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ScienceDirect

Transportation Research Procedia 14 (2016) 2025 – 2034

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Exposure-based road traffic fatality rates by mode of travel in France

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Abstract

Travel practices are changing: bicycle and motorized two-wheeler (MTW) use are rising in some of France's large cities. These are cheaper modes of transport and therefore attractive at a time of economic crisis, but they also allow their users to avoid traffic congestion. At the same time, active transport modes such as walking and cycling are encouraged because they are beneficial to health and reduce pollution. It is therefore important to find out more about the road crash risks of the different modes of transport. To do this, we need to take account of the number of individuals who use each, and, even better, their travel levels.

We estimated the exposure-based fatality rates for road traffic crashes in France, on the basis of the ratio between the number of fatalities and exposure to road accident risk. Fatality data were obtained from the French national police database of road traffic casualties in the period 2007-2008. Exposure data was estimated from the latest national household travel survey (ENTD) which was conducted from April 2007 to April 2008. Three quantities of travel were computed for each mode of transport: (1) the number of trips, 2) the distance travelled and (3) the time spent travelling. Annual fatality rates were assessed by road user type, age and sex.

The overall annual fatality rates were 6.3 per 100 million trips, 5.8 per billion kilometers travelled and 0.20 per million hours spent travelling. The fatality rates differed according to road user type, age and sex. The risk of being killed was 20 to 32 times higher for motorized two-wheeler users than for car occupants. For cyclists, the risk of being killed, both on the basis of time spent travelling and the number of trips was about 1.5 times higher than for car occupants. Risk for pedestrians compared to car occupants was similar according to time spent travelling, lower according to the number of trips and higher according to the

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Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.170

distance travelled. People from the 17-20 and 21-29 age groups and those aged 70 and over had the highest rates. Males had higher rates than females, by a factor of between 2 and 3.
When exposure is taken into account, the risks for motorized two-wheeler users are extremely high compared to other types of road user. This disparity can be explained by the combination of speed and a lack of protection (except for helmets). The differential is so great that prevention measures could probably not eliminate it. The question that arises is as follows: with regard to public health, should not the use of MTW, or at least of motorcycles, be deterred? The difference between the fatality risk of cyclists and of car occupants is much smaller (1.5 times higher); besides, there is much room for improvements in cyclist safety, for instance by increasing the use of helmets and conspicuity equipment. Traffic calming could also benefit cyclists, pedestrians and perhaps moped users.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Road traffic accidents; travel survey; mobility; risk assessment; risk exposure

1. Introduction

When promoting active modes of transport, i.e. walking and cycling, with a view to improving public health (World Health Organization 2004a), it is important to improve our knowledge about the crash risk associated with these two modes of transport and to compare them with other modes, in particular the car as this is the most frequently used mode, but also MTWs whose use is increasing in some major cities, Kopp (2011). The use of bicycles is also on the increase in some large cities, Papon and De Solère (2010). These two modes have two similar advantages for their users. First, they allow them to avoid most traffic congestion, and second, they are less expensive than car use, which is an asset at a time of economic crisis. In order to compare the crash risks of different modes of transport we must have appropriate measures of their use. The number of vehicles or number of users provided an approximate starting point. The best approach is to measure road users' travel levels: Elvik et al. (2009), Santamariña-Rubio et al. (2013). This can be done on the basis of number of trips: Pucher and Dijkstra (2000), Beck et al. (2007), De Geus et al. (2012), distance travelled : Harrison and Christie (2005), Christie et al. (2007), Elvik (2009), De Geus et al. (2012) or time spent travelling : Tin Tin et al. (2010), De Geus et al. (2012). Distance travelled is the most frequently used of these, as it can be approximately measured on the basis of petrol sales and the fleet of motor vehicles. In this study, by using a travel survey, we can estimate all three quantities of road users' travel. The first, the number of trips, provides an initial indicator of users' travel. The best way of refining this indicator is to take account of distance travelled or time spent travelling. We shall present the fatality risks for these 3 measures, as they do not reveal the same information. We tend to favor the time spent travelling over the distance travelled, as time spent travelling is less elastic, Schafer (2000), i.e. time spent travelling during a day is fairly similar across different road user types, whereas distance travelled is not.

With regard to crash risk, we have restricted this study to fatality risk, as road fatalities are well-reported whereas non-fatal casualties are not, Amoros et al. (2006). This is the case both in France and worldwide, Elvik and Mysen (1999).

2. Materials and Methods

2.1. Data

Two data sources were used. The travel data were provided by the latest French National Travel Survey (ENTD) conducted in 2007- 2008. Data collection was spread over one full year (April 2007 to April 2008), in 6 waves, in order to eliminate seasonal variations in travel. This survey was based on a sample of 20,200 surveyed households, making it the largest travel survey ever conducted in France: Grimal (2010), Armoogum et al. (2011).

This survey was conducted by the Ministry of Transport, and it was mandatory for selected individuals to participate. The individuals were asked to describe all their short and long trips. The collected information included, for each trip, the mode(s) of transportation used, the distance covered, the time spent travelling and the purpose of the trip. A trip could only have one purpose, and could include one or more transport modes. However the survey selected a dominant mode for each trip. This was based on the hierarchy of weights: 1) walking, or using 2) a bicycle, 3) a MTW, 4) a car, or 5) public transport.

We estimated 3 quantities of road users' travel: the number of trips, the distance travelled, and the time spent travelling. The number of trips provides an initial rough measure of travel level. As mentioned above, distance travelled is often used, as it was the first indicator to be estimated using data on petrol sales and the fleet of vehicles. The time spent travelling has the advantage of being the least elastic measure (Schafer 2000); in other words, the time-budget is more comparable across road users than the distance-budget.

Our crash data were obtained from the French national road crash database, which is based on police crash reports (ONISR 2009). We selected the crash data in accordance with the population studied in the national travel survey: individuals aged 6 years and over, living in metropolitan France and who were killed in a crash that occurred in 2007 or 2008.

2.2. Statistical Analysis

The risk of fatal road crashes is defined as a ratio, in which the numerator is the number of fatalities occurring during the study period and the denominator is the measure of exposure during the same period. We estimated the annual fatality rates by using three different measures of exposure: number of trips, distance travelled and time spent travelling. The exposure data were weighted to take account of the design of the survey sample.

Fatality rates were computed according to gender, age and road user type. Age was classified into the same categories as a recent study (Mindell et al. 2012) to allow direct comparisons: [6-16], [17-20], [21-29], [30-39], [40-49], [50-59], [60-69] and [70 +].

The following road user types were studied: pedestrians (including skateboard and roller skate users), cyclists, motorized two-wheeler (MTW) users (including motorcycles, mopeds and quads), car occupants (including individuals in taxis and light goods vehicles), and (road) public transport users (including buses, coaches, trams and trolleybuses).

Fatality rates for public transport users were not reported by age and sex due to an insufficient amount of data. However, their characteristics in terms of travel and crashes were taken into account in the overall fatality rates.

For MTWs and bicycles, the results according to age and sex are often based on low frequencies, which means that we must be very cautious when interpreting them.

In addition to the three measures of exposure previously mentioned, we computed fatality rates per inhabitants using the census population data provided by the French National Institute for Statistics and Economic Studies (INSEE).

The 95% confidence intervals (95% CI) of fatality rates were computed using exact Poisson confidence limits based on the link between the Chi square and the Poisson distributions (Grimal 2010). Statistical analysis was performed using SAS software (version 9.3).

3. Results and interpretation

3.1. Police-reported road traffic fatalities data

During the 2007-2008 study period, the annual average number of crash fatalities in metropolitan France recorded by the police was 3,634. These were mostly males (76.0 %) and the 21-29 age group accounted for nearly a quarter of all fatalities. With regard to road user type, car occupants accounted for 56.3% of all fatalities, MTW users for 27.0%, pedestrians for 13.1%, cyclists for 3.4% and public transport users for 0.3% (Table 1).

3.2. Road users' travel levels

According to the 2007-2008 national travel survey, the population of France spent 18,506 million hours travelling per year, covered 624,442 million kilometers and made 57,762 million trips (Table 1).

Table 1. Distribution of fatalities and measures of exposure according to sex, age and road user types, France, 2007-2008.

Characteristics	Annual average		Annual measures of exposure					
	Fatalities		Person-hours spent travelling (million)		Person-kilometers travelled (million)		Person-trips (million)	
Total*	N=3,634	%	N=18,506	%	N=624,442	%	N=57,762	%
Sex								
Male	2,763	76.0	9,409	50.8	332,278	53.2	27,934	48.4
Female	871	24.0	9,097	49.2	292,164	46.8	29,828	51.6
Age groups								
6-16	156	4.3	2,329	12.6	67,601	10.8	7,998	13.9
17-20	458	12.6	945	5.1	28,391	4.6	2,612	4.5
21-29	843	23.2	2,527	13.7	91,690	14.7	8,095	14.0
30-39	509	14.0	3,352	18.1	129,648	20.8	10,907	18.9
40-49	456	12.5	3,041	16.4	109,133	17.5	9,789	17.0
50-59	348	9.6	2,683	14.5	92,274	14.8	7,660	13.3
60-69	252	6.9	2,178	11.8	69,120	11.1	6,283	10.9
>=70	614	16.9	1,452	7.8	36,584	5.9	4,418	7.6
Road user types								
Pedestrians	475	13.1	3,163	17.1	11,405	1.8	13,009	22.5
Cyclists	124	3.4	536	2.9	5,409	0.9	1,662	2.9
MTW users	981	27.0	273	1.5	8,543	1.4	980	1.7
Car occupants	2,045	56.3	13,170	71.2	572,426	91.7	39,682	68.7
Public transport	10	0.3	1,364	7.4	26,661	4.3	2,429	4.2

Car occupants accounted for the largest amount of travel, whatever the measure: around 70% according to number of trips or time spent (respectively 68.7%, 71.2%) and the very high figure of 91.7% according to distance travelled. Pedestrians accounted for about 20% of the number of trips or hours spent travelling (respectively 22.5% and 17.1%) and for a very small percentage of the kilometers covered (1.8%). Cyclists accounted for about 3% of the number of trips or hours spent travelling (2.9% for both), and a smaller percentage of the kilometers covered (0.9%). MTW use accounted for less than 2% of travel whatever the measure: 1.7% of the number of trips, 1.5% of the hours spent travelling and 1.4% of the kilometers travelled. The disparity between the small percentage of travel that is made by MTW (less than 2%) and the far larger percentage of fatalities the mode accounts for (27%) is already apparent.

Public transport accounted for around 4% of person trips and kilometers travelled (respectively 4.2% and 4.3%) and a somewhat higher percentage of time spent travelling (7.4%). There is a disparity here too, but in the opposite direction, between public transport’s low level of fatalities (0.3%) and its non-negligible percentage of travel.

3.3. Fatality rates among different subgroups

Fatality rates for each population subgroup are provided in Table 2. The overall fatality rate was 63.5 per million inhabitants ; this is lower than the rate published by the international road traffic and analysis group (International

Traffic Safety Data and Analysis Group (IRTAD) 2010). This is because we excluded from the fatalities those whose were not residents of France, as the exposure we use (number of inhabitants do not include non-residents).. The fatality rates for males were 3.4 times higher than for females. In terms of age, the 17-20 and 21-29 age groups had the highest fatality rates, about 2 times higher than the 30-39 age group. This applied to both males and females, with perhaps a slightly higher rate for females aged 17-20 (3 times higher than for females aged 30-39). People aged 70 years and over also had a rather higher fatality rate than the 30-39 age group. This was especially the case among women (3 times higher than the 30-39 female age group).

Table 2. Annual fatality rates per million inhabitants, by sex and age, France, 2007-2008.

Characteristics	Male		Female		Total	
	Rate	95% CI[†]	Rate	95% CI	Rate	95% CI
Age groups						
6-16	25.4	20.8-30.6	11.7	8.6-15.5	18.7	15.9-21.9
17-20	224.6	202.3-248.8	57.1	45.9-70.2	142.7	129.9-156.4
21-29	206.7	191.9-222.5	36.7	30.6-43.7	121.4	113.4-129.9
30-39	103.3	93.8-113.5	17.9	14.1-22.5	60.4	55.2-65.9
40-49	86.2	77.6-95.4	20.0	16.0-24.6	52.6	47.8-57.6
50-59	64.0	56.4-72.2	20.9	16.7-25.7	41.9	37.7-46.6
60-69	61.1	52.1-71.2	29.6	23.7-36.5	44.7	39.3-50.5
>=70	114.6	102.9-127.4	56.3	49.8-63.5	79.1	73.0-85.6
Total	100.1	96.4-103.9	29.4	27.4-31.4	63.5	61.4-65.6

3.3.1. Fatality rates per 100 million trips

The overall fatality rate was 6.3 per 100 million trips (95% CI: 6.1-6.5). If we take car occupants as the reference group, MTW users were about 20 times more likely to be killed, cyclists 1.5 times more, and pedestrians 0.7 times less likely. This surprising result of lower risk for pedestrians may be explained by the fact that their risk of being hit by a vehicle is low when they are walking on footpaths that are separated from the traffic by parked vehicles.

For the different road user types, men were between 2 and 3 times more likely to be killed than women. With regard to age, the 17-20 and 21-29 age groups had higher fatality rates than the 30-39 age group. This is especially the case for car occupants, where the risk of being killed for the 17-20 age group was 7 times higher than for the 30-39 age group (7 times for men and 7.8 times for women). In the case of pedestrians, the risk for the 17-20 age group was “only” twice that for the 30-39 age group (for both men and women). For MTW users aged between 21 and 29 years, risk for men was about 3 times higher than for women.

Overall fatality rates for the 70+ age group were high, especially for females and to lesser extent for males. Risk for this group was about 3 times higher than for the 30-39 age group (1.9 times higher for males and 8.8 times for females). For male pedestrians, risk for the 70+ age group was about 5 times higher than for the 30-39 age group.

3.3.2. Fatality rates per billion kilometers travelled

The overall fatality rate was 5.8 per billion kilometers travelled (95% CI: 5.6-6.0). On the basis of kilometers travelled, the risk of being killed for MTW users was 32 times higher than for car occupants. The corresponding figures for cyclists and pedestrians were 6.4 and 11.6 respectively. With this measure of travel, pedestrians appear to be more at risk than cyclists. This is not easy to understand because cyclists are much more often mixed with motorized traffic than pedestrians are and travel at higher speed. The risk for cyclists compared to pedestrians is to some extent reduced because of helmet wearing, but in France only 14.5% of cyclists wore a helmet in 2005 (Richard et al. 2013). This apparent higher risk could also be due to under-estimation of the distance travelled on foot: when a trip is made with different modes, and it is rather typical to walk to reach a bus stop or to reach one own car, the heaviest mode of transport is retained in the survey.

On the basis of distance travelled, male fatality rates were also higher than those for females, by a factor of between 2 and 3. With regard to age, for all road user types considered together, the 17-20 and 21-29 age groups had higher fatality rates than the 30-39 age group and this pattern is very similar to that observed for car occupants: the fatality risk for the 17-20 age group was 7 times higher than for the 30-39 age group (7.4 times higher for males and 6.4 times higher for females). The 21-29 age group had 3 times the risk of the 30-39 age group (2.8 for males and 2.6 for females). Overall, the risk for the 70+ age group was about 4 times higher than for the 30-39 age group (3.1 times higher for males and 11.3 for females). For male pedestrians, the risk for the 70+ age group was higher than the 30-39 age group by a factor of about four. For car occupants, males aged 70 + had 4 times the risk of males aged 30-39, while females aged 70 + had about 9 times the risk of females aged 30-39.

3.3.3. Fatality rates per million hours spent travelling

Table 3. Annual fatality rates per million hours spent travelling, by road user types, according to sex and age, France, 2007-2008.

Characteristics		Pedestrians		Cyclists		MTW users		Car occupants		Total	
		Rate*	95% CI†	Rate	95% CI	Rate	95% CI	Rate	95% CI	Rate	95% CI
Sex	Age groups	-	-	-	-	-	-	-	-	-	-
Male	6-16	0.05	0.03-0.09	0.12	0.06-0.22	3.22	2.37-4.28	0.06	0.04-0.08	0.09	0.07-0.11
	17-20	0.23	0.13–0.38	*0.16*	*0.05-0.38*	2.28	1.89-2.73	1.02	0.89-1.16	0.80	0.72-0.89
	21-29	0.18	0.12-0.27	*0.27*	*0.12-0.51*	6.79	6.03-7.63	0.39	0.36-0.43	0.55	0.51-0.60
	30-39	0.16	0.10-0.23	*0.19*	*0.09-0.37*	4.20	3.63-4.83	0.14	0.12-0.16	0.25	0.22-0.27
	40-49	0.23	0.15-0.33	*0.25*	*0.10-0.51*	3.32	2.83-3.88	0.13	0.11-0.16	0.24	0.22-0.27
	50-59	0.16	0.11-0.23	0.25	0.13-0.44	4.07	3.20-5.10	0.14	0.11-0.16	0.19	0.17-0.22
	60-69	0.14	0.09-0.20	0.36	0.21-0.56	2.53	1.41-4.17	0.12	0.10-0.15	0.15	0.13-0.17
	>=70	0.52	0.42-0.63	1.03	0.68-1.51	3.20	1.60-5.73	0.47	0.40-0.53	0.51	0.45-0.56
	Total	0.20	0.18-0.22	0.28	0.22-0.34	3.92	3.67-4.19	0.21	0.20-0.23	0.29	0.28-0.30
Female	6-16	0.05	0.03-0.08	*0.10*	*0.02-0.30*	*0.60*	*0.22-1.31*	0.04	0.03-0.06	0.04	0.03-0.06
	17-20	*0.06*	*0.02-0.13*	*0.19*	*0.01-0.82*	6.35	3.23-11.23	0.28	0.22-0.35	0.18	0.15-0.23
	21-29	*0.03*	*0.01-0.06*	*0.21*	*0.06-0.51*	1.66	0.97-2.64	0.11	0.09-0.14	0.10	0.09-0.12
	30-39	*0.04*	*0.02-0.07*	*0.06*	*0.01-0.18*	1.82	0.87-3.35	0.04	0.03-0.06	0.05	0.04-0.06
	40-49	0.05	0.03-0.10	*0.03*	*0.001-0.15*	1.96	1.09-3.23	0.05	0.04-0.07	0.06	0.05-0.07
	50-59	0.08	0.05-0.12	*0.24*	*0.08-0.57*	*3.59*	*1.17-8.38*	0.06	0.05-0.08	0.07	0.05-0.08
	60-69	0.09	0.06-0.14	*0.26*	*0.06-0.71*	*0*	*0-1.29*	0.08	0.06-0.10	0.08	0.07-0.10
	>=70	0.41	0.34-0.49	*0.58*	*0.20-1.30*	-	-	0.35	0.29-0.41	0.35	0.31-0.39
	Total	0.11	0.09-0.13	0.14	0.09-0.21	1.65	1.27-2.10	0.09	0.08-0.10	0.10	0.09-0.10
Total	-	0.15	0.14-0.16	0.23	0.19-0.27	3.59	3.37-3.82	0.15	0.14-0.16	0.20	0.19-0.20

The overall fatality rate was 0.20 per million hours spent travelling (95% CI: 0.19-0.20). The fatality rates according to road user type, gender and age are set out in Table 3.

If we compare the different types of road user on the basis of time spent travelling, the fatality risk compared to that of car occupants was 24 times higher for MTW users, 1.5 times higher for cyclists, and similar for pedestrians. In addition, whatever the type of road user, the risk for men was between 2 and 3 times higher than for women, with the largest gender differences occurring for MTW users and car occupants.

With regard to age differences, the 17-20 age group had a high fatality risk, about 3.2 times higher than for the 30-39 age group (3.2 for males, 3.6 for females). Fatality risk for the 21-29 age group was about 2 times higher than the 30-39 age group. The 70+ age group also had a high fatality rate, but this also varied with gender: the fatality risk for males aged 70 + was 2 times higher than for males aged 30-39, while for females aged 70 + it was 7 times higher than for females aged 30-39. This pattern was particularly apparent among car occupants and pedestrians (fatality rates according to age group for cyclists and MTW users are often based on very small frequencies).

4. Discussion

This study shows that, whatever unit of exposure is considered, MTW users have much higher fatality rates than other types of road user. This group is between 20 and 32 times more likely to be killed than car occupants. Our results are consistent with the study by Lin and Kraus (2009), who estimate that, per vehicle mile travelled, the risk of death in a crash for MTW riders is 34 times higher than for other motor vehicle drivers. In the United States, Beck et al. (2007) also report a 58-fold higher fatality risk per trip for MTW users than other motor vehicle drivers.

The difference between MTW users and car occupants is smaller in France than in the USA, probably because helmet wearing is mandatory for MTW users in France. However, the difference in France (20-30 times higher risk for MTW users) is still very large. This much higher risk of fatal crashes for MTW users can largely be explained by the intrinsic combination of a lack of the protective shield that exists in cars, and speed (even when they do not break the speed limit), as kinetic energy is proportional to mass times the square of the speed. There are a number of prevention measures that could decrease the fatality risk, but not by very much. Hence, the public health question that arises is should we not discourage the use of MTWs, or at least of motorcycles, as the latter’s speed and hence the vulnerability of their users is higher than that of mopeds? However, very few studies have compared the two types of MTW taking account of travel levels, and they seem to be in disagreement: Blackman and Haworth (2013), White et al. (2013).

Previous studies have also shown that fatality and injury rates are high for pedestrians and cyclists, for the three measures of user travel: Pucher and Dijkstra (2003), Pucher and Buehler (2008), Tin Tin et al. (2010). These groups are vulnerable because they do not benefit from protection either (apart from a helmet, in the case of a small proportion of cyclists). Pucher and Buehler (2008) report a higher fatality risk for cyclists than motorists in the United States. Also, some studies report a high fatality risk for cyclists with low use: in the USA, for example, where the fatality rate of cyclist is high at 58 fatalities per billion kilometers travelled, Pucher and Buehler (2008), cycling only accounts for 1% of trips, Beck et al. (2007). On the contrary, the fatality rate of cyclists is low in Northern Europe countries, Pucher and Buehler (2010) where the use of the bicycle as a means of transport is common. This is known as the “safety in numbers” effect, and applies to both cyclists and pedestrians: the more cyclists there are, the more they are expected, and the more they are seen, so their risk decreases, Jacobsen (2003).

Males have a higher risk of being killed for all modes of transport. This is a frequent finding and can be explained by behaviors − in particular, men take more risks: Bina et al. (2006), Lin and Kraus (2009). Fatality rates are linked to age: there is a peak in the 17-20 and 21-29 age groups and an increase over 70 years of age. This concurs with other studies, for example Beck et al. (2007). The peak in teenagers and young adults can be explained by risk-taking behaviors in this age group, which apply to their behavior in general not only when driving (Bina et al. 2006). The increased fatality rate in people aged 70 years and over is probably due to their physical vulnerability. Our findings for exposure-based fatality rates for the different sexes and age groups, are similar to those for population-based fatality rates (i.e. we identified the same population groups as being most at risk).

4.1. Limitations of the study

This study has some limitations. The survey provided us with overall exposure for each trip, assigned to the dominant mode, according to the hierarchy adopted in the survey design, SOeS (2010). For example, going to the cinema by car, should ideally be split into a walking trip to where the car was parked, followed by a car trip, then another walking trip from the car park to the cinema itself. In the national survey, this was considered as one trip and was assigned to the dominant mode, the car in this case, according to the hierarchy based on the weighting adopted in the survey design. Thus, both the time spent and the number of kilometers travelled were only known for the entire trip and not for each of its component modes. This method leads to an underestimation of exposure for the lightest modes, and hence an overestimation of the risk of fatal road crashes for the lightest modes, particularly walking which is the most commonly used mode for reaching a motorized mode (public transport, but also a car).

One could claim that only 0.7% of all the trips that were described used two or more modes. But this is an under-estimation as road public transport represents 3.2% of all trips, and individuals usually walk to get to a bus stop. This under-estimation of pedestrian exposure means that the fatality risk of pedestrians has been somewhat over-estimated.

The confidence intervals of the fatality rates were computed taking account of random variation in the numerator (fatality counts) and assuming that the denominator (the amount of travel) was constant. This assumption that is usually made as it is difficult to take account of the random variation of a denominator, particularly in the case of a two-stage survey design. The result of this is that our confidence intervals were rather too narrow.

Lastly, the study excludes foreign tourists as well as people in transit through metropolitan France, as the travel survey covered only people living in France.

4.2. Strengths of the study

This is the first time that the risk of being killed on French roads has been assessed on the basis of individuals' travel levels, using three different measures, and across all road users, in particular pedestrians and cyclists. This was achieved through the combined use of a travel survey and police fatality data. The national travel survey is extremely valuable and road traffic fatalities are well-defined and well-reported by the police. In France, the risk of being injured in a road crash has also been estimated, but on a regional basis, using a road trauma registry and a regional travel survey: Licaj et al. (2011, Blaizot et al. (2013).

Using road users' travel levels is necessary in order to compare the risk associated with different modes of transport; users' travel levels were assessed on the basis of their number of trips, distance travelled, and time spent travelling, for each mode of transport. These different measures provide different results when comparing different types of road users, especially when we compare pedestrians or cyclists with car occupants. For a given distance, for instance 10 km, the fatality risk is respectively 12 and 6 times higher for pedestrians and cyclists than for car occupants. However pedestrians take much longer to cover this distance than car occupants. It could be argued that it is partly for this reason that pedestrians are much more at risk. If we compare these road users over 1 hour, pedestrians' fatality risk is similar to that of car occupants and that of cyclists is 1.5 time higher. It is also strange to find the same level of risk for pedestrians and car occupants, because for a crash that involves a given kinetic energy, pedestrians will sustain more serious injuries than car occupants, merely because they have no protection. But the fact that risk is similar for pedestrians is probably because pedestrians spend more time on footpaths than crossing roads, and when they are on footpaths that are separated from traffic by parked cars they are at little risk of being hit by a motorized vehicle. It would be interesting to evaluate the risk for pedestrians in various situations: on pedestrian crossings, on pavements not separated from traffic (a difference in height between the road and the pavement is not a proper separation), and on pavements separated from traffic (by parked cars in towns, or by guard rails in some rural areas). Such studies have been performed for cyclists and have shown that crash risk is lower on separated cycling paths, Reynolds et al. (2009).

4.3. Public health implications

Promoting walking and cycling is part of a wider national plan launched in 2001 by the French government (World Health Organization 2004a). It advises a well-balanced diet accompanied by regular physical activity, especially for children in order to prevent obesity and chronic diseases: Bassett et al. (2008), Gordon-Larsen et al. (2009) which are the principal causes of death in the world.

Active transport modes are also encouraged on the grounds of sustainable development, in order to reduce air pollution. Lastly, the economic crisis may lead to people choosing means of transport that cost less than cars, such as MTWs, public transport, and bicycles.

Although some results seem to differ according to the choice of exposure, it is shown in this study and others that cyclists and pedestrians are at a higher risk of death than car occupants. If walking and cycling are to increase, they should therefore be accompanied by measures to reduce the associated road risk. Such measures should target infrastructure, vehicles and users.

Traffic-calming and speed reduction policies for motorized users improve pedestrian and cyclist safety (Retting et al. (2003), Constant and Lagarde (2010). Dedicated infrastructure for cyclists that separates them from motorized traffic also reduces the crash risk for cyclists, Reynolds et al. (2009). Separating footpaths from traffic by parked cars in towns could help to reduce pedestrian risk, Zegeer and Bushell (2012).

With regard to vehicles, there are two possible directions: one targets motorized vehicles and sets out to make them less aggressive for pedestrians and cyclists, Wegman et al. (2012), and the other targets bicycles and sets out to ensure they have better lights and reflective material.

Some behaviors should be encouraged, for example the use of a helmet and conspicuity clothing by cyclists, Constant and Lagarde (2010). In France, it is not mandatory for cyclists to wear helmets and in 2010, only 22% of cyclists did so, which nevertheless represents an improvement on the figure of 14.5% in 2005, Richard et al. (2013). With regard to conspicuity, much research has been conducted on MTW users, Lin and Kraus (2009), but not as much on cyclists and even less on pedestrians although these two groups could probably benefit from them, Zegeer and Bushell (2012). Lastly, prevention campaigns should raise the awareness of all road users about the higher risk of vulnerable road users, Constant and Lagarde (2010).

5. Conclusion

A better understanding of the road traffic fatality rates for all types of road user can lead public authorities to encourage research into safety improvements as well as implement safety policies and prevention programs that target the most vulnerable road users, such as MTW users, cyclists and pedestrians. These are especially needed as active transport modes, such as walking and cycling, are encouraged.

In the future we can also expect that more countries will make tables of exposure-based fatality rates available to facilitate international comparisons, both overall and by mode of transport. In particular, this would permit comparisons between countries that have different travel practices. It could also help identify countries that have successful safety programs.

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