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The Future of Traffic Safety and Sustainable Transportation

Murray Mackay

INDIAN INSTITUTE OF TECHNOLOGY DELHI

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Murray Mackay
Emeritus Professor, University of Birmingham
United Kingdom

1. Introduction

Historically, personal mobility has been a basic human aspiration after the needs for security, shelter and food have been met. For millennia the speed of travel for the human race was limited to the speed of a galloping horse, some 40 - 50 km/hr. Then, some 200 years ago, with the invention of the steam engine and thus the railways, people, collectively, could move over long distances at unheard of speeds of 100 km/hr or more. A further evolutionary step occurred just over 100 years ago with the invention of the horseless carriage, and the car was born. Mass production techniques in North America and Europe lead to individual, personal mobility which has literally changed the face of the earth.

The motor car brings many gifts. Indeed the World Bank, as a matter of policy, defines development as being synonymous with a highway network. The American writer Frederick Lewis Allen has noted:

"The automobile has altered our landscape, dominated our cities, changed our social interactions, the shape of family life, our fashions, shopping habits, slang, and the places and positions in which we make love."

But along with the pleasures of individual, comfortable, private, powered transport come many questions, exemplified by the comment of an anthropologist, Professor Hooton of Harvard, who said:

"The once erectly striding biped abandons human locomotion and whizzes through the landscape, crouched over wheels and levers worked by his still prehensile hands and his flat vestigial feet, less useful for this purpose than those of his simian ancestors. He breathes a mixture of gasoline fumes and carbon monoxide and reeks of evolutionary decay."

In the industrialised countries motorisation occurred over a period of around 50 to 80 years. In India the same phenomenon is occurring in a much shorter period of time. One of the major side effects of motorisation is death and injury on a scale which, for a number of countries, has dwarfed all but the most global of wars or natural disasters.

In this paper I seek to outline the appropriate technologies and policies which may help India tackle the increasing burden of road traffic injuries. All of us can learn from the experiences and research over the last hundred years of motorisation. I also want to discuss how to create different and appropriate solutions for a growing country in a period when demands for energy and climate change and the consequences of carbon emissions are becoming obvious to everyone.

My main concern is traffic safety, and how it must move up the list of priorities within a sustainable transport system. In the end, I conclude that an environmentally sustainable transport system and traffic safety are not just complementary to each other, they are mutually dependent. You cannot have one without the other.

2. Some Background Philosophy

Traffic safety represents one of those elite subjects, like cricket, politics and religion, about which everybody instinctively knows what is right. It is a subject which has had more than its fair share of pre-scientific, prejudiced, folklore thinking. Thus the traditional approach to reducing road accidents has been that it is "obvious" that they should be prevented from taking place, and because the predominant "cause" of road accidents rests on road user errors of one sort or another, it is again "obvious" that road user behaviour needs to be changed.

Down the years the record of parliamentary debates, governmental and institutional

		Pre-crash	Crash	Post-crash
Host	**Road User**	Experience, Fatigue, Psychological & Social Factors	Biomechanical tolerance, Seat belt and helmet use	Age, physical condition, First aid knowledge
Agent	**Vehicle**	Speed, Brakes, Lights, Stability, Visibility	Crashworthiness, Compatibility, Exterior design	Emergency alerts, Extrication factors
Environment	**Physical, Social Environment**	Road design, Weather, Lighting, Speed controls, Surveillance, Policing	Forgiving road designs, Barriers, Run-off zones, Lamp post design	Emergency responses, Treatment and rehabilitation

Table 1. The Haddon Matrix – applying the public health concept of the host, agent and environment of disease control to traffic crashes.

actions on road safety reflect this thinking. Objective analysis is abandoned and the wishful thinking of exhortation, safety days, propaganda, generalised safety campaigns, licensing and training, punitive sentencing for traffic offences and training schemes for school children have absorbed the energies of politicians and spent the meager road safety budgets of many countries.

The trouble with this approach is that people have their limitations. We make mistakes, we are often impulsive or impatient, we like alcohol, our attention wanders, our physical capabilities diminish with age. Thus proposals for changing road user behaviour to demonstrably reduce traffic accident involvement, quickly founder on the subtleties of human response and the political limitations of social engineering. H. L. Mencken once remarked that for every complex problem there is a solution which is simple, neat and wrong. Unfortunately many traditional road safety programmes come in that category.

In western countries the major gains in road transport safety historically have come predominantly from engineering solutions: better highway engineering and traffic management, improved vehicle design. The tragedy is that by chasing the chimera of improving road user behaviour, the “if only” solutions such as “if only people would be more attentive”, “if only motorcyclists wouldn’t drive so fast”, the government and road safety establishments have neglected to provide the funding and institutional arrangements for enacting mainly engineering countermeasures of proven effectiveness.

William Haddon in the United States was perhaps the first notable and successful proponent of a more rational approach to the reduction of traffic deaths and injuries. Coming from a public health background he applied the host, agent, environment framework to traffic safety countermeasures with his well known matrix.

Since the 1970s when Haddon introduced these concepts in the United States, this approach has been gradually adopted in most other motorised countries, although the health dimension of injury control has been largely neglected. Ministries and Departments of Health throughout the world rarely have an active programme and appropriate budgets to address road injuries as a disease.

The Haddon matrix contains one significant omission – it does not include the benefits from control of exposure. Land use planning, urban design, public transport systems, parking and road pricing policies, fiscal or legal incentives to move from risky forms of travel to safer forms, all have a profound influence on levels of personal risk to traffic injury. Even today the United States is almost unique in measuring the success of its traffic safety policies in terms of deaths per miles traveled. This metric is one of vehicle safety,

	2002 - 2005 United States	2002 - 2005 Germany
Traffic fatalities per 100,000 people/year	14.7	6.5
Car fatalities per billion miles of car travel	14.4	12.2

Table 2. Relative risks in the United States and in Germany.
(Sources: Traffic Safety Facts 2008, NHTSA. Brookings Institution (2009). Making Transportation Sustainable: Lessons from Germany.)

not personal safety, which is assessed in terms of deaths per head of population.

In the United States the average annual car mileage is 15,000 miles (24,000 km), in western European countries it is approximately 7,000 miles (11,300 km). Germany is the most motorized of EU countries. Comparisons between the United States and Germany show the following:

Table 2 shows that although the fatality rates per distance traveled in the United States and Germany are similar, the average German is two and a quarter times safer than the average American because his exposure is much less.

The next main philosophical advance came from Claes Tingvall in Sweden in 1997. He argued that traffic deaths could be eliminated in Sweden if roads were designed to be forgiving, vehicles had improved crashworthiness and their speeds were so controlled that only survivable collisions would occur. More importantly he outlined the mechanisms whereby these changes could be made. All the various stakeholders in the transport system, such as employers, insurers, highway departments, vehicle manufacturers, the alcohol industry, health departments, schools, shop keepers, parents, and local and central governments, should recognize their responsibilities in contributing to a vision zero policy. Such an approach recognizes the fallibility of human behaviour as a basic component of the transport system. Thus each stakeholder must contribute to making the transport system so forgiving and safe that fatalities will not occur, and should be held liable if their contributions are inadequate. In practical terms however, the Swedish government set a target of a 50% reduction in deaths from 1997 to 2007. The outcome was that in fact only a reduction of 10% was achieved over that time period. But the very fact of setting an ambitious target did galvanize the newly recognized stakeholders to participate for the first time in implementing a much more comprehensive set of countermeasures. The concept of a forgiving road system, tolerant of human error, has now become an accepted policy in many countries.

In a small, high income country which is socially cohesive and egalitarian, such an aim as Vision Zero is possible to achieve over time, although most other countries in Europe have less ambitious goals. Given that vehicle ownership is approaching saturation levels, the preferred policy is to set targets for reducing deaths and serious injuries over a period of years, usually a decade. Thus the European Union as a whole, when there were 15 member countries in 2000, set a target of a 50% reduction in deaths between 2000 and 2010. This target will likely be met some 2 years late, although a number of EU countries have already achieved that goal. Achieving the original target was made more complicated by the addition of 10 new countries from Eastern Europe in 2004 and two more, Romania and Bulgaria, in 2007.

Overall in the income countries (HICs), it is now well recognized that there is a list of scientifically based, proven countermeasures available which, if applied effectively, have the potential of reducing road traffic risks to the same order of magnitude as other modes of travel and other common work and recreational activities in those HICs.

Country Level	1990	2000	2010	2020
Industrialised	150K	about the same	a little less	a little less
Developing	350K	800K	1.3M	1.9M
Global Total	500K	950K	1.4M	2M

Table 3. Predicted traffic fatalities worldwide.

Furthermore, there is now the political will in some HICs to find the resources and actually to implement those countermeasures, increasingly involving the various stakeholders who historically have been reluctant to be active on traffic safety issues. Thus now the car industry actively promotes active and passive safety technologies, the insurance companies are involved in promoting improved safety activities, police, the alcohol industry, local and national highway departments are all moving towards the acceptance of the basic tenets of the Vision Zero philosophy.

So much for the high income, industrialised countries, where the levels of car ownership have reached asymptotic levels of around one vehicle for every 2 to 3 people over the last 50 years. What is of much greater importance is the rapid economic development of low and middle income countries in the rest of the world, and the concomitant growth in vehicle ownership and traffic casualties. Before addressing the relevance of the experience of the highly motorised countries for the emerging countries elsewhere, it is appropriate to outline the size and nature of traffic deaths and injuries globally.

3. The Scale and Nature of Traffic Injury Worldwide

Today there are around 850 million cars, trucks and buses in the world. Rough estimates suggest that there are also 300 - 400 million motorcycles (including scooters and mopeds). No one really knows how many bicycles there are, but it is likely to be over a billion. The current annual production of bicycles in China is 70 to 80 million (60% of world production) and data from China indicate that in that country there are about 400 million in use, but declining steadily.

Current estimates indicate that there were 1.2 million traffic fatalities globally in 2004 (WHO 2009). However under-reporting, particularly in low and middle income countries, means that this number is likely an under-estimate. Most reporting systems rely on police data. Sample studies comparing coroners' and hospital records with police data show significant under-reporting within the police systems. For example, in the Netherlands police data only recorded 90% of the total number of deaths compared with hospital and other sources (SWOV 2009). Studies in low and middle income countries suggest that police recorded deaths only cover between 65 – 80% of the real totals (Jacobs et al 2000).

In 1901 Karl Benz (of the Daimler Benz partnership) noted that "The world market for cars will be saturated at one million because only a very small proportion of the working class are educatable as chauffeurs."

So forecasting is a risky business. However, in 2000 I estimated that by the year 2020 there would be some 2 million road traffic deaths globally (Table 3, based largely on the increasing trends in vehicle ownership and the rapid motorisation of India, China, Brazil, Indonesia and elsewhere, but allowing for the decrease in overall risk which occurs with increasing vehicle ownership (Mackay 2000).

Taking the current situation, the old industrialized countries contribute little to the global total. Some 85% of traffic deaths occur in low and middle income countries. The latest tally for the total number of deaths was 1,200,000 in 2004 (WHO 2009).
Putting traffic deaths into the broader context of deaths from all causes, WHO in 2008, made some projections to 2030 and showed that traffic deaths are likely to rise from ninth to fifth in the overall rankings of causes of deaths (Table 4).

2004	2030
1 Ischaemic heart disease 12.2%	1 Ischaemic heart disease 12.2%
2 Cerebrovascular disease 9.7%	2 Cerebrovascular disease 9.7%
3 Lower respiratory infections 7.0%	3 Chronic obstructive pulmonary disease 7.0%
4 Chronic obstructive pulmonary disease 5.1%	4 Lower respiratory infections 5.1%
5 Diarrhoeal diseases 3.6%	5 Road traffic injuries 3.6%
6 HIV/AIDS 3.5%	6 Trachea, bronchus, lung cancers 3.5%
7 Tuberculosis 2.5	7 Diabetes mellitus 2.5%
8 Trachea, bronchus, lung cancers 2.3%	8 Hypertensive heart disease 2.3%
9 Road traffic injuries 2.2%	9 Stomach cancer 2.2%
10 Prematurity and low birth weight 2.0%	10 HIV/AIDS 2.0%
11 Neonatal infections and other 1.9%	11 Nephritis and nephrosis 1.9%
12 Diabetes mellitus 1.9%	12 Self-inflicted injuries 1.9%
13 Malaria 1.7%	13 Liver cancer 1.7%
14 Hypertensive heart disease 1.7%	14 Colon and rectum cancer 1.7%
15 Birth asphyxia and birth trauma 1.5%	15 Oesophagus cancer 1.5%
16 Self-inflicted injuries 1.4%	16 Violence 1.4%
17 Stomach cancer 1.4%	17 Alzheimer and other dementias 1.4%
18 Cirrhosis of the liver 1.3%	18 Cirrhosis of the liver 1.3%
19 Nephritis and nephrosis 1.3%	19 Breast cancer 1.3%
20 Colon and rectum cancers 1.1%	20 Tuberculosis 1.1%

Table 4. Leading Causes of Death Worldwide – 2004 and 2030 compared.
(Source: World Health Statistics 2008 www.who.int/whosis/whostat/en/index.html)

Fundamental to understanding the situation in low and middle income countries (LICs and MICs) is to appreciate that the casualties are very different from those occurring in HICs. The great majority of the fatalities in LICs and MICs are pedestrians, motorcyclists (MTWs) and bicyclists, not vehicle occupants. Table 5 shows these proportions for a selection of countries.

GNI/ head is the annual Gross National Income divided by the population of the country. LIC is defined as $935 or less, MIC is $936 - $11,455, HIC is $11,456 or greater. These data are from the World Development Indicators database, World Bank 2008.

There are two general conclusions from the above samples of countries. The vulnerable road users (pedestrians, riders of motorcycles and scooters and cyclists) are very predominantly the largest group of the fatalities. Even in some HICs, these VRUs are in the majority. The United States stands out as the oddity, but even there the VRUs amount to a quarter of the annual traffic deaths.

Secondly, amongst low and middle income countries there are wide variations in the proportions of pedestrians, MTWs and cyclists within the VRU grouping.

Fatalities are only a part of the overall traffic injury picture. On a number of measures the surviving casualties are a greater burden on society. In economic terms, or in terms of medical and social costs, the survivors are more important. For every death there are at least 4 survivors with serious, permanent disabilities, brain damage, spinal cord injury or major loss of function of the lower limbs which inhibits walking (ETSC 2007). The costs of those survivors, often young and with a normal life span, are extremely high in both economic and social dimensions.

Country	Level	GNI/head 2007 US$	Peds	MTWs	Cyclists	Vehicle Occups.	Other
Bangladesh	LIC	470	54%	8%	3%	26%	9%
Cambodia	LIC	540	13%	63%	5%	15%	4%
Ghana	LIC	590	42%	5%	4%	46%	2%
Zambia	LIC	800	50%	4%	11%	36%	-

Country	Level	GNI/head 2007 US$	Peds	MTWs	Cyclists	Vehicle Occups	Other
Egypt	MIC	1580	20%	< 1%	2%	48%	30%
Indonesia	MIC	1650	15%	61%	13%	7%	4%
China	MIC	2360	26%	28%	9%	22%	14%
Brazil	MIC	5910	28%	20%	5%	10%	37%
Malaysia	MIC	6540	10%	58%	3%	23%	6%

Country	Level	GNI/head 2007 US$	Peds	MTWs	Cyclists	Vehicle Occups	Other
Italy	HIC	33,540	13%	26%	6%	49%	6%
U.K.	HIC	42,340	21%	19%	4%	55%	1%
Netherlands	HIC	45,820	12%	18%	24%	46%	-
United States	HIC	46,040	11%	11%	2%	72%	4%
Sweden	HIC	46,060	12%	16%	6%	65%	1%

Table 5. Proportions of fatalities by road user category. (Source: WHO 2009 and national reports). MTWs are motorized 2 and 3 wheeled vehicles.

The global scale of traffic injury beyond fatalities is impossible to estimate with any accuracy. This is largely because of the absence of data at the national level. Even in HICs there is gross under-reporting of some categories of casualties in police records, which constitute the source of accident data in almost every country. Sample studies in the U.K. comparing hospital and police records indicate that some 36% of casualties are not reported to the police (Hopkin, 1993). This is particularly so for single vehicle, cyclist and motorcyclist casualties, many of whom are of such a severity that hospital admission is clinically appropriate. In addition some 20% of accidents reported to the police go unrecorded by the police (Simpson 1996).

Most countries which collect accident data use three categories: fatal, serious, slight. There are substantial differences in the definitions of these three categories, but using correction factors to allow for those differences gives ratios of fatal : serious : slight of 1 : 7 : 23 for casualties in the European Union (Mackay 2005).

	Nigeria	Britain
Pedestrians	1:2:3	1:8:22
Cyclists	1:4:3	1:16:61
Motorcyclists	1:3:2	1:17:42
Vehicle Occupants	1:2:2	1:13:50

Table 6. Ratios of fatal to serious and to slight casualties in Nigeria and Britain.

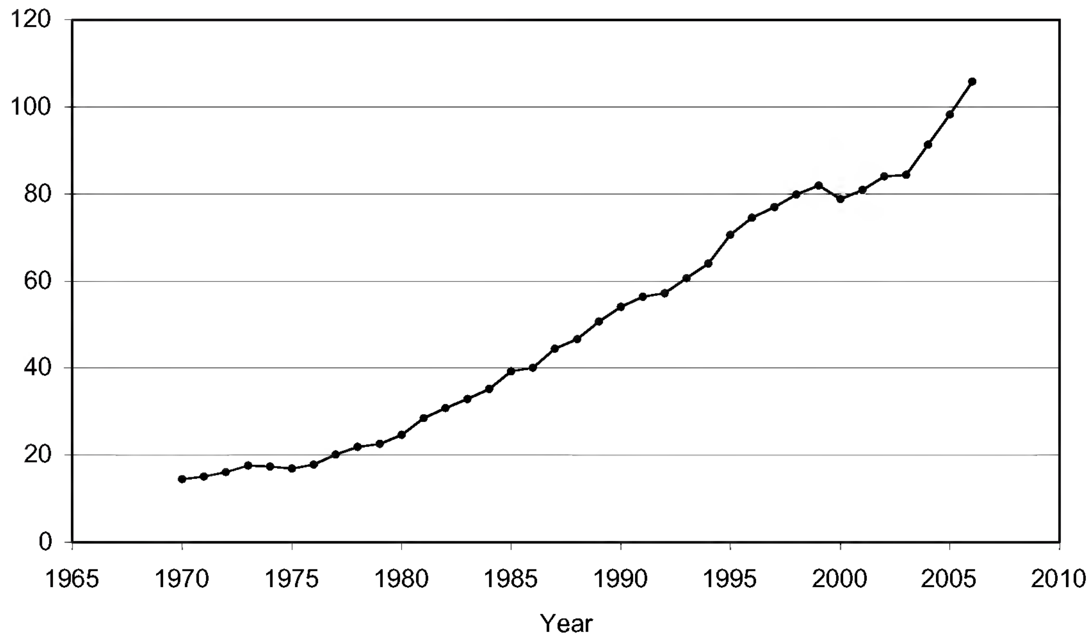


Figure 1. Traffic fatalities in India from 1970 to 2006 (Mohan et al. 2009).

As an example of the scale of under-reporting of surviving casualties in a low income country, table 6 compares data from Britain and Nigeria (Mackay 2000). Clearly the characteristics of accidents in the two countries cannot explain the differences in this table – gross under-reporting is the explanation. Hence, the difficulties of quantifying the surviving casualties on a global basis are too great for anything other than the broadest of estimates. WHO estimated that up to 50 million people are injured annually, an estimate which is broadly in line with the ratios above (WHO 2009).

4. The Situation in India

In summarising the traffic injury situation in India, I have drawn liberally on the report by Dinesh Mohan and others published by the University of Michigan (Mohan et al 2009).

For 2006 the official number of traffic fatalities reported in India was 105,725. That figure appears in the WHO Global Status Report on Road Safety (WHO 2009). In that report an interesting modeling process is applied to a number of low and middle income countries to assess what would be the number of fatalities on the basis of several variables which consider exposure (population, vehicle fleet, income level, etc), risk factors and mitigating factors in each country. Those being factors which influence the outcome in terms of traffic deaths. The process involves a negative binomial regression process. For India the predicted number of deaths was 196,445, with 90% confidence levels between 155,727 and 266,999. Thus the actual reported number of deaths was much lower than even the modeled lower confidence number. For most other countries modeled in this manner the actual number was between the modeled range. This suggests that India has traffic conditions and risk factors which are different from the assumptions in the model used by WHO in this exercise or that deaths are grossly under-reported, which seems unlikely. Thus this exercise shows that the circumstances of Indian traffic accidents are very different from the circumstances implied in the WHO modeling exercise.

The graph in figure 1 above shows the growth in traffic fatalities over the last four decades. The growth rate has increased in the last four years and currently is running at some 8% annually.

For comparison, the chart in figure 2 shows the fatality rate per million persons for India against a range of countries within the European Union and the United States.

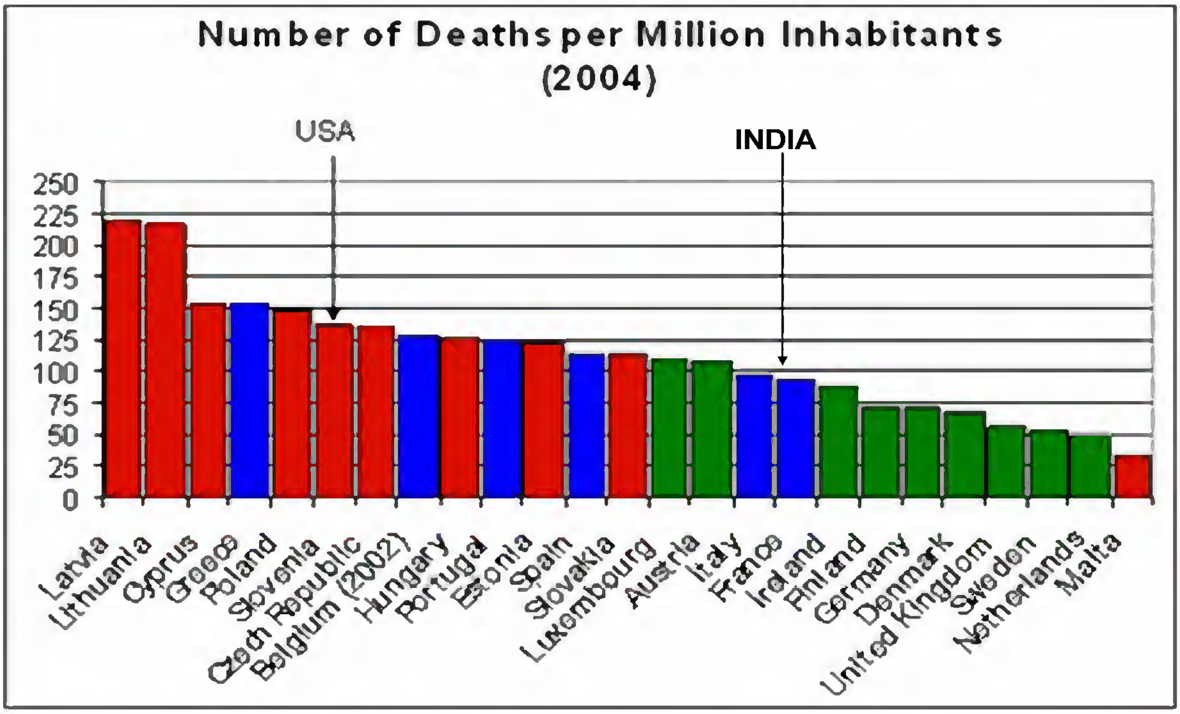


Figure 2. Traffic death rates in the European Union countries, India and the United States. Red bars represent the countries which joined the EU in 2004 (ETSC 2007).

The composition of the vehicle fleet in India is very different from that of more motorized countries. The size of the fleet has increased from 300,000 in 1951 to 73,000,000 in 2004.

These data are based on vehicle registrations the real numbers may be 20 – 30% smaller because there are no effective records of the scrappage rates.

Figure 3 shows the growth of the various categories of vehicles in India over time. Over 70% of motorized vehicles are motorcycles, and they are five times more numerous than cars. Buses and trucks together are about as numerous as cars. Car sales have averaged 16% growth annually over the last five years, whilst motorized two-wheeled vehicle sales have increased by 9% annually. It seems highly likely that there will be a continuing high growth in cars as more small, cheap cars become available, offering a more comfortable and safer mode of travel than on a motorcycle.

The 2007 report of the National Crime Records Bureau noted that there were in 2006 105,725 traffic fatalities and 452,922 non-fatal road traffic injuries, a ratio of 1 : 4.28. Those two figures appear in the WHO Global Survey Report of 2009. Mohan et al (2009) point out that the likely ratios of fatal to hospital treated to slight injury cases are likely 1 : 15 : 70, based on various sample studies and the experience of other countries. On that basis, allowing for 5% under-reporting of deaths, in 2006 there were some 1,650,000 serious casualties requiring hospital treatment and 7,700,000 cases of minor injuries; very different from the number reported to the WHO.

National data are not available for the proportions of the various road users who die in traffic crashes. However, Mohan and Tiwari (2000) have provided such data for a selection of locations, shown in the table 7 below.

For the urban environments of Mumbai and Delhi, around 90% of the fatalities are VRUs, and even on highways the percentage of VRUs is 68%.

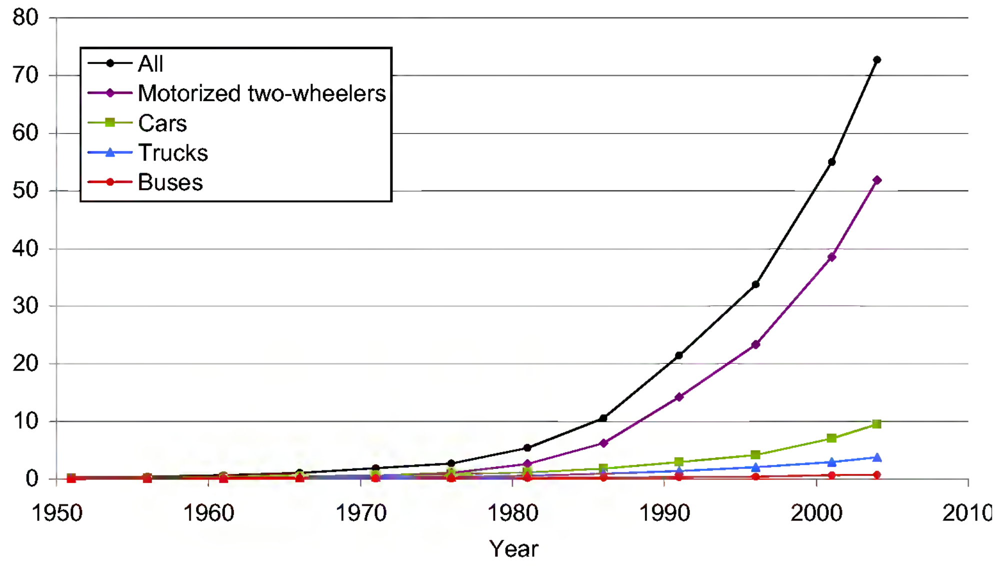


Figure 3. Growth in vehicles in India from 1950 (Mohan et al 2009).

5. Problem Areas and Proposed Countermeasures

Mohan et al (2009) in their comprehensive review of the Indian traffic injury situation identify six specific problem areas and they suggest appropriate countermeasures. These are listed in Table 8 below taken from their report.

Whilst a number of the countermeasures are specifically focused on available or emerging technologies, other suggestions relate to environmental or more general issues of urban design and the evolution of our current vehicles. In the next section of this paper I discuss these broader questions in the context of the mounting evidence of energy sustainability and environmental degradation.

6. Sustainable Transport and Traffic Safety

Two opposing global trends dominate national and international politics and industry at the present time. First, it is predicted that the demand for energy will almost double by 2030. Secondly, global warming is strongly related to absolute increases in greenhouse gases and a proportion of those gases most likely come from human activity. The size of that proportion is still the subject of debate. But policy makers the world over are waking up to the twin consequences of climate change and the unsustainable use of energy. The rapid industrialisation of many developing countries, particularly the two largest countries in the world, India and China, has shown that, in terms of the unfettered use of fossil fuels, business as usual is no longer a practical modus operandi.

Climate change is a bit like traffic safety in that it has more than its fair share of folklore, muddled thinking and prejudice surrounding its origins and consequences. MacKay (2009) brings some clarity and objective thinking to this murky topic.

He plots the concentration of CO_2 over the last thousand years (based largely on ice core measurements) to show that somewhere around 1800 AD an unusual rise in the quantity of CO_2 in the atmosphere began and has continued at an accelerating rate to today. He notes that that rise has been coincident with the industrial revolution, starting in Britain, fired literally by the mining and burning of coal. Coal production doubled fairly regularly every 20 or 30 years during the 19th century, and then as industrialisation spread around the world and oil was discovered, the burning of fossil fuels has provided the energy needed to support western life styles (Figure 4).

Type of road user fatality	Location (percent)		
	Mumbai	Delhi	Highways*
Truck	2	2	14
Bus	1	5	3
Car	2	3	15
Three-wheeled scooter taxi	4	3	-
Motorized two-wheeler	7	21	24
Human and animal powered vehicle	0	3	1
Bicycle	6	10	11
Pedestrian	78	53	32
Total	100	100	100

**The data are for 14 selected locations, and thus might not be representative for the entire country. (Tractor fatalities are not included.)*

Table 7. Percentage of traffic fatalities by road user and type.

CO_2, like methane and oxides of nitrogen, is a greenhouse gas. In the atmosphere it absorbs infra-red radiation from the earth and retransmits it in all directions. So instead of the infra-red heat going out into space a proportion of it is sent back to earth producing a warming effect, like a quilt.

There are other candidates likely contributing towards global warming. Sun spots, volcanic activity, cattle, changes in oceanic currents for example are cited, but to the non-specialist the simple coincidence of the increase in CO_2 concentrations with the burning of fossil fuels appears to be inescapable.

MacKay also quantifies the greenhouse gas emissions in terms of CO_2 equivalent units per person for a selection of countries, (figure 5).

These data emphasize how historically industrialisation has gone hand in hand with greenhouse gas emissions. India's contribution currently is less than half the global average, and, per person, an Indian's contribution to greenhouse gases is less than one quarter that of the average Japanese or Brit, and only one tenth that of the average American.

But Kakodkar (2007) noted "The Indian population corresponds to one sixth of world population. However, the carbon dioxide emission from India is only around 4% of the global emissions. On the basis of current energy mix and the present day technologies for electricity production, the CO_2 emission from India alone could become as much as half of the present level of global emission in a few decades from now."

Of the several sources of greenhouse gases, road transport contributes around 15 to 20% of the total (Kahn 2007). The current concerns with greenhouse gases and consequent worries about climate change are leading to major investments in alternative energy sources, nuclear, solar, wind, tidal, et al. Road transport presents special challenges because of the need for a mobile energy source. Virtually all powered road vehicles at present are driven by hydrocarbon fuels.

Well before the current concerns about global warming, air pollution from motor vehicles has been a significant source of early deaths because of respiratory and heart disease, particularly in the large and growing cities of Asia (Cropper et al 1997). Suspended particulates (especially from badly tuned diesel engines), sulphur dioxide, carbon monoxide and oxides of nitrogen have greatly exceeded safe limits in these cities for the last two decades, with motor vehicles as the major source (Smith et al 2009, Gadhok 2002).

Problem area	Exposure	Risk	Consequences
Pedestrians and other non-motorists in urban areas	Separation of motorized and non-motorized traffic on arterial roads	Speed control Roundabouts Restrictions on free left turns	Pedestrian-friendly front ends of vehicles
Pedestrians, other non-motorists, and slow vehicles on highways	Special facilities for slow and local traffic all along highways	Pedestrian detection technology Forward collision warning systems	Pedestrian-friendly front ends of vehicles Crashworthiness of slow vehicles
Motorcycles and small cars in urban areas		Daytime running lights Improved lighting and signaling	Enforcement of helmet-use and seatbelt laws Introduction of passive measures like airbags Pedestrian/motorcycle impact standards for small cars
Over-involvement of trucks and buses		Speed control Rest regulations for truck drivers Improved vehicle conspicuity	Safer vehicle fronts
Nighttime driving		Improved headlighting Improved vehicle conspicuity Random alcohol breath testing Rest regulations for truck drivers	
Wrong-way drivers on divided highways	Highway designs incorporating local needs Enforcement	Forward collision warning systems	

Table 8. Problem areas and proposed countermeasures in Indian traffic. *(Mohan et al 2009)*

The motorcycles on India's roads used to be a lot more polluting than newer small cars. Emission standards have been tightened considerably and now India (and Taiwan) have the most stringent standards for 2/3 wheelers in the world, somewhat more severe than the standards required for 4 wheeled vehicles. These requirements have driven the designs of new machines towards using four stroke engines but it will take some years for the older machines to be phased out. CO_2 emissions, even with complete combustion remain as a contributor to greenhouse gases.

Thus concerns about the immediate effects of air pollution, especially in India's large conurbations, combined with the broader issues of greenhouse gases and global warming, come together and lead to the need for a fundamental rethink about the nature of the vehicles we drive and the environments in which we use them.

These environmental concerns coupled with the growing recognition that the current levels of deaths and injuries in traffic accidents, the attendant social and economic costs, and the annual foreseeable increases in those costs if a laisse faire attitude continues, means that environmental and safety issues must be studied as two parts of the same problem. Mohan et al (2009) refers to a number of modeling studies of the growth rates of traffic deaths in India. Fatalities at present are growing at a rate of 8% per year whilst in earlier years the rate was 5%. Using the Koornstra model (Koornstra 2007), if one assumes that the current growth rate of 8 % declines in a linear manner to zero in 2030, then in that year one must expect 260,000 traffic fatalities in India.

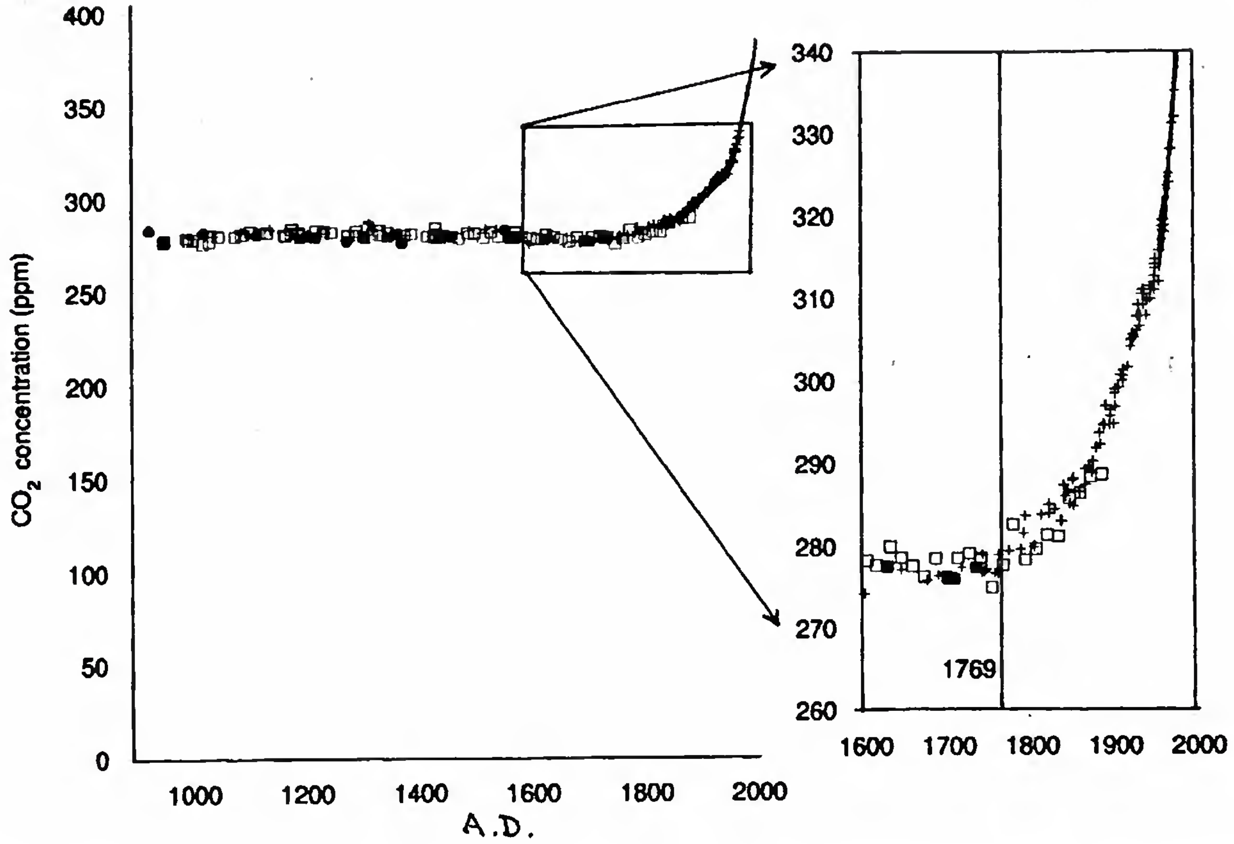


Figure 4. CO_2 concentrations over the last 1000 years (MacKay 2009).

In economic terms, using the conservative method of "human capital cost", it is likely that the current cost of traffic accidents in India is between 1 – 2% of GDP. If the "willingness to pay" approach is used, which gives greater weight to the less tangible consequences of traffic death and injury such as pain and suffering, the cost of traffic deaths and injuries will be about double at 2 – 4% of GDP (WHO 2004).

7. Speed and its Consequences

Injury is a consequence of an intolerable amount of mechanical (kinetic) energy being transferred into the human frame. Kinetic energy increases according to the square of the velocity. The severity of a collision is measured in terms of the change in velocity which occurs in the impact (Δv km/hr). In-depth studies in Britain and the United States of collisions involving occupants wearing seat belts show that as Δv increases from 20 km/hr to 100 km/hr, the probability of fatal injuries increases from close to zero to almost 100%. The probability of serious injury is three times as great at 48 km/hr and four times as great at 64 km/hr compared with the risks at 32 km/hr. (Mackay and Hassan 2000). For the North American environment at a Δv of 80 km/hr, the likelihood of death is 20 times what it would be in a collision at Δv 32 km/hr (IIHS 1987).

Pedestrians have a 90% chance of surviving an impact with a car at 30 km/hr or below, but less than a 50% chance of surviving impacts at 45 km/hr or above. The probability of a pedestrian being killed rises by a factor of eight as the impact speed increases from 30 km/hr to 59 km/hr (Ashton and Mackay 1983). This is evident from the steepness of the graphs below, derived from data from four different data bases from around the motorised world.

Thus the role of speed, particularly in the mixed road user environment of big cities, is a dominant factor in injury risk. Speed also of course influences energy consumption, pollution, noise, stress on road users and vehicle and highway maintenance.

8. Speed and Current Vehicle Design

Vehicle design in the industrialised countries has evolved in such a way that the design parameters do not match the conditions under which the machines are actually used. With very few exceptions, almost all cars manufactured in the west are capable of at least 200 km/hr (124 mph). This is patently absurd in that almost every motorised country has an upper speed limit of 120 -130 km/hr.

The consequences of this additional performance are that such cars are heavier, consume more fuel and require more maintenance than need be under the conditions in which they are actually used, especially in urban areas. This is especially obvious in the cities of North America where the streets have a rectilinear pattern and there are traffic signals at many junctions.

Cars accelerate rapidly in platoons and then brake severely only to wait at the next light. Even for normal traffic flow conditions, they are stationary for up to 20% of their journey time. Fuel consumption under such conditions for most US cars is around 12 litres/100 km or more.

In contrast a 125cc motorcycle consumes around 2 to 3 litres/100 km., whilst a Volkswagen Polo will consume 4 to 5 litres/100 km.

The very fact that western cars are capable of such high speeds and levels of acceleration leads to a large proportion of all drivers using that performance. Thus speeding is endemic in almost all motorised countries. An outstanding example comes from a low income country, Ghana, where the speeds of cars were measured in the main street of a town which had a speed limit of 50 km/hr. (Derry 2006). The mean speed measured

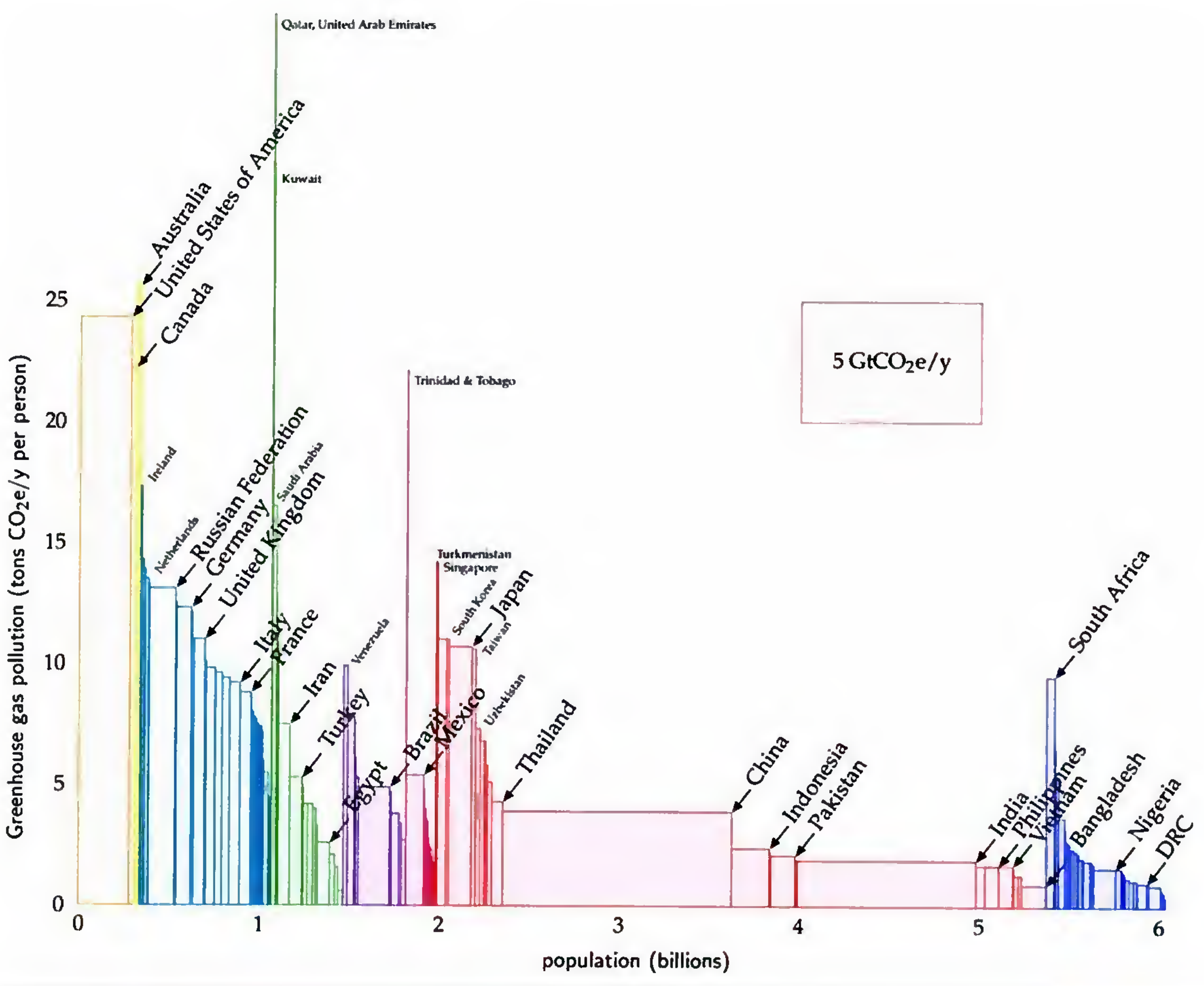


Figure 5. CO_2 equivalent emissions per year, per person by country. *(MacKay 2009).*

was 1.8 times the speed limit, with a significant number of vehicles traveling at well over twice the limit.

The enforcement of speed limits is now done in many western countries with the use of speed cameras and fines, but that requires an effective enforcement agency coupled with a transparent legal system.

Having excessive power therefore leads to excessive speeds, excessive braking, increased injury risks for all road users, especially VRUs, increased energy use, increased greenhouse gases and air pollution with further health risks, increased noise, increased road and tyre wear, and a pervasive level of fear in many road users.

9. Sustainable Traffic Safety for Indian Urban Conditions

Indian cities have already reached levels of congestion equal to or worse than that of European and American cities. The heterogeneous nature of Indian traffic, with large numbers of motorcycles, cyclists, three-wheeled taxis, as well as cars, trucks and buses, in fact results in higher flows of equivalent passenger car units than classical traffic flow theory predicts, based on western traffic mix. The history of attempts to reduce congestion all over the world by providing more and more roads is one of failure. Traffic volumes merely grow to fill up the additional capacity.

Therefore alternatives must be developed to meet the demands of less congestion, greater safety and less pollution. The most obvious and immediate priority for city governments is to develop appropriate public transport. Dedicated bus lanes with cheap, comfortable and frequent services are needed, coupled with parking policies and road pricing regimes to discourage private car and motorcycle use. Provision of separate bicycle and pedestrian lanes with preferential treatment at junctions are needed.
The health benefits of walking and cycling have been well documented but pollution levels need to be much reduced before those benefits can be achieved (Horton 2009).

Speed control and traffic calming are central to reducing traffic injury risk. Roundabouts, chicanes, speed humps, pedestrian refuges, improved street lighting, distinct facilities for

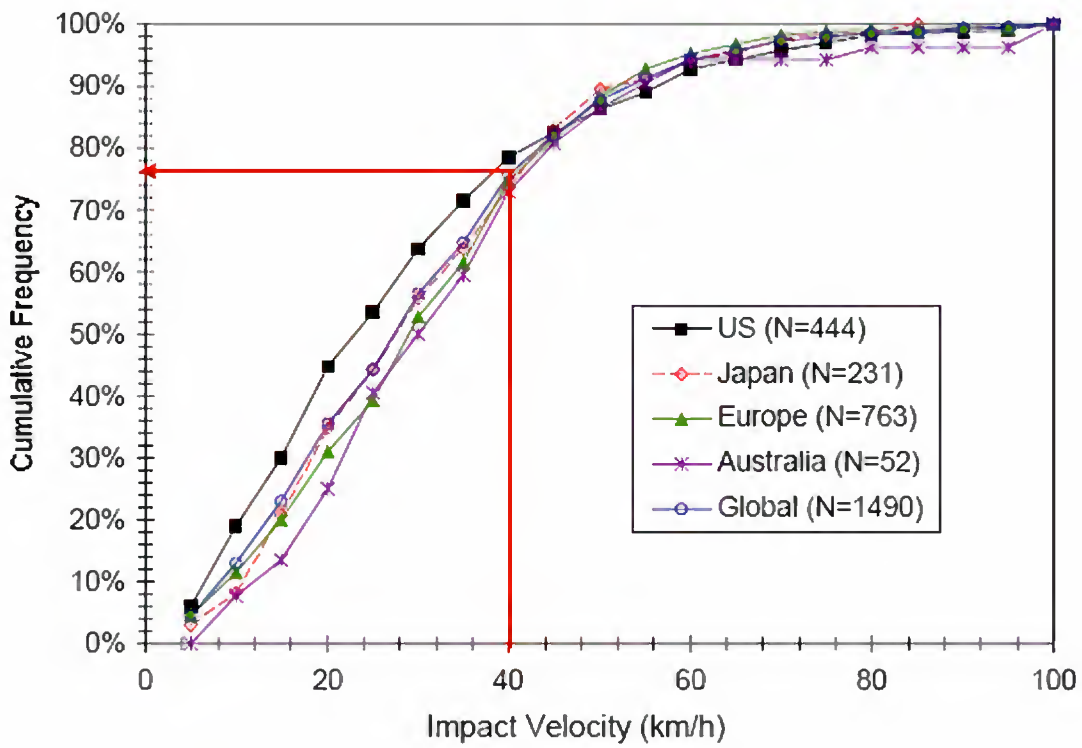


Figure 6. Distribution of impact speeds for pedestrians who receive AIS 3+ injuries (Mizuno 2003).

pedestrians and cyclists are all well established countermeasures for the urban environment. Tax, parking and fuel pricing policies can actively discourage large, polluting vehicles and are now used in many countries very aggressively.

The economic attractions of a motorcycle for Indian cities are obvious. Motorcycles are cheap to buy and run in comparison to even cheap used cars. Parking is relatively easy and motorcycles have a big advantage over a car in congested conditions. Their safety can be improved with daytime running lights, better lights for night time, antilock braking and leg protection (Zhang et al. 2008).

The pollution from motorcycles can be improved with better engine design and exhaust systems, but a longer term aim should be to move to electrically powered machines. Although electric motorcycles use energy more efficiently than petrol driven machines, there is still the greater issue of how the nation generates its electricity. Around 70% of India's power comes from burning coal. Cleaner generation of electricity is thus a high priority.

Electric bicycles and scooters are an attractive option which should be encouraged for urban Indian traffic. They are cheap, have health benefits, and emerging battery technology promises to reduce weight, charging times and replacement costs. With improved batteries, speeds of 50 km/hr and a range of 80 km will be likely in the next three years. The contribution to calmer, quieter traffic would be substantial.

China now has an active policy to encourage electric bicycles. In 1996 bicycles and petrol-powered scooters were banned on major routes in many cities, including Beijing and Shanghai (Parkash 2008). Somewhat belatedly dedicated bicycle lanes (including electric bicycles) are being installed along selected city arterial routes. In 2008 the production of electric bicycles in China was

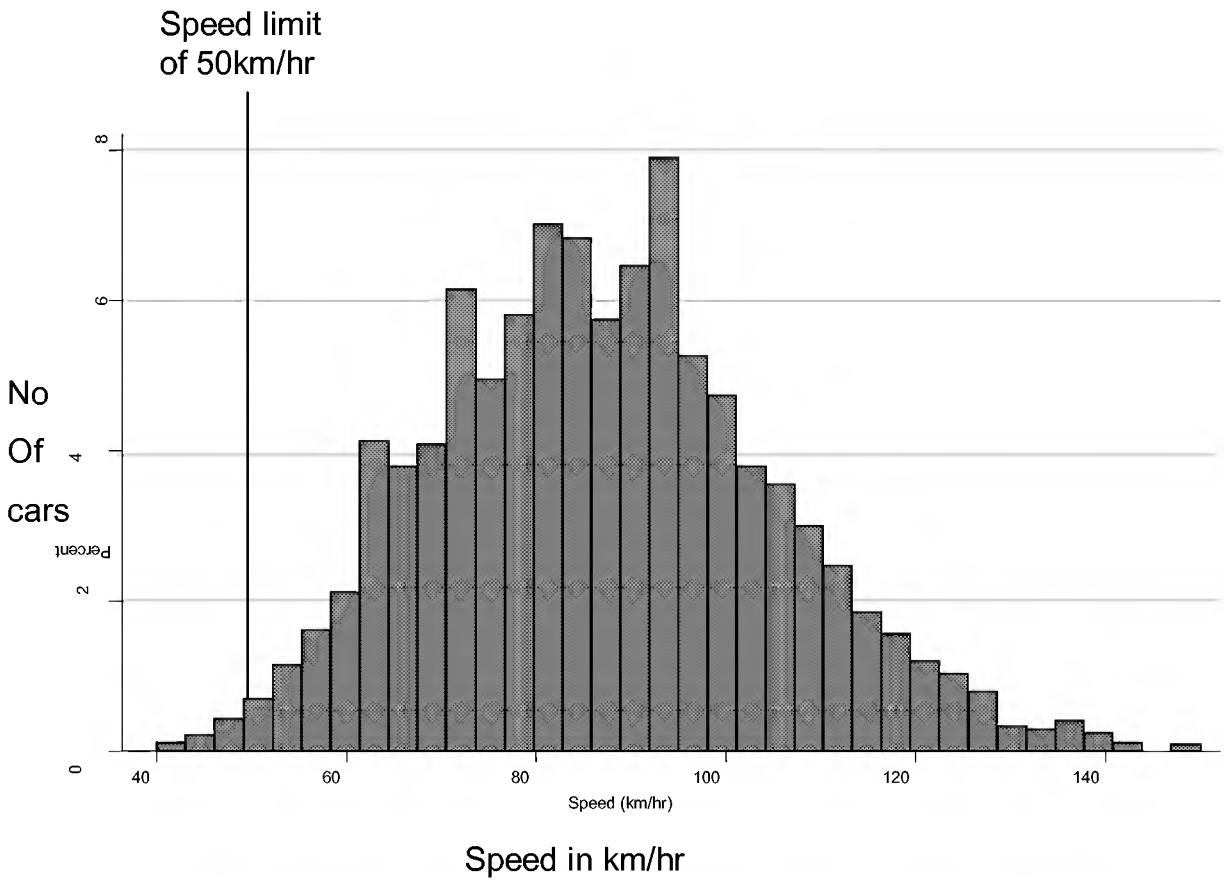


Figure 7. Distribution of traveling speeds in a town in Ghana with a 50 km/hr speed limit. *(Derry 2006).*

21 million, compared with car production of 9.4 million (Ramzy 2009).

Given the economic and tactical advantages of a motorcycle in Indian cities, the predicted levels of economic growth will not lead to a major swing away from motorcycles towards cars in the medium term. With over 70% of urban vehicles being motorcycles or scooters and only 14% being cars, motorcycles will dominate urban traffic for at least the next decade. Hence the need to reduce the risks by controlling speeds through encouraging the electrification of two wheeled travel.

There is also a need for an urban car to be designed for the specific conditions of the megacities of India. The general design parameters should be for a small, lightweight, fuel efficient, low emission, two person car, with a top speed of around 65 km/hr. Emissions and fuel use could almost match that of motorcycles. It would be possible to design a vehicle with two seats in a fore and aft configuration so that the width of the vehicle would not be much greater than that of a motorcycle. The smallest electric car to be produced by Renault in 2011, bizarrely named the Twizy ZE, has such a configuration. Its width is just over one meter, giving it a similar manoeuverability to that of a motorcycle. The claimed range is 90 km and a top speed of 70 km/hr. The Tata Nano is another example of a move towards a lower emission car, but its size, being a four/five seat vehicle, and performance are not dissimilar to that of the current Suzuki 800.

There are wider regulatory issues to be addressed. The word “car” is applied to a whole range of vehicles, from the Nano and the Smart car to a BMW 7 series or a Range Rover. With minor variations the same safety requirements are applied across the whole range of cars, SUVs and, in most jurisdictions, to pick-up trucks. An implicit assumption is that all cars can be used everywhere. If a car is designed for the conditions of urban India then the priorities for safety in its design are different from the requirements specified in the standards promulgated by E.C.E. or other regulatory bodies in the world.
Given the traffic mix in urban India and a specified upper limit to its speed of say 65 km/hr then the standard crash performance requirements for conventional cars are not necessarily appropriate for a city car. The prime safety concern must be pedestrian (and VRU) protection. Careful control of the front exterior geometry and compliance of the structures which will be struck by pedestrians can provide major benefits. European standards exist for exterior design to reduce pedestrian injuries, but they are not as effective as they could be. This is one area of vehicle design where the Indian vehicle industry could be a world leader.

It would be useful to set up an independent group of experts to question this “one size fits all” view of safety standards for cars in the context of vehicles appropriate for India’s megacities. To agree on the appropriate safety standards for small, light weight, low emission, low speed, urban cars would bring clarity to a muddled subject and provide an incentive for the development of such vehicles.

All major vehicle manufacturers are seriously developing hybrid electric-petrol cars or pure electric vehicles. Battery efficiency is still a major difficulty, but lithium-ion batteries are likely to be much better, lighter and cheaper in the next 3 – 5 years. The greater problem is access to charging facilities. Here government can and should provide the lead in establishing charging stations throughout the cities’ road network. Government can also encourage the electrification of cars in many different ways such as tax breaks for low emission vehicles and preferential parking facilities.

The electrification of the vehicle fleet is likely to take a generation or two because the costs are relatively daunting and the provision and distribution of electricity on the scale needed is an enormous investment. The process will likely begin in the rich countries of Western Europe, for example in Denmark, Sweden and the Netherlands. However, Renault is aiming to produce 100,000 electric cars by 2011/12. It will be interesting to follow that initiative.

There are many specific parts of urban traffic where energy saving technologies should be applied more widely. Regenerative braking in commercial vehicles can save up to 30% of the energy used by a bus or truck. Having engines which automatically stop when the car is stationary and then start when the accelerator is depressed are currently available. Under urban conditions they reduce energy use by over 10%.

There is great enthusiasm and much technical development over crash avoidance and injury mitigation systems within the car industry at present. Short range radar and automatic proximity braking, pedestrian detection systems, enhanced night vision, adaptive lighting systems, lane departure warning, brake assist, intelligent speed adaptation all offer some potential safety benefits. Predicting what these benefits might be is difficult because many of them alter the relationships between the driver, the vehicle and the road. Risk compensation is a well established phenomenon in man/machine relationships so many of the claims currently made for these new technologies may well be optimistic.

Current costs of these technologies rule them out for the majority of the new car fleet in India, but the application of some of these technologies in buses and trucks used in the urban environment would be appropriate at the present time. In particular, automatic proximity braking and pedestrian sensing systems would likely yield significant benefits.

10. Traffic Accidents on the Highways of India

Mohan et al (2009) identify several specific issues relating to traffic crashes on intercity routes. These are:

1. Pedestrians, other non-motorists and slow vehicles on the main highways,
2. Over-involvement of trucks and buses, especially in fatal crashes,
3. Night-time driving,
4. Wrong-way driving on divided highways.

Western road design standards are based on the assumption that pedestrians and slow traffic are largely absent from rural and intercity roads. That is not the case in India and therefore such western design standards are inappropriate. On such highways, provision for pedestrians and motorcycles need to be built into the basic designs. Frequent cross over facilities are therefore needed for pedestrians and separation of motorcycles from car, trucks and buses should be introduced where possible. In Malaysia separate motorcycle lanes have been built alongside some of the major divided highways with significant safety benefits (Umar 1995), but such lanes are only practical on intercity routes where limited access is appropriate.

Current truck and bus designs are very hostile to standard cars and vulnerable road users. The concept of compatibility, particularly between the structures of trucks and passenger cars allows the latter to penetrate under the high rigid load platforms of trucks with devastating effect on the car occupants. Under-run guards at the rear and sides have become legal requirements in almost all motorized countries. Front under-run protection is now built into many truck and bus designs. Such designs are unpopular with operators because they add cost and weight to the vehicle. This is a prime case where government legislation is needed to overcome market pressures. The cost effectiveness of such legislation has been shown to be high in terms of the savings in deaths, injuries and health care costs but truck owners do not directly see those benefits.

Night-time collisions rates in both urban and rural conditions are roughly double daytime rates. For highways, vehicle lighting can be much improved with automatic lights and adaptive lights, where the headlights automatically adjust to the light output of approaching vehicles, the headlights turn when a bend is being negotiated and move vertically for hills and declines. LED lighting provides better performance and offers significant energy saving benefits, and will become widespread over the next decade.

The poor conspicuity of all vehicles and pedestrians, under both day and night conditions, is a frequent contributing factor noted in detailed crash investigation studies. White and reflecting materials provide tangible benefits and are legal requirements in many countries for trucks and buses.

Similarly speed governors are specified through regulations in many places for trucks and buses. Again this is an area where government must lead because the perception of the operators is that it puts them at a cost disadvantage.

Wrong-way driving on divided highways is largely a consequence of the inadequate provision of cross-over facilities and feeder roads to meet the needs of the local population. Frontage roads and crossing points are necessary to meet the local requirements of the Indian countryside.

Proximity collision warning systems with automatic braking might provide a technological solution, at least for trucks and buses, but with a combined approach velocity of perhaps 220 km/hr it would be very difficult to have a system that would discriminate accurately without too many false alarms. Accurate detection would have to occur when two vehicles, each traveling at 110 km/hr, were over 200m apart. That only allows three seconds before impact for the systems to work.

11. Behavioural Issues

So far I have concentrated on technological countermeasures relating to road design, traffic management and vehicle design. I have done so in the belief that, for India in particular, with the rapid growth in vehicle ownership, with very rapid urbanization, the low but increasing level of national income per head and the absence of many institutional arrangements taken for granted in high income countries, technological changes will be more effective than countermeasures aimed at changing road user behaviour. The history of traffic safety shows that behavioural changes to be effective require an underlying community structure for enforcement, a level of knowledge of what is good practice in terms of road user behaviour and an acceptance by the general public that individual freedoms have to be restricted for the common good.

Too often western consultants have been applying western countermeasures to the traffic injury problems of LICs. Too often they make implicit assumptions about large and efficient enforcement agencies and lots of expensive technology which in fact are absent in many low income countries.

But there are some behaviour issues highlighted in a number of studies in LICs where rapid motorisation is occurring and behavioural change can be effective.

Mandatory Seat Belt Use – When enforced, seat belt usage levels in LICs can reach levels of 70% for drivers, although lower for passengers.

Helmet Use by MTWs – Again when enforced, helmet use levels can reach over 90% (Umar et al. 2000).

Driving and Alcohol – Although not adequately researched in India, it appears likely that alcohol is a factor in a significant and increasing number of traffic accidents, especially at night and also with pedestrians at night. Random breath testing does take place and when enforcement occurs there is a deterrent effect (ETSC 2003). But to be truly effective in changing attitudes to drinking and driving, random breath testing requires a level of testing and hence police resources which can only be done in HICs. For example in some states in Australia where random breath testing is practiced, on average one driver in three can expect to be tested once a year. In Britain the equivalent number is one driver in six. With such levels of testing real behavioural changes occur. By contrast in the United States where levels of testing are about one driver in a thousand, alcohol remains a factor in some 40% of fatalities.

The technology for detecting alcohol by sampling breath remotely from a sensor in the steering wheel is becoming available. This represents a new way of controlling drinking and driving which has obvious benefits, particularly for fleet operators and commercial drivers. Alcohol interlocks are now used as part of the sentencing procedures for drivers convicted of drinking and driving, but to be effective that requires robust and expensive policing procedures.

Fatigue – Although under researched it is highly likely that fatigue is a major factor, especially in night time accidents on the highways, and especially involving trucks and buses. Driving distances are long and the economic incentives to drive those long distances are attractive. This is an area where fleet operators particularly could act in their own interests by controlling driving hours and supervising their drivers more carefully.

With GPS and electronic tachographs becoming cheap, it is good management practice to reduce the risk of crash involvement by monitoring and controlling driving hours and rest periods.

Data Needs – In developing appropriate countermeasures for India's road system, there is a clear need for better knowledge about the characteristics and extent of traffic crashes, injuries and their consequences. Crash investigation is a specialized skill which needs to be recognized and nurtured within the police service and within highway departments. Establishing robust data collection systems means linking local, regional, state and national organizations together. Traffic crashes and their consequences cover both transport and health sectors. Hence data bases should also be linked. Only by knowing the nature and characteristics of Indian traffic accidents will it be possible to develop the most appropriate countermeasures. Only by having such data will it be possible to measure the effectiveness of changes which are made. Guesswork is no substitute for data.

12. Conclusions

Economic growth in India has lead to an enormous increase in the demand for energy. At the same time urban air pollution and climate change issues lead to the need to reduce energy consumption and in particular reduce the use of fossil fuels.

Along with those conflicts, urban traffic congestion, noise and the real fear of traffic injury dominate life in cities and on the highways. In moving towards a sustainable transport system all of these needs must be addressed. Sustainable transport will not become a reality unless traffic injury risk is reduced.

In this superficial review I have concentrated on the technological countermeasures possibly appropriate for Indian traffic, in the areas of highway design and traffic management, and vehicle design. I have done this because the history of traffic safety shows that engineering countermeasures work more quickly and more effectively than programmes aimed at altering behaviour. However, many of the measures which work in high income countries are not appropriate for Indian traffic because the vehicle fleet is so different. Thus there is a real need to develop new solutions recognizing the vulnerable road users in particular. Where motorcycles and pedestrians dominate, new traffic management solutions are required.

The straight jacket of western car safety standards needs to be examined. Many crashworthiness standards applicable for heavy, high speed cars operating on limited access expressways need to be questioned in the context of vehicles appropriate for India's megacities.

The worldwide need to move from fossil fuels towards the electrification of traffic presents a great opportunity for new designs of motorcycles, cars, trucks and buses. The private sector will be able to advance such developments but government must encourage such progress by setting the framework in which these developments can thrive.

This can happen in many ways. In moving towards a low carbon economy, local, state and national governments must produce the appropriate incentives and penalties. Preferential treatment for zero and low emission, low speed vehicles, extensive traffic calming schemes, disincentives for high speed, high fuel use, high polluting vehicles are examples. At the same time new solutions for controlling congestion and new traffic management techniques for traffic which is predominantly motorcycles and pedestrians need to be researched.

The use of safety and environmental audits for governments is an important mechanism in evaluating new road developments, traffic management schemes and vehicle technologies. Building that capacity to create a forgiving road system is the immediate challenge for government. Thus energy use, climate change, congestion and traffic safety are intimately linked. Sustainable energy and sustainable transport will only be addressed successfully if traffic safety is also addressed.

13. References

Brookings Institution 2009. Making Transportation Sustainable – Insights from Germany. Washington DC.

Derry J. et al. 2006. Report on Vehicle Speeds on a Major Highway in Ghana. Building and Road Research Institute, Kumasi, Ghana. Sept.

E.T.S.C. 2003. Cost Effective EU Transport Safety Measures. European Transport Safety Council, Brussels, Belgium.

E.T.S.C. 2007. A Report on the Social and Economic Consequences of Road Traffic Injury in Europe. European Transport Safety Council, Brussels, Belgium.

Gadhok T. 2002. Risks in Delhi: Environmental Concerns. Geographical Information Service. Gis. development. net.

Hopkin M. 1993. Police and hospital recording of non-fatal road accident casualties. Transport Research Laboratory Ltd. Report 379. Crowthorne, England.

Horton R. 2009. The Climate Dividend. The Lancet, Vol 374, p1869-1870, Dec. London.

IIHS 1987. Facts: 55 mph Speed Limit. Insurance Institute for Highway Safety. Arlington, Virginia.

Jacobs G. et al. 2000. Estimating global road fatalities. Report 445, Transport Research Laboratory, Crowthorne, England.

Kahn R., et al. 2007. Transport and its infrastructure. In Eds. Metz B. et al., Climate change 2007: mitigation contribution of the working group III to the fourth assessment report of the I.P.C.C. Cambridge University Press, Cambridge, England.

Kokodkar A. 2005. Energy in India for the coming decades. Dept. of Atomic Energy, Mumbai, India.

Koornstra M. 2007. Prediction of traffic fatalities and prospects for mobility becoming sustainable-safe. Sadhana Academy proceedings in Engineering Sciences. 32, p365-395.

MacKay D.J C. 2009. Sustainable Energy – without the hot air. UIT Cambridge Ltd., Cambridge, England.

Mackay M. 2000. Folklore and science in traffic safety: some new directions. In: Eds. Mohan D. and Tiwari G. Injury Prevention and Control. p. 89 -98. Taylor and Francis, London, England.

Mackay M. and Hassan A. 2000. Age and gender effects on injury outcome for restrained occupants in frontal crashes. Proc. 44th Annual Conf. of A.A.A.M., Chicago, Illinois. p75-92.

Mackay M. 2005. Quirks of Mass Accident Data Bases. J. Traffic Inj. Prev., Vol 6, Issue 4, p. 308 – 311, Dec.

Mohan D. et al. 2009. Road Safety in India; Challenges and Opportunities. University of Michigan, UMTRI Report-2009-1, January, Ann Arbor, Michigan, U.S.A.

Mizuno Y. 2003. Summary of the IHRA Pedestrian Safety Working Group Activities. Proc. E.S.V. Conf. paper 580, published by NHTSA, Washington DC.

Parkash M. 2008. Promoting environmentally sustainable transport in the Peoples Republic of China. Asian Development Bank, Manila, Philippines.

Ramzy A. 2009. On the streets of China, electric bikes are swarming. Time Magazine, June, 14, New York.

Simpson H. 1996. Comparison of police and hospital casualty study data. Transport Research Laboratory Ltd. Report 173. Crowthorne, England.

Smith K. et al. 2009. Public health benefits of strategies to reduce greenhouse emissions: health implications of short-lived greenhouse pollutants. Lancet, London, Nov. 25.

SWOV 2009. Road Crash Casualties in the Netherlands. Fact Sheet, Sept., SWOV Institute for Road Safety Research, Leidschendam, The Netherlands.

Umar R. et al. 1995. Preliminary analysis of exclusive motorcycle lanes along the federal highway FO2, Shah Alam. J. Int. Assoc. Traffic & Safety Sciences, Vol 19, No 2, p93-98, Oct.

Umar R. et al. 2000. Multivariate Analysis of Motorcycle Accidents. J. Crash Prevention and Injury Control. Vol 2. No. 1. p11-18.

W.H.O. 2004. World report on road traffic injury prevention. Ed. M. Peden et al., World Health Organisation, Geneva, CH.

W.H.O. 2009. Global Status Report on Road Safety. World Health Organisation, Geneva, CH.

Zhang W. et al. 2008. Road Safety in China: Challenges and Opportunities. UMTRI Report 2008-1, University of Michigan, Ann Arbor, Michigan.

TRANSPORTATION RESEARCH AND INJURY PREVENTION PROGRAMME

Origin

The Transportation Research & Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi (IiTO) began life in 1997 when we discovered that many faculty members in different departments of IiTO were working separately on transportation related issues in their individual capacities. Their strength was their expertise and commitment. Their weakness èabsence of synergy among them and insufficient impact of their work on the society around them.

We combined our resources to develop a concept paper for the establishment of TRIPP and circulated it to national and intemational researchers, senior govemment officials, industry executives and international and non-government organisations. Their comments were consolidated into a vision document and it was used to raise endowment and infrastructure funds from the Government of India, industry and other sources. With the seed money in place, TRIPP was established as an interdisciplinary programme of IITD.

Vision

The shared vision of researchers at TRIPP is to produce knowledge that addresses the unique transporrtation issues in less motorised countries. An effort to set up a system of research activities that respond dynamically to problems defined in localised contexts by including a heterogeneous set of practitioners integrating internaational concerns in an internally consistent format. The idea is to experiment with new forms of knowledge generation where there is continuous negotiation between disciplines on the one hand and between scientists and society on the other.

Objective

The objective of TRIPP is to reduce the adverse health effects of transport by integrating mobility, safety and environmental concerns specific to India, in particular, and other less motorised countries in general.

Action

The establishment of TRIPP has facilitated interaction among faculty members from different departments in IITD and with professionnals from outside IITD (Indian Statistical Institute Delhi, Sanchal Hazard Centre Delhi, St. Stephen's Hospital Delhi, AI/India Institute of Medical Sciences Delhi, Institute of Democracy and Sustainability Delhi) to work on complex intradisciplinary problems associiated with urban transport. The group is unique because it combines expertise in transportaation planning, road safety, computer sciences, biomechanics, epidemiollogy, medicine, social sciences and econometrics for work on transporrtation issues.

Coordinator TRIPP

People

Standing Advisory Committee

Professor Deepak Nayyar
Professor of Economics,
Jawaharlal Nehru University
New Delhi.
Former Vice Chancellor,
Delhi University.

Mr. Nitn Desai.
Distinguished Fellow TERI (New Delhi), former Under-Secretary-General for Economic and Social Affairs, United Nations.

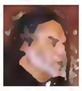
Dr. V. Sumantran.
Special Advisor to the Managing Director, Ashok Leyland ltd.

Research Faculty

A.K. Gosain, Ph.D. IIT Delhi.
Civil Engineering Department. Geographical Information Systems, hydrologic modelling, watershed management.

A. R. Ray, PhD (Delhi University). Centre for Biomedical Engineering. Biomaterials. Vaccines and Drug Delivery, Tissue Engineering, Polymer Science.

Anoop Chawla, Ph.D. IIT Kanpur. Mechanical Engineering Department. Artificial intelligence, computer graphics and design methodology and modeling in CAD/CAM/CAE, vehicle crash simulation and crash reconstruction.

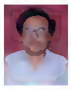


Dinesh Mohan, Ph.D. University of Michigan, Ann Arbor.
Coordinator TRIPP
Centre for Biomedical Engineering. Biomechanics of human tolerance to injury and epidemiology of road traffic injury, analysis of causative factors associated with road accidents in various locations, injury analysis and computer modeling of vehicle crashes.

Geetam Tiwari, Ph.D. University of Illinois, Chicago.
Civil Engineering Department. Specialisation in traffic flow analysis, transportation planning with special reference to environnment, safety and non-motorised vehicles, development of a bicycle masterplan for Delhi, analysis of traffic on Indian highways, crash analysis on rural and urban roads, public transport planning.

K.N. Jha, Ph.D.
Civil Engineering Department
Construction technology and management.

M. Balakrishnan. Ph.D. IIT Delhi.
Computer Science and Engineering Deparrtment. Application specific processor design, high-level design and modelling. FPGA based design and design tools, hardware-software codesign and system synthesis.



N. Chatterjee, Ph.D. University of London. Department of Mathematics. Machine translation, artificial intelligence, reasoning, statistical modelling and application of algebra in computer applications.

Puneet Mahajan, Ph.D. Montana State University. Applied Mechanics Department. Finite elements, contact and impact mechanics of composites, vibration behavior of tractors, helmet design.

R.R. Kalaga, Ph.D. IIT Kharagpur.
Civil Engineering Department. Mass Transit Planning, Traffic Flow Modeling and Road Accidents Analysis.

S. Sanghi, Ph.D. University of New York. Applied Mechanics Department. Turbulent flows and non-linear dynamics and chaos, second order modeling of turbulent flows including studies on atmospheric turbulence, application of chaos theory to different problems of interest, development of educational software .

Sudipto Mukherjee, Ph.D. Ohio State University. Mechanical Engineering Department. Mechanical system design, computer controlled mechanisms, kinematics, AI, robotics, crash modeling, human tissue properties, mechatronics .

Sunil R Kale, Ph.D. Stanford University. Mechanical Engineering Department. Heat transfer and two-phase flow, combustion modeling, pollution and energy conservation. air flow in vehicle.

Subhashis Banerjee, Ph.D. Indian Institute of Science, Bangalore. Department of Computer Science & Engineering. Computer vision, robotics, real-time systems, image processing and pattern recognition, image based Rendering, vehicle recognition software.

V.B. Upadhyay, Ph.D. (McMaster) Humanities and Social Science Department. Econometrics, monetary economics and development economics.

Collaboration

Division of Social Medicine, Karolinska Institutet, Stockholm: **Professor Leif Svanstrom**, **Head of Division**. Organisation of courses/workshops on injury control and safety promotion.

Hazards Centre, Sanchal Foundation, Delhi: A. K. (Dunu) Roy, Director. Working with TRIPP on analysis of transportation issues in Delhi and its relationship with land use patterns, and sociooeconomic issues concerning science and technology.

INRETS, France: Farida Saad, Marie-ehantal Jayet, Nicole Muhlrad, Sylvain Lassarre. The Institut National de Recherche sur les Transports et leur Securite, France has signed an agreement to facilitate the exchange of students, researchers and research resources between the two organizations in order to promote academic, scientific and technical cooperation and common research projects.

Institute for Social and Health Sciences, UNISA, South Africa: Professor Mohamed Seedat, Director. Organisation of courses on Traffic Safety in South Africa. Professor Seedat spent a year at TRIPP on his sabbatical leave.

Institute of Democracy and Sustainability, Delhi: Rajendra Ravl, Director. Working on nonnmotorised transportation, reclamaation of space, and street vendor issues.

St. Stephens Hospital, Delhi:

Mathew Varghese. Head Department of Orthopaedics. Involved in trauma care, particularly in constructive surgery for complex trauma of the musculo-skeletal system, road accident injury control and injury epidemiology research and pre-hospital care.

Ahamedall M. Hassan. Birmingham Automotive Safety Centre, University of Birmingham, UK.

Elaine Wodzin, International Research Council on the Biomechanics of Injury, USA.

Harald Zellmer, Autoliv Research and Development, Autoliv, Germany.

Hermann Knoflacher, Institute for Transport Planning and Traffic Engineering, Technical University of Vienna, Austria.

Janusz Kajzer, Chalmers University, Sweden.

Joseph Fazio, Civil Engineering, South Dakota School of Mines & Technology, USA.

Kavi Bawa Bhalla, Harvard Center for Population and Development Studies, Harvard University, Cambridge, USA.

Madhav Badami, School of Urban Planning and McGill School of Environment, McGill University, Montreal, Canada.

Mark H.P. Zuidgeest, Department of Urban and Regional Planning and Geooinformation Management, ITC International Institute for Geo-information Science and Earth Observation, The Netherlands.

Professor Murray Mackay, OBE, FREng, is Emeritus Professor of Transport Safety, University of Birmingham, England. He established the Birmingham Accident Research Centre at the University of Birmingham in 1964, and ran it until 1996. He has specialised in in-depth crash investigation, in understanding the epidemiology of traffic crashes, the mechanisms of impact injury and the performance of safety systems and their limitations. For several years he worked with the WHO in developing science-based traffic safety policies in developing countries. He is a founding director of the Parliamentary Advisory Council on Transport Safety in Britain and the European Transport Safety Council in Brussels. He is president of the International Research Council on the Biomechanics of Injury (IRCOBI). He has published and broadcast widely on transport safety matters in the UK and elsewhere. His awards include, S.A.E. Seigel Transportation Safety Award, N.H.T.S.A. Award for Safety Engineering Excellence, Joint recipient of the Volvo International Traffic Safety Award, The Safety Award in Mechanical Engineering from the Institution of Mechanical Engineers, London, The Award of Merit of the American Association for Automotive Medicine.

Transportation Research & Injury Prevention Programme
Indian Institute of Technology Delhi
New Delhi 110016

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