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Abstract
Context: Authorizing powered two-wheeler drivers to drive in lanes reserved to buses is a measure that is sometimes mentioned to improve mobility conditions for these users. But what effect would this measure have on the safety of these users and on the safety of the other users with whom they share the traffic space?
Objective: The objective of this study is to contribute elements to help answer this question. More precisely, the objective is to estimate the risk of having an accident per kilometer driven by powered two-wheeler drivers who drive in bus lanes and to compare this risk with that of powered two-wheeler drivers who drive in general traffic lanes.
Method: Using the bodily injury accidents recorded by the police over two years on thirteen roads in the city of Marseille and a campaign of periodical observations of powered two-wheeler traffic, we estimated the risk per kilometer driven by powered two-wheeler drivers who drive in bus lanes and compared it with that of drivers who do not drive in them.
Results: The results show that the risk for powered two-wheeler drivers who drive in bus lanes of being involved in a bodily injury accident is significantly higher than the risk run by drivers who drive in general traffic lanes. For the thirteen roads studied, it is on average 3,25 times higher (95% CI: 2,03; 5,21).
Conclusion: In the current situation, powered two-wheeler drivers who drive in bus lanes are less safe than those who drive in general traffic lanes. The analysis of police reports suggests that part of this increased risk comes from collisions between automobile drivers turning right and powered two-wheelers driving in the bus lane who continue straight ahead.

1. Introduction

As in many European countries, the use of powered two-wheelers has been on the rise in France. The number of kilometers driven annually by powered two-wheelers in France rose from 8.8 billion kilometers in 2001 to 11.5 billion in 2012 (Filou, 2002, 2003; SOES, 2013). This increase is mainly due to the increase in the fleet of motorcycles on the road. The results of the last national inquiry on travel and transports suggest that the use of powered two-wheelers has increased the most in large urban areas with traffic congestion, where the space allocated to automobiles has decreased the most[1] (collective work, 2010). The results of studies carried out in more limited areas confirm this. Maestracci *et al.* (2012), for example, report that, in the centre of Paris, powered two-wheeler traffic increased by 64% between 1997 and 2009. In Marseille, the number of daily trips with a powered two-wheeler increased by 80% over the same period, according to Marseille's Urbanism Agency (2011). In the centre of these two metropolises, powered two-wheelers has accounted for nearly 17% of all traffic in recent years (Maestracci *et al.*, 2012; Michel et al. 2013). Indeed, these vehicles are not without advantages, including for the community. They contribute to reducing traffic congestion (Yperman, 2011) and they take up less space, both in traffic and when parked (Albalate and Fernandez-Villandangos, 2010). They can contribute to energy savings, at least for the least powerful among them (collective work, 2007). They cost less to use than cars. Moreover, they give their users better control over their travel time, making these vehicles more in step with the needs of contemporary societies which increasingly demand responsiveness and flexibility.
One measure that is sometimes mentioned to facilitate traffic in urban areas is to allow vehicles to drive in bus lanes (see Kopp, 2011, for example). Yet what effect would this measure have on the safety of their occupants and on the other users with whom they cohabit in the public space? Knowledge is lacking in this area, even though several major European municipalities such as Barcelona, London, Madrid and Stockholm allow powered two-

[1] Space that has in most cases been reduced to make room for traffic space reserved to public transportation, such as bus lanes.

wheeler drivers to use all or part of their network of bus lanes. A few assessment studies have been carried out, notably in the United Kingdom, where several municipalities have decided to let motorcycles to use bus lanes (see Balcombe, 1996; Transport for London, 2004, 2008; York et al., 2005; York, et al., 2008 ; York et al., 2010 ; York et al., 2011). But no clear trend has been observed for most of them in terms of the effects that this type of measure has on accident risks. This is for a large part due to the small number of sites covered by the analyses and the short periods of time taken into account before and after the decision was made. The only assessment study on the subject that is relatively solid is the study carried out by York et al. (2010), who studied the effects of the decision taken by the mayor of London in January 2009 allowing powered two-wheelers to use bus lanes at 28 sites equipped with bus lanes and at 28 control sites that are not equipped with bus lanes. Ten months after this authorization, the results indicate that the number of crashes involving motorcyclists per million motorcyclists on the road had significantly increased at the test sites compared with the control sites. The number of crashes involving motorcycles more than doubled for the test sites compared with the control sites. Cyclists' crash risk also increased significantly. The risk to pedestrians on the other hand did not change significantly.
The study reported on in this paper aims to help improve our understanding in this field. More precisely, the objective is to estimate the risk of being involved in a bodily injury accident per kilometer driven by powered two-wheeler drivers using bus lanes and to compare this risk to that of powered two-wheeler drivers using general traffic lanes.

2. Material and method

The study carried out concerns thirteen roads located in the center of Marseille. With more than 1.5 million residents, Marseille is the second largest urban area in France after Paris in terms of the number of residents. Located in the south of the country on the Mediterranean coast, it has a long history of high powered two-wheeler use. The city has a network of bus lanes covering some thirty kilometers. As is the case in the rest of France, powered two-wheelers are not allowed to use these lanes. Vehicles other than buses, however, are authorized to use them. These notably include taxis, ambulances and, at certain sites, bicycles. The thirteen sites covered by the study are mostly main roads in the city's road network. Each site is equipped with a bus lane located to the right of the traffic lanes. The length of the sites studied ranges from 500 meters to 1,800 meters. The set of the sites studied represent 13,450 meters.

For each of the thirteen roads, we estimated the risk of being involved in a bodily injury accident in 2007 and 2008 for powered two-wheeler drivers who used bus lanes. To do this, we compared the number of powered two-wheeler drivers involved in bodily injury accidents as they were driving in a bus lane to the number of powered two-wheelers x kilometers exposed to this risk (number of powered two-wheelers having driven in the bus lane in 2007 and 2008 multiplied by the length of the site). The same approach was adopted for drivers of powered two-wheelers driving on the same sites in the general traffic lanes. We then expressed the relationship between these rates in the form of a relative risk to obtain on each site an estimation of the increased risk or reduced risk for powered two-wheeler drivers of having an accident while driving in a bus lane and of powered two-wheeler drivers driving in general traffic lanes. Lastly, an overall relative risk and its 95% confidence interval were calculated for all the sites by undertaking a meta-analysis. For this, we based our work on the method described in Elvik and Vaa (2004). We should point out that the investigations covered weekdays (Mondays to Saturdays, excluding public holidays) during daytime hours (from 6:00 am to 10:00 pm) during the years 2007 and 2008.

To determine the number of powered two-wheeler drivers involved in bodily injury accidents at each site while driving in the bus lane or in the general traffic lanes, we first used the bodily injury accident file drawn up by the police. This file enabled us to determine the number of accidents involving a powered two-wheeler that occurred at each of the 13 sites during the study period (years 2007 and 2008, weekdays and daytime hours). We then undertook an in-depth analysis of the corresponding police reports to determine, for each case, whether the powered two-wheeler was driving, or not, in the bus lane at the time of the accident.

The number of powered two-wheeler drivers exposed to risk was estimated using the hourly traffic data gathered during the years 2007 and 2008 by the inductive loop traffic counters set up at each of the thirteen sites. We then sought to estimate the share of this traffic represented by powered two-wheelers driving in the bus lanes and outside bus lanes. For this, we undertook a campaign of periodical observations of powered two-wheeler traffic during the year 2011. We put forward the assumption that the share of total traffic represented by powered two-wheelers and the proportion of powered two-wheelers driving inside and outside bus lanes did not change between 2007, 2008 and 2011. This assumption appears acceptable to us[2].

Fifty-two hours of observations were carried out at the thirteen sites with random distribution throughout the entire year of 2011. Each sequence of observations lasted one hour, covered one site and was carried out by a team of two investigators positioned on the sidewalk. One investigator recorded the total road traffic. The other recorded the powered two-wheeler traffic, distinguishing between mopeds, light motorcycles, heavy motorcycles and unidentified, as well as their position on the carriageway (in the bus lane or outside the bus lane). We should point out that the investigators, who stayed next to each other at all times, did not stay at a fixed point but constantly moved around at the rate of a slow walk all along the site. This strategy was adopted due to the great deal of volatility in the use of bus lanes by powered two-wheelers. For example, if a taxi stops in a bus lane to drop off a passenger or a deliveryman to deliver a package, use of the bus lane stops at this spot for several minutes. On the other hand, if traffic is stopped in the general traffic lanes, for example if an upcoming traffic light turns red, most powered two-wheeler drivers move into the bus lane to filter forward ahead of the stopped vehicles and maximum use is then made of the bus lane at this spot. The observation point thus strongly conditions the results for bus lane use by powered two-wheelers. That is why we chose to make these observations by moving from place to place in order to take bus lane use into account for the entire site. Another possibility would have been to use video recordings made by the video surveillance cameras that exist on the study sites and by cameras that we could have installed at these same sites. But this would have entailed having a large number of cameras to film the use made of bus lanes by powered two-wheelers in all the sections studied and not just at a few points where video surveillance cameras are installed, for example. Furthermore, the use of video cameras placed at height certainly would not have allowed us to distinguish between the different categories of powered two-wheelers.

3. Results

According to data released by the police, 164 powered two-wheeler drivers were involved in bodily injury accidents in 2007 and 2008 at the thirteen sites studied (see table 1). Among these drivers, 64, or 39 %, had the accident while they were driving in a bus lane and 100, or 61 %, had it as they were driving in general traffic lanes. Among the different categories of

[2] We feel that this hypothesis is acceptable insofar as, according to the Commissariat Général au Développement Durable (CGDD, 2012), the average annual growth rate for powered two-wheelers in road traffic for the 2007-2011 period was 2,1 % (see CGDD, 2012, p.61).

powered two-wheelers, mopeds users proportionally had the most accidents in bus lanes. 43 % of them were driving in a bus lane when the accident occurred. Then come the drivers of light motorcycles (41 %) and heavy motorcycles (33 %).

Table 1. Number of drivers involved in a bodily injury accident at the 13 sites during the selected periods in 2007-2008, according to whether they were driving in a bus lane or in general traffic lanes

	Number of drivers involved in a bodily injury accident – 13 sites – Weekdays – 6:00 am to 10:00 pm	Of which	
		Driving in the bus lane at the time of the accident	Driving in general traffic lanes at the time of the accident
Powered two-wheeler drivers	164*	64 (39%)	100 (61%)
Moped drivers	56	24 (43%)	32 (57%)
Light motorcycle drivers	58	24 (41%)	34 (59%)
Heavy motorcycle drivers	49	16 (33%)	33 (67%)

* Among the 164 powered two-wheelers involved in a bodily injury accident, we were unable to identify the vehicle's administrative category (between moped, light motorcycle and heavy motorcycle) in one case.

Concerning exposure to risk, the periodical observations of powered two-wheeler traffic carried out throughout the year 2011 showed that, on average, powered two-wheelers accounted for 16,3 % of the traffic at the 13 sites studied. Among the 7,032 powered two-wheelers observed, light motorcycles were the most numerous. They accounted for 48 % of the powered two-wheeler traffic. Then came heavy motorcycles and mopeds, which accounted for 32 % and 20 % of the traffic, respectively. Concerning the use of bus lanes, 22,8 % of powered two-wheeler drivers were driving in bus lanes when they were observed. This proportion is relatively similar for the different categories of powered two-wheelers (*cf*. table 2).

Table 2. Estimation of the number of drivers exposed to bodily injury accident risk at the 13 sites during the periods selected in 2007-2008, according to whether they were driving in a bus lane or in general traffic lanes

	Number of drivers exposed to bodily injury accident – 13 sites – Weekdays – 6:00 am to 10:00 pm	Of which	
		Driving in the bus lane	Driving in the general traffic lanes
Powered two-wheeler drivers	16 388 642*	3 738 282 (22,8 %)	12 650 360 (77,2 %)
Moped drivers	3 296 353	806 481 (24,5 %)	2 489 872 (75,5 %)
Light motorcycle drivers	7 577 891	1 704 870 (22,5 %)	5 873 021 (77,5 %)
Heavy motorcycle drivers	5 027 157	1 107 513 (22 %)	3 919 644 (78 %)

*Among the 16.388.642 powered two-wheelers exposed to bodily injury accident, the vehicle's administrative category was unidentified for 487.241 of them.

Table 3 presents the number of powered two-wheeler drivers involved in a bodily injury accident for each site according to whether or not they were driving in a bus lane, risk exposure being expressed in vehicles x kilometers, estimation of relative risk and the 95% confidence interval.

Table 3. Number of powered two-wheeler drivers involved in a bodily injury accident at each site during the periods selected in 2007-2008, according to whether or not they were driving in the bus lane, number of kilometers driven by powered two-wheeler drivers in bus lanes and in general traffic lanes, estimation of the relative risk and the 95% confidence interval.

Sites	Number of PTW drivers involved in accidents in the bus lane Weekdays 6:00 am to 10:00 pm	Number of PTW drivers involved in accidents in general traffic lanes Weekdays 6:00 am to 10:00 pm	PTW x km driven in the bus lane Weekdays 6:00 am to 10:00 pm	PTW x km driven in general traffic lanes Weekdays 6:00 am to 10:00 pm	RR	95 % CI	
Schlœsing Bvld	3	4	586 741	874 181	1,12	0,25	4,99
Baille Bvld	9	17	283 875	1 127 511	2,10	0,94	4,72
Duparc Bvld	7	8	360 239	719 006	1,75	0,63	4,82
Michelet Bvld (towards Mazargues)	6	6	433 679	3 770 634	8,69	2,80	26,96
Michelet Bvld (towards Prado)	4	11	218 006	2 017 770	3,37	1,07	10,57
Corderie Bvld (towards Corse)	5	2	72 146	288 213	9,99	1,94	51,48
Corderie Bvld (towards Place)	2	5	53 022	270 044	2,04	0,40	10,50
Mazargues Ave	4	5	155 123	283 447	1,46	0,39	5,44
Rome St	8	3	611 208	337 821	1,47	0,39	5,56
Prado 1 Bvld (towards Castellane)	9	9	164 107	2 065 734	12,59	5,00	31,71
Prado 1 Bvld (towards Michelet)	6	15	162 963	1 994 370	4,90	1,90	12,62
Prado 2 Bvld (towards David)	0,5	9,5	36 770	716 013	1,02	0,06	17,61
Prado 2 Bvld (towards Michelet)	1	6	38 723	1 038 989	4,47	0,54	37,15

NB: The values presented in the fourth and fifth columns correspond to the product of the number of powered two-wheelers having driven on each site during the periods studied in the bus lane (or in general traffic lanes) multiplied by the total length of the bus lane at the site (or by the length of the general traffic lanes on the same site).

The meta-analysis of the results obtained individually at each site gives an overall relative rate with heterogeneity of 3,38 (95 % CI [2,42; 4,71]) and an overall adjusted relative rate of heterogeneity[3] of 3,25, with a 95% confidence interval of [2,03; 5,21]. The same approach

[3] The test of heterogeneity carried out was that described in DerSimonian and Laird (1986). The results of the test did not make it possible to conclude that there was no heterogeneity in the results for the different sites as Q=22 and p=0,037. The method used for estimating the average relative risk in the presence heterogeneity was that laid down in DerSimonian and Laird (1986).

was adopted for drivers of the different powered two-wheeler categories. It appears that mopeds that drive in bus lanes run a risk of being involved in a bodily injury accident that is 4,51 times higher (95% CI [2,56; 7,96]) than for mopeds that drive in general traffic lanes. For light motorcycle drivers, this increased risk amounts to 4,01 (95% CI [2,32; 6,94]. For heavy motorcycle drivers, it is 3,07 with a 95% confidence interval of [1,64; 5,75]. But no significant difference, in the statistical sense, is observed between the different categories of two-wheelers. Additional investigations analyzing more sites and/or years would be needed to draw conclusions on this point.

4.Discussion

The results presented above show that powered two-wheeler drivers who drive in bus lanes in Marseille run an accident risk that is, on average, 3,25 times higher that that of drivers who use the general traffic lanes. How can this difference in risk be explained? First of all, it may be that powered two-wheeler drivers who use bus lanes do not have the same risk factors as those who do not use them, for example in terms of age, experience or driving style. In another study (Clabaux et al., 2013), however, we observed that four-wheeled vehicle drivers who take bus lanes, notably taxi and bus drivers, also appear to run a risk of being involved in bodily injury accidents that is significantly higher than those who drive (during the same times and on the same sites) in the general traffic lanes. This increased risk is 2,50 (95% CI [1,71; 3,64] for four-wheeled vehicle drivers, all types of four-wheeled vehicles taken as a whole, and 9,45 for taxi and bus drivers, with a 95% confidence interval of [1,30; 68,76]. This last result is still fragile given the small number of accidents involving these vehicles that were taken into account in the analyses. And yet, *a priori*, there is no reason to think that taxi and bus drivers who drive in bus lanes differ from those who do not, since these vehicles are allowed to drive in these lanes. Elements other than those concerning drivers' characteristics are no doubt at work in this difference in the risk. It is possible, for example, that powered two-wheeler drivers who use bus lanes drive at higher speeds than those who do not, notably during rush hours. Moreover, this is what the results of York *et al*. (2010) on London suggest; showing a significant increase in speeds driven after the decision to allow motorcycles to drive in bus lanes was taken. It may also be that the position of bus lanes to the right of the traffic lanes leads to more complexity in the interactions between the users of the general traffic lanes making a right-hand turn and bus lane users going straight ahead. Once again, this is suggested by the results obtained in London by York *et al*. (2010). The authors demonstrate that a large part of the increase in the number of crashes involving motorcycles at the sites where they have been authorized to drive in bus lanes comes from an increase in accidents between a motorist turning across the path of a motorcyclist driving in the same direction in the bus lane. Of the thirteen sites that we studied, an in-depth analysis of police reports shows that, in 2007 and 2008, this type of accident accounted for nearly 51 % (32 cases out of the 63 cases[4]) of all accidents involving powered two-wheelers driving in a bus lane. Moreover, this crash type is nearly six times more frequent on sites with bus lanes than on sites without bus lanes (Clabaux et al., 2011).

The work presented here needs to be consolidated, notably by taking into account a larger number and a wider variety of sites, for example sites equipped with bus lanes running in the direction opposite the general traffic or sites located further toward the periphery of the city. Moreover, it is based on a relatively small number of observations of risk exposure. Furthermore, the accident risk per kilometer driven that we obtained for powered two-wheelers driving in bus lanes and for those driving in general traffic lanes was an

[4] 63 cases involving powered two-wheelers driving in a bus lane were recorded in 2007 and 2008 on the thirteen sites studies. Among these 63 cases, one case involved two powered two-wheelers.

approximation insofar as we did not precisely measure the kilometers driven by powered two-wheelers in the bus lanes and in the general traffic lanes. Nonetheless, these initial results suggest that, in the current situation, powered two-wheeler users who drive in bus lanes are less safe than those who drive in general traffic lanes. Any measures aimed at reducing their use of bus lanes would probably help to improve their safety.

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