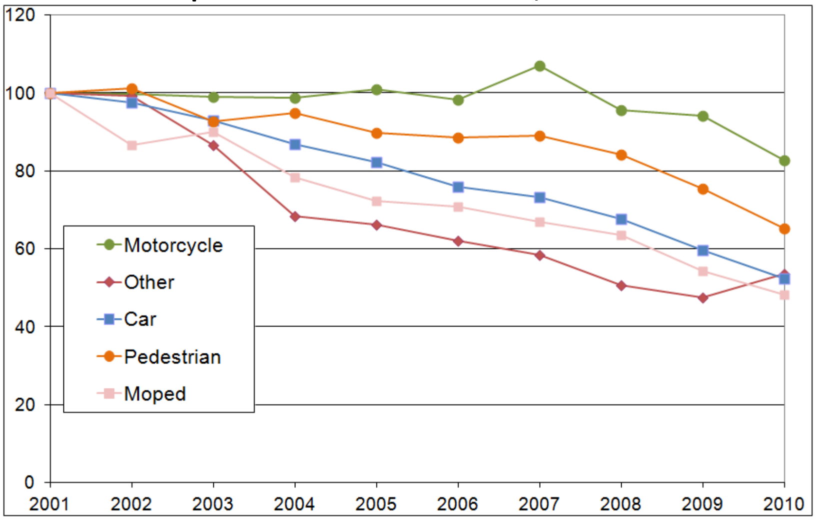
Powered two-wheelers (PTW), mopeds and motorcycles, constitute a mode of transport with specific characteristics compared to other vehicle types, namely the circulation on two wheels, their small width and therefore their greater maneuverability. These characteristics make them particularly attractive in areas with congested road networks, since they allow increasing the capacity of road and parking infrastructure, reducing travel times and gas emissions (Wigan et al., 2000). Furthermore, the reduced acquisition and operation cost of PTW compared to passenger cars, combined with the fact that, in many countries, young people under 18 years old are allowed to drive only small engine size powered two-wheelers, results to increased number and popularity of such vehicles among the younger. At the same time, the vehicle dynamics and the fact that the driver is not separated from the surrounding environment provides a sense of "freedom", in particular in countries where the weather is good (Avenoso, Beckmann, 2005).

An important growth in motorcycling has occurred during the last decades in most parts of the world (Haworth, 2012), resulting in the powered two-wheeler (PTW) gradually becoming a true mobility tool, attracting an increasingly vast and varied population. In 2010 it is estimated that there are approximately 33 million powered two-wheelers across Europe, constituting

14% of the total private vehicle fleet (passenger cars and PTW), whereas killed PTW riders accounted for 15% of the total number of road accident fatalities in 2010 in 24 European countries (J. Broughton et al., 2012).

In spite of a remarkable improvement in traffic safety for all road users (including motorcyclists) in OECD countries, motorcyclists have seen their exposure to road risk increase to the point that in some countries the number of motorcyclists who died in road crashes actually increased over the past two or three decades (Shinar, 2012), while the mortality of other road users declined significantly. As indicated in the Figure 1, the trend for motorcycle riders' fatalities differs clearly from the trend for other modes of transport. Motorcycle is the only mode of transport for which number of fatalities has increased over the first seven years of the decade 2001-2010 and only during the last year there was significant decrease compared to 2001. However, this is still eight times less than next smaller one of pedestrians which stresses the importance of taking immediate appropriate counter measures (J. Broughton et al., 2012).

Figure 1: Index (2000=100) of motorcycle and moped fatalities compared to other modes EU-20, 2001-2010



Source : Broughton et al. 2012

PTW users are confronted with an excessive risk on the road, which has been qualified as "unfair" by Elvik (2009), insofar as for the same number of kilometres driven they have a much higher risk of being killed or severely injured than car occupants. They are clearly overrepresented among road traffic casualty figures, even when they are not overrepresented in crash occurrences.

The increased involvement of PTW riders in road accidents is often analysed according to increased risk factors, which can be grouped into the following categories: driver, vehicle, road environment and other road users (Yannis et al., 2007). By default, driving a moped or a motorcycle is a complex process, which requires excellent driving skills and knowledge, and physical coordination. There is the intrinsic difficulty to drive a PTW, due to the necessity to control the balance, its lower friction capacity and its greater sensibility to environmental perturbations (wind, gravel, any change in road surface, etc.) which may destabilize the vehicle. PTW riders also have a higher risk of injury due to their greater vulnerability, resulting from a lack of protection compared to passenger cars. Moreover, by its very nature, driving a PTW may induce a specific behaviour pattern on the road which is different from the drivers of four-wheeled vehicles. Such behaviour is not necessarily "deviant" according to the law, but may surprise other road users. Even "normal" behaviour, i.e. common to PTW riders, may be atypical for other vehicle operators (Van Elslande et al. 2013).

Some riders are likely to have limited reflexes, which increases the potential risk of accidents (NTUA, 2003). Moreover, others tend to drive at higher speeds than drivers of other vehicles and overtake inappropriately (Horswill et al. 2003; Preusser et al., 1995). Particularly young and novice PTW drivers tend to overestimate their abilities while using the vehicle as a means of self-demonstration (Papaioannou et al., 2008). Driver related risk factors such as speeding and alcohol appear to be a bigger problem in PTW drivers than in other drivers (Horswill et al. 2005; Soderstrom et al. 1995).

On the other hand, vehicle factors are only a minor proportion of PTW road crash contributory factors. Road design and road environment factors have mostly an important influence on the crash severity (e.g. roadside obstacles and barriers) rather than on crash occurrence, although PTW are more sensitive to infrastructure design (e.g. alignment, curves, etc.), and maintenance deficits (ACEM, 2009).

Overall, the literature on the PTW safety problem is extensive, but focuses on their over-representation in crashes, their excessive risk and the related risk factors. However, there are several other factors that may contribute to the understanding and improvement of PTW safety issues, such as contextual and cultural characteristics, attitudes, perceptions and motivations of PTW riders and all road users, legislation and other PTW safety measures, PTW rider compliance and measures enforcement, the overall road safety level in terms of infrastructure, vehicles and user behaviours etc. These factors, and especially their interrelations, have received less attention in the literature.

Within this context, the SUNflower methodology (Wegman et al. 2005) is based on a holistic approach, according to which the road safety 'footprint' of a road safety system (e.g. a country) at a specific point in time can be described on the basis of a pyramid that includes a target hierarchy of five levels of distinct road safety components: the structural and cultural characteristics, the implemented road safety programmes and measures, the road safety performance indicators, the final outcomes in terms of road casualties and finally the total cost of road accidents. This approach has been extensively used at a country level, for comparing countries on a system wide basis, and to a lesser extent for comparing individual components of the road safety system e.g. road user groups, vehicle types etc.

The objective of this study is to analyse the powered two-wheelers road safety level, by implementing and evaluating the SUNflower methodology. The methodology is implemented at country level, with Greece being selected as an example for several reasons. In Greece, there is increased motorcycle ownership and traffic compared to other European countries, partly due to the favourable climate and a more widespread motorcycling culture, and also the PTW safety problem is more pronounced than in most European countries. On the other hand, legislation, enforcement and road user behaviour are in most cases less systematic and efficient than in other European countries. The SUNflower methodology may confirm these intuitive hypotheses and shed some light on the way various components of the system interact, resulting in increased PTW road accident risk in Greece.

The SUNflower methodology

The SUNflower methodology was developed within the framework of the research project SUNflower (Koornstra et al., 2002; Wegman et al., 2005), which was carried out in two phases, the first during 2000-2001 concerning the analysis of road safety factors in Sweden, the UK and The Netherlands, countries which at that stage had the best road safety performance in Europe, and the second phase (SUNflower+6) in which six more European countries were included (Greece, Portugal, Spain, Czech Republic, Hungary and Slovenia) (Handanos et al., 2006). These countries were compared overall, as well as on specific road safety issues (e.g alcohol) on the basis of the SUNflower pyramid.

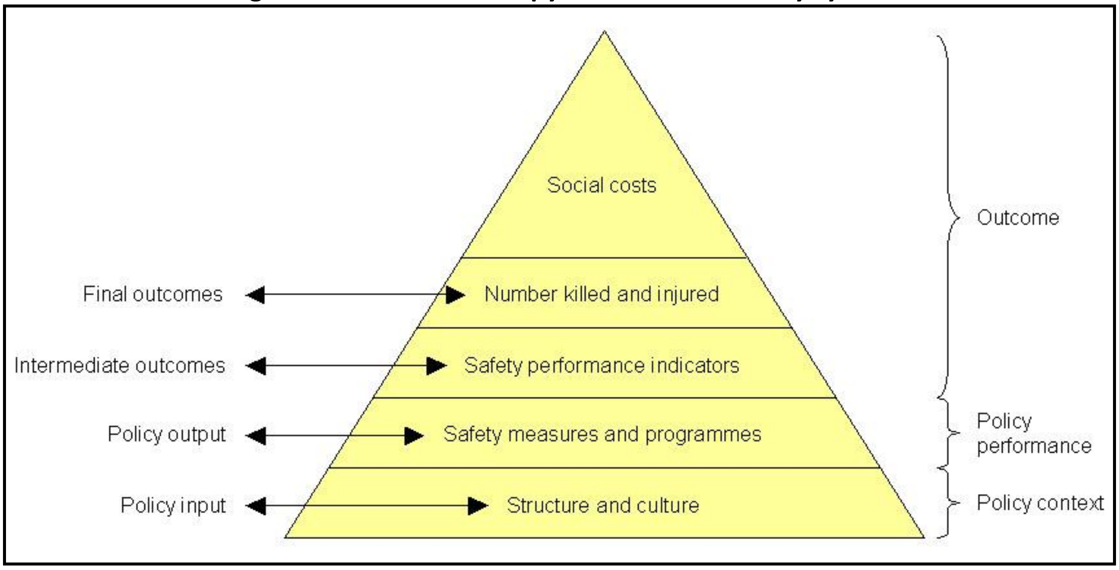
The SUNflower methodology is based on a holistic road safety approach, according to which the road safety 'footprint' of a country at a specific point in time can be described on the basis of a three-dimension pyramid that in the first (vertical) dimension includes a target hierarchy of five levels of distinct road safety components, starting from the bottom, as follows (see Figure 2):

- The road safety performance of a country is related to structural and cultural characteristics (i.e. policy input) at the bottom level.
- It is consequently related to common practice (i.e. safety measuresand programs – policy output), resulting from these structural and cultural characteristics, at level 2.
- To link these first two layers to the actual road accident outcomes, an intermediate layer specifies the operational level of road safety in the country, containing road safety performance indicators (SPIs) on issues like speeding, drinking and driving, as well as a concise depiction of the road network and the main features of the vehicle fleet.
- Final outcomes expressed in terms of road casualties are then necessary to understand the scale of the problem. This type of information is found at level 4, and consists of different types of road risk indicators.
- The top of the pyramid includes an estimate of the total social costs of road accidents.

A second dimension (horizontal) concerns the distribution of these road safety components (levels) to different transport components (vehicle types, road infrastructure types, road user types, etc.). These two dimensions can be examined using time series data, thus time is the third dimension of the pyramid.

According to this methodology, understanding and analyzing causes and consequences of the road safety issues included in each of the above mentioned hierarchical levels is a prerequisite for a successful evaluation of the country's road safety level.

Figure 2: The SUNflower pyramid of road safety systems



Source : Koornstra et al., 2002

Analysis of the powered two-wheelers road safety in Greece

By implementing the SUNflower methodology it is possible to define the main components of each layer that relate to the powered two-wheelers road safety performance in Greece.

3.1 Structure and culture

Regarding the structural and cultural characteristics of a country, these may include basic country characteristics (e.g. demographic, climate etc.), the development of specific road safety programs targeted to powered two-wheeler riders, the existence of road safety authorities with special provision for powered two-wheeler riders. Moreover, the road user motivation for riding powered two-wheelers, the conditions for riding powered two-wheelers, the PTW riders attitudes towards risk taking are factors that could affect the PTW road safety performance. In Greece, the available information/data on the above mentioned structural and cultural factors are limited.

3.1.1. Basic country characteristics

The population density in Greece in 2010 was 86 inhabitants/km^2, lower than the European average (110 inhabitants/km^2) and the population composition could be distributed to 16% children (<15 years old), 63% adults (15-64 years old) and 21% elderly (>65 years old). Furthermore, the country's Gross Domestic Product (GDP) per capita accounted for 20,400€ (quite lower than the EU average) and almost 40% of the population lives inside urban areas (similarly to the EU average).

A mountainous mainland and large complexes of islands are some specific country characteristics of Greece. The climate and weather conditions are extremely favorable for the use of powered two-wheelers in Greece since during the year the weather is mostly sunny and dry. According to 2010 data, the average winter temperature (November to April) is 16^{o}C and the average summer temperature (May to October) is 24^{o}C, comparing to the respective average European temperatures of 6^{o}C and 16^{o}C. Additionally, the annual precipitation level was 390mm, comparing to 747mm in the rest of Europe.

According to IRTAD data, motorcycles constitute 18% of the vehicle fleet, while the average share in Europe is around 6%. The related exposure data recorded in Greece in 2004 was 4.5 billion vehicle-kms for mopeds and motorcycles vs. around 65 billion for passenger cars (DaCoTA, 2012).

3.1.2. Structure of road safety management

Overall, the coordination of all actors involved in road safety management in Greece, is ensured by the Inter-Ministerial Committee on road safety chaired by the Minister of Citizen Protection. However, its role remains limited as the corresponding coordination secretariat has never been established.

The Ministry of Infrastructure, Transport and Networks is responsible for all vehicles licensing and technical inspection, including motorcycles. Mopeds licensing, on the other hand, falls within the responsibilities of the Traffic Police (Ministry of Citizen Protection).

There is not enough information on the existence of specific road safety authorities with special provision for powered two-wheeler riders, especially at regional and local level. Several NGOs are involved in PTW mobility and safety issues, such as the Motorcyclists Association of

Greece, the Technical Chamber of Greece, the Hellenic Institute of Transportation Engineers etc.(DaCoTA, 2012).

3.1.3. Attitudes towards risk-taking

Regarding attitudes towards risk taking, according to SARTRE-4 data (Cestac and Delhomme, 2012) Greek PTW riders admit unsafe behaviours much more often than riders from other countries, especially for too close following and inappropriate overtaking. Greek riders believe that speeding on motorways, interurban and country roads, as well as in urban roads, occurs to a greater extent by Greek riders compared to other countries' perceived rider speeding. On the other hand, there is somewhat more support among Greek riders for stricter legislation than among riders in other countries and additionally, the perceived probability of being checked for alcohol is somewhat higher in Greek riders than in other countries' riders.

Table 1: Road safety attitudes and behaviour of riders in Greece

	Greece	SARTRE-4 average
Riding behaviour	**% of riders that show behaviour often or more**	
Self-reported too close following	45,0%	15,9%
Self-reported inappropriate overtaking	50,0%	23,2%
Perceived exceeding speed limit by motorcyclists on motorways	81,7%	72,9%
Perceived exceeding speed limit by motorcyclists on main inter-urban roads	85,6%	71,3%
Perceived exceeding speed limit by motorcyclists on country roads	85,6%	67,4%
Perceived exceeding speed limit by motorcyclists in built-up areas	65,3%	50,7%
Supporting stricter legislation	**% of riders that support stricter legislation**	
Higher penalties for speeding offences	56,9%	40,9%
Higher penalties for drink-driving offences	73,8%	77,8%
Lower BAC levels	40,1%	60,9%
Perceived probability of being checked	**% of riders that believe that probability is high**	
Alcohol use	82,2%	76,6%

Source : SARTRE-4, 2012

3.2 Programs and measures

With reference to the second level of the pyramid, this may include several elements, starting from the road safety vision and strategy in a country, to specific road safety programmes and measures, including the quality of education for obtaining a driving license (temporary or permanent depending on experience) and the adoption of compulsory driving lessons (practice), the minimum age for obtaining a driving license, the existence of related campaigns, the legislative framework for protective equipment, the systematic recording of enforcement and penalties, as well as the periodical technical inspections.

3.2.1. Road safety strategy, plans and targets

The current Greek strategic plan has adopted the vision of “sustainable road safety” and consists of 5 general safety principles:

- functionality of roads
- homogeneity of mass and/or speed and direction

- forgivingness of the environment and of road users,
- predictability of road course and road user behaviour by a recognizable road design,
- state awareness by the road user.

Greece has adopted the European target for 50% reduction of all road casualties by year 2020, however no specific target for motorcycles was adopted (DaCoTA, 2012).

3.2.2. Road Infrastructure

Data on the design specifications of road infrastructure in relation to powered two-wheelers (visibility zones without barriers, pavement quality) are not available at international level. In Greece in particular, the quality of road design standards with respect to powered two-wheeler specifications is not at a satisfactory level.

3.2.3. Traffic laws & enforcement

Regarding specific traffic laws and measures adopted for the powered two-wheelers, a special rule of 80km/h speed limit is valid for light motorcycles (A1) independently of the road network (rural/motorways).

Motorcycles are not submitted to mandatory periodical technical inspections.

The permitted BAC level for powered two-wheeler drivers is 0,2 ‰ and helmet wearing is obligatory for moped and motorcycle riders. The effectiveness of helmet wearing legislation enforcement in Greece, according to an international respondent consensus (scale = 0-10) (DG-TREN, 2010), is 7, lower than the most common scoring in European countries (9).

3.2.4. Road user education, training and information campaigns

Concerning the training programs for issuing a powered two-wheeler driving license, theoretical and practical courses and corresponding exams are obligatory, while the age limit for its acquisition is dependent on the type of vehicle. For mopeds and motorcycles less than 125cc the threshold is 16 years old, whereas it is 18 years old for other types of motorcycles.

Additionally, during the last years, some public awareness campaigns on helmet wearing have been carried out in Greece for powered two-wheelers.

3.3 Road Safety Performance Indicators

Road safety performance indicators reflect the current operational level of road safetyin a country, and include elements related to the behaviour of road users, the quality of the infrastructure and the vehicle fleet. More specifically for motorcyclists'safety, the rate of helmet use, the distribution of powered two-wheelers in the total vehicle fleet of a country by type and the driving experience of the riders may be examined. The number of PTW riders who drive under the influence of alcohol, drugs or fatigue, or data on the PTW speeding behaviour and the related offences, the existence of active safety systems (ABS, etc.), the use of protective clothing, technical control and degree of compliance with the design specifications of road infrastructure, are also essential elements for the development of appropriate road safety performance indicators of this category of users, but are seldom available. In Greece most of the basic data/information that can be used to develop appropriate indicators are not available.

3.3.1. Protective equipment

Regarding helmet use, a recent roadside survey showed that the percentage of non-helmet use in Greece by PTW riders amounts to 25,7 % (± 1,3% error at 95% confidence interval), while according to the same survey, the helmet use by type of road reached almost 100% on the interurban road network, comparing to 73% on urban roads, as shown in Table 2 (Yannis et al., 2012).

Table 2: Motorcycle helmet wearing rates per area type and rider type

	Urban area		Rural area		Total	
	Driver	**Passenger**	**Driver**	**Passenger**	**Driver**	**Passenger**
Helmet wearing by	73%	41%	96%	91%	75%	46%
Error (95% CI)	±1.46%	±3.57%	±2.27%	±6.12%	±1.37%	±3.43%

Source:Yannis et al. 2012

3.3.2. Vehicles

Regarding the PTW fleet distribution, 2.96 million two-wheelers (motorcycles and mopeds) were recorded in 2009 by the Greek Statistical Office, representing approximately 37% of the total recorded fleet.

3.3.3. Speeding and alcohol

Finally, concerning alcohol and drugs related PTW accidents, information is partially available (alcohol only). In 2005 in Greece, 273 accidents occurred with at least one powered two-wheeler rider involved and at least one driver with an alcohol level above the legal limit. No data is available on PTW speeding in Greece.

3.4 Road safety outcomes

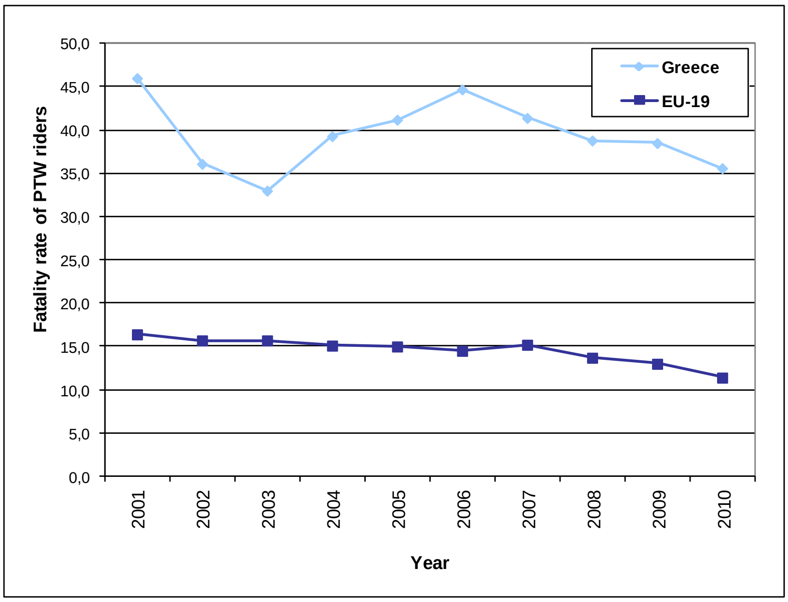
Regarding the assessment of the current level of PTW safety the number of road accidents involving motorcycles and mopeds is usually calculated, as well as the number of PTW riders casualties (fatalities, seriously and slightly injured), the fatality rate per million population and vehicle-kms or other types of exposure data.

3.4.1. General positioning

Greece is one of the worst performing countries in terms of road safety in Europe. The same is the case for PTW safety. According to IRTAD data, the PTW fatalities per million inhabitants in Greece was 35.6 on 2010, which is from 3 to 6 times higher than the respective fatality rates of other European countries. It may be also worth mentioning that this fatality rate is more than double than the respective rate of other Southern European countries (e.g. Italy and Spain).

Considering trend comparisons for PTW riders between 2001 and 2010, a reduction in the number of PTW fatalities by almost 20% was noted in Greece, comparing to a 33% reduction of the total number of road accident fatalities during the same period (J. Broughton et al., 2012). In the following Figure 3, the PTW fatality rate per million inhabitants for the decade 2001-2010 in Greece and in the EU is presented.

Figure 3: Fatality rates of PTW riders (2001-2010)

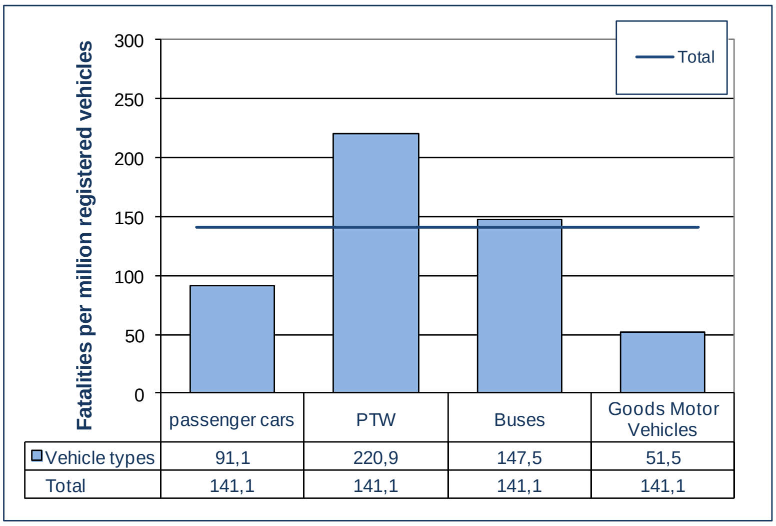


Source : CARE database (2013)

3.4.2. Basic figures

The number of PTW riders road accident casualties (fatalities, serious and slight injuries) is equal to 403, 726 and 7,355 persons respectively for 2010. For the same year, the fatality rate was 91.8 for riders between 15-24 years old and 46.5 for PTW riders between 25-44 years old. In Figure 4, the PTW fatalities per million registered vehicles is compared to the related rates for other transport modes in Greece for 2010, revealing that the rates for PTW are more than double compared to passenger cars

Figure 4: Fatalities per million registered vehicles and mode of transport (Greece, 2004)



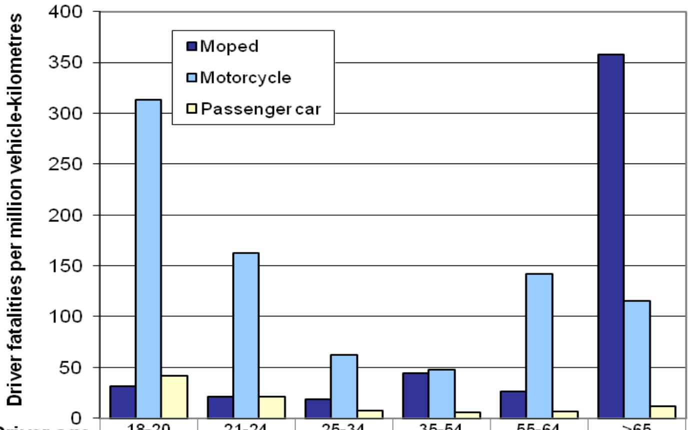
Source : CARE database, Greek Statistical Office (2013)

3.4.3. Risk figures

Taking into account more detailed risk/exposure data (vehicle-kilometres of travel) of the PTWs, representative and more accurate risk rates can be developed. For Greece, in 2004, the fatality risk of moped drivers (<50cc) per million vehicle-kilometres of travel was 40, the respective risk for motorcycle driver fatalities (>50cc) was 77.8, while the respective fatality risk for passenger car driver was considerably lower (8,0) (NTUA, 2005).

More disaggregate risk figures are presented in Figures 5 and 6. More specifically, young motorcycle riders (18-20 years old) have significantly increased fatality risk compared to older ones. Somewhat increased fatality risk is also observed among older riders (>55 years old). Moped rider risk increases with rider age, although the strikingly high risk of elderly moped riders should be considered with some caution, due to the small sample.

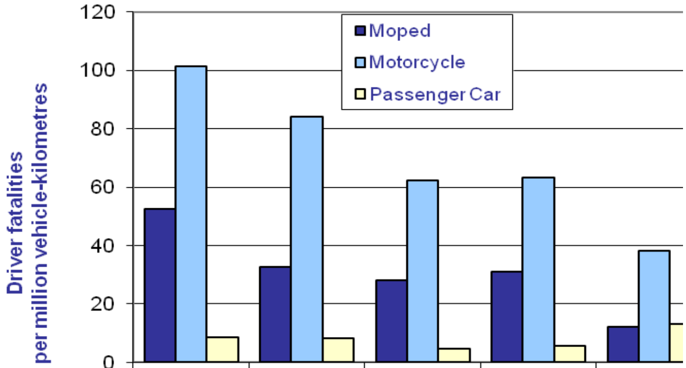
Figure 5: Driver fatalities per million vehicle-kilometres per driver age and vehicle type (Greece, 2004)



Driver age	18-20	21-24	25-34	35-54	55-64	>65
Moped	31.1	20.8	18.4	44.4	26.6	357.8
Motorcycle	313.1	162.7	62.3	47.7	141.9	115.4
Passenger car	41.5	20.7	7.7	5.8	6.5	11.5

Source: NTUA, 2005

Figure 6: Driver fatalities per million vehicle-kilometres per vehicle age and vehicle type (Greece, 2004)



	<1 year	1-2 years	3-5 years	6-10 years	> 10 years
Moped	52.5	32.8	28.0	31.1	12.2
Motorcycle	101.3	84.1	62.1	63.4	38.3
Passenger Car	8.5	8.3	4.5	5.6	13.3

Vehicle age group

Source: NTUA, 2005

In Figure 6, rider fatality risks are disaggregated per vehicle age. PTW rider fatality risk is significantly increased for newer vehicles, while the opposite is the case for passenger car drivers (there, older vehicles are associated with increased fatality risk).

3.4.4. Casualty under-reporting

An effort to estimate the underreporting of motorcycle casualties in Greece calculated the related correction coefficients to 6.54 for serious injuries and 7.03 for slight injuries according to the Length of Stay in the hospital and to 7.57 for serious injuries and 10.91 for slight injuries, according to the MAIS score (J. Broughton et al., 2010).

3.5 Social costs

Finally, regarding the social cost of road accidents, the related data associated with fatal, non-fatal and damage only accidents of PTW were calculated for Greece. In particular, the safety benefits that would occur annually by preventing PTW accidents and their casualties were calculated using appropriate methodologies and monetary units, such as generalized accident costs, value of statistical life in Greec etc. (Yannis et al., 2008). More specifically, if it was possible to avoid all annual 7,234 PTW road accidents with casualties, the related 8,284 casualties (2007), the benefits in financial terms would amount to 1,14 billion €.

Conclusions

The application of the SUNflower methodology could be used for the assessment of the PTW road safety performance in Greece, since it is an integrated approach to analyse and monitor the level of road safety of this specific road user group, using combined data and information from various technical, social and economic levels.

As indicated from the related analysis, both the significant number of PTW traffic in a favourable climate, the non PTW-friendly infrastructure and the inadequate enforcement of traffic laws, as well as the inappropriate attitudes and behaviour of active and passive safety of PTW riders, are the main factors for the high road accident rates of this road user group in Greece.

The road safety performance indicators in particular reveal that, the increased road accident risk of the PTW riders in Greece can be attributed to the large number of motorcycles and mopeds, the inappropriate driving behavior of all drivers, as well as the low helmets wearing rates. Moreover, the absence of measures and programs towards a single direction combined with inadequate driving education of road users and the general structure and organization at State level concerning road safety which can be further improved are the primary factors contributing to increased risk of PTW riders in Greece.

Based on the analysis of available data and information for PTW riders for each of the pyramid levels, it was revealed that important benefits (in monetary terms) could result annually by avoiding road accidents and the respective casualties. Moreover, proper integration of mopeds and motorcycles in the Greek transportation system, with emphasis on the improvement of all vehicle drivers' behavior, may be a key factor to reduce the risk and severity of accidents involving PTW in Greece.

The implementation of the Sunflower method for the analysis of the PTW safety problem in Greece revealed that various components interact, resulting in the increased fatality risk of PTW riders. These include both cultural elements and road safety management and enforcement characteristics, resulting in risky and inappropriate road user behaviour, which in turn results in increased fatality rates. It may be worth noting that, had the analysis focused on the risk figures of PTW only, it would have been simply concluded that young motorcyclists and new PTW are at increased risk. On the contrary, the implementation of the Sunflower methodology allowed for a more global exploration of the PTW safety problem, and the identification of specific causes related to the country background, policy implementation and road user behaviour.

In order to properly implement the SUNflower methodology and improve the road safety level of powered two-wheelers in Greece, additional necessary data and information should be collected and organized through macroscopic behavioural and in-depth studies and observations , with emphasis on issues related to speeding, aggressive behaviour of PTW drivers, riding under the influence of alcohol and fatigue. It may be concluded that safety performance indicators are the weakest component of the implementation of the Sunflower methodology in Greece, due to poor data availability, although the existing data provided valuable insight into the PTW safety problem. Moreover, it is advisable to draw up specific analyses to link the effects of the current road safety level of PTW riders with behavioral data and road safety performance, as well as the road safety measures with appropriate performance indicators.

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