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TRAFFIC SAFETY AND THIRTY YEARS OF BIOMECHANICS RESEARCH: A PERSONAL ADVENTURE

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ABSTRACT

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 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 crashworthiness of vehicles, transportation planning, exposure control, intelligent separation of non-motorised traffic on major roads, and traffic calming are likely to play a much more important role.

KEYWORDS

Biomechanics, Road Safety, Epidemiology, Injuries, Developing Countries

I DROVE INTO ANN ARBOR, MICHIGAN, on a cold wintry morning in January 1971. I was on my way to start a new career in biomedical engineering after a few years of dabbling with mechanical and aerospace engineering. All I knew was that I had admission to the graduate programme in Bioengineering at the University of Michigan and financial aid might be available after discussion with the appropriate faculty members. The secretary in the office looked at my papers and suggested that I talk to Professor James H. McElhaney since I wanted to work in biomechanics. She dialled a number and told me he was on the line. I introduced myself and explained that I had admission to graduate school and was looking for a research assistantship. He asked me if I owned a car since his laboratory was away from the main campus. When I said yes, he asked me "what do you drive?" "Triumph Spitfire" I said. "Come over right away" was his response.

I drove to the Highway Safety Research Institute (now University of Michigan Transport Research Institute) and met Professor McElhaney. Fifteen minutes later I was a research assistant in the biomechanics department and was put to work on head impacts with Richard Stalnaker. This was a completely unexpected development, as I had primed myself to work on aids for the disabled with orthopaedic surgeons. I knew nothing about human tolerance to impact.

The next four years were a hectic learning experience. F. Gaynor Evans, J. H. McElhaney, Richard Stalnaker, John Melvin, Don B. Chaffin and Richard Snyder taught me everything I know about head, chest and extremity impact (Stalnaker and Mohan, 1974; Stalnaker and Mohan, 1975; Melvin, 1975) soft and hard tissue mechanics (Melvin, Mohan and Stalnaker, 1976; Mohan and Melvin 1982), seat belts and child seats, cadaver testing, experiment design and ergonomics (Mohan and Kim, 1973). . Those were heady days. It was also fun being involved in the process that decided USDOT FMVSS standards. Some of those standards remain unchanged twenty-five years later.

In late 1975 I was wrapping up my work on the dynamic properties of thoracic aortic tissue when I got a phone call from Brian O'Neill of the Insurance Institute of Highway Safety (IIHS) in

Washington D.C. saying that they were looking for someone with a background in biomechanics of human injury. Two months and two very uncomfortable interviews later, with William J. Haddon, Jr., President IIHS, I found myself working at IIHS. The next three years saw me working with Richard Snyder and Bruce Bowman on free falls (Mohan et al, 1979) with Murray Mackay on pedestrian impacts (Ashton and Mackay, 1979), with Herbert Kingsbury on helmet properties (Kingsbury, Mohan and Herrick, 1979), with Larry Schneider and Bruce Bowman on infants in laps of front seat occupants and motorcycle impacts (Mohan and Schneider, 1979; Bowman, Schneider, Rohr, and Mohan, 1981), and with John Melvin on head impact with baseballs and child restraints (Jones and Mohan, 1984).

One of the most challenging and exciting projects we did in 1976 was the analysis of the effectiveness of airbags in real world crashes (Mohan, Zador, O'Neill and Ginsburg, 1976). By 1976 over a hundred airbag equipped General Motors cars had crashed and their details were available with NHTSA. We compared the injuries sustained by front seat occupants of these cars involved in frontal crashes with passengers (belt restrained and unrestrained) in similar cars matched for crash severity. Our results, which were very controversial at the time, showed the superiority of airbags over belts. It took another fifteen years or so for airbags to be accepted as safety equipment in cars. It is a source of some satisfaction that our estimates of twenty-five years ago were not very much off the mark compared to data available today.

Involvement in this study was a life learning experience for me. Spurred on by Haddon we worked with a missionary zeal. Haddon also took it upon himself to "educate" me. He would call me into his office, give tutorials on the principles of injury control, and quiz me on chapters from his book *Accident Research* (Haddon, Suchman and Klein, 1964).). On afternoons when he was in a more pensive mood, he would discuss the American Constitution, ways the Senate and the Congress worked, and the complexities of rule making. Many of those interchanges were unpleasant, heated and irritating. But they left an impact. I was no more just a bioengineer, but began to understand that the traffic crash was part and parcel of the wider socio-economic system of a society.

When I moved to the Indian Institute of Technology in 1979 I thought I was well equipped to change the road safety situation in India! Twenty one years later I can quite humbly admit that all my training and efforts have had little impact on actual policies and road traffic crash rates in India. In 1980 there were approximately 28,000 road traffic fatalities in India. Last year there were more than 80,000. The experience has been quite sobering. It has been almost impossible to put in place most of the policies that we know would be effective in reducing road traffic injuries and fatalities. I list below some of the successes:

1. Enactment of mandatory helmet laws for motorised two-wheeler riders (MTW). However, the law is not being enforced in all states of the country because of resistance from small vociferous groups.
2. Seatbelt equipped cars along with other safety features like laminated windshields, etc., and enactment of seatbelt use laws. The use law is not being enforced in any state.
3. Law against use of cell phones in moving vehicles.
4. Fronts and backs of trucks and buses and three-wheeled scooter taxis are painted yellow in some states to make them more conspicuous. The effectiveness of this measure has not been evaluated.

However, these are not enough to make much of dent in the crash and death statistics in India. The situation is not very different in most other low or middle-income countries (LMIC). This has forced us to review the situation afresh. I discuss below the issues involved.

THE INTERNATIONAL SITUATION

Table 1 shows estimates of the distribution of road traffic deaths and mortality rates, by WHO Region and income group (Krug. 1999). These statistics are based on the estimates made by Murray and Lopez (1996) for the WHO and World Bank. According to these estimates 1,170,694 persons died of road traffic injury (RTI) world-wide in 1998. Deaths from RTI were the 10th leading cause of death among all ages, accounting for 2.2% of the global mortality. Males sustained 73.0% of RTI fatalities and the mortality rates were 28.8 per 100,000 population for males and 10.8 for females. Among young adults (15-44 years) RTIs were the 2nd leading cause of death (21.7 deaths per 100,000) and the

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

COUNTRY	AFR	AMR		EMR	EUR		SEAR	WPR		WORLD
INCOME GROUP		High	Low/ middle		High	Low/ middle		High	Low/ middle	
Total RTI 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

Source: Krug, 1999

3rd 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 RTIs expected to move from ninth position in 1990 to third position in 2020. This is mainly due to increasing incidence of road traffic crashes LMICs. In most LMICs, deaths due to RTIs are among the 2-6 leading causes of death in the age groups within 5 - 60 years.

In the last three decades the incidence of traffic crash fatalities and injuries has been reduced significantly in the high income countries (HIC). 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 LMIC 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 LMIC 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 one hundred LMICs. 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 LMICs 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 LMICs is less than desirable.

What needs to be understood is that some of the theoretical base of RTI 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 HICs have centred around the automobile and the automobile occupant. Road and intersection designs are based largely on car, bus, and truck movement. The roads in LMICs are dominated by motorcycles, 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 HICs were put in place on the roads of LMICs, the decrease in fatality rates would not be of the same magnitude as experienced in the HICs.

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 HICs this does not pose as serious problem as most people possess motorised transport. However, in LMICs the countryside may be heavily populated on both sides of the expressway by people of low income who need to interact with each other. 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 under-passes. 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 HICs developed at certain historical junctures. They have an imprint of the prevailing socio-economic situation embedded in them. When the HIC 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 LMICs also sets up a demand for instituting systems and technologies that imitate those in HICs. 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 LMICs can experience high growth rates for some periods, most of the other countries will continue to function as LMICs for quite some time to come.

LOW AND MIDDLE INCOME COUNTRY ISSUES

Table 2 shows that in LMICs the vulnerable road users - pedestrians, bicyclists and motorised two-wheeler riders, sustain a vast majority of the fatalities and injuries due to RTIs (Mohan and Tiwari, 2000). These countries are also experiencing higher rates of motorisation with increase in incomes as compared to HICs 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 HICs have per capita incomes in excess of USD 20,000 per year. Whereas, most LMICs have per capita incomes less than USD 10,000 per year. These LMICs also constitute more than two-thirds of the world population. Therefore, we can very safely assume that most LMICs will not become highly motorised societies in the next two decades or so. Consequently, vulnerable road users will remain the main victims of RTIs for some time to come.

The traffic patterns in LMICs are also much more complex than those in HICs (Tiwari, 1996; Mohan and Tiwari, 1998). The reasons for greater complexity in LMC urban areas are: (a) a large proportion of low income people living in shanty towns; (b) high share of non-motorised and two-wheeler trips; (c) presence of locally designed para-transit vehicles; (d) high density living and mixed land use; and (e) severe limitation of resources (Tiwari, 1999). The composition of traffic and accident patterns in modern LMICs are not only different from those prevailing today in the HICs, but they are also substantially different from those prevailing in the HICs at a comparable stage of

Table 2. Proportion of road users killed in various modes of transport as a percent of all fatalities.

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

\+ LMICs # HICs

development in the past. In the absence of relevant research and applicable knowledge, LMICs will continue to have high injury and fatality rates, unacceptable pollution levels and inefficient transportation systems.

A very large proportion of the decrease in RTIs in HICs is the result of the availability of cars which provide much greater safety to the occupants in crashes, and the result of a very significant reduction of the presence of pedestrians and bicylists on HIC streets and highways. Recent estimates from UK suggest that the number of trips per person on foot fell by 20% between 1985/86 and 1997/99 (*Walking in Towns and Cities*, 2001). Such trends suggest that reduction in pedestrian, bicycle and MTW 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 (1998) also show that in LMICs buses and trucks are involved in a much greater proportion of crashes than in HICs, but relevant safety standards for these vehicles are lacking. 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 HICs with almost no input from the HMICs where there is very little expertise on these issues. Most automobiles are traded internationally these days and this has four effects:

- Vehicles exported to LMICs very often do not satisfy the existing safety standards prevalent in HICs. This amounts to cross-border transmission of a vector (vehicle) which is responsible for the agent (energy) causing RTI. Therefore, it would make sense for such vehicles to conform to some minimum international standards.
- Because very little road safety research is done in LMICs and multinational corporations dominate vehicle design, the concerns of LMICs do not get incorporated in vehicle safety standards. Some of these issues would 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 design standards for pedestrians, bicycles and motorcycles impacts with buses and trucks.
- Marketing of cars follows a very aggressive pattern in every country and has a huge financial backup. This results in the neglect of public transport infrastructure and other policies which would benefit a majority of the population in LMICs. 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 LMICs manufacture vehicles locally (three-wheeled scooter taxis, *tuk-tuks*, jeepneys, etc) which are not used in HICs. These vehicles are generally used as taxis but have very little scientific input for their crashworthiness. Since they are not used in LICs there is little pressure to improve their designs.

The above discussion shows why it the replication of HIC safety policies in LMICs 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 LMICs.

INTERNATIONAL KNOWLEDGE BASE FOR CONTROL OF ROAD TRAFFIC INJURIES

Road safety research in the HICs has involved a large number of very well trained professionals from a variety of disciplines over the past four decades. Some very innovative work has resulted in a theoretical understanding of “accidents” as a part of a complex interaction of sociological, psychological, physical and technological phenomena. The results could be exchanged and solutions transferred from one HIC to another because the conditions in these countries were roughly similar. This understanding of injuries and accidents has helped us design safer vehicles, roads and traffic management systems. A similar effort at research, development and innovation is needed in LMICs. A much larger group of committed professionals needs to be involved in this work for new ideas to emerge.

International co-operation in the area of road safety should focus on exchange of scientific principles, experiences of successes and failures, and in scientific training of a large number of professionals in the LMICs. The scientific principles of road safety can be exchanged for the benefit of everyone. However, the priorities in road safety policies cannot be global in nature because of the differing patterns of traffic and RTIs around the world. We analyse below the risk factors and the availability of known road safety countermeasures in the context of LMIC concerns.

RISK FACTORS. The following risk factors have been adapted from a summary prepared by Norton, Hyder and Peden (2001) for the WHO:

Individual risk factors : male gender , younger and older age groups , lower socio-economic groups, alcohol, non-wearing of seat belts, non-wearing of motorcycle and bicycle helmets non-conspicuity of bicycles and motorcycles.

Vehicle factors : absence of appropriate vehicle safety standards

Environmental factors : high traffic speed, inappropriate road and infrastructure design,

Elvik and Amundsen (2000) have also done an analysis of the potential for improving safety, the cost effectiveness and cost benefit ratios of road safety measures in Sweden. Since they have evaluated all possible measures in use in Sweden, we have used the results of this analysis to highlight our concerns. Table 3 has been adapted from Elvik and Amundsen (2000). The items in bold were not there in the original table and have been added to illustrate the additional concerns of LMICs. Items with a questionmark at the end are those found effective in Sweden, but for which designs/policies may have to modified in LMICs.

RESULTS OF SYSTEMATIC REVIEWS

Individual factors, legislation and enforcement:

(1) Most attempts at enforcing road traffic legislation will not have any lasting effects, either on road-user behaviour or on accidents; imposing stricter penalties (in the form of higher fines or longer prison sentences) will not affect road-user behaviour; imposing stricter penalties will reduce the level of enforcement (Bjornskau, and Elvik, 1992).

(2) Increased normal, stationary speed enforcement is in most cases cost-effective. Automatic speed enforcement seems to be even more efficient. There is no evidence proving mobile traffic enforcement with patrol cars is cost-effective (Carlsson, 1997).

(3) The *only* effective way to get most motorists to use safety belts is with good laws requiring their use. When laws are in place, education and/or advertising can be used to inform the public about the laws and their enforcement (O'Neill, 2001a).

(4) In general the deterrent effect of a law is determined in part by the severity and swiftness of the penalty for disobeying it, but a key factor is the perceived likelihood of being detected and sanctioned. Laws against drinking and driving are effective when combined with active enforcement and support of the community.

Individual factors, campaigns and education:

(1) Road safety campaigns are often aimed to improve road user behaviour by increasing the knowledge and by changing the attitudes. There is no clearly proved relationship between knowledge and attitudes on one hand and behaviour on the other hand (OECD, 1994). Most highway safety educational programs do not work. They do not reduce motor vehicle crash deaths and injuries. Only a few programs have ever been shown to work, and contrary to the view that education cannot do any harm some programs have been shown to make matters worse. Education programs by themselves usually are insufficient to change behaviour. They may increase knowledge, but increased knowledge rarely results in appropriate behaviour change (O'Neill, 2001b). There is, however, no reason just to waste money on general campaigns. Campaigns should be used to put important questions on the agenda, and campaigns aimed at changing road user behaviour should be focused on clear defined behaviours and should by preference fortify other measures such as new legislation and/or police enforcement.

(2) The effects of campaigns using tangible incentives (rewards) to promote safety belt usage have been evaluated by means of a meta-analytic approach. The results (weighted mean effect) show a mean short-term increase in use rates of 12.0 percentage points; the mean long-term effect was 9.6 percentage points (Hagenzieker, Bijleveld, and Davidse, 1997). Research first from Australia, later many European countries, then Canadian provinces, and finally some U.S. states clearly shows that the *only* effective way to get most motorists to use safety belts is with good laws requiring their use. When laws are in place, education and/or advertising can be used to inform the public about the laws and their enforcement

(3) Licensing : Studies show that driver education may be necessary for beginners to learn the elementary skills for obtaining a license, but compulsory training in schools leads to early licensing.

Table 3. Measures which have the potential for improving safety (Adapted from Elvik and Amundsen, 2000). Items in bold letters have been added for their relevance in LMICs, and items with a (?) at the end may need more research and modification for effectiveness in LMICs.

GENERAL PURPOSE POLICY INSTRUMENTS	VEHICLE DESIGN AND PROTECTIVE DEVICES
Road safety audits Motor vehicle taxation Automatic accident warning and location (GPS) ROAD DESIGN AND ROAD FURNITURE Grade separated pedestrian crossing facilities (?) Motorways (?) Reconstructing motor traffic roads to motorways Bypasses (?) Roundabouts (?) Staggered junctions Interchanges Roadside safety treatment (?) Reconstructing roads to new 13m design General rehabilitation of roads Road lighting Guard rails along embankments Median guard rails on wide roads	Roadside inspection of trucks High mounted stop lamps Self leveling head lamps on cars Requiring pedestrians and cyclists to wear reflective devices Mandatory use of bicycle helmets Seat belt reminders in cars Ignition interlock for seat belts Air bags (continued diffusion) Intelligent cruise control Intelligent speed adaptation system Improving rear and side under run guard rails Front impact protection device on trucks Crash data recorders for cars New safety standard for front and bumper on cars **VRU friendly bus and truck fronts?** **Crashworthiness of LMIC specific vehicles?**
Game fences Curve treatment **Design of highways for mixed traffic?** **Guidelines for provision of crossings for local traffic?** **Provision of services for non motorised traffic?**	DRIVER TRAINING Compulsory training of problem drivers (3) Defensive driving training for truck and bus drivers Reforming basic driver training
ROAD MAINTENANCE	PUBLIC EDUCATION
Improving winter **and rainy season (?)** maintenance of roads **Low cost maintenance methods (?)**	**Education of policy makers** **Education of professionals** **Education of public in support of other measures**
TRAFFIC CONTROL	POLICE ENFORCEMENT
Redesigning roads to 30 km/h standard Redesigning roads to 50/30 km/h standard Redesigning roads to walking speed standard Stop signs at junctions - four way stop Traffic signals at junctions Seasonal speed limits (?) Optimal speed limits (?) Vision zero speed limits (?) Upgrading pedestrian crossings (?) Bicycle lanes and advanced stop lines (?) Feedback signs	Speed enforcement (conventional techniques) Random breath testing (drinking and driving) Seat belt enforcement Speed cameras (automatic enforcement) Red light cameras (automatic enforcement) Ignition interlock device for alcohol Vehicle impoundment for unlicensed driving **Effective policing methods in LMIC ?**

There is no evidence that such schemes result in reduction in road crash rates. On the other hand they may lead to increased road crash rates (Williams and O'Neill, 1974; Vernick, et al, 1999; Mayhew and Simpson, 1996; Lund and Williams, 1985). While there may be a need to train professional drivers in the use of heavy vehicles, there is no evidence that formal driver education should be compulsory in schools and colleges.

(4) Helmet use reduces bicycle-related head and facial injuries for bicyclists of all ages involved in all types of crashes including those involving motor vehicles (Thompson and Rivara, 2001). Similar results have been confirmed for motorcyclists.

Policing methods and enforcement techniques have to be optimised for LMICs to be effective at much lower expenditure levels. There are no systematic studies evaluating different techniques followed around the world. Research needs to be done on effectiveness of professional driver education, driver licensing methods and control of problem drivers in LMIC settings.

Vehicle factors: Vehicles conforming to EU or USA crashworthiness standards provide significant safety benefits to occupants and the effectiveness of the following measures has been evaluated:

(1) Use of seat belts and airbag equipped cars can reduce car occupant fatalities by over 30% (Parkin, Murray and Framton, 1993; O'Neill and Lund, 1993). It is estimated that air bag deployment reduced mortality 63%, while lap-shoulder belt use reduced mortality 72%, and combined air bag and seat belt use reduced mortality by more than 80% (Crandall, Olson and Sklar, 2001).

(2) High mounted rear brake lights reduce the incidence of rear end crashes (ETSC, 1993).

(3) A meta-analysis of 17 studies that have evaluated the effects on traffic safety of using daytime running lights on cars shows that such use reduces the number of multi-party daytime accidents by about 10-15% for cars using daytime running lights (Elvik, 1996). Similar results have been confirmed for use of daytime running lights by motorcyclists (Radin, Mackay and Hills, 1996).

However, not enough work has been done to make vehicles safer in impacts with vulnerable road users, and on vehicles specific to LMICs.

Environmental factors:

(1) The road environment and infrastructure must be adapted to the limitations of the road user (Van Vliet and Schermers, 2000).

(2) Traffic calming techniques, use of roundabouts and provision of bicycle facilities in urban areas provide significant safety benefits (elvik, 2001; Hyden and Varhelyi, 2000).

(3) Limited access highways with appropriate shoulder and median designs provide significant safety benefits on long distance through roads (Elvik, 1995; Ogden, 1997).

A great deal of additional work needs to be done for rural and urban road and infrastructure design suitable for mixed traffic to make the environment safer for vulnerable road users. Some of these issues are highlighted in Table 3.

Pre-hospital care :

A recent Cochrane Review (Bunn etal, 2001) has concluded that:

(1) There is no evidence from randomised controlled trials to support the use of early or large volume intravenous fluid administration in uncontrolled haemorrhage. There is uncertainty about the effectiveness of fluid resuscitation in-patients with bleeding

(2) The effect of pre-hospital spinal immobilisation on mortality, neurological injury, spinal stability and adverse effects in trauma patients therefore remains uncertain. Because airway obstruction is a major cause of preventable death in trauma patients and spinal immobilisation, particularly of the cervical spine, can contribute to airway compromise, the possibility that immobilisation may increase mortality and morbidity cannot be excluded.

(3) In the absence of evidence of the effectiveness of advanced life support training for ambulance crews, strong argument could be made that it should not be promoted outside the context of a properly concealed and otherwise rigorously conducted randomised controlled trial.

None of the interventions examined have been shown to be effective and for pre-hospital fluid administration and cervical spine immobilisation in particular, the potential for harm cannot be excluded. If such widely used interventions increased the risk of poor outcomes by just a few percent, because many thousand of patients receive these interventions, they could be responsible for thousands of extra deaths. Similarly, if they could be shown to reduce the risk of poor outcome by a few percent then this would protect thousands from death or disability. Before we export expensive pre-hopital care systems to LMIC locations, it is necessary that their effectiveness is established.

BIOMECHANICS

Biomechanics and ergonomics research has played a critical role in designing safer cars, equipment and road infrastructure. Much of this knowledge is international in nature with minor variations due to differences in body size across communities and differences in tissue properties due to changes in nutritional levels. Once we know what these differences are, it is possible that they can be accommodated within the normal anthropometric variation of human beings.

A more serious issue, which the biomechanics community has to deal with, is the relative stagnation in theoretical research in human tolerance to injury. Most of the standards and injury criteria we are using today were developed almost twenty-five years ago. This is particularly true for minor and moderate injuries. We have not advanced much in understanding mechanisms of pain. Theoretical work in these areas needs to be taken up on a much wider scale and international co-operation may be of great help in giving the necessary thrust.

ROLE OF INTERNATIONAL AGENCIES, CONSULTANTS AND CORPORATIONS

As outlined above, the pattern of traffic in LMICs a very new phenomenon - high two wheeler ownership, high pedestrian and bicycle presence, presence of high velocity vehicles with slower means of transport, presence of indigenously designed vehicles like *tuk-tuks, becaks, jeepneys* and three-wheeled scooter taxis. This has little precedence in HICs and therefore international consultants do not possess adequate insights, and to make matters worse, not enough expertise is available locally. Therefore, the market mechanism alone is unable to provide adequate solutions.

International organisations like the World Bank (WB), Asian Development Bank (ADB), and the WHO have initiated some activity for control of RTIs. However, this activity is still at very sub-critical levels. The priorities identified by WB and ADB are controversial and many professionals have expressed their unhappiness at the policies not being based on a scientific understanding of the problem or on data based analysis. The WB in association with the International Red Cross and industrial groups has launched the Global Road Safety Partnership (GRSP). This initiative is also very small and suffers from the same criticisms as levelled against the WB and ADB:

"*As part of the World Bank's Global Road Safety Partnership initiative, a web page (GRSProadsafety.org) disseminates "good practice" for road safety. This site includes a list that "focuses on the key issues that you need to know about ensuring greater safety in transport." Included is the following statement about driver training and testing. 'With road user error contributing to the vast majority of road crashes, the development of safe drivers, skilled in defensive driving techniques, should be the primary objective of any road safety program. Driving examiners in developing countries are rarely given special training and driving tests are an inadequate test of ability to drive safely in traffic on real roads.' This statement and others in the same document simply are wrong. The World Bank is choosing to ignore science when it promotes driver training as a "primary" countermeasure."* (O'Neill, 2001b)

A study published by the Global Traffic safety Trust comes to the conclusion that HIC governments have very few programmes to attend to the RTI problem in LMICs. Almost no bilateral aid agreement between HICs and HMICs includes road safety as a thrust area (GTST, 1998). Commercial interests (car companies, oil companies, road builders) limit their activities to propaganda campaigns, which have been shown to be of little benefit. The leading players (international) at present are the World Bank, WHO, ADB, a few car and oil companies (eg Volvo, Ford, Honda, Shell). The World Bank is trying to include road safety audits as a part of its road construction loans. But this activity is still very weak.

International institutions would be much more effective in promoting road safety around the world if they made governments and professionals aware of the evidence based countermeasures and of policies which are not likely to work. Since a great deal of work has to be done to evolve LMIC specific designs and highway safety policies, international agencies and multinational corporations could play a catalytic role in funding research and pilot projects in these locations.

CONCLUSIONS

The patterns of road traffic and road traffic injuries are very different in HICs as compared to those in LMICs. The situation obtaining in LMICs has not been experienced in the past by HICs. Vulnerable road user injuries and involvement of buses and trucks dominate the scene in many LMICs. Since very little work has been done to develop VRU friendly highway and urban street designs, all construction work sponsored by international agencies follows international designs or some scaled down version of the same in HMICs. 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-motorised traffic on major roads, and traffic calming are likely to play a much more important role in LMICs. All vehicle and infrastructure designs need to be much more VRU 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 RTC control. Most of them are still operating on principles which were discredited over three decades ago.

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