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REVIEW

Road safety in less-motorized environments: future concerns

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In the last three decades, the incidence of traffic crash fatalities and injuries has been reduced significantly in the high-income countries but not in the low- and middle-income countries. The traffic patterns in the former are not only different but are also less complex than those in the latter. Traffic in low-income countries comprises a much higher share of vulnerable road users and so vehicles, roads and the environment have to be designed for their safety. Solutions for such problems are not readily available and very innovative work needs to be done around the world to arrive at new policies and designs. In addition to crash-worthiness of vehicles, transportation planning, exposure control, intelligent separation of non-motorized traffic on major roads, and traffic calming are likely to play a much more important role.

Keywords Biomechanics, road safety, epidemiology, injuries, developing countries

Table 1 shows estimates of the distribution of road traffic deaths and mortality rates, by World Health Organization (WHO) Region and income group.[1] These statistics are based on the estimates made by Murray and Lopez for the WHO and World Bank.[2] According to these estimates 1 170 694 people died of road traffic injury worldwide in 1998. Deaths from road traffic injuries were the tenth leading cause of death among all ages, accounting for 2.2% of the global mortality. Males sustained 73.0% of road traffic injury deaths and the mortality rates were 28.8 per 100 000 population for males and 10.8 for females. Among young adults (15–44 years) road traffic injuries were the second leading cause of death (21.7 deaths per 100 000) and the third leading cause of death among those aged 5–14 years (13.7 deaths per 100 000). Deaths from road traffic injuries were also among the 15 leading causes of death for those aged 0–4 years (13.7 deaths per 100 000) and those aged 45–59 years (22.8 deaths per 100 000). The global burden of disease due to road traffic injuries is expected to move from ninth position in 1990 to third position in 2020. This is mainly due to increasing incidence of road traffic crashes in low- and middle-income countries. In most less-motorized countries, deaths due to road traffic injuries are among the 2–6 leading causes of death in the age group 5–60 years. While the wider effects of road traffic injuries are experienced in rich as well as poor countries, the total number of fatalities has shown a declining trend in many of the rich countries over the past two decades. On the other hand deaths due to road traffic injuries are still increasing in most of the less-motorized countries.

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Table 2 shows that in less-motorized countries the vulnerable road users—pedestrians, bicyclists and motorized two-wheeler riders—sustain a vast majority of the fatalities and injuries due to road traffic injuries.[3] These countries are also experiencing higher rates of motorization with increase in incomes as compared to high-income countries, as the latter are closer to a steady state situation because of very high levels of vehicle ownership. The point to be noted is that most high-income countries have per capita incomes in excess of US$20 000 per year, whereas most less-motorized countries have per capita incomes less than US$10 000 per year. These less-motorized countries also constitute more than two-thirds of the world population. We can very safely assume that most less-motorized countries will not become highly motorized societies in the next two decades or so. Consequently, vulnerable road users will remain the main victims of road traffic injuries for some time to come. Therefore, in this paper we examine some of the specific issues regarding road traffic injuries in less-motorized countries with a special focus on vulnerable road users.

Burden of road traffic injuries

Recent estimates of national economic loss due to road traffic injuries show that these range from 1% to 2% of the gross domestic product (GDP) of nations around the world.[4] The estimates for less-motorized countries as a per cent of GDP are in general lower than those in high-income countries. We need to be careful in drawing conclusions from such numbers, as recent estimates for high-income countries are based on more detailed and comprehensive calculations including the willingness to pay, quality-adjusted life years and disability-adjusted

Table 1 Distribution of road traffic deaths and mortality rates by World Health Organization (WHO) Region and income group (high and low/middle), 1998 (Ref. 1)

	WHO Region									
	Africa	Americas		Eastern Mediterranean	Europe		South-East Asia	Western Pacific		World
Income group		HIC[a]	LMC[b]		HIC	LMC		HIC	LMC	
Total RTI[c] deaths (000)	170	49	126	72	66	107	336	25	220	1171
% of global RTI deaths	14.5	4.2	10.8	6.1	5.6	9.1	28.6	2.1	18.8	100
RTI deaths per 100 000	28.2	16.1	25.3	15.2	16.8	22.4	22.6	12.6	15.5	19.9
% of all deaths due to RTI	1.8	1.9	4	1.9	1.7	2	2.5	1.7	2.1	2.2

[a] High-income countries.

[b] Less-motorized countries.

[c] Road traffic injury.

Table 2 Percentage of road users killed in various modes of transport as a proportion of all fatalities

City, nation (year)	Pedestrians	Bicyclists	Motorized two wheelers	Motorized four wheelers	Others
Delhi, India (1994)[a]	42	14	27	12	5
Thailand (1987)[a]	47	6	36	12	–
Bandung, Indonesia (1990)[a]	33	7	42	15	3
Colombo, Sri Lanka (1991)[a]	38	8	34	14	6
Malaysia (1994)[a]	15	6	57	19	3
Japan (1992)[b]	27	10	20	42	1
The Netherlands (1990)[b]	10	22	12	55	–
Norway (1990)[b]	16	5	12	64	3
Australia (1990)[b]	18	4	11	65	2
USA (1995)[b]	13	2	5	79	1

[a] Less-motorized countries.

[b] High-income countries.

life years, etc. On the other hand, to the best of our knowledge, such concepts have not been used in making estimates in less-motorized countries.

Studies from less-motorized countries also report that road traffic injury patients can occupy 30–70% of orthopaedic beds in hospitals. Road traffic injuries are also a major cause of orthopaedic and mental disabilities. The experience of poor communities in coping with medical catastrophes is very different than that experienced by economically well off communities. The special problems faced by poor families can include the following:[5] inappropriate or absence of treatment leading to complications and longer treatment time; re-allocation of labour of family members and reduced productivity of whole family; permanent loss of job for the victim even if he/she survives; loss of land, personal savings, and household goods; poor health and educational attainment of surviving members; and dissolution or reconstitution of household.

None of the above issues are factored in the standard economic calculations done for estimating the cost of road crashes in poor societies. When someone in a poor family is injured and is bedridden at home or in hospital, the whole family gets involved in the care of the patient. This results in the re-allocation of labour of all family members—those on daily wages lose their income; children may not go to school; and older family members may spend less time in the care of children and infants. The household has to cope with the time and financial demands of the situation and this can have a permanent effect on the health of children and infants in the family. This can be the result of loss of income, less attention, worsening hygiene at home, etc.

Since a very large number of poor households depend on daily wages and temporary jobs, do not have health insurance, or the assistance of social welfare schemes, a serious injury can result in permanent reduction of income. In cases of prolonged treatment or death of the victim, the family may end up selling most of their assets and land and getting trapped into long-term indebtedness. Investment in treatment of a seriously ill family member stops only when all assets get sold.[6] A study from Thailand shows that 60% of involuntary land sales were to finance treatment of a family member. Death of a male head of household creates a household headed by a woman. Such families have to suffer serious social and economic hardships and this can have negative health effects on children.

It is clear that the outcome of a serious injury or death of a family member in poor communities has many long-term effects, socially, economically and psychologically, on all the other family members and the community. Many of these outcomes are permanent and soul destroying for individuals and possibly for the larger community. There is very little work done to understand these issues. Therefore, we must not stop at the calculation of losses in purely monetary terms. For poor communities, our methods do not even capture the economic losses in all their complexity. The effect of injury and death on the family structure, crushing of hopes and aspirations of future generations, and the psychology of the community are just not factored in. These issues will have to be taken much more

seriously in the future and not neglected just because they cannot be defined in monetary terms.

International trends in road traffic injury control

In the last three decades the incidence of traffic crash fatalities and injuries has been reduced significantly in the high-income countries. This has been possible because of a careful analysis and evaluation of the factors associated with crashes and implementation of policies resulting from the same. However, most of these policies are tailored to the specific situations and problems in those countries. The standards instituted for vehicles, roads and highway furniture are based on the traffic patterns and types of crashes that are more prevalent in those societies. On the other hand, almost no less-motorized country has been successful in reducing the number of lives lost and people injured due to road traffic crashes in the last two decades. This is a curious situation as all the less-motorized country societies have been seriously concerned with the significant loss of lives due to road crashes for more than a decade. One cannot attribute this failure to the forms of government, culture or religious practices obtaining in more than 100 less-motorized countries. Among these countries there is a great variation in size (populations can vary from less than a million to more than one billion), religions, cultural practices and forms of government. If these factors had a determining influence then there should have been a few less-motorized countries where road safety policies were successful. The fact that this has not happened means that there must be other reasons why the road safety situation in the less-motorized countries is less than desirable.

What needs to be understood is that some of the theoretical base of road traffic injury control countermeasures may have international applicability but many of the actual physical solutions may not. There is clearly a poverty of theory. For example, most road safety measures instituted in high-income countries have centred on the automobile and the automobile occupant. Road and intersection designs are based largely on car, bus, and truck movement. Motorcycles dominate the roads in less-motorized countries; along with human powered vehicles, pedestrians carrying loads, and locally designed vehicles. No traffic flow models and computer programmes are able to account for this mix. Even if all the solutions developed in high-income countries were put in place on the roads of less-motorized countries, the decrease in fatality rates would not be of the same magnitude as experienced in the high-income countries.

A good example of the above is the role of expressways in intercity travel. When an expressway is built through the countryside, it divides the landscape into separate zones. People from one side of the expressway cannot go to the other side of the expressway easily on foot or on a bicycle. In high-income countries this does not pose a serious problem as most people possess motorized transport. However, in less-motorized countries people of low income who need to interact with each other may populate the countryside on both sides of the expressway. They need to cross the expressway carrying or pulling heavy loads. In such a situation they do not like to go long distances to cross the expressway at designated over- or underpasses. They end up breaking the fences and cross the expressway at locations convenient to them. This makes the expressway much more hazardous for everyone concerned. The decision makers and international consultants come from a different stratum of society which is only concerned with increasing the flow of intercity motor traffic and which sees the villagers as impediments to 'progress'.

Like all other developments in science and technology, road safety measures in the high-income countries developed at certain historical junctures. They have an imprint of the prevailing socioeconomic situation embedded in them. When the high-income country policies and designs are transferred to societies that have much lower per capita incomes, then large parts of these policies and designs are not successful. However, the attempt at introducing these measures in less-motorized countries also sets up a demand for instituting systems and technologies that imitate those in high-income countries. Since this is not always possible at low levels of income, these projects either become status symbols without much functional value, or remain in place as demonstration projects. While a few small less-motorized countries can experience high growth rates for some periods, most of the other countries will continue to function as less-motorized countries for quite some time to come.

Low- and middle-income country issues

The traffic patterns in less-motorized countries are also much more complex than those in high-income countries.[7,8] The reasons for greater complexity in less-motorized country urban areas are: (1) a large proportion of low-income people living in shanty towns; (2) a high proportion of non-motorized and two-wheeler trips; (3) the presence of locally designed paratransit vehicles; (4) high density living and mixed land use; and (5) severe limitation of resources.[9] The composition of traffic and accident patterns in modern less-motorized countries are not only different from those prevailing today in the high-income countries, but they are also substantially different from those prevailing in the high-income countries at a comparable stage of development in the past. In the absence of relevant research and applicable knowledge, less-motorized countries will continue to have high injury and fatality rates, unacceptable pollution levels and inefficient transportation systems.

A proportion of the decrease in road traffic injuries in high-income countries is the result of the availability of cars which provide much greater safety to the occupants in crashes, and a very significant reduction in the presence of pedestrians and bicyclists on high-income country streets and highways. Recent estimates from the UK suggest that the number of trips per person on foot fell by 20% between 1985/86 and 1997/99. Such trends suggest that reduction in pedestrian, bicycle and motorized two-wheeler fatalities could be largely because of the reduction in exposure of these road users and less because the road environment has been made 'safer' for them. Mohan and Tiwari also show that in less-motorized countries buses and trucks are involved in a much greater proportion of crashes than in high-income countries, but relevant safety standards for these vehicles are lacking.[3] In particular, a strong case can be made for evolution of pedestrian friendly fronts for buses and trucks, but such issues are not given any priority at present.

Car design and safety standards are decided in the high-income countries with almost no input from the low-income

countries where there is very little expertise on these issues. Most automobiles are traded internationally these days and this has four effects:

Vehicles exported to less-motorized countries very often do not satisfy the existing safety standards prevalent in high-income countries. Therefore, it would make sense for such vehicles to conform to some minimum international standards.

Marketing of cars follows a very aggressive pattern in every country and has huge financial backup. This results in the neglect of public transport infrastructure and other policies that would benefit a majority of the population in less-motorized countries. The bus and rail sectors do not have as powerful international lobbies as the car and motorcycle industry. This obviously results in a higher rate of injuries, pollution levels and lack of mobility for the less well off.

Many less-motorized countries manufacture vehicles locally (three-wheeled scooter taxis, *tuk-tuks*, jeepneys, etc.) that are not used in high-income countries. These vehicles are generally used as taxis but have very little scientific input for their crashworthiness. Since they are not used in high-income countries there is little pressure to improve their design.

The above discussion shows why the replication of high-income country safety policies in less-motorized countries will not be as effective. However, we do have a body of knowledge available internationally, and we should build on this to improve the road safety situation in less-motorized countries.

Future directions

The priorities in road safety policies cannot be global in nature because of the differing patterns of traffic and road traffic injuries around the world. We analyse below the risk factors and the availability of known road safety countermeasures in the context of less-motorized country concerns.

Vehicle standards

Cars

Less-motorized countries could apply their own standards in addition to make vehicles more suitable for their specific traffic conditions. Some of these issues could include the possibility of making turn indicator lights more conspicuous and more easily visible to pedestrians, motorcyclists and bicyclists, pedestrian safety standards for small cars, and impact standards for bicycles and motorcycles with cars.

Country-specific motor vehicles

In many less-motorized countries there has been a growth of vehicles that have been designed locally and do not conform to international safety standards. There are a wide variety of these vehicles but they can be broadly classified into three groups: (1) three-wheeled vehicles, (2) four-wheeled vehicles, and (3) trailers pulled by tractors or other similar vehicles. For these country specific motor vehicles, construction methods, materials used and economic considerations will not allow for the imposition of international car safety standards. It will also not be very easy to design efficient crash attenuating frontal structures for them. However, design changes can be attempted in the following areas: (1) improvements in rollover characteristics of the vehicles; (2) body designs which restrict passenger ejection from vehicles; (3) removal of all pointed and sharp objects (e.g. bolts, rivets, etc.) from the inside surfaces of the cabin; (4) provision of impact absorbing padding in areas where passengers are likely to hit the vehicle surfaces during a crash; (5) improvements in the conspicuousness of the vehicles and lighting arrangements. These types of changes will not require heavy investment in research and can be implemented with local initiative. A crash modelling exercise to improve the safety of the three-wheeled scooter taxi has been attempted in India, which indicates that this is possible.[10] Co-operation and involvement of biomechanics experts from around the world as short-term consultants can make a significant contribution in making these vehicles much safer.

Design of less aggressive fronts for buses and trucks

During the past decade, the pedestrian safety problem for impacts with cars in high-income countries has been studied using mathematical models, epidemiological studies, and impact tests with mechanical dummies and biological materials. Various recommendations for the front structure design of vehicles (mainly cars) have been made. However, the fronts of buses and trucks have not been designed to be 'forgiving' in impacts with vulnerable road users. Preliminary studies show that it is possible to design fronts of buses such that impact forces in a bus pedestrian impact can be reduced significantly.[11] This is done by making the front of the bus 'softer'. A similar study has also been done for fronts of trucks.[12]

The work cited above indicates that standards will have to be set for crash compatibility between all kinds of vehicles, especially with reference to bumper height. In general, bumper heights have to be lowered for buses and trucks, front surfaces of trucks and buses have to be almost vertical with no hard objects below adult head height, there needs to be an offset between the bumper and grill surface, and space provided behind the grill for impact attenuating properties. Much more work needs to be done to optimize padding properties for impacts at different velocities and for different age groups of pedestrians. Once these material properties are determined, then designs will have to be developed for retrofitting old vehicles. Standards will have also to be developed for crashworthiness of buses and trucks in impacts with pedestrians and bicyclists.

Bicycles and motorcycles

Since bicycles and motorcycles constitute a significant proportion of vehicles in most less-motorized countries, and their riders a large proportion of road crash victims, we need to invest much more in research for the safety of these road users. Areas which need continued attention are conspicuousness of these vehicles, design changes to make them more stable, and work on making helmets lighter and more comfortable at high ambient temperatures.

Road factors

Blackspots and quality of roads

Blackspot analysis and treatment is given maximum importance in all international consultancy projects in less-motorized countries. This is in spite of the fact that there is no consensus on the actual effectiveness of blackspot treatment in high-income countries. A recent review concludes that '... the results of before-and-after studies of road accident blackspot treatment depend strongly on which of the confounding factors studied one controlled for. Large reductions in the number of accidents,

generally in the order of 50–90%, were found in studies not controlling for any confounding factors ... Studies simultaneously controlling for general trends, regression to the mean and accident migration did not find any statistically reliable effect of blackspot treatment on the number of accidents.'[13]

A study of blackspot treatment in Malaysia showed that some sites had a reduction in accidents whereas the other showed a 'substantial increase' in accidents.[14] A project undertaken in Korea on blackspot treatment reported that 53% of the sites showed a decrease in accident rates and that installation of speed humps was found to be most effective.[15] Another study done in Indonesia reports that blackspot treatment at three locations resulted in a decrease in accidents.[16] However, they also mention that there could have been some underreporting of accidents in the post-treatment period. None of these studies controlled for all the confounding factors considered important by Elvik. In many cases where blackspots were identified as those locations where pedestrians get hit while crossing a road, a fence was installed to stop such road crossings. The 'after' study obviously showed much improvement since pedestrians were removed from that location. Such changes cannot be considered as 'improvements' because no analysis was made of the different locations where the pedestrians migrated. In addition, the inconvenience caused to pedestrians was not taken into account. Though there is no conclusive evidence regarding effectiveness of blackspot treatment from less-motorized countries, all policy documents list this countermeasure as the most effective.

The quality of roads issue has to be addressed in terms of providing better facilities to non-motorized road users, developing suitable designs for heterogeneous traffic and those for slowing traffic in residential areas. Even on national highways, the majority of people killed are pedestrians, bicyclists, two-wheelers, and there are also crashes with tractors/bullock carts in many less-motorized countries. Therefore, unless these issues are addressed and methods developed for area wide safety improvements we will not be gaining much by concentrating on blackspot treatment.

Traffic separation

Pedestrians and non-motorized vehicles are forced to share road space with motor vehicles because there is either no separate space earmarked for them or the designated space is inconvenient to use. Many crashes take place because pedestrians and bicyclists are hit by vehicles that may not have noticed them, especially at night. A study done in Delhi indicates that when bicycles are not segregated on arterial roads one lane operates as a *de facto* bicycle lane.[17] This means that when bicycle traffic on a three-lane road is not segregated, only two lanes remain available for motor vehicle traffic. Therefore, by segregating traffic we not only make the roadway safer for vulnerable road users, we may also improve traffic flow rates in urban areas.

Intersection designs for roads that have segregated non-motorized vehicle traffic is an area where we need much more data from real world experience. Non-motorized vehicle riders find it very difficult to make turns at intersections without coming into conflict with motor vehicles. Traffic light cycles and guidelines for traffic control at intersections where non-motorized vehicles have a presence is one area where much more innovative work is necessary. New roundabout designs hold a great deal of promise for improving safety both on urban and rural roads.

Speed control

Speed control measures have particular relevance for less-motorized countries. Use of restraint systems by vehicle occupants are not likely to make a large dent in the overall road traffic injury fatality rates because car occupants constitute less than 10–20% of the fatalities. Speed limiting devices on vehicles, limits on engine power, and traffic calming measures hold the greatest promise in less-motorized countries. There is an urgent need for research on traffic calming measures for roads with a high percentage of motorcycles and safer design of intercity roads with non-motorized traffic. The latter issue is particularly important because motorized traffic is increasing in less-motorized countries and such countries will not be able to afford limited access motorways for intercity travel. Environmental, energy conservation and financial concerns are also exerting a push toward downsizing of vehicles in less-motorized countries. There are severe physical limits to safer design of very small cars. Lower speed limits would be necessary wherever these smaller vehicles are introduced.

Speed control appears to be one of the most effective and promising ways to reduce injuries and deaths in road traffic crashes in the next decade.[18–22] In less-motorized countries this holds great promise because a majority of those killed are road users other than car occupants. The effects of lower speeds on safety of vulnerable road users would be more significant than safer vehicle designs. Any money spent on research to develop vehicle and road designs that control speeds automatically would be money well spent.

Vehicle speeds in urban areas can be controlled by adopting traffic calming measures in urban areas. In the past few years many guidelines for traffic calming have been published in the high-income countries.[23,24] Most of the ideas included in these guidelines apply to less-motorized countries also. However, these designs are most suitable to traffic situations where cars constitute a vast proportion of road traffic. These ideas have to be modified for traffic situations where non-motorized vehicles and motorized two-wheelers may be a significant proportion of road traffic. For example, chicanes, road closures, entry treatment and traffic throttles may slow down cars but may not have the same effect on motorized two-wheelers. On the other hand, some of these obstructions may make it difficult for bicycle *rickshaws* and hand-pulled carts to operate. Therefore, a fresh look has to be given for designing traffic calming measures for less-motorized countries. This is particularly relevant for intercity roads passing through the centre of small towns.

Intercity highways

The incidence of vulnerable road user fatalities on intercity highways is significant in less-motorized countries. This is partly because of the high density of low-income habitations along many stretches of the highway. For such situations, we need to develop standards for provision of convenient tunnels and other crossing facilities in terms of designs and frequencies. In addition there would also be a need for provision of 'service roads' along the highways for short distance trips for local traffic. At present there are no such guidelines to help the local designer and planner.

Conclusions

The patterns of road traffic and road traffic injuries are very different in high-income countries compared to those in less-motorized countries. High-income countries have not experienced the situation obtained in less-motorized countries in the past. Vulnerable road user injuries and involvement of buses and trucks dominate the scene in many less-motorized countries. Since very little work has been done to develop vulnerable road user-friendly highway and urban street designs, all construction work sponsored by international agencies in less-motorized countries follows international designs or some scaled down version of the same. These designs produce inefficiencies and make the lives of local people more difficult by introducing fast transport without facilities for local needs.

Therefore, transportation planning, exposure control, intelligent separation of non-motorized traffic on major roads, and traffic calming are likely to play a much more important role in less-motorized countries. All vehicle and infrastructure designs need to be much more vulnerable road user friendly. Designs and policies for such interventions which are likely to succeed are not entirely clear or available. Research programmes and demonstration projects need to be funded and started immediately. The above will not be possible unless methods are devised to educate national policy makers and executives in multilateral agencies like the Word Bank about modern methods of road traffic injury control. Most of them are still operating on principles that were discredited over three decades ago.

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