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Comparative analysis of road accidents in the European motorways

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Abstract

The objective of this research is the analysis of road safety related parameters in the European motorways through the exploitation of the EU CARE database with disaggregate data on road accidents, as well as of other international data sources (OECD/ IRTAD, Eurostat etc.). Time series data on motorway road accidents from 24 EU countries over a period of 10 years (2004-2013) are correlated with basic safety parameters such as the mode of transport, the manoeuvre type, the age, gender and road user type of the persons killed, as well as the lighting conditions and seasonality. This comparative analysis revealed a decrease of 48% in road accident fatalities on motorways in the decade 2004 - 2013, slightly higher than the respective decrease of 45% in the total number of fatalities. It was also found that in 2013 users of two-wheeled vehicles killed in accidents on motorways were fewer than those killed on non-motorway roads. Additionally, on motorways, the proportion of drivers' fatalities was highest for the 50-64 age group, whereas on the remaining road network it was highest for the 25-49 age group. As regards the lighting conditions, the highest percentage of fatalities on motorways occurred in accidents during daylight or twilight. The results of the analysis allow for an overall picture of the road safety level on the European motorways in comparison to the remaining road network, providing, thus, useful support to all decision makers working for the improvement of safety on the European road network.

1. Introduction

More and more European governments are committed to road safety due to the impact of road accidents as a public health threat. Except for regulation, providing better road infrastructure is a key strategy to enhance the road safety level. Motorways form an important part of the overall road infrastructure system in a country and are generally acknowledged as the safest roads by design (Elvik and Vaa, 2004).

In 2012, the total length of motorways in the 28 European Union countries was 73.246 km, constituting 2% of the total road network (EC, 2015). Many European countries are developing their motorway network, while some countries are upgrading some of their rural roads, in various ways, to high speed rural roads as cost-effective alternatives to motorways. It is noted that there are no motorways in Malta, Latvia and Estonia, since in these countries, the main road sections with high traffic volumes are not long enough to attract financial resources for building motorways (ETSC, 2015).

Many more road users die on rural and urban roads than on motorways. On the other hand, the existence of higher speed limits than on the remaining road network and the increased number of drivers violating these limits, seem to have a large impact on the severity of road accidents on motorways (KfV, 2005). Between 2004 and 2013 more than 27.500 people were killed on motorways in the EU. This number represents only about 7% of all road accident fatalities in the EU, however, the proportion of fatalities on motorways has been stagnated since 2004.

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For that reason, and given that the motorway networks are continuously developing across Europe it is essential that motorway road accidents are investigated and continuously monitored, allowing the implementation of appropriate accident mitigation measures.

The objective of this research is the analysis of basic road safety parameters on the European motorways, through the exploitation of the EU CARE database with disaggregate data on road accidents. More specifically, time-series data on motorway road accidents from CARE for 24 EU countries over a period of 10 years (2004-2013) are correlated with basic safety parameters, such as the mode of transport, the manoeuvre type, the age, gender and road user type of the persons killed, as well as the lighting conditions and season of the year. The paper is based on work done within the development of the Traffic Safety Basic Facts 2015 – Motorways (European Commission, 2015), as well as within the SAFETYNET and DaCoTA EC co-funded research projects and the European Road Safety Observatory (ERSO - http://ec.europa.eu/transport/wcm/road_safety/erso/index-2.html).

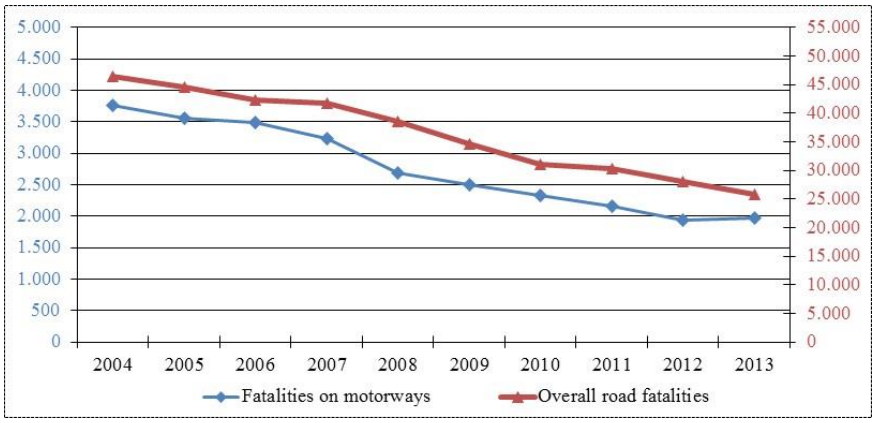
The results of the analysis allow for an overall assessment of the road safety level on the European motorways in comparison to the remaining road network, thus providing useful support to decision makers working for the improvement of safety in the European road network.

2. Overall road safety trends on the motorways of the European countries

Motorways are designed to carry heavy traffic at high speed with the lowest possible number of accidents. They are also designed to collect long-distance traffic from other roads, so that conflicts between long-distance traffic and local traffic are avoided (Elvik and Vaa, 2004). According to the European definition, motorways are roads specially designed and built for motor traffic, which does not serve properties bordering on it and which (a) is provided, except at special points or temporarily, with separate carriageways for traffic in two directions, separated from each other, either by a dividing strip not intended for traffic, or exceptionally by other means; (b) has no crossings at the same level with any road, railway or tramway track, or footpath; and (c) is especially sign-posted as a motorway and is reserved for specific categories of road motor vehicles. Entry and exit lanes of motorways are included irrespectively of the location of the sign-posts. Urban motorways are also included in this definition (UNECE-ITF-EUROSTAT, 2009).

In order to assess the safety level of motorways at the EU level, analyses of related accident data maintained into the EU CARE database can be performed. CARE is the Community database on road accidents resulting in death or injury, consisting of data with high level of disaggregation, contrary to most other existing international databases. This structure allows maximum flexibility and potential, with regard to analysis of the information available.

In order to monitor the evolution of the safety level on European motorways, accident trends for the decade 2004 - 2013 were considered. According to the following Figure 1 there was a decrease of 48% in road accident fatalities on motorways in 2013 compared to the 3.755 fatalities in 2004, though the total number of road accident fatalities also fell significantly, by almost 45%, in the European Union countries within the same decade. Over the same period, the length of the motorway network in the European Union increased by about a quarter (ETSC, 2015). Specifically, in 2008, the highest annual decrease in motorway road accident fatalities (17%) was recorded while, within the same year, the decrease in the overall number of road fatalities was 8%. It is also worth noting that in 2013 the number of fatalities on motorways in the 24 EU countries increased slightly, whereas the overall number of road accident fatalities in the EU decreased by 7,7%.



Source: CARE database, data available in May 2015

Fig. 1. Number of fatalities on motorways and all road fatalities, EU, 2004-2013

The following Table 1 provides an overview of the change in the number of fatalities on motorways per country between 2004 and 2013. It can be seen that in Germany, in 2013, more persons were killed on motorways than in any other of the examined EU countries (428 persons killed, 25% more than Italy, the country with the second higher figure). It should be noted that in three countries (Germany, Greece, and Poland) a significant number of fatalities are recorded in the CARE data as being on non-specified road network type (it is not known whether or not they occurred on a motorway).

Table 1. Number of fatalities on motorways by country in the EU, 2004-2013

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BE	125	161	164	153	139	150	106	120	91	94
BG	-	-	-	-	-	36	-	-	-	-
CZ	58	45	37	48	30	25	28	21	22	25
DK	27	31	16	24	31	24	27	12	8	12
DE	694	662	645	602	495	475	430	453	387	428
IE	6	2	11	10	2	4	9	9	5	5
EL	116	111	147	140	120	108	87	81	57	79
ES	925	855	776	618	496	465	418	341	304	294
FR	316	323	296	273	233	225	238	268	223	238
HR	-	-	-	65	67	43	33	23	43	41
IT	648	577	590	526	452	350	376	338	330	321
CY	9	9	13	13	8	7	9	7	3	2
LU	7	4	6	11	6	36	29	4	7	6
HU	62	48	55	61	54	38	44	49	31	30
NL	-	-	-	-	-	83	64	43	68	59
AT	118	89	74	74	71	61	59	46	50	31
PL	42	33	55	53	35	43	28	37	44	40
PT	116	98	84	128	96	89	111	84	58	44
RO	19	37	50	41	21	25	18	16	17	24
SI	37	20	33	37	13	30	19	20	20	16
SK	21	21	15	19	14	9	14	-	-	-
FI	17	10	17	14	9	12	4	11	13	8
SE	42	24	28	25	18	21	24	20	18	21
UK	166	206	189	185	160	132	118	106	89	102
EU*	3.755	3.550	3.486	3.238	2.689	2.491	2.329	2.159	1.938	1.970
Annual change		-5,5%	-1,8%	-7,1%	-17,0%	-7,4%	-6,5%	-7,3%	-10,2%	1,6%
CH	51	25	31	47	27	34	23	22	63	23

Source: CARE database, data available in May 2015

* Totals for EU include latest available data (Data for Estonia, Latvia, Lithuania and Malta not included in totals)

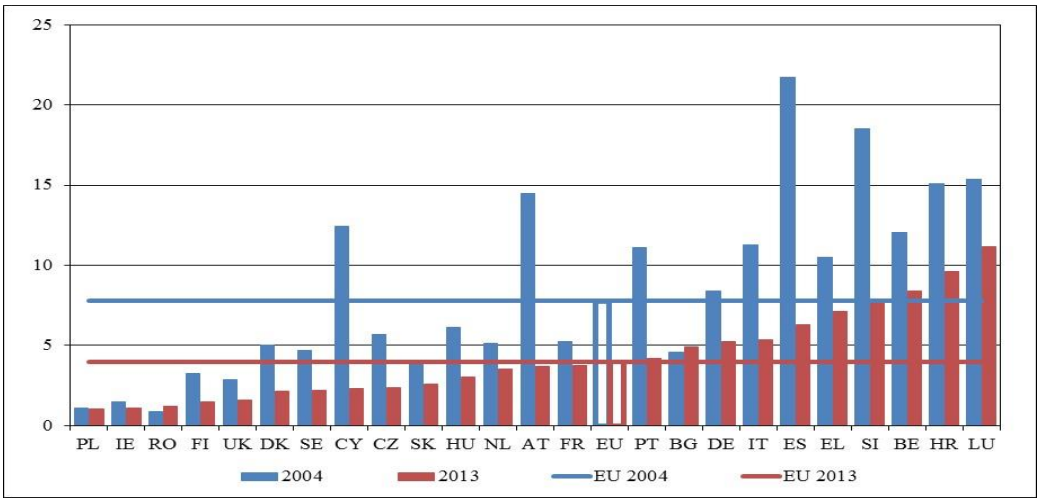
In road safety analysis exposure data is often used to calculate risk estimates, those being defined as the rate of the number of accidents (or casualties) divided by the amount of exposure of a population over a time period (Hakkert and Braimaster, 2002, Hauer, 1995). On that purpose data from other international databases such as OECD/IRTAD, Eurostat etc. were also used. Since there is no reliable data available about vehicle kilometres or person kilometres travelled on motorways in the European countries, the population and the length of motorway network are used to calculate exposure. The calculated risk figures may be used for different purposes, but their main objective is to enable the comparison of safety performance among different units, populations or countries.

In Table 2 it can be seen that the fatality rates on motorways per million inhabitants in Croatia and Belgium are higher than the respective rates in the other EU countries, and hence the average rate of the EU, for 2013. It is noted that the latest available data are used, meaning 2009 data for Bulgaria and Estonia, 2010 data for Malta and Slovakia, and 2012 data for Ireland as proxies for 2013 data.

Table 2. Motorway fatality rates per million population by country, 2004-2013 or latest available year

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BE	12,0	15,4	15,6	14,5	13,0	13,9	9,8	10,9	8,2	8,4
BG	4,6	4,7	4,7	4,8	4,8	4,8	4,9	4,9	4,9	4,9
CZ	5,7	4,4	3,6	4,7	2,9	2,4	2,7	2,0	2,1	2,4
DK	5,0	5,7	2,9	4,4	5,7	4,4	4,9	2,2	1,4	2,1
DE	8,4	8,0	7,8	7,3	6,0	5,8	5,3	5,5	4,7	5,2
IE	1,5	0,5	2,6	2,3	0,4	0,9	2,0	2,0	1,1	1,1
EL	10,5	10,0	13,2	12,6	10,7	9,7	7,8	7,3	5,1	7,1
ES	21,7	19,8	17,6	13,8	10,9	10,1	9,0	7,3	6,5	6,3
FR	5,2	5,3	4,8	4,4	3,7	3,6	3,8	4,2	3,5	3,7
HR	15,1	15,1	15,1	15,1	15,5	10,0	7,7	5,4	10,1	9,6
IT	11,3	10,0	10,2	9,0	7,7	5,9	6,4	5,7	5,6	5,4
CY	12,4	12,3	17,5	17,2	10,3	8,8	11,0	8,3	3,5	2,3
LU	15,4	8,7	12,8	23,1	12,4	72,9	57,8	7,8	13,3	11,2
HU	6,1	4,8	5,5	6,1	5,4	3,8	4,4	4,9	3,1	3,0
NL	5,1	5,1	5,1	5,1	5,1	5,0	3,9	2,6	4,1	3,5
AT	14,5	10,9	9,0	8,9	8,5	7,3	7,1	5,5	5,9	3,7
PL	1,1	0,9	1,4	1,4	0,9	1,1	0,7	1,0	1,2	1,1
PT	11,1	9,3	8,0	12,1	9,1	8,4	10,5	7,9	5,5	4,2
RO	0,9	1,7	2,4	1,9	1,0	1,2	0,9	0,8	0,8	1,2
SI	18,5	10,0	16,5	18,4	6,5	14,8	9,3	9,8	9,7	7,8
SK	3,9	3,9	2,8	3,5	2,6	1,7	2,6	2,6	2,6	2,6
FI	3,3	1,9	3,2	2,7	1,7	2,3	0,7	2,0	2,4	1,5
SE	4,7	2,7	3,1	2,7	2,0	2,3	2,6	2,1	1,9	2,2
UK	2,9	3,5	3,2	3,1	2,7	2,2	1,9	1,7	1,4	1,6
EU	7,8	7,3	7,2	6,6	5,5	5,1	4,7	4,4	3,9	4,0
CH	6,9	3,4	4,2	6,3	3,6	4,4	3,0	2,8	7,9	2,9

Source: CARE database (EUROSTAT for population data), data available in May 2015



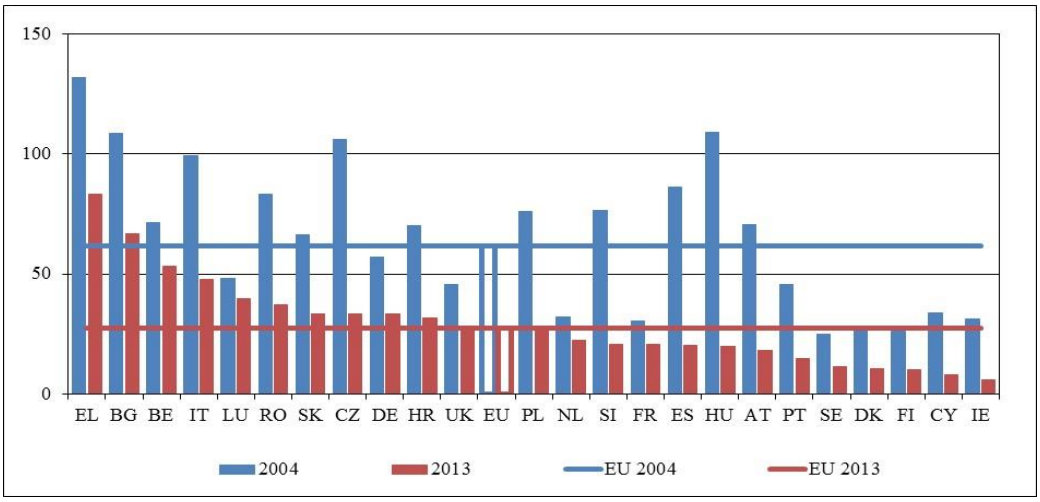
Source: CARE database (EUROSTAT for population data), data available in May 2015

Fig. 2. Motorway fatality rates per million population by country, 2004 and 2013 or latest available year

Additionally, it is evident that between 2004 and 2013 the fatality rate on motorways decreased by almost 49% (from 7,8 per million inhabitants in 2004 to 4,0 in 2013), compared to an approximate 46% decrease (from 97 to

52) in the corresponding fatality rate on the total road network. Austria and Spain are the countries which experienced the most significant reductions during that decade (75% and 71% respectively), whereas in Romania the fatality rate actually increased (by 36%). Poland had the lowest fatality rate (1,1 in 2013), whereas in ten of the countries the fatality rate was higher than the average rate of all EU countries for 2013. Progress in countries performing better than average is a result of a comprehensive mix of measures, including improved infrastructure safety and road user behaviour (such as better compliance with speed limits or increased seat belt use) (ETSC, 2015).

A more reliable comparison of the changes on the safety level of motorways in different countries involves calculating the fatality rate per thousand kilometres of motorway. Taking this exposure indicator (motorway network length) into account, it was found that within the examined period, Hungary experienced the most considerable reduction in fatality rates on its motorway network (82%) (Figure 3). Furthermore, the average rate for EU fell by 56% between 2004 and 2013.



Source: CARE database (EUROSTAT for road length data), data available in May 2015

Fig. 3. Motorway fatality rates per 1.000 km of motorways by country, EU, 2004-2013 or latest available year

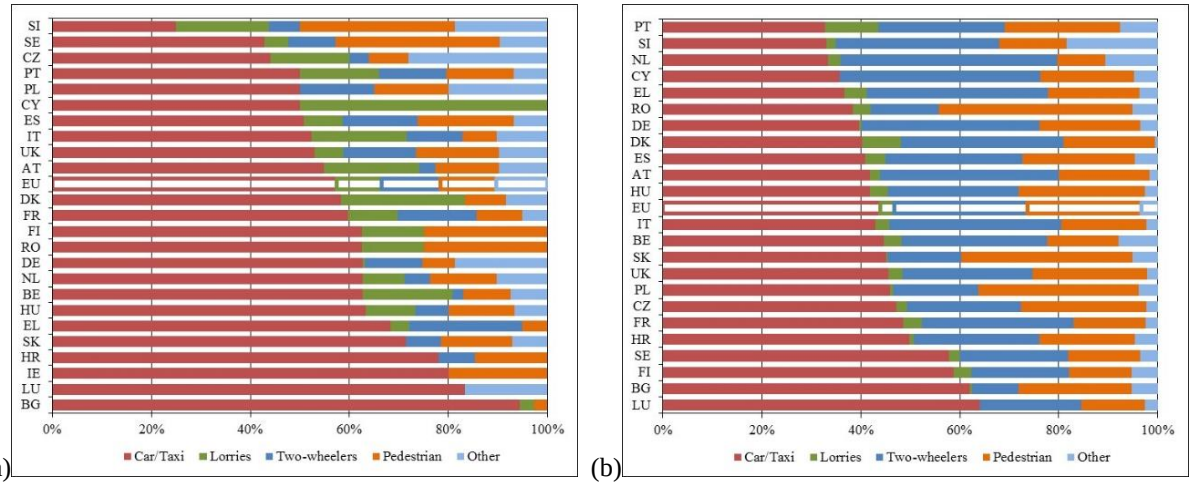
Greece is the country with the highest number of fatalities on motorways per thousand kilometers of motorway network in 2013. Conversely, the fatality rate in Ireland in 2013 (5,6) is significantly lower than the average rate for EU countries (27,3), while at the same time the length of the Irish motorway network was multiplied by four (ETSC, 2015).

According to the analysis performed, the ratio of fatalities on motorways to all fatalities in the European Union countries has been stagnated since 2004. Especially in Spain, almost 18% of the overall road accident fatalities in 2013 occurred on motorways, the largest proportion in the EU, whereas in Poland and Romania fatalities on motorways constitute the smallest proportion of road accident fatalities.

3. Road safety parameters of the European motorways

The analysis of the distribution of road accident fatalities according to the mode of transport used on motorways and on non-motorway road network, showed that almost 58% (1.147 persons) of the fatalities on motorways across the European countries concern passenger car or taxi occupants. Another interesting outcome of the analysis was that, on average, only 11,6% of the fatalities occurring on motorways in the examined 24 EU countries concerns two-wheelers (motorcycle, moped or pedal cycle users), with Greece having the largest percentage (23%), though the absolute number is small (18 fatalities). On the other hand, the two-wheeler user fatalities on the non-motorway road network constitute 27% of the respective number of fatalities, with the Netherlands having the largest share (44%).

Even though pedestrians are prohibited to use motorways, they account for 11% of motorway accident fatalities. Figure 4 shows that in 2013, 33% of fatalities on motorways in Sweden were pedestrians, the highest proportion among the EU countries. Furthermore, Slovenia, Romania and Finland had high proportions of pedestrian fatalities on motorways, 31% and 25% respectively. Pedestrians killed on motorways might be vehicle users who have left their vehicles for some reason, workers in work zones or individuals who entered the motorway on foot illegally (ETSC, 2015).



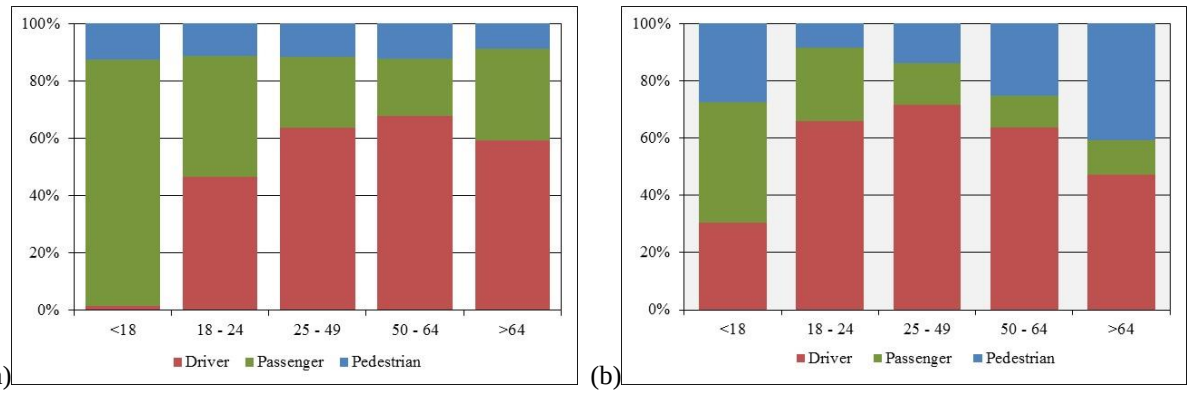
Source: CARE database, data available in May 2015

Fig. 4. (a) Distribution of fatalities on motorways by country and mode of transport, 2013 or latest available year, (b) Distribution of fatalities on non-motorway road network by country and mode of transport, 2013 or latest available year

The data analysis also revealed that the single biggest category of fatalities occurring on motorways, in terms of vehicle manoeuvre type, in almost all EU countries (26,1%) concern fatalities resulting from accidents in which occupants killed were in a vehicle moving straight ahead and where no other manoeuvre took place. However, the corresponding percentage for this manoeuvre on non-motorway network is lower (20,8%), maybe due to the large number of "not defined" manoeuvres. More specifically, in 8 countries (Bulgaria, Czech Republic, Germany, Croatia, Italy, Slovakia, Finland and Sweden) almost all manoeuvres on motorways and on non -motorways are "not defined".

Age and road user type of the persons killed were also considered. As Figure 5 indicates, pedestrians constitute 9% - 13% of the overall fatalities occurring on motorways depending on age group. However, children (persons younger than 15 years old) and elderly people (persons older than 64 years old) seem to be more vulnerable pedestrians on the remaining road network, as 27% and 41% of fatalities amongst children and elderly people respectively are pedestrians.

Furthermore, a larger proportion of middle age drivers (25 - 64 years old) are killed on motorways (72%), compared with those of other age groups, whereas younger drivers (18 - 49 years old) constitute the largest proportion of fatalities occurring on the remaining road network. Finally, drivers up to 18 years old are mainly killed on the remaining road network and not on motorways, where the respective percentages are significantly lower: there is a relatively small number of fatalities in this age group on motorways (72 people, compared to 1.081 people on the remaining road network), possibly indicating that young people drive more on the non-motorway network.

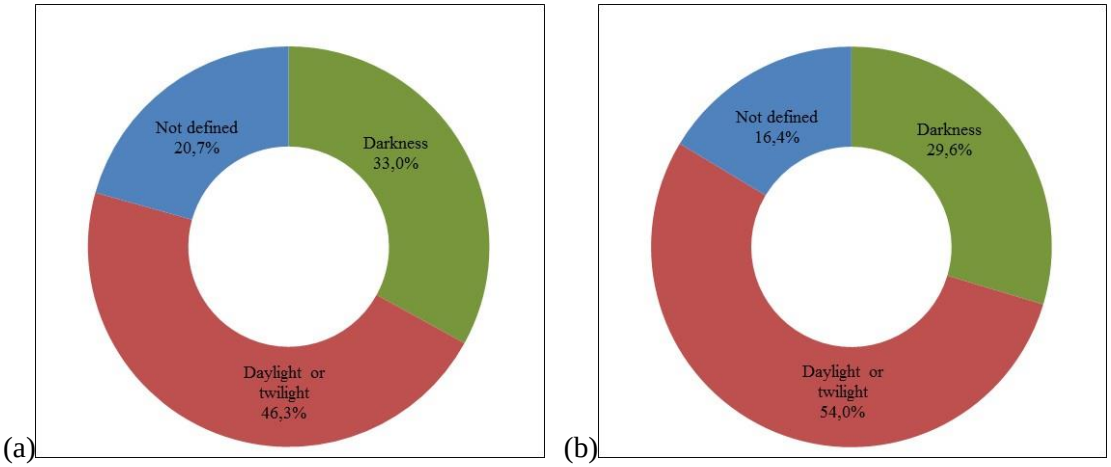


Source: CARE database, data available in May 2015

Fig. 5. (a) Distribution of fatalities on motorways by age group and road user type, EU, 2013 or latest available year, (b) Distribution of fatalities on non-motorway road network by age group and road user type, EU, 2013 or latest available year

Finally, with reference to the lighting conditions, 46% of the fatalities on motorways in the EU countries occurred in accidents during daylight or twilight. The respective percentage for the remaining road network in the EU appears to be only slightly higher (54%), as shown in Figure 6. It is noted that the high percentage of fatalities

for which the lighting condition is “not defined” means that the actual percentages are rather higher. Furthermore, 33% of the fatalities on motorways occurred in darkness, whereas on non-motorway network, the respective percentage is lower, almost 30%.



Source: CARE database, data available in May 2015

Fig. 6. (a) Distribution of fatalities on motorways by lighting conditions, EU, 2013 or latest available year (b) Distribution of fatalities on non-motorway road network by lighting conditions, EU, 2013 or latest available year

The peak period for fatalities on motorways in the EU in 2013 was in July/August (24%). However, the peak periods differ among countries. The highest percentage of fatalities on motorways per fatalities on non-motorways, in the EU, was almost 12% and was recorded in July, whereas the lowest respective percentage (7,5%) was recorded in October. Although for 2013 the EU average monthly percentage was between 7,5% and 11,8%, there were considerably higher percentages in some countries during some months. A very high percentage of motorway fatalities occurred in Slovenia in September (45%).

4. Conclusions

The various road safety parameters examined have different impact on the motorways safety level than on the remaining road network due to the specific design characteristics but also to the different behaviour of the drivers on motorways.

According to studies on motorways safety, the special driving conditions on this road network type, in which average speeds measured are high and distances between vehicles are often surprisingly small (Aron et al., 1999) result to different accident frequency and severity than on the remaining road network. Especially in cases where motorway traffic is low, the increased relaxation felt by the driver can lead to overcompensation in speed and subsequently to the detriment of his safety (Martin, 2002).

Analysis of motorway road accident data derived from the Community CARE database for the decade 2004 - 2013 showed a decrease of 48% in accident fatalities on motorways in 2013 compared to 2004, which was slightly higher than the respective reduction of the overall road accident fatalities in the European Union. CARE accident data were also combined with exposure data (population, length of motorways), allowing the more accurate comparison of the calculated rates between the EU countries. According to the results of the analysis, the fatality rates on motorways per million inhabitants in Croatia, Belgium and Slovenia are higher than the respective rates in the other EU countries, for 2013, whereas Ireland, Finland and Denmark had the lowest motorway fatality rates. As regards the fatality rates per thousand kilometers of motorway network, Greece was the least safe in 2013.

The data analysis also revealed that almost 58% of the fatalities on motorways across the EU countries concern passenger car or taxi occupants and another 11,6% of the fatalities occurring on motorways concerns two-wheelers, which is much lower than the respective percentage of fatalities on the remaining road network. Even though pedestrians are prohibited to use motorways, they account for 11% of motorway accident fatalities. Furthermore, a larger proportion of middle age drivers (25 - 64 years old) are killed on motorways (72%), compared to those of other age groups, whereas drivers up to 18 years old are mainly killed on the remaining road network and not on motorways.

The results of the analysis allow for an overall assessment of the safety level on the European motorways relatively to the remaining road network, providing, thus, useful support to decision makers working for the improvement of safety on the European road network. Certainly, the effort of data-collection is an on-going challenge and there are additional data that could help shed light to the problem of road safety on motorways. Of

particular interest are exposure data related to the mobility of road users (veh-kms, passenger-kms travelled). Furthermore, the macroscopic analysis presented in this paper could, in the future, be combined with more detailed analysis using statistical models, which is necessary for the identification of the combined correlation of the parameters with an impact on motorway road safety and the underlining reasons behind the motorway casualties.

Acknowledgements

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Appendix A. Country abbreviations

Belgium	BE
Bulgaria	BG
Czech Republic	CZ
Denmark	DK
Germany	DE
Estonia	EE
Ireland	IE
Greece	EL
Spain	ES
France	FR
Croatia	HR

Italy	IT
Cyprus	CY
Latvia	LV
Lithuania	LT
Luxembourg	LU
Hungary	HU
Malta	MT
Netherlands	NL
Austria	AT
Poland	PL
Portugal	PT

Romania	RO
Slovenia	SI
Slovakia	SK
Finland	FI
Sweden	SE
United Kingdom	UK

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