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Safety of motorised two-wheeler riders in the formal and informal transport sector

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Declaration

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Safety of motorised two-wheeler riders in the formal and informal transport sector

Maria Isabel Gutierrez Martinez and Dinesh Mohan

1 INTRODUCTION

Road traffic fatalities are a largely preventable major public health problem with a large socioeconomic impact and are on the increase, rising by 20% from an estimated 1,117,119 deaths in 1990 to 1,342,284 in 2016 (Global Burden of Disease Collaborative Network, 2017). According to these estimates, in low and middle-income countries (LMIC), vulnerable road users (pedestrians, bicyclists and motorcyclists) comprise a majority of the fatalities (~63%), whereas in high-income countries the majority are motor vehicle occupants (~58%). The Global Burden of Disease (GBD) estimates also show that of 251,259 motorised two-wheeler (MTW) fatalities worldwide 84% occurred in LMIC. Most collision victims worldwide are males. In LMIC, 87% of vehicles involved in collisions are driven by males (Peden et al., 2004). Road traffic injuries are the main cause of mortality in the 15 to 24-year-old age group (Facility Institute For Health Metrics And Evaluation, 2014). They are associated with socioeconomic status, where poorer people are more likely to be affected. This does not appear to be due to the behaviour of these individuals but rather to risk exposure (Peden et al., 2004).

Transport safety issues and the provision of transport are becoming increasingly important social equity issues. Economic and population growth of cities, largely due to migration, often by poor, rural and sometimes displaced citizens has led to urbanization with high densities of citizens. Public transport systems and road infrastructure have been unable to meet the demands of these developments in cities. Consequently, current road infrastructure is often unsafe and public transport systems are running over their capacity. It is often the poorest citizens who cannot afford private vehicles who are affected the most.

The large number of private, public and informal transport vehicles on the road has led to an increasing number of traffic collisions as vehicles compete in limited, unsafe spaces. This necessity for the expansion and improvement of public transport in contexts of high levels of unemployment and congested cities has led to the establishment of innovative and unregulated forms of informal transport. Informal transport refers to transport services that do not have governmental approval that makes them illegal. The informal sector of transport includes bicycle taxis, cycle rickshaws, MTW taxis, a number of locally developed small taxis (e.g auto rickshas in South Asia and Indonesia, tuk-tuks in Thailand, Jeepneys in Philippines, etc.), unregulated car taxis, jeep-buses[1] (e.g “Gualas” in South America) and mini-buses all over the world (Figure 1).

Due to the lack of regulation of this sector, safety issues are a major concern, particularly as the drivers and vehicles are not always obliged to abide by safety regulations and may not be

[1]Guala.https://images.google.no/imgres?imgurl=http%3A%2F%2Fwww.elpais.com.co%2Ffiles%2Farticle_multimedia_main_gallery%2Fuploads%2F2017%2F02%2F22%2F58ad99de4f106.jpeg&imgrefurl=http%3A%2F%2Fwww.elpais.com.co%2Fmultimedia%2Ffotos%2Fen-imagenes-asi-operan-las-gualas-en-la-ladera-y-la-zona-rural-de-cali.html&docid=h7Vj-jFtzBsYOM&tbnid=yERrrfmTosT5vM%3A&w=922&h=598&source=sh%2Fx%2Fim Accessed 2017-11-14.

Transport safety issues and the provision of transport are becoming increasingly important social equity issues.

Figure 1. Jeep-buses. "Gualas" in Cali, Colombia-South America.

Public transport systems and road infrastructure have been unable to meet the demands of these developments in cities.

registered. This is not to say that the informal sector is not organised as many providers of informal transport belong to groups with leaders. They have their own rules to abide by, and they may be quite organised (Arora & Jawed, 2011; Biona, Culaba, & Purvis, 2007; Cervero & United Nations Centre for Human Settlements (Habitat), 2000; Ibitayo, 2012; Kumar, Singh, Ghate, Pal, & Wilson, 2016; Odero, Garner, & Zwi, 1997).

This necessity for the expansion and improvement of public transport in contexts of high levels of unemployment and congested cities has led to the establishment of innovative and unregulated forms of informal transport. Informal transport refers to transport services that do not have governmental approval that makes them illegal.

MTW such as motorcycles, mopeds and scooters are a relatively cheap, fast and convenient form of transport that have become popular as private vehicles both in the formal and informal transport sector. Between 2010 and 2013 the number of motorised two-wheelers grew by 27% (Facility Institute For Health Metrics And Evaluation, 2014). In fact, in many countries in South and South-East Asia MTW are now the predominant motorised vehicles on the road. For instance, in India, Cambodia, the Lao People's Democratic Republic, Malaysia and Viet Nam, 51% to 95% of all vehicles belong to this group (WHO, 2015). In the informal sector, these vehicles can often be older and poorly maintained that contribute to higher pollution levels in cities (Cervero & United Nations Centre for Human Settlements (Habitat), 2000). Furthermore, MTW are associated with a higher rate of injury compared to automobiles (Facility Institute For Health Metrics And Evaluation, 2014) and users are more likely to suffer injuries and fatalities (Peden et al., 2004). This is partly explained by their ability to gain high speeds, their small size (hence less conspicuous) and lack of physical protection. Multiple body-sites are normally injured in MTW collisions with the lower-extremities being the most common site and head injuries are most frequent cause of fatalities (Burns ST, 2015). In MTW collisions, the most frequent orthopaedic injuries are tibia/fibula, spine, and forearm fractures and the most frequent non-orthopaedic injuries are concussions, skull fractures, face fractures, haemothorax and pneumothorax (Peden et al., 2004).

The number of MTW is on the rise thus safety problems surrounding their use are becoming increasingly important public health issues.

1.1 MTW taxis

MTW taxis are widely available all over the world as a form of low-cost public transport especially in low and middle-income countries where MTW form a large proportion of the vehicle fleet. They are particularly common in many countries of South and South-East Asia, Africa and Latin America. They also operate in small numbers in few large cities of high-income countries. For example, a motorcycle for-hire service started in California and New York City in 2011 where passengers are supplied with helmets and operate somewhat like taxi aggregator systems.[2] This model is being introduced in many parts of the world. For example, cab aggregator Uber entered the bike taxi market in 2016 in cities around Delhi (India) in 2016 with the launch of UberMOTO (the option of choosing a bike taxi is integrated into its current app). Many other operators in India have introduced similar services. Users recognise them by different trade names like Rapido, Baxi:The Taxi, YAYA Moto cab, etc.[3] Similarly, GrabTaxi is a leading transportation platform across Southeast Asia. That operator has extended its product platform to include motorcycle taxis (GrabBike), Safemotos in Rwanda, and Uber for motorcycle taxis in Uganda, Rushbike in Thailand, Amarbike in Bangladesh and other start-ups are emerging in most parts of the world.[4] The success or extent of these operations in India or other countries is not known. In addition, couriers and food deliveries in all nations of the world increasingly use MTWs.

The aim of this paper is to examine the pertinent safety and social equity issues in MTW especially in the informal transport sector and suggest how they should be addressed.

2 MOTORISED TWO-WHEELER EXPERIENCE IN LOW AND MIDDLE-INCOME COUNTRIES

2.1 Relationship between MTW share in vehicle fleet and fatality rates

Figure 1 shows percent motorised two-wheeler (MTW) fatalities in Organization for Economic Cooperation Development (OECD) countries for the years 2001 and 2011 and Indian cities in 2013 vs. per cent MTW in fleet (Mohan, Tiwari, & Mukherjee, 2016; OECD/ITF, 2015). Data for different countries are strictly not comparable with urban data as vehicles on urban roads may operate under different conditions than those on rural roads. However, these data provide us with some pointers for further study. These data show that though there is a general tendency for proportion of MTW fatalities to increase with increase in proportion of MTW in the fleet, the relationship is not very strong. For example, in 2011 Finland, Japan and Switzerland had similar proportions of MTW in their fleets (13%, 14% and 15% respectively) but MTW of fatalities were very different at 13%, 18% and 23% respectively. In the six Indian cities, the share of MTW in the fleet is similar, but proportion of MTW fatalities differ substantially. The explanations for differences in MTW fatalities could include differences in driving speeds, distance driven per year, helmet use, the dominant age group using MTW, the quality and access to public transportation and engine size of MTW.

[2]Motorcycle taxi. https://en.wikipedia.org/wiki/Motorcycle_taxi#External_links. Accessed 2017-10-21

[3] https://rapido.bike, https://play.google.com/store/apps/details?id=taxi.baxi.customer&hl=en, http://www.yaya.co.in. All accessed 2017-10-21.

[4] SafeMoto. http://www.safemotos.com; Uber for motorcycle taxis. http://www.news24.com/Africa/News/Ugandas-Uber-for-motorcycle-taxis-shows-it-pays-to-be-safe-20150624. https://angel.co/motorcycle-taxi. All accessed 2017-10-21.

Car occupant fatality rates range from a low of 2.1 in United Kingdom to a high of 10.5 in Czech Republic, and, for MTW riders from a low of 39 in Switzerland to a high of 253 in Czech Republic. There are no clear explanations available why car occupant risk rates differ by a factor of five and MTW rates by a factor of six in these OECD countries.

In Israel MTW riders have nine times higher risk of dying than car occupants and in United States this ratio is 31. More detailed research studies are needed to understand the reasons behind these different rates.

We have no explanation why MTW fatalities per billion vehicle km in Indian cities are lower than those seen in European countries, this could be an interesting point for further research using standardized methods to look for protective and risk factors at each site.

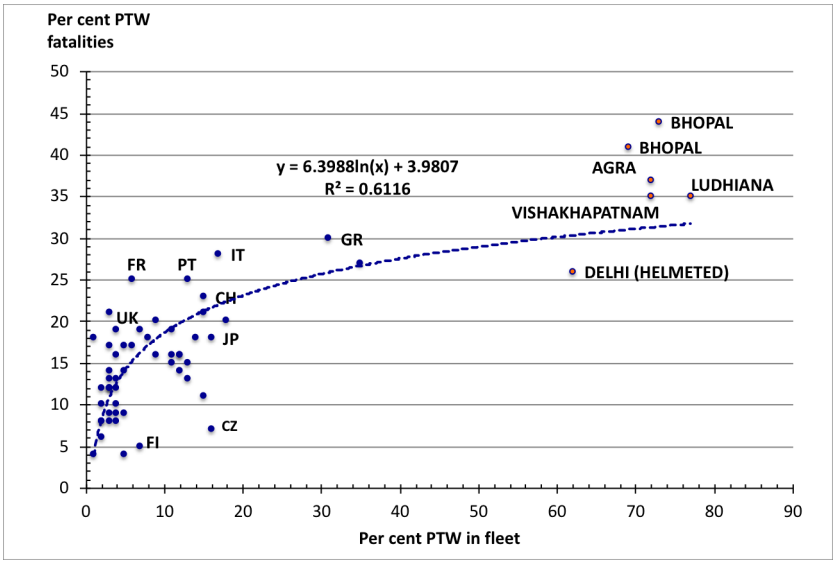

Figure 2. Percent motorised two-wheeler (MTW) fatalities in OECD countries (with codes, some with no labels) for the years 2001 and 2011 and Indian cities (with labels) in 2013 vs. percent MTW in fleet (Data from references Dinesh Mohan, Tiwari, & Mukherjee, 2016; OECD/ITF, 2015).

The data also shows that the safety in numbers effect may be true for MTW riders as MTW fatalities do not seem to increase in proportion to the number of MTW in the fleet, especially when MTW proportions are high in large urban areas such as Delhi. However, this could be explained in a further analysis of each country's rates. Safety in numbers is the phenomenon by which a motorcyclist's risk of being killed declines as the proportion of motorcyclists increases in a fleet, city or country (Jacobsen, Ragland, & Komanoff, 2015), which can be applied to all types of road users. This may be explained by a study showing that on simulators, people perceive motorcycles more quickly in simulations with a high prevalence of motorcycles. (Beanland, V., Lenné, M. G., & Underwood, G. 2014).

2.2 Fatality risk per billion vehicle km

Table 1 shows data for selected OECD countries for fatalities of MTW and car occupants per billion vehicle km. Car occupant fatality rates range from a low of 2.1 in United Kingdom to a high of 10.5 in Czech Republic, and, for MTW riders from a low of 39 in Switzerland to a high of 253 in Czech Republic. There are no clear explanations available why car occupant risk rates differ by a factor of five and MTW rates by a factor of six in these OECD countries. The last column in Table 1 gives the ratio between car and MTW fatality rates per billion-vehicle-km for each country. In Israel MTW riders have nine times higher risk of dying than car occupants and in United States this ratio is 31. More detailed research studies are needed to understand the reasons behind these different rates.

Similar data are not available from most LMIC. We use data from six Indian cities to compare MTW occupant risk with that of car occupants. Table 2 shows MTW and car occupant atality data from six cities in India (Mohan & Bhalla, 2016; Mohan et al., 2016). These data are not available at the country level. Vehicle mileage data for Delhi and Vishakhapatnam were obtained from special surveys (Mohan, Goel, Guttikunda, & Tiwari, 2014). Vishakhapatnam vehicle-use data were used for other cities as they are similar in size. Helmet use is compulsory for all MTW riders by law in India (Ministry of Road Transport and Highways, 1988) but out of the six cities included in Table 2, the law was being enforced only in Delhi, which may explain the relatively low fatality rate in Delhi. Agra has the highest fatality rates for the three categories of vehicles compared to the other cities.

The reasons for these differences are unknown, however one could analyse the effect of different protective countermeasures. The fatality rates per billion vehicle km for each category of vehicles differ by more than a factor of five. The differences among these cities are similar in magnitude as those observed for OECD countries. Detailed epidemiological data are not available at present to account for these differences. It would be very useful if data are obtained to understand the reasons for the differences between high rate and low rate cities for each category of vehicles.

In OECD countries, all cars are required to conform to crashworthiness standards and seat belt wearing rates in a majority of the countries are more than 80%. In contrast, in cars in Indian cities do not have to conform to crashworthiness standards (Mohan, Tiwari, & Bhalla, 2015) and seatbelt use is likely less than 20% overall as the law is applicable only to front seat passengers and not enforced strictly except in Delhi during daytime (Mohan, 2009). Use of seat belts by drivers, front seat passengers and rear seat passengers is expected to reduce fatalities by 50%, 45% and 25%, respectively (Elvik & Vaa, 2004). According to Farmer and Lund (2015), between the years 1984 and 2009 the risk of driver death declined by an estimated 42% in cars, 44% in pickups, and 75% in SUVs in USA. Therefore, we should expect fatality rates of car occupants in Indian cities to be about double those in the OECD countries with better safety records. Average country fatality rates for vehicles can be higher than city rates due to lower average velocities in the latter, therefore, it is possible that the car fatality rate per billion vehicle km is higher than the average city rate quoted above. However, it appears that the highest and lowest fatality rates for cars on an average in India are about double those in the OECD countries. This factor may partly account for the low MTW/Car risk ratio in Indian cities

Table 1. MTW and car occupant fatalities per billion vehicle km in OECD countries (Data source: OECD/ITF, 2015)

Country	Fatalities/billion vehicle km		MTW/ Car Ratio
	MTW	Car	
Australia	71.8	5.2	14
Austria	59.7	4.7	13
Belgium	76.9	5.9	13
Canada	62.9	4.9	13
Czech Republic	252.6	10.5	24
Denmark	49.5	4.2	12
France	72.4	4.9	15
Germany	59.5	3.3	18
Ireland	60.8	2.5	24
Israel	45.7	5.1	9
Netherlands	64.0	3.0	21
Slovenia	112.5	4.3	26
Sweden	43.9	2.2	20
Switzerland	39.2	2.3	17
United Kingdom	72.0	2.1	34
United States	155.0	5.0	31

Table 2. MTW and car occupant fatalities per billion vehicle km in selected Indian cities (Data source: Mohan & Bhalla, 2016; Mohan et al 2016)

Indian City	Fatalities per billion vehcle km		MTW/Car ratio
	MTW	Car	
Delhi	17	4	4.3
Agra	71	25	2.8
Bhopal	32	7	4.6
Ludhiana	13	5	2.6
Vadodara	28	12	2.3
Vishakhapatnam	51	21	2.4

included in Table 2. However, we have no explanation why MTW fatalities per billion vehicle km in Indian cities are lower than those seen in European countries, this could be an interesting point for further research using standardized methods to look for protective and risk factors at each site.

The risk of fatality for MTW riders in countries in South and South East Asia may be lower than in Western Europe and North America and the comparative risk compared to car occupants not as high. The reasons for these differences may be due to driving speeds, or other factors described in this paper, but these are unknown and further research is needed.

The situation in Vietnam which has a much higher proportion of MTWs on the road seems to be similar to that in India. In Vietnam, there were ~ 37 million MTW in 2013-2014 (~95% of all vehicles) and there were ~ 9,800 MTW fatalities (70% of total) (Ha et al., 2017; Ivers, Nguyen, & La, 2014). We assume that MTWs drive 25 km per day in Vietnam, then we get a MTW fatality rate of 30 per billion vehicle km, and the rate for 50 km/day would be 15. This rough calculation shows that MTW fatality rates in Vietnam where the helmet law was not enforced uniformly in 2013-2014 were similar to those in Indian cities. These findings show that the risk of fatality for MTW riders in countries in South and South-East Asia may be lower than in Western Europe and North America. In addition, the comparative risk compared to car occupants is not as high. This is in spite of the fact that helmet wearing is not as high in Asian countries as in Western Europe. The reasons for these differences may be due to driving speeds, or other factors described in this paper, but these are unknown and further research is needed.

2.3 Motorised two-wheelers and risk to other road users

The most interesting feature emerging from this analysis is the involvement of motorised two-wheelers as striking vehicles for pedestrian fatalities.

Figure 2 shows the data for the distribution of road traffic fatalities by road user category versus the respective struck vehicles/objects for two cites, Agra and Bhopal in India. These two cities are representative of the patterns in 1 million plus cities. In both the cities the largest proportion of fatalities for all road user categories (especially vulnerable road users) are associated with impacts with buses and trucks rather than cars (Mohan et al., 2016). The most interesting feature emerging from this analysis is the involvement of motorised two-wheelers as striking vehicles for

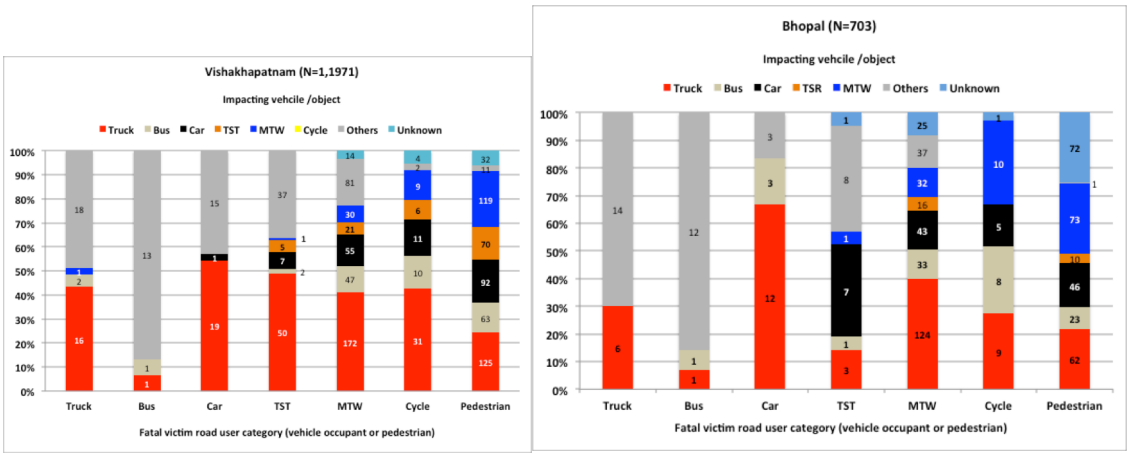

Figure 3. Fatal RTI victim road user category and impacting vehicles/objects in Vishakhapatnam and Bhopal (numbers in bars represent number of cases). Source: Mohan, Tiwari, & Mukherjee, 2016.

pedestrian fatalities. The proportion of pedestrian fatalities associated with MTW impacts ranges from 8 to 25% of the total. The highest proportion was observed in Bhopal. The involvement of MTWs as impacting vehicles in vulnerable road users (VRU) fatalities may be due to the fact that pedestrians and bicyclists do not have adequate facilities on arterial roads of these cities and they have to share the road space (the curb side lane) with MTW riders. A study in Cali, Colombia documented the difficulties that pedestrians encountered walking in the city. Their responses focused mainly on the lack of respect by pedestrians and other vehicle users, particularly motorcycle riders. "…there is no respect for pedestrians. Motorcycles ride over sidewalks. There is no culture among motorcyclists…." (Fox et al., 2015; Villaveces et al., 2012). Such data are not available at the national level or city level for most countries in Asia, Africa and Latin America. It is possible that the Indian experience will be similar in many of the cities in the low and middle-income countries. If this is true than much more importance must be given to MTW and road design so that VRU fatalities associated with MTW may be reduced. Enhanced MTW safety standards are likely to play an important role in reducing road traffic injuries (RTI) fatality rates of MTW occupants as well as other VRU. At present, there are no detailed scientific studies examining the design of MTWs and its influence on pedestrian and cyclist injuries. Such a study would help in identifying motorcycle structures associated with pedestrian injuries.

3 EVIDENCE ON SAFETY ISSUES AND POSSIBLE INTERVENTIONS

Four groups of causes can be used to explain traffic collisions in motorised two-wheeler vehicles in the formal and informal transport sector: MTW safety standards (poor conspicuousity, etc), MTW rider behaviour, road design, existence of appropriate traffic laws or and/or enforcement, and regulation of the informal transport sector. While many highly cost-effective preventative measures exist to avert road traffic collisions and the subsequent injuries and fatalities, they are often not given the political priority that they deserve. Preventative actions involve mounting surveillance systems, health promotion including the enforcement of effective personal protective equipment, smart road designs, improved MTW safety standards and the creation and enforcement of public policies and laws.

3.1 MTW standards

3.1.1 Vehicle visibility

MTW are small which makes them relatively inconspicuous to other vehicles and pedestrians and they are more likely to enter blind spots of other vehicles. Furthermore, due to their ability to weave around stationary and non-stationary vehicles, their movements are less predictable to other road users. The effectiveness of different equipment and clothing to increase motorcyclists' visibility to prevent collisions varies vastly in the literature with some studies finding them to be effective and others not, even after the introduction of laws to regulate their use (M.-R. Lin & J. F. Kraus, 2009). A New Zealand case-control study found that the following interventions reduced risk of collisions after adjusting for potential confounding factors: use of reflective or high visibility clothing (37%), use of a white-helmet instead of a black helmet (24%), use of a light-coloured helmet in place of a dark-coloured helmet (19%) and daytime headlight use (27%) (Burns ST, 2015). This study did not find a difference in collision risk in the frontal colours of MTW or motorcyclists' clothing (Facility Institute For Health Metrics And Evaluation, 2014). Studies which have not found these preventative measures to be successful in reducing collisions have been criticised for failing to measure other confounding factors and certain types of collisions, thereby potentially underestimating their effectiveness (M. Lin & J. Kraus, 2009). For instance, many studies measured only multiple-vehicle collisions, and thereby failed to recognise that also single vehicle collisions are averted through preventative measures as motorcyclists dodge other vehicles and collide with inanimate objects. (Victoria Espitia-Hardeman et al., 2008; Wells et al., 2004).

One measure which has been found to be effective around the world is the use of daytime running lights (keeping the headlamp on at all times). The fact that daytime running lights (DRL)

One measure which has been found to be effective around the world is the use of daytime running lights (keeping the headlamp on at all times). The fact that daytime running lights (DRL) can reduce MTW rider fatalities significantly was brought to our attention more than thirty years ago.

can reduce MTW rider fatalities significantly was brought to our attention more than thirty years ago (Zador, 1985). Since then other studies have also estimated that because of DRL reduction in serious injuries and fatalities can range from 10%-20% in tropical climates also (Davoodi & Hossayni, 2015; Radin Umar, 2006; Yuan, 2000). The effectiveness of DRL is based on an understanding that the presence of a bright light source in front of the MTW makes the vehicle more conspicuous and alerts the other motor vehicle users. However, we do not have any idea whether this would reduce pedestrian crashes also. This is an issue worth examining.

The Ministry of Road Transport and Highways (India) notified the following regulation for MTWs in 2016:

> 'Every two-wheeler manufactured on and after the 1st April, 2017, shall have one or two head lamps, conforming to the applicable standards in force for performance and installation requirements as notified by the Central Government from time to time vide according to sub-rule (1) of rule 124, which shall automatically switch on when the engine is running.'

In countries where MTW fatalities can range from 30 to 70 per cent of total deaths, DRL enforcement would be the fastest and most cost-effective method to reduce total deaths by 5-10 per cent almost overnight.

The fact that DRL laws could be enforced in Malaysia over a decade ago and that the manufacturers in India have agreed to the above standard recently suggest that such laws and standards can be put in place in al LMIC immediately. The DRL law is relatively easy to enforce as the subjective perception of the rider of the probability of being apprehended is high (Bjornskau & Elvik, 1992; Carlsson, 1997). In countries where MTW fatalities can range from 30 to 70% of total deaths, DRLenforcement would be the fastest and most cost-effective method to reduce total deaths by 5-10% almost overnight.

3.1.2 Combined braking and ABS systems for MTW

Real world studies indicate that ABS equipped MTWs can reduce occupant fatalities by an estimated 50%. They should also have a significant influence in reduction of pedestrian injuries and deaths in collision with MTW. This needs a detailed mechanic evaluation and study.

Anti-lock braking can prevent the front wheels of a motorcycle from locking and help to maintain stability. Antilock braking systems (ABS) are estimated to reduce stopping distance by about 60% and combined braking systems by about 40%. Real world studies indicate that ABS equipped MTWs can reduce occupant fatalities by an estimated 50% (Rizzi et al., 2015), however a reliable estimate for combined braking systems is not available. No studies are available that estimate the effect of MTW ABS and combined braking systems on impacts with pedestrians. However, since these more efficient braking systems reduce distance of stopping significantly, they should also have a significant influence in reduction of pedestrian injuries and deaths in collision with MTW. This needs a detailed mechanic evaluation and study.

The European Union voted in favour of mandatory ABS for new motorcycles over 125cc from 2016 and the Ministry of Road Transport and Highways (India) has notified the following regulation for MTW in 2016:

> *'New MTW models exceeding 125 cc on after 1 April 2017 shall be fitted with antilock braking system. Existing MTW models exceeding 125 cc on after 1 April 2018 shall be fitted with antilock braking system. New MTW models not exceeding 125 cc on after 1 April 2017 shall be fitted with combined braking system. Existing MTW models not exceeding 125 cc on after 1 April 2018 shall be fitted with antilock braking system.'*

If the combined braking system and ABS in MTW can be mandated in India, it should not be difficult to have the braking standards and DRL applied internationally as there are just a handful of manufacturers who supply these vehicles to all the countries in the world. These two measures have the possibility of reducing MTW fatalities by over 20-30% and possibly reduce pedestrian fatalities in many locations.

3.2 Road design

Traffic calming measures reduce the velocity of motor vehicles and include speed bumps, curb extensions, chicanes, roundabouts, and the provision of separated pavements and bicycle lanes to reduce exposure to motor vehicles (Hyden, 2016; Pollack et al., 2012). However, many traffic calming measures like road narrowing, chicanes, ill-designed roundabouts and neck-downs may not always slow down MTW especially in non-peak hours, while vertical measures like speed-humps and rumble strips have been found to be successful. Evaluations of these measures need to be done in countries with high MTW use.

Lane filtering is when MTW weave around stationary or slow-moving traffic. This includes passing between two lanes of traffic which are moving in the same or opposite direction and between parked and moving vehicles (Wells et al., 2004). Laws in the state of Victoria, Australia were introduced to control how MTW lane filter. For instance, they can only filter between lanes up to 30km/h, "if safe to do so" and if it is not prohibited by road signs. They are not permitted to filter between lanes of traffic travelling in opposite directions, between traffic an adjacent curb or in bicycle lanes (M. Lin & J. Kraus, 2009). A French study found that MTW who lane filtered were at 3.9 times greater risk of colliding on urban roads compared to those who did not (M. Lin & J. Kraus, 2009). However, they did not control for possible confounding factors such as age, sex, vehicle size and so forth, so this risk may be overestimated.

Some countries have also experimented with special lanes for MTW (Osorio-Cuéllar et al., 2017; Radin Sohadi, Mackay, & Hills, 2000) starting with Malaysia, some experiments in Colombia, and more recently reasonably widespread use in Vietnam. Radin Sohadi et al. (2000) state that "A clear benefit of this lane is observed when the traffic flow exceeds 15,000 vehicles per day per lane for motorcycle proportion of between 20% and 30%. Besides supporting the notion for motorcycle segregation, this finding provides an initial guideline on the warrants for an exclusive motorcycle lane for highly motorcycled countries in Asia". However, there are very few such studies available which do a before and after scientific analysis of the benefits of separate motorcycle lanes. It is important that such studies are done as a systematic review of the benefits of separate bicycle lanes concludes that "Generally, there is a lack of high quality evidence to be able to draw firm conclusions as to the effect of cycling infrastructure on cycling collisions" (Mulvaney et al., 2015). It is possible that they may be of benefit but the studies done are not good enough to convince us. However, bicycle lanes seem to be appreciated buy users and increase bicycle use.

In Vietnam, MTW have been given space in special lanes on the right side of the road in many locations (Figure 4) but no evaluations of these experiments and policy measures are available in the public domain. Since there are many locations where experiments to segregate MTW from larger vehicle are being undertaken in some countries, it is important that special studies be undertaken to understand the effect of these design changes.

3.3 MTW driver training and licensing.

A Cochrane review looked at the evidence for MTW rider training pre and post licensing to improve motorcyclists' safety but found no evidence that training prevents collisions, injuries or

Many traffic calming measures may not always slow down MTW especially in non-peak hours, while vertical measures speed humps and rumble strips have been found to be successful. Evaluations of these measures need to be done in countries with high MTW use.

Since there are many locations where experiments to segregate MTW from larger vehicles are being undertaken in some countries, it is important that special studies be undertaken to understand the effect of these design changes.

On the basis of the existing evidence, it is not clear if (or what type of) training reduces the risk of crashes, injuries, deaths or offences in motorcyclists and the selection of the best rider training practice can therefore not be recommended.

It is important that all countries enforce the helmet law effectively as education and awareness campaigns on their own do not seem to increase helmet use above 15-20%.

traffic offences (Cerrelli, 1996; K. Kardamanidis, A. Martiniuk, R. Q. Ivers, M. R. Stevenson, & K. Thistlethwaite, 2010). Kardamanidis et al conclude that:

> 'The findings suggest that mandatory pre-licence training may present a barrier to completing a motorcycle licensing process, thus possibly indirectly reducing crash, injury, death and offence rates through a reduction in exposure to riding a motorcycle. However, on the basis of the existing evidence, it is not clear if (or what type of) training reduces the risk of crashes, injuries, deaths or offences in motorcyclists and the selection of the best rider training practice can therefore not be recommended.'

However, the studies that were found for the review were of poor quality and more research is therefore needed.

Graduated driver licensing is the gradual exposure of new drivers to potentially higher risk situations, such as driving at night, carrying passengers and driving while accompanied by adults with valid licenses for a defined amount of time. A separate Cochrane review analysed the effects of various graduate licensing strategies and found that they all had a positive effect to varying degrees (Williams, 2003). One of its conclusions was that more research is needed to measure the impacts of the different components of graduate licensing programmes.

3.4 Helmet use and protective clothing

MTW helmet use has been found to reduce risk of severe injury by greater than 70% and death by nearly 40% (Mayhew, 1990). In another study, after adjusting for age and crash characteristics, helmeted motorcyclists were 2.4 times less likely to sustain brain injuries or skull fractures than non-helmeted motorcyclists (K. Kardamanidis, A. Martiniuk, R. Ivers, M. Stevenson, & K. Thistlethwaite, 2010). Laws imposing helmet use can increase their use to over 90% if they are enforced effectively (Russell, Vandermeer, & Hartling, 2011). The introduction of compulsory helmet laws has generally been associated with a decline in head injuries, fatalities, hospital stays and medical costs (Liu et al., 2008) (Deutermann, 2004) (Espitia-Hardeman et al., 2008). Helmet quality is important, with standard-helmets being associated with less-severe head injuries than nonstandard helmets (Kraus et al., 1991; Servadei et al., 2003). A Malaysian study found that only 54% of 500 motorcyclists used helmets properly and that younger, less educated males without licenses were less likely to wear helmets (M. Lin & J. Kraus, 2009).

However, it is important that all countries enforce the helmet law effectively as education and awareness campaigns on their own do not seem to increase helmet use above 15-20%. However, as soon as mandatory helmet laws are enforced with enough political support helmet use increases to over 80% in most locations (Hill et al., 2009; Mayrose, 2008; Mohan, 2016; Preusser, Hedlund, & Ulmer, 2000; Tsai & Hemenway, 1999; Wada et al., 2017; Watson, Zador, & Wilks, 1981; WHO, 2006). A recent study from Vietnam shows that a significant increase in helmet use after enforcement of helmet laws has reduced MTW injury rates even though substandard helmets are in widespread use (Ha et al., 2017).

There are a limited number of studies on MTW protective clothing which is not economically accessible to many. However, in collision victims they appear to prevent injuries to the areas they are covering and do so to a greater extent when particular body armour is worn (jackets, trousers for leg injury only, gloves and boots). Additionally, protective clothing was associated with a reduction in soft tissue injury (all forms of clothing), hospitalization and therefore injury severity (jackets, trousers and gloves) and improving wellbeing after collisions (V Espitia-Hardeman et al., 2008). They were not found to prevent fractures. The use of protective clothing may have detrimental effects. In one study, foam inserts in the back of jackets were associated with increased risk of back injury (WHO, 2006) and in hot weather, protective clothing may cause thermal discomfort and heat strain (Kulanthayan, Umar, Hariza, Nasir, & S, 2000; Peek-Asa, McArthur, & Kraus, 1999). These factors may affect cognition and therefore the ability to drive safely.

4 MOTORCYCLE TAXI ISSUES ('INFORMAL SECTOR')

Due to the lack of regulation in this sector and high levels of unemployment in the countries where the informal sector is large, there is little control and planning over the supply and demand of services public transport services. This can create fierce competition for passengers which can lead to anti-social behaviour and erratic, chaotic driving (Government, 2015). Because they do not have permitted pick-up and drop off areas drivers of taxis cut across lanes, drive at excessive speeds, stop in inappropriate and dangerous places and curb crawl looking for passengers, all of which can increase congestion and cause collisions (Government, 2015). Excessive vehicle speeds have been reported to be an important cause of collisions (Clabaux, Fournier, & Michel, 2017).

To increase profits of informal services, vehicle maximum passenger capacity is often not respected and helmets and high visibility or reflective clothing are often not provided for passengers, and if they are provided they may be of poor quality. Drivers do not always hold valid licenses for their vehicles. Those without valid licenses and who are less experienced (measured by number of years of possession of a valid license) have been found to have higher collision rates (Høye, 2014). A study in Australia, Japan, Malaysia and Singapore that looked at license types and duration of driving, found that those with a provisional license were most likely to have collisions, followed by those who had a full license for one year (Lardelli-Claret et al., 2005).

Public transport companies have required employment standards for potential drivers which include the ownership of valid licenses for a minimum number of years, nil or minimal previous traffic violations and collisions, minimum and maximum ages and once employed they may receive additional training and can be subject to random alcohol and drug tests. Furthermore, registered transport vehicles and/or drivers will have liability insurance to protect themselves, passengers, their vehicles and third parties. None of these standards can be guaranteed by drivers in the informal transport sector. Many informal workers do not own their vehicles but are rented to them for their shift. Drivers that do not own their own vehicles may be unfamiliar with them and have been found to have a higher collision risk (Høye, 2014).

Young males are most likely to work in the informal transport sector and they belong to the group which are most likely to speed (Lardelli-Claret et al., 2005). Males are more likely than females to have collisions in industrialized countries, even after controlling for other confounding factors (McLean et al., 1990). Teenage drivers are also more likely to have serious collisions at night and when carrying passengers (Kraus et al., 1991). Young drivers also have less experience and are more likely to have collisions than older drivers (National Center for Statistics and Analysis, 2014).

The informal transport sector is both appreciated and under-valued by government and traffic officials. Many see its benefits in the provision of a needed service which they are unable to provide, while others see it as a dangerous, illegitimate sector that creates social problems. It is therefore shown varying levels of tolerance. It may be permitted to run with little interference or

conversely, it is penalised in the form of monetary fines or other penalties, such as temporary vehicle confiscation (Teoh & Campbell, 2010). However, these actions do not always act as a deterrent to the drivers if they have limited options for work.

The informal transport sector is both appreciated and under-valued by government and traffic officials. Many see its benefits in the provision of a needed service which they are unable to provide, while others see it as a dangerous, illegitimate sector that creates social problems.

Strong arguments for and against the regulation of the informal transport sector exist which are eloquently presented in Cervero's UN Habitat document "Informal Transport in the Developing World" (Pollack et al., 2012). The most important argument to regulate this sector is to prevent traffic collisions and the subsequent injuries and fatalities. Agreed standards for drivers can be set which could include defining where and when the drivers operate (Transportation, 2017), their maximum vehicle passenger capacity, the provision of safety equipment for drivers and passengers, liability insurance, driver fitness standards (minimum and maximum age and maximum number of previous accidents and infarctions) and vehicle requirements (periodic roadworthiness certificates). In some countries, there is an oversupply of workers which results in fierce competition for passengers that is associated with antisocial and risk-taking behaviour of the drivers. Through regulation this could be controlled and prevented. Pricing too can be controlled so that passengers are not overcharged.

If informal transport was prohibited without the provision of adequate public transport, it would have detrimental effects on the mobility of the poorest citizens, their subsequent economic productivity and livelihoods.

Arguments against regulating this sector include the loss of competition and profitability and some previously potential drivers will no longer meet the requirements for this job and will be remain unemployed (Cervero & United Nations Centre for Human Settlements (Habitat), 2000). If informal transport was prohibited without the provision of adequate public transport, it would have detrimental effects on the mobility of the poorest citizens, their subsequent economic productivity and livelihoods. If steps are taken to regulate this sector they should be tailored to their context and be culturally appropriate. Many government officials foresee that the sector will be "tolerated" until the state is able to provide alternative transport. However, until this happens, unsafe practices will continue and citizens will be put at risk.

Many of these "unregulated" informal transport services are "regulated" unofficially. Normally they belong to a group which has a leader. They earn minimum wage or less and are vulnerable to exploitation by their "leaders" of the informal transport sector

There are also reasons to regulate this sector for the rights of its workers. As previously mentioned, many of these "unregulated" informal transport services are "regulated" unofficially. Normally they belong to a group which has a leader. They earn minimum wage or less and are vulnerable to exploitation by their "leaders" of the informal transport sector (Cervero & United Nations Centre for Human Settlements (Habitat), 2000). As they are informal, they have no workers' rights. They work unsafe hours, often working over 70 hours per week (Bank, 2002) which has a detrimental effect on their driving. Many are not part of health or pension schemes and obviously they are only contributing to taxes through their purchase of fuel, vehicles and other equipment.

5 SAFETY STANDARDS, RECOMMENDATIONS AND CONCLUSIONS

Evidence on the safety issues concerned with MTW in the informal transport sector is scarce. Five groups of risk factors were used to

explain traffic collisions in MTW in the formal and informal transport sectors: MTW design, MTW rider behaviour, road design, existence of appropriate traffic laws and their enforcement, and regulation of the informal transport sector.

The proportion of MTW in fleets has been both positively and negatively associated with MTW fatalities in different contexts. Explanations for these differences may include variations in driving speeds, distance driven per year, helmet use, the dominant age group using MTW, and engine size of MTW. Surprisingly, it was found that the risk of fatality for MTW riders in South and South East Asian countries may appear to be lower than in Western Europe and North America, even though the comparative risk compared to car occupants is not as high. This is despite lower helmet use in Asian countries compared to Western Europe. The reasons for these differences are not known and further research is urgently needed. While many highly cost-effective preventative measures exist to avert road traffic collisions and the subsequent injuries and fatalities, they are often not given the political priority that they deserve. Preventative actions involve implementing surveillance systems, health promotion including the enforcement of effective personal protective equipment, smart road designs, improved MTW safety standards (including DRL and ABS) and the creation and enforcement of public policies and laws.

This topic needs to attract more attention from decision makers. Successful, evidence based policies should be promoted and implemented internationally to prevent MTW fatalities, particularly because most of the safety issues discussed in this paper are predictable and preventable. Questions that arose for future research and actions to be implemented were mentioned throughout the paper. The option of slowing traffic speed to protect road users in cities with high traffic densities was explored. Finally, can access to a good and efficient public transportation be considered a social equity issue? A former mayor from a LMIC city with successful transport policies stated that when you invest more on public transportation, citizens will choose the formal over the informal system, so the latter does not need to be regulated and generate formal opportunities to work.

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