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Global bikeshare: What the data tells us about safety

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ABSTRACT
Bikeshare has emerged as a rapidly growing mode of transport in over 700 cities globally, up from just a handful in the 1990s. The global bikeshare fleet is now well over 400,000 bikes, most of which are integrated with technology capable of tracking their usage. Some analysts had forecast a rise in the number of bike crashes after the introduction of bikeshare. By combining ridership data with crash data, this paper documents the safety record of bikeshare programs in selected North American, Australian and European cities. The results suggest bikeshare may be safer, on a per kilometre basis, than private bike riding, for both fatal and non-fatal crashes. According to the results of this analysis, a bikeshare user is half as likely to be fatally injured, per kilometre travelled, than a general cyclist, in jurisdictions in which a bikeshare program operates. Indeed the bikeshare fatality rate was found to be comparable to that of the safest countries for cycling, the Netherlands and Denmark. Some explanations for this somewhat surprising finding include the possibility of increased driver awareness and cautiousness around bikeshare users, an upright riding position and slower speed. These results suggest that bikeshare programs may have a positive impact on road safety outcomes. Improved data collection of crashes involving bikeshare riders will assist future efforts to document the safety of bikeshare users.

Keywords: safety, bikeshare, cycling, urban, cities, shared transport.

1 INTRODUCTION

Bikeshare has rapidly emerged as a new transport option in over 700 cities, from less than a dozen little more than a decade ago [1]. Bikeshare began in Amsterdam in the 1960s with the *White Bike* program, however the absence of security mechanisms led to widespread theft and vandalism and the program ended soon after it began [2]. Increasing interest in the benefits associated with urban cycling [3], as well as increasingly available and affordable tracking and payment technology has facilitated a surge in interest in bikeshare [4]. Almost all of the bikeshare programs that have been established in the past decade are known as *3rd generation*, IT based systems that rely on automated payment and tracking technologies [2]. It is these programs that have proved to be the most successful and are enjoying substantial growth in North America, Europe and Asia [4].

The benefits associated with bikeshare include increased physical activity, reduced

congestion, lower transport costs and time savings [5]. A crucial issue attracting attention recently has been the level of safety of those using bikeshare, and particularly whether bikeshare is associated with an increase or decrease in the risk of injury [6, 7]. Prior to the introduction of North America's largest bikeshare program in New York City, a bicycle researcher was quoted in the New York Times predicting *'at least a doubling and possibly even a tripling in injuries and fatalities among cyclists and pedestrians during the first year'* [8]. This serves to highlight the safety concerns associated with bikeshare have been prominent at times, particularly around the launch of new programs.

This paper sets out to compare crash risk from different bikeshare programs through the use of ridership and crash data for 2013. Where possible, data on general bike crash rates is also included, in the interest of offering a comparison between bikeshare and private bike riding crash risk. Finally, it should be noted that this paper focuses on individual crash rates, rather than effects on overall road safety due to the introduction of a bikeshare program.

2 BRIEF LITERATURE REVIEW

The bikeshare literature, whilst all relatively recent, tackles a wide range of issues, from technological advancements [9], approaches to tracking bicycle movements and rebalancing [10-12], research on bikeshare barriers and facilitators [13], impacts on societal attitudes to cycling [14] and quantification of impacts [13, 15-18]. The focus of this brief review of the literature is restricted to published research relating to bikeshare safety.

2.1 Crash and injury statistics

Very little published research examining bikeshare safety exists. Shaheen et al.'s [19] North American, multi-system study included questions to operators regarding safety data. The process found that operators employ different data collection procedures but crash rates are generally low. Of the operators involved in the study, 14 kept records on accidents, with an average of 1.36 crashes in 2011 (per system). Different methods were used by operators to express the crash rate. One operator reported one accident for every 50,000 – 60,000 rides. Another said they experienced one accident per 100,000 miles of riding. It is not clear what level of injury severity was sustained in these accidents or the precise method used to determine crash rates. The report notes that for systems with more than 1,000 bicycles, there is an average of 4.3 accidents per year.

A study by Graves et al. [20] has attracted significant interest from the media and other researchers recently [21, 22]. Graves et al. [20] assessed hospital injury data from a range of different North American cities, divided into two categories; bikeshare cities and non-bikes share cities. Hospital admissions data in the 24 months before the implementation of the bikeshare program was compared with 12 months of data post bikeshare implementation. Though not included in the article by Graves et al., Figure 1 has used the data published in the article [20] and shows a dramatic reduction in the total number of hospital recorded injuries in the bikeshare cities, post implementation. Importantly, the data contained in Figure 1 includes an adjustment to account for the fact that the pre-implementation data was collected over 24 months, whereas post-implementation data was collected only over 12 months, as noted above.[1] The drop is particularly striking because the amount of bicycle use is likely to have increased due to the introduction of the bikeshare program [23]. This is suggestive of a decrease in the likelihood of injuries per kilometre cycled in cities where bikeshare programs were implemented.

[1] The specific adjustment was to halve pre-implementation figures.

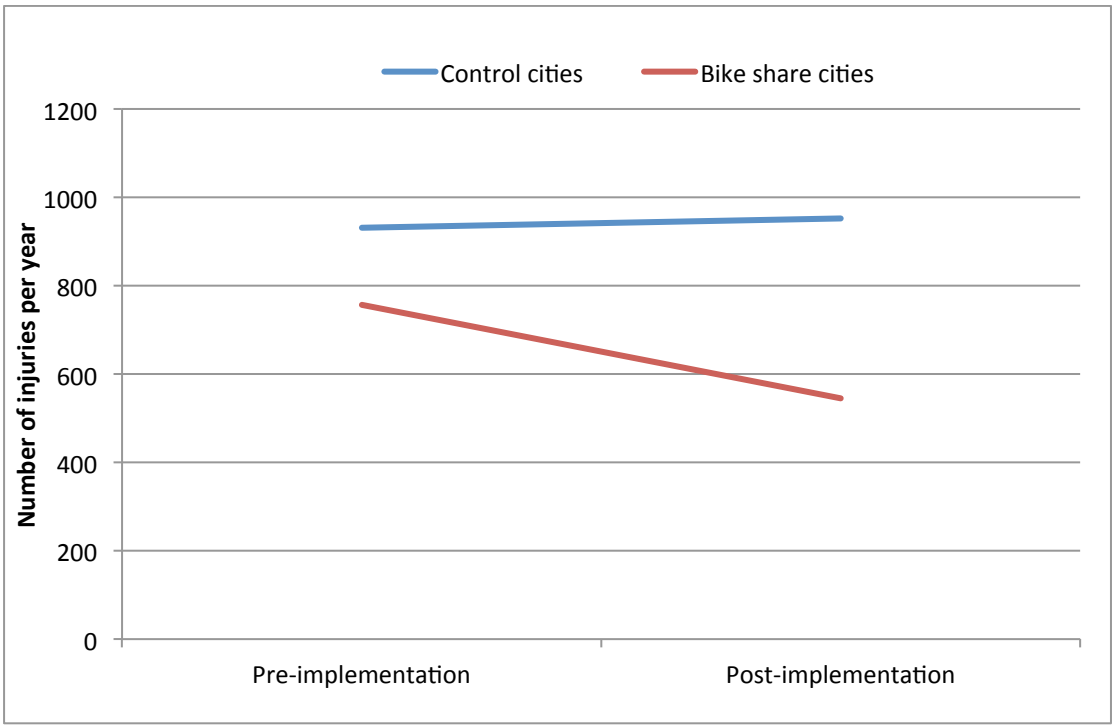

Figure 1. Injuries (all types), bikeshare cities and non-bikeshare cities (control)
Source: [20]

Although the reduction in injuries (both head and non-head injuries) reduced in bikeshare cities, the rather contentious [21] conclusion reached by the researchers was that helmets should be made available by bikeshare operators because the *proportion* of head injuries was found to be higher. The authors' failure to acknowledge the reduction in head injuries in bikeshare cities has attracted criticism from other scholars [22]. The data reported by Graves et al. [20] is significant given that the overall amount of cycling increases after a city introduces a bikeshare program [23] and is therefore somewhat counter intuitive, but is generally supported by the *safety in numbers* effect [24].

2.2 Health impacts of bikeshare

Some studies have examined the safety (crash risk) of bikeshare users, with some offering a comparison between crash risk and health benefits associated with greater amounts of physical activity. Much of this work builds on the analysis conducted by de Hartog et al. [25], who found the health benefits of cycling (non-bikeshare) outweigh the increased risk associated with cycling. A health impact assessment on the Barcelona bikeshare program published in 2011 [26] sought to compare the risks and benefits of using bikeshare compared with car driving. Physical activity, air pollution and road traffic incidents were included in the analysis. The benefits were found to greatly exceed the health risks, although some methodological weaknesses reduced the validity of some of the conclusions [27], particularly in terms of assumptions regarding the transport mode that would have been used if bikeshare was unavailable.

A recent study of the London bikeshare program [28] assessed the health impacts of the scheme in terms of physical activity, crashes and exposure to air pollution. The results of the study suggest that on balance, the program delivers more benefit than harm, although the effects are not uniform for all age groups or gender. Interestingly, the researchers found that more benefit would be gained if users were older, as older people

have less healthy life years to lose. Conversely, when a young person crashes, they have much more healthy life years at risk. It is important to note however that an older person is less likely to fully recover from the same crash that involves a younger person, i.e. older people are more vulnerable [29]. When the researchers applied the general crash risk for all cycling in central London, they found a negative health impact for women, due to the greater fatality rate among female cyclists in London [28].

2.3 Bikeshare speed and helmet use

A higher cycling speed may be related to more severe crashes [30, 31]. A study among bikeshare users in Lyon showed that average speed - in real conditions and for average users - was 13.5 km/h, with lowest speeds recorded on weekends (10km/h) and fastest average speeds (15km/h) on weekday mornings [32]. Studies on private bike operational speeds in other countries tend to vary between 15 and 25 km/h meaning that operational speeds for bikeshare users are low [30, 33].

Helmets and bikeshare has been a contentious issue, with cities having to weigh the benefits of helmets in the evident of a collision [34], with the difficulties of incorporating helmets within a bikeshare program [13], such as losses from theft and hygiene issues. An observational study conducted in Boston and Washington, DC. compared helmet-wearing prevalence between private and public bike riders. The researchers found private bike riders were four times more likely to wear a helmet, after controlling for age and gender [35]. These findings are supported by a London study which found 16% of bikeshare riders wear helmets, compared to 64% for those on private bikes [14]. Evidence from Australia (where helmet use in mandatory) shows some reluctance from potential users in carrying a personal helmet with them [13, 23, 36, 37]. Members of the two Australian bikeshare programs (located in Brisbane and Melbourne) reported using bikeshare less because of mandatory helmet legislation [38].

3 METHODOLOGY

This study examines crash risk for bikeshare programs in Melbourne, London, Chicago, New York City, Minneapolis/St Paul, Washington, D.C., Montreal and Paris. The data collected for this study can broadly be described as consisting of three parts. Firstly, the respective bikeshare operator has provided ridership and system data in the aforementioned cities. This includes the number of trips and trip duration, which allow for estimates for total distance travelled, by applying an assumed travel speed of 10.16km/h. This speed, derived from previous studies [32], includes an adjustment to account for stops made between origin and destination, such as dwell times at intersections. The average number of trips per day per bike is a function of the total number of trips for 2013, the average number of bikes in operation and the number of days that system was open in 2013.

The second component this study uses is the number of crashes reported to the bikeshare operator. It is standard practice for bikeshare users to be required to report crashes to the bikeshare operator and although it is possible (indeed likely) that some incidents fail to be reported, this measure has been used because it is a relatively easily captured data source and provides a comparable data source across different systems. Police and hospital records do not typically differentiate between a private and public bicycle incident and are therefore not able to be used when specifically investigating bikeshare crashes. In the bikeshare operator data used in this study, crash severity has been divided into three classifications, based on established United Kingdom standards [39]. The classifications are *slight, serious* and *fatal.* A *slight* injury is defined as ‘an injury of minor character such as a sprain (including

neck whiplash injury), bruise or cut which are not judged to be severe, or slight shock requiring roadside attention. This definition included injuries not requiring medical treatment' [39, p. 238]. A *serious* injury is defined as one in which *'a person is detained in hospital as an "in-patient", or any of the following injuries whether or not they are detained in hospital: fractures, concussion, internal injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment and injuries causing death 30 or more days after the accident'* [39, p. 238]. A *fatality* is defined as a death occurring within 30 days of the incident.

The bikeshare operators were provided with a description of the categories of severity and asked to identify the number of incidents reported to them in each category, for 2013. The severity classification used by Paris's bikeshare operator is broadly similar, and therefore was generally compatible to the methods employed in this paper. The Washington, D.C. and Montreal operators provided a description of all recorded incidents in 2013 and the authors used their judgement to classify them using the aforementioned severity classification. Incidents reported to the New York City bikeshare operator were classified by the authors using a combination of monthly operating reports prepared by NYC Bikeshare [40] and other publically available data [41]. Combining each of the above two components has allowed this paper to provide crash rates on a per million kilometre basis. To gain a measure of risk, in terms of injury and fatality per unit of distance, travel survey data for the Paris region and Greater London were combined with police recorded crash figures between 2009 and 2011.

4 RESULTS

4.1 System use

Table 1 provides an overview of the bikeshare programs included in this study, detailing key metrics, in terms of size and use. The average number of trips per bike per day is illustrated and this offers an indication of how well a system is used, controlling for system size. It should also be noted that in North America, some systems are not open during the winter months, due to severe weather and for New York City, the program only opened in May of 2013.

The cities in Table 1 are ordered according to the total estimated distance travelled. Paris recorded the largest number of bikes in fleet, trips and distance travelled of the cities shown in Table 1. Paris also has the highest intensity of use, closely followed by New York City, with each bike being used 5.3 and 4.8 times per day, respectively. Other researchers have found that some 28% of all bicycle trips in Paris are covered by shared bikes [42]. The presented annual averages in Table 1 do however hide seasonal variation. During summer for instance, New York City recorded almost 10 trips per bike per day. The total distance covered during 2013 by all cities included in Table 1 was over 181 million kilometres.

Table 1. Selected bikeshare programs, size and usage data, 2013

	Ave. no. bicycles in fleet	Total trips for 2013	Days of operation	Ave. no. trips per day per bike	Est. ave. trip duration (min.)	Est. distance travelled per year (KM)
Paris	18,130	35,021,999	365	5.3	20	118,607,837
London	9,083	8,045,459	365	2.4	17.5	23,841,377
New York City	5,754	6,053,870	219	4.8	17.0	17,427,074
Montreal	4,036	3,792,801	214	4.4	-	9,861,282
Washington, D.C.	2,551	2,616,653	365	2.8	15.8	7,000,768
Chicago	1,765	759,937	187	2.3	21.9	2,818,150
Minneapolis/St Paul	1,306	308,052	214	1.1	17.5	912,860
Melbourne	543	161,135	365	0.8	17.5	600,282

4.2 Crash types

Montreal was the only city included in this study in which the bikeshare operator provided detailed information regarding type of incident/crash and these are provided as proportions in Figure 2. About half of the crashes were crashes with no motor vehicle involved. This is less than the share of non-motor vehicle crashes reported in medical registrations (e.g. from hospitals) but significantly more than in police statistics [34, 43, 44]. Definitive conclusions cannot be drawn because we do not have information on the reporting rate for collisions.

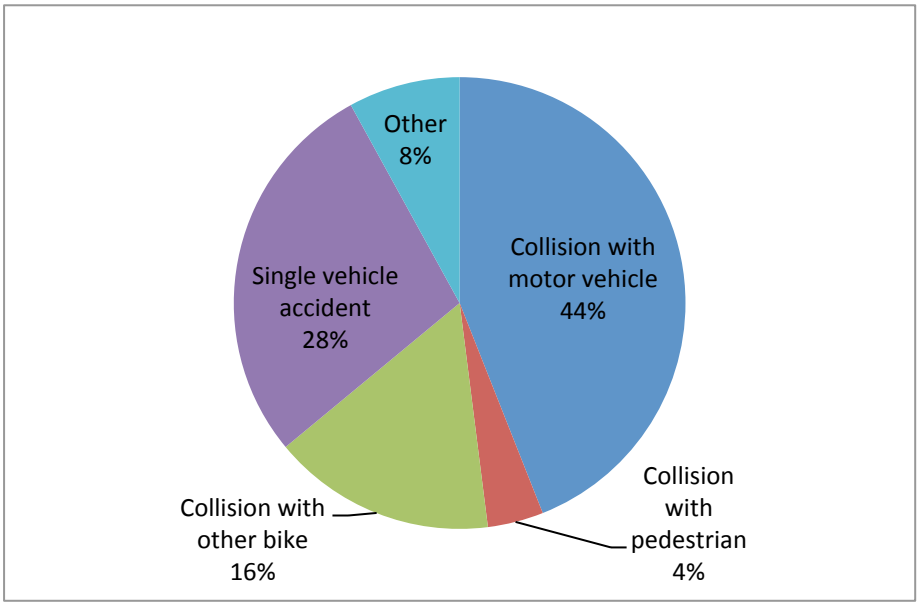

Figure 2: Reported crash type, Montreal bikeshare, 2013
Source: [45]

4.3 Crash rates for bikeshare programs

Table 2 illustrates the number of injuries reported by users to bikeshare operators. As one might expect, the majority of injuries are in the *slight* category and this is broadly consistent with data on cycling crashes in general [43, 44, 46]. Cities with greater bikeshare use (see Table 1) also have the highest number of reported injuries. Melbourne and Minneapolis/St Paul recorded no incidents throughout 2013.

Table 2. Number of reported incidents to bikeshare operators, selected cities, 2013

	Slight injury	Serious injury	Fatal
Paris	159	19	0
London	62	17	1
New York City	71	9	0
Montreal	22	0	0
Washington, D.C.	23	2	0
Chicago	5	2	0
Minneapolis/St Paul	0	0	0
Melbourne	0	0	0
All city total	*342*	*49*	*1*

Sources: Pers. Comm. between authors and bikeshare operators. New York City data derived from monthly operating reports [40], information provided in news reports and a Citi Bike spokesperson [41]

Table 3 expresses injury rates on a per million kilometre basis for two levels of severity. In terms of *slight* injuries, New York City recorded the highest rate of slight injuries, followed by Washington, D.C. London and Chicago recorded the highest estimated serious injury rate, at 0.7 serious injuries per million kilometres travelled. However, overall the differences between programs are very small when considering they are expressed per million kilometres. The average number of slight injuries per million bicycle kilometres is 1.9. The numbers of serious injuries are too low to compare between bikeshare systems.

Table 3. Injuries and fatalities per distance travelled, selected cities, 2013

	Slight injuries per million km	Serious injuries per million km
Paris	1.3	0.2
London	2.6	0.7
New York City	4.0	0.5
Montreal	2.2	0
Washington, D.C.	3.3	0.3
Chicago	1.8	0.7
Minneapolis/St Paul	0	0
Melbourne	0	0
All city average	*1.9*	*0.3*

Of the cities included in this study, only London recorded a fatality in 2013 [28]. This is too low to reliably estimate an average fatality rate for bikeshare systems. Instead, an average fatality rate is calculated using Paris data collected between 2007 and 2012, during which time police recorded eight deaths among bikeshare users [47]. Usage during this time period is estimated at some 0.58 billion-bicycle kilometres. By combining these figures to those in Table 1 and 2, a bikeshare fatality rate of some 12 per billion bicycle kilometres (9 fatalities divided by 0.76 billion bicycle kilometres) has been estimated.

4.4 Comparing bikeshare crash rates to general bicycle crash rates

General bicyclist injury rates for Paris and London are shown in Table 4, using data collected for the jurisdiction known as *Île-de-France* (which encompasses Paris) as well as Greater London. The other cities included in this paper do not have sufficiently detailed travel survey data available to estimate the amount of bicycle use. Without knowing the number of kilometres cycled, it is not possible to estimate crash rate. In this analysis, travel survey data [42, 48] has been combined with police recorded crash figures between 2009 and 2011 for Île-de-France [49, 50] and Greater London [51]. Table 4 reveals that Paris is considerably safer for non-fatal crashes than London, but both cities are almost identical in terms of fatalities per billion kilometres.

Table 4. Injuries and fatalities, bicycle use and injury rates between 2009 and 2011 in Île-de-France and Greater London

Injury numbers	***Slight injuries***	***Serious injuries***	***Fatalities***
Île-de-France	2859	599	36
Greater London	10184	1416	43
Bicycle use	***Billion bicycle km***		
Île-de-France	1.4		
Greater London	1.8		
Injury rates	***Slight injuries per million km***	***Serious injuries per million km***	***Fatalities per billion km***
Île-de-France	2.0	0.4	25
Greater London	5.8	0.8	24

We start our comparison with fatalities because the reporting rate will be more reliable than non-fatal crashes. Paris and London data have been combined, as numbers are too small to present individually. However, the figure is largely based on Paris for which a longer time period could be used. We estimated the fatality rate for the average bikeshare system at 12 fatalities per billion bicycle kilometres. Figure 3 in which the fatality rates are included shows that the fatality rate for bikeshare systems is lower than the fatality rate for Île-de-France and Greater London. This suggests that the average bikeshare user is less likely to be fatally injured than other cyclists in the same jurisdiction. Even though the estimate for bikeshare systems is based on a low number of only nine fatalities, it is still remarkable that the average is at the same level as the level in the two safest countries for cyclists in the world, the Netherlands and Denmark [52].

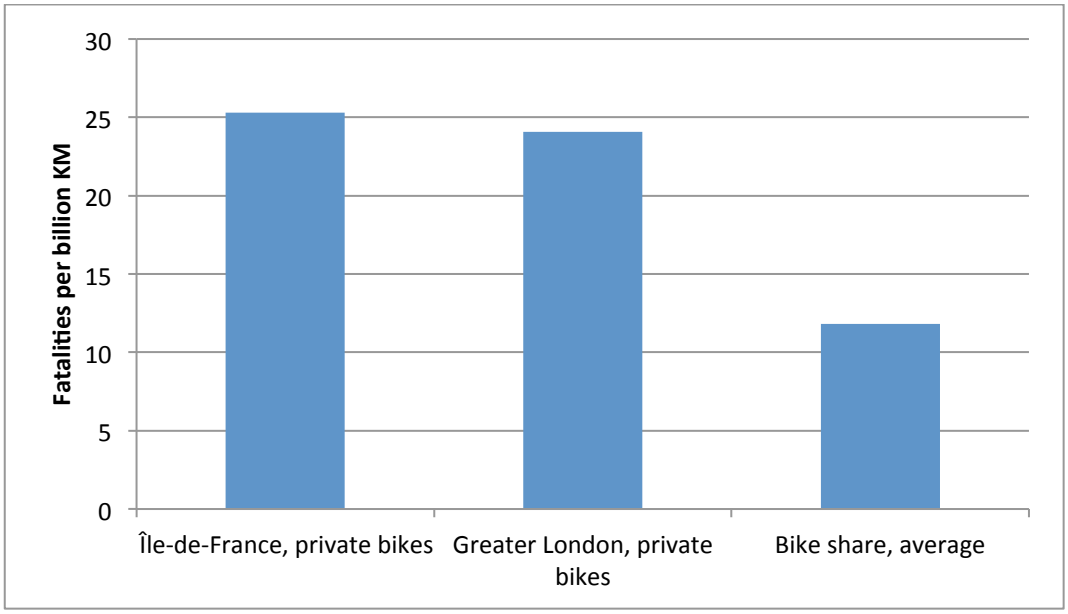

Figure 3: Fatality rates per billion bicycle km for the average bikeshare system and the two jurisdiction containing the largest bikeshare systems in our sample

Figure 4 compares the injury rates of the Paris and London bikeshare systems to the injury rates in the jurisdictions of which these are part. For both levels of severity and both bikeshare systems the injury rates are lower for bikeshare. This is consistent with the estimates for fatality rates and may show actual safety differences. However, a lack of information on the reporting rate by bikeshare operators compared to the police prevents us from drawing definitive conclusions.

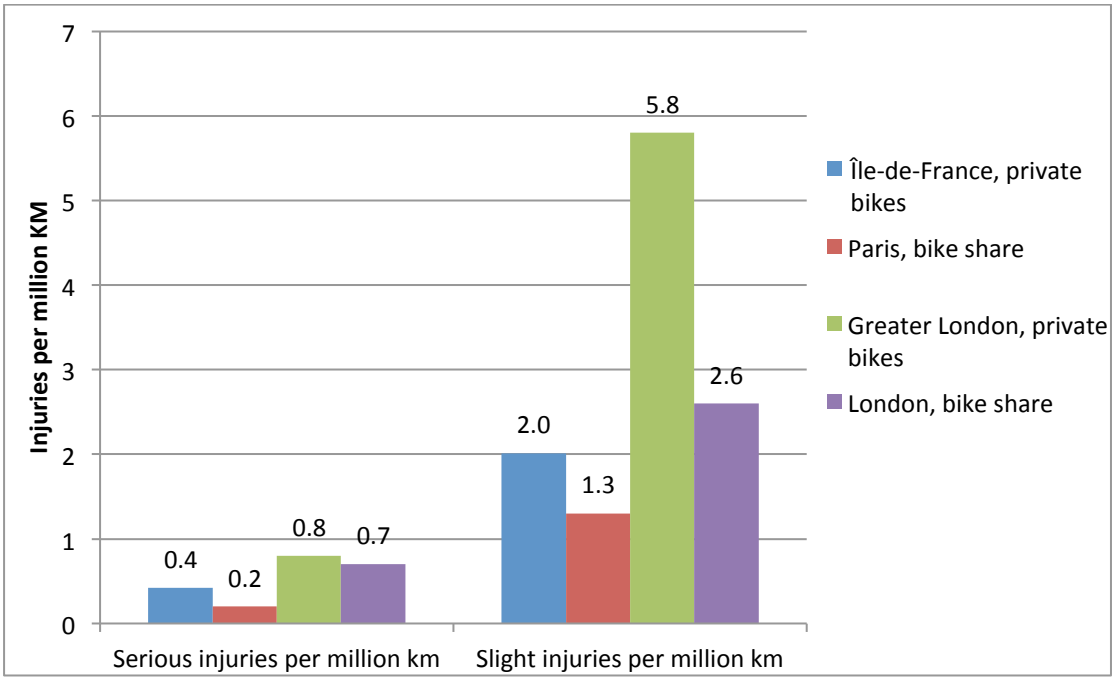

Figure 4: Injury rates for the Paris and London general cycling and their respective bikeshare programs

5 DISCUSSION

The results of this study suggest that bikeshare users are less likely than other cyclists to sustain fatal, severe or slight injuries. A relatively reliable measure for this is the fatality rate which was in the same range as the safest cycling countries in the world, the Netherlands and Denmark [53]. According to the results of this analysis, a bikeshare user is half as likely to be fatally injured, per kilometre travelled, than a general cyclist, in jurisdictions in which a bikeshare program operates. However, the number of fatalities on which this comparison is based is still relatively low. Comparing serious and slight injuries leads to the same conclusion, but this comparison is hampered by the fact that our numbers for bikeshare were based on data reported to operators while the numbers for other cyclists were based on police reported crashes. Although there are uncertainties, the fact that the literature and outcomes for all levels of injury severity point in the same direction yields some support for lower risk for bikeshare users compared to other cyclists.

An explanation for why bikeshare reduces road safety risk is not immediately obvious. One explanation might be that their speeds are substantially lower than for other cyclists. Bikeshare speeds are generally in the same range as countries such as the Netherlands [54]. A slower speed increases the time available for cyclists to react to avoid crashes that may have occurred at higher velocities. It is also possible that motorists perceive bikeshare users to be less experienced and/or tourists and display greater level of caution, as revealed in qualitative research on perceptions of bikeshare [13]. Bikeshare users in this same study also reported significantly improved levels of perceived awareness and respect from motorists when using bikeshare bikes compared to their private bicycles. The notion that drivers behave differently depending on the appearance of the cyclist has been established by Walker [55] who found that drivers overtook closer to helmeted cyclists. The upright position may improve cyclists' visual observation of the road environment, potentially helping to avoid crashes.

6 RECOMMENDATIONS

This analysis of the available data on bikeshare safety has highlighted some important shortcomings regarding current practice. Firstly, there is no established industry standard for the reporting of bikeshare incidents. The use of a standard online form, with some modifications accounting for different local contexts would provide individual bikeshare operators, the wider industry and government with easily comparable data. This would enhance the ability of relevant stakeholders to identify emerging safety issues, providing an important tool in maximising the safety of bikeshare users, and the wider public. A suggested starting point for a common reporting template has been provided in Appendix 1. Related to the first point is the need to remind bikeshare users to report crashes, even those of a minor nature.

Secondly, researchers may be able to match crashes from difference sources (e.g. hospital and police records, as well as bikeshare operators) by using date and time of crash, as well as victims' age. A similar technique has been used by other road safety researchers [e.g. see 56] who coupled the police crash database and hospital registration. Finally, including *'bikeshare'* as an option on police and hospital incident forms in cities with bikeshare would also enhance data quality.

7 LIMITATIONS

Several important limitations are identified in this study. Firstly, although ridership data is collected automatically when a bike is taken or returned to a docking station, there are

instances in which errors occur and these errors may have been included in the data provided to the authors. Secondly, and perhaps most importantly, no standard procedure is used across the bikeshare industry to record incidents and therefore the data obtained for this study is subject to error. Some incidents go unreported and others may be insufficiently detailed to be accurately categorised as slight or severe. The New York City incident data in particular may have inaccuracies associated with their compilation as presented in the Monthly Operating Reports, although the operator should be commended for making these reports available from their website, providing a range of operating data [57].

8 CONCLUSIONS

Bikeshare programs are still in their infancy and data collected on crashes by bikeshare operators have not been standardised [19], and this makes it difficult to develop a clear picture of the relationship between bikeshare and safety. Nevertheless, this paper has been able to use the information that does exist, on usage and crashes, to develop a risk per distance travelled, for a number of bikeshare programs. This analysis suggests that bikeshare users are less likely to be killed or injured compared to private bicycle riding in the same city. These results are broadly supportive of earlier studies showing the risk of a crash on bikeshare may be lower than general cycling [28] and that the number of cyclist casualties in hospital data drops after the introduction of a bikeshare program [20]. The adoption of an industry wide standard for the reporting of bikeshare incidents would greatly enhance the quality and comparability of international bikeshare safety data and would ultimately serve to enhance road safety outcomes.

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10 APPENDIX 1 BIKESHARE CRASH REPORTING

The following contains suggested content for a bikeshare crash reporting form. When a user calls to report a crash, the following questions should be asked, and recorded by the operator. Where possible, check boxes and drop down menus should be built into an online form, to maximise consistency/compatibility of recorded data. Open field boxes should be kept to a minimum to reduce variability in how operators record crash data. Finally, it should be noted that the following points are suggestions only and the bikeshare industry and government partners are encouraged to work together to develop a consistent form that they find practical for their purposes.

○ Name (Open text field)
○ Date of birth (Drop down boxes for day, month, year)
○ Gender (Radio button, Male, Female)
○ Crash date (Drop down boxes for day, month, year)
○ Crash time (Drop down boxes for hour and minute)
○ Crash location - use tool to place a pin on a map, with provides an automatic geocode (e.g CrowdSpot.com.au). The operator can enter an address or cross street and then drop a pin on a map, which places the geocode within the database.
○ Crash type: (Drop down box for fall, collision with an obstacle, collision with another road users (if yes, other bike, pedestrian, car, van, motor cycle, moped, lorry, or other)
○ Have police attended at scene (Radio button, Yes/No)
○ Have the police been contacted otherwise (Radio button, Yes/No). Record incident number if available (Open text field)
○ Injury severity: (Drop down box for no medical treatment and not injured, no medical treatment but slight injury, treated by a general doctor, treated at an Emergency Department, admitted to hospital, fatal). Record patient number if available (Open text field)
○ Injury details: (Radio buttons for the 30 most common cyclist injuries, plus 'other'). Can select multiple injuries.
○ Customer's consent for safety researchers to contact you in the future (Radio button Yes/No)
○ If YES to above, customers email address and cell phone number.