HOW SAFE WE ARE IN ROBUST DESIGN OF ROAD TRANSPORT IN INDIA NOW?

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ABSTRACT
Indian roads have high traffic mortality rate as compared to many European nations, U.S and Japan. It is the need of the hour to look for causes for the higher mortality rates and aim for the robust design of road transport. In the robust design of road transport, three aspects are important: Vehicle, infrastructure, and the driver. Coming to the vehicles, cars available in India are fairly designed for safety from all angles, except few cars coming in to the market without airbags. If the laws are enforced to prevent suppliers selling cars without airbags, we can say that the cars on the roads are designed for safety. The second aspect, infrastructure plays a greater role in reducing traffic mortality rates. China had achieved drastic reduction in traffic mortality to one fourth that of India in a decade, with massive investment in infrastructure, despite her doubling vehicle population, which speaks of her will to achieve sustainable transportation system. It is to be noted that both India and China are not good at law enforcement regarding traffic rule violations. Obviously there is scope for India to move towards lower traffic mortalities than the current alarming levels.

Keywords: Traffic Mortality, Road Transport, Robust Design, Vehicle, Infrastructure, Driver

I. INTRODUCTION
About 1.2 million people die on the world’s road on wheels every year and Indian roads account for 1, 30,000 lost lives per annum. Global Status Report on Road Safety 2013 by WHO1 indicates that this is the third leading cause of death in the prime age group of 30-44 years. Because 3/4th these victims in road accidents are the bread winners, we can understand the havoc this can create to society. This is of great concern to all professionals as to why this alarming road fatality does not come down despite the advances and discoveries in science and technology that are in vogue in the last decade.

The statistics for Indian roads are even more intriguing, the traffic injury causality has steadily increased during the decade to nearly from 8 to 12 lives per 100000 populations (Fig.1). This one may argue that it can be justified on account of increase in new vehicle registration at the rate of 10% per annum during these periods. But the fatality when expressed per 100000 of population does not show much deviation from country to country. When it is expressed in terms of 100000 vehicles registered, there is huge variation from country to country, reflecting many underlying causes for the fatalities?
The fatality rate expressed per 1,00,000 vehicles for India is 116. The fatality rate per 100,000 vehicles for 20 different countries averages to 10 as shown in Table I. Therefore it looks like Indian roads are not fit enough for safe road transport, as fatality rate is 11 times that of many of the developed nations.

Robust Design of road transport for safety is primarily dependent on three factors, the car, infrastructure and the driver. The design of car permits conditions for safe use across the whole life cycle of the car. Next, the safety of cars in turn depends on the design of infrastructure in which it operates and also on the driver who is the sole operator of the car. Thus all the three individually and together form essential part of road transport and therefore contribute to the safety of the passenger.

![Trends in Road Traffic Deaths](source: Road Accidents in India, 2009, Ministry of Road Transport and Highways, Transport Research Wing)

This paper aims at getting a close up view of the issues facing the car owners choose Indian roads a robust means of transport with regard to safety.

### TABLE I: Road Traffic Mortality Rate Per Annum In Various Countries

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II. PROBLEM DEFINITION

2.1 Complexity of Design of Road Transport

Acquiring knowledge about the use and conditions of use is essential for safe design. Common factor in accidents is that the breakdown of the product occurs when used outside its predefined limits. The underlying question is that the specific use should have been predicted, and prevented in the design stage itself, so that a mishap does not arise in practice. A simpler example: It is impossible to lock the door outside driver’s seat without using the key, which prevents forgetting to take the key and subsequent theft of car due to negligence of driver.

Fadier and De la Garza-2004, bring out the concern that designers often have a far too limited vision of what environment their products will end up in. The emphasis is to coordinate the design efforts on user’s safety requirements, rather than assigning causes to human error and designer keeping himself sheltered by a disclaimer.

In a process industry, we see the adequate control over all aspects of the design of the plant and its environment with just one principle conductor, the plant manager. Such is not the case with a car, where the environment itself is changing continuously and the operator (driver) has to be continuously aware of the situation he is going to face himself every split second and be prepared for the inevitable consequences of his erroneous actions at any instant.

We can envision that the designer’s task is to exert maximum influence on all factors that can increase the risk of accidents and ensuring that their disturbing influence is either eliminated or controlled.

From the studies of decision making that the standard response to complexity is for the decision maker to simplify and leave out aspects of the problem that are not within the control of the decision maker. This is known a bounded rationality. Certain influences are ignored as being negligible or uncontrollable or simply not taken account of for lack of time or knowledge.

(Courtesy: WHO, Global status Report on Road safety, 2013)
Baram\textsuperscript{3} 2006 argues that the designer’s responsibility for constraining the use of a product should depend on the competence of those who will use it. The more competent the user is, the more the designer can leave the boundary of acceptable use less rigidly defined. The less competent the user as in the case of road transport, the more this boundary needs to be defined and protected against unsafe usage.

One of the possibilities which we need to influence in design process is to try to enlarge the designers’ feeling of responsibility for understanding how the product is used and to see it as a challenge and not as an impossible task to accomplish robust design that is safe under varying environment or user conditions, like a car or a road transport.

Where there are separate designers of different system elements, such as the infrastructure, vehicles and traffic control systems of transport systems, there are particular requirements for mandating some form of collaboration, so that safety problems do not appear out of the cracks where the different subsystems do not fit each other.

This paper aims at getting a close up view of the issues facing the car owners choose Indian roads a robust means of transport with regard to safety. The Consumers of road transports for private usage is our primary focus. Here we exclude all public transports, heavy vehicles like trucks, buses, tractors, etc from our purview.

The safety aspect of road transport for private usage depends upon the car, infrastructure and driver aspects combined. Therefore each of these three aspects will be studied individually first. And upon getting to know the limitations on safety of each component, the overall safety aspect of road transport will be assessed.

### 2.2 Safety of Road Transport

Before going into the safety aspects, it is necessary to know the big picture of road transport under consideration. As we have seen earlier, road transport system has three parts, the first is the vehicle (car) the second comes the infrastructure (road) and then the third is the operator (driver.)

First we shall focus on the cars available in India.

### III. SAFETY FEATURES OF CARS

Seat belts and Airbags are the two features that are available with every vehicle sold to the consumers. These two are mandatory on all cars. There are more than dozen aspects that give additional safety of the passengers for preventing accidents and reducing mortality during crash. These safety features will be discussed below.

#### 3.1 Brands and Models on Indian roads

There are 29 global brands that are available in Indian and out of these brands around 180 models are being sold by dealers. Of these brands, it would be reasonable to focus on the top 20 leading models which form 80% of the cars preferred for private use in Indian scenario.

#### 3.2 Seat Belts and Airbags

A seat belt, also known as a safety belt, is a vehicle safety device designed to secure the occupant of a vehicle against harmful movement that may result during a collision or a sudden stop.
Steven D Levitt⁴ 2001 finds that by wearing seat belt reduces the likely hood of mortality by roughly 60% and airbags reduce mortality by around 16% in direct-frontal impacts. Cameron S. Crandall⁵ 2000 asserts that driver air bags independently reduced head on passenger car crash mortality by 25% and wearing seat belts mortality reduced by 75%.

### 3.3 Body design
Yong Han⁶ 2012, reports that pedestrian fatalities have been a major safety problem, with prevalence of injury region being head and chest. The traffic fatalities for pedestrians comprised 12% in US, and 35% in Japan and 26% in China. Investigation of injury mechanism of pedestrian chest collision with passenger vehicles of various frontal shapes reveals that one box type passenger vehicle causes a high chest injury risk. BMW had come out with a pedestrian air bag that will open when the car dashes against a pedestrian. This air bag opens outside the car just below the wind shield where the pedestrian’s head is likely to collide with.

### 3.4 Electronic Stability Control
Vito Cerone⁷ 2009 developed a Vehicle Dynamic Control (VDC) system for tracking the desired vehicle behavior. A 2-DOF control structure is proposed to prevent vehicle skidding during critical maneuvers through the application of differential braking between the right and left wheels in order to control yaw motion.

### 3.5 Adaptive cruise control
Shigeharu Miyata⁸ (2010) describes the Adaptive Cruise Control system (ACC), a system which reduces the driving burden on the driver. The ACC system primarily supports four driving modes on the road and controls the acceleration and deceleration of the vehicle in order to maintain a set speed or to avoid a crash. This paper proposes more accurate methods of detecting the preceding vehicle by radar while cornering, with consideration for the vehicle sideslip angle, and also of controlling the distance between vehicles. By making full use of the proposed identification logic for preceding vehicles and path estimation logic, an improvement in driving stability was achieved. This uses forward-looking sensors like radar and cameras to monitor the distance to a lead vehicle. The system will automatically slow the vehicle down in traffic to maintain a safe following distance without the driver having to do anything. As traffic speeds up, the vehicle accelerates to maintain the preset speed.

### 3.6 Forward Collision Avoidance System
Lee and Peng⁹ (2005) mentioned that the leading vehicle acceleration is a critical step for developing practical collision warning/avoidance systems. Good estimation of relative acceleration is the key to reduce the false alarm of FCWS. Using the same forward-looking sensors, these pre-crash warning systems alert drivers with visual or auditory cues when the vehicle is getting too close to the one in front. Experimental results show that the proposed algorithm can pass all 3 tests of ISO 1562 and issue valid warnings to the driver without false alarms for the expressway tests.
3.7 Autonomous Braking
If the driver doesn't respond to the warning, some systems are able to brake automatically to prevent a collision or lessen the impact. Systems that combine forward-collision warning and auto-brake are the most effective.

3.8 Adaptive Headlights
Also known as cornering lights, this innovative technology, which allows drivers to see, better as they round a curve, surprised researchers with how well it performed. According to Highway Loss Data Institute research, property damage liability claims fell as much as 10 percent with adaptive headlights.

3.9 Night Vision for Pedestrian Detection
In terms of pedestrian crashes on a worldwide scale, over 400,000 pedestrians die every year with over half of these deaths occurring in low-income countries. While many countries do have strategies to mitigate pedestrian crashes, it is clear that many low-income countries are lacking in pedestrian safety amenities. Tarak Gandhi\textsuperscript{10} 2007 gives an account of pedestrian protection system that could identify presence of pedestrian on the road. The night vision control detects the pedestrian when he is about to step by the side of the car on the road and the vehicle brake activated automatically.

3.10 Lane Departure Warning
The National Highway Traffic Safety Administration (NHTSA) has long recognized that the single vehicle road departure crashes leads to more fatalities than any other crash type. One emerging technology that the NHTSA believes may have great potential to save lives is lane departure warning. These systems assist the driver by providing a warning (passive or active) when their vehicle is about to depart the road line. The actual number of lives saved would depend upon the effectiveness of the lane departure warning system.UMTRI\textsuperscript{11} 2006 describes the lane departure warning system that was tested by U.S. Department of Transportation and the University of Michigan Transportation Research Institute along with its partners.

3.11 High End Cars with Additional Controls
In addition to some of the safety controls specified above, high end cars have several safety provisions like, backup camera, reverse backup sensors, side view assist, parking assist, driver drowsy or under alcohol influence. It can give speed limit violation warnings or even keep limitations on speeds.

3.12 How Important ‘Vehicle Safety’ Is In New Vehicle Purchases?
All cars have seat belts and airbags for the protection of passengers during the crash. SARACII\textsuperscript{12} 2005 gives details of how important ‘Vehicle safety’ is in new vehicle purchases? It is important to note that most consumers don’t attach importance to safety while choosing their most preferred car brand. Studies point out that among private users of cars, 20% of them are willing to pay for safety as priority. Most of car users give importance to aspects like fuel consumption, brand reputation, reliability, etc. Even though 20%
of the consumers consider safety belt and airbags are essential for their safety, air bag and seat belts together give 75% safety to the passenger during crash. Therefore there is 75% probability of protecting car owner who don’t want safety (number of car owners who do not prefer safety on account of additional financial burden is 80%) during crash, since all cars are fitted with air bags and seat belts.

IV. INFRASTRUCTURE

Indian has road network of 3.3 million KM of road (Padma S\textsuperscript{13}) and is second largest road network in the world. However qualitatively India’s roads are a mix of modern highways and narrow unpaved roads and they are undergoing drastic improvement. Roughly half of Indian roads are paved.

4.1 Road density based on population: Indian roads adjusted for its large population, has less than 4 km per 1000 people, including paved and unpaved roads. In terms of quality, all season 4 or more lane high ways, India has less than 0.07 km of highways per 1000 people.

4.2 National High ways and Express ways: In India and China.

Padma S\textsuperscript{13} reported that, National Highways in India account for less than 2% of the road net work and they carry 40% of the transport. Ruikar\textsuperscript{14} reported that the road transport fatality on National High ways in India is 37% of total road transport fatalities of all roads in India. If 2% of the roads account for 37% of the fatalities, then it is necessary to construct these roads with limited access for entry and exit. In other words, these roads should be express ways. The high traffic density on these could be attributed as one of the major causes of fatal crash on these highways. The number of vehicles also increases by 10% per annum in the last 5 years and may continue to be so in future. But qualities of roads to withstand higher capacities of vehicles were not constructed. The Express ways constructed in India is very small (200 km) or negligible part 79,200 km of National Highways.

Coming to China, it has 1, 04,000 km of express ways, constructed over a period of 24 years. Though India had constructed 21,300 km of 4 and 6 lane National Highways, constructing express ways is likely to take much longer period, when it is planned and executed.

Now we can look at the fatalities per 1, 00,000 vehicles. India has 116 fatalities as against 31 in China. China and India are similar when it comes to total population. Since China has almost twice the number of vehicle registered as compared to India, it could be expected that the fatalities in road traffic of China may be twice that of India. But the fatality rate is approximately one fourth that of India. From table II with regard to effectiveness of law enforcement in speed, drunk driving, and seat belt usage for both India and China, there is hardly any difference. Therefore infrastructure remains as the major differentiating factor between India and China.

India and China were at the same stage in number of Traffic fatalities in the year 2004, perhaps China had 20% more fatalities than India as can be seen from Fig.2.. Only difference that happened during this period in China is the growth of infrastructure, which brought the road mortalities to one fourth that of India, despite China’s vehicle population getting doubled during this period. This is a commendable achievement and this need to be duplicated in India.
The speed of construction of expressways in China doubled every four years so that they could achieve 1.04 lac km in 24 years. India is far away from such massive plan of development of infrastructure, as it is not so strong in industrial or farm sector productivity. Without huge potential for growth in these areas, proposal for such massive infrastructure development is unlikely in the near future. However, a modest beginning is already in place by selectively prioritizing locations recording highest rate of road mortalities.

TABLE II: Traffic Mortality Rate and Effectiveness of Law Enforcement County Wise.

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<th>Fatalities/Lakh Vehicles</th>
<th>Speed Law Effectiveness (0-10 Scale)</th>
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AVG*: The average of the variables intentionally excludes data pertaining to India or China
(Courtesy: WHO, Global status Report on Road safety, , 2013)

4.3 Heavy Vehicle Separation on the Roads

Ulf Bjornstig\(^{15}\) (2008) reported that between 1995 and 2004, 293 passenger car occupants died in collisions with other vehicles in northern Sweden (annual incidence: 3.3 per 100,000 inhabitants, 6.9 per 100,000 cars), half of these deaths involved heavy vehicles. The annual number of passenger car occupant deaths per 100,000 cars in car–truck/bus collisions has remained unchanged since the 1980s, but in car–car collisions it has decreased to
one third of its former level. As crash objects, trucks and buses killed five times as many car occupants per truck/bus kilometer driven as did cars.

Since heavy vehicles, ie trucks, buses, and tractors kill 5 times more than passenger cars, it is necessary to reduce the number of heavy vehicles or phase out, reduce the timing of plying heavy vehicles or assign the heavy vehicle to least congestion periods. Speed limits for heavy vehicles should be lower than passenger cars and it would be better if they are assigned to separate lane ever it is possible.

![Graph showing traffic mortalities in India and China](image)

Fig.2 Comparison between Traffic mortalities in India and China (Courtesy, Ministry of Road Transport and Highways, India, Road Accidents in India 2012,)

4.4 Intelligent Transport System (ITS)

Information technology (IT) has transformed many industries, from education to healthcare to government, and is now in the early stages of transforming transportation systems. While many think improving transportation solely means building new roads or repairing aging infrastructure, the future of the transportation system lies not only in concrete and steel, but also increasingly in using IT. IT enables elements within the vehicles, roads, traffic lights, message signs, etc to become intelligent by embedding them with microchips and sensors and empowering them to communicate with each other through wireless technologies. In the leading nations in the world, ITS brings significant improvement in the transportation system performance, including congestion and increased safety and travel convenience.

Unfortunately India is nowhere in sight when we compare the leaders in ITS, like Japan, Singapore and South Korea. It is dubious as to India has cognisance of the technology used in the developed countries and realising in its suitability in its present stage of development of highways.

4.5 Legislation for traffic regulations on roads and law enforcement.

The safety regulation regarding seat belt is enforced in the European countries, like Norway, Sweden, Switzerland, Spain, Netherland, Japan and other countries like Brazil, Singapore, and Australia. The enforcement level in these countries in a scale of 10 is found to be 7. In India the enforcement level for seat belt
is 2 or at the weakest level. It shows India is yet to realise the extent of safety offered by seat belt to the passenger during crash.

Evidence from many such countries show their dramatic successes in preventing road traffic injuries can be achieved through concerted efforts at national level. Such responses involve implementation of a number of proven measures that addresses not only the safety of the road user, but also vehicle safety, and the road environment. In 2010, the United Nations General Assembly adopted a resolution 64/255, which proclaimed a Decade of Action for Road Safety. The goal of the decade (2011-2020) is to stabilize and reduce the increasing trend in road traffic fatalities, saving an estimated 5 million lives over the decade.

4.6 Strict regulation in assessing fitness for issuing driving license:
1. The driving license test should adopt digitalized process to prevent human intervention.
2. Cancellation of license upon violation of traffic regulation. Those violating the laws need to cease driving on the roads.

4.7 Driver aspects for safety
Jagnoor\textsuperscript{16} specifies that all India road data confirms that 83\% of the accidents were due to driver’s fault. The most common form of infringement of traffic regulation is drunk driving and speeding. In addition drivers are also found to use mobile and electronic devices for messaging or talking while driving.

As per NHTSA 2013 report, when a driver engages in visual manual tasks such as messaging, the risk of crash increases by a factor of three. The three essential aspects to be considered for minimising usage of cell phone during driving are effective laws and regulations, strong and consistent enforcement, and pervasive education.

VI. RISK ASSOCIATED WITH DEFECTIVE VEHICLE COMPONENTS:
Steering wheel, Brakes and Tires are the three major defects occur frequently and chances of causing accidents goes up considerably as they critically affect control aspects of the vehicle and possibility of crash increases under such breakdown. However the contribution towards fatality of this aspect usually exceeds 2\%.

VII. METHODOLOGY:
Robust Design of Road Transport requires all three aspects, the car, infrastructure and the choice of driver have been ascertained strictly by analysis based on facts. To this end, data collection is being carried out for ascertaining Robustness of road transport in providing safety of passengers in all three aspects of (1) Design of the vehicle (2) Design of Infrastructure and (3) Driver choice.

7.1 Is the Vehicle designed for safety?
With regard to cars, it was found that 75-80\% of the cars are low end cars. Such cars have seat belts and airbags as major safety devices for their rescue during crash. Also, only 20\% of the buyers are willing to pay for their safety during transport and therefore opt for high end cars with adequate safety provisions. This means far less than 15\% of the consumers are really interested in safety of their lives. The safety of vehicles other than seat
belts and airbags are many. Electronic Stability Control, Adaptive cruise control, Adaptive Braking, Night vision for pedestrian detection, Traction control, Lane departure control, Driver distraction, Driver Drowsy, etc are some of support systems for the rescue of passengers which makes the road transport fit enough for safety of passengers from the vehicle point of view. All these controls are available for a price and only consumers very much conscious of safety afford such provisions.

7.2 Is the Infrastructure regulated for safety of passenger cars?
Usage of Infrastructure is governed by laws and enforcement agent. Infrastructure is under the government and it is imperative to follow the regulations and meant for those who follow the regulations. To prevent misuse or causing accidents goes against the general interests or common good of society. Do they have laws that will govern the users of passenger cars to prevent misuse of the infrastructure that may lead to collision of vehicles? Is the laws adequate to prevent users infringing upon the rights of fellow users who want safe transport through the infrastructure. Is the enforcement agency strictly following the regulatory laws to enforce them in to practice so as to coerce the drivers follow best driving practices?

7.3 Is the Driver driving for safety of passengers of his car as well as safety of those who use the same infrastructure?
Driver aspect of the vehicle is the most crucial one, because despite the vehicle and infrastructure being completely safe in all respect, still there is 30% chance of accidents if the driver is not aware of the consequences of his negligence towards driving. Drunk driving and speeding beyond the limits is prone for crash and this should be borne in mind. Talking while driving and sending text messages are equally dangerous and it is necessary to abstain from these two, throughout driving. Effective laws and strong and consistent enforcement of regulator laws, and pervasive education on these aspects will make drivers aware of the consequences of their action and be prepared for any eventuality.

VIII. RESULTS

8.1 Robust Design of Cars for India
All the cars sold in India have seat belts and airbags for drivers and front seat passengers and the probability of mortality during a crash is less than 25%. This gives adequate safety in case of crash. The vehicle owners in India are around 10% of the population as against 50-70% in most of the western European nations, America and in many developed nations across the world. The leading car manufactures in the world give several features of safety for a price; we can say that cars sold in India are designed for safety. If India passes a safety regulation to prevent car suppliers selling cars without airbag as an offence and such laws are enforced effectively, from the point of view of vehicle the road transport is safe in India.
8.2 Robust Design of Infrastructure in India

We had seen that the traffic fatalities in India are 3.7 times that of China. From table I and II we can make out that China and India are similar when it comes to enforcement of laws for traffic regulation. Both are lenient towards drivers who are found speeding, drunk driving and also found not using seat belts. What makes difference to the road traffic is that China has 1,04,000 km of express ways and India has a miniscule 200 km of expressways. This makes all the difference in terms of mortality rates in both countries: India has close to 4 times traffic fatality compared to China. This data could be further verified, and India needs to plan for reducing the mortality rates in the coming decade.

8.3 Robust Design of Regulation for Drivers and Cars using infrastructures

It is noted that India has neither laws which makes it mandatory to prohibit drivers from driving on the road and also issuing driving licence to those who are really fit enough for driving on the road. The identity of driver should be recognized from unique ID, a digitalized system. Secondly the process of ascertaining fitness for driving should also be digitalized, so that every malpractice could be avoided. Identity of cars also should follow similar checks and there by tampering with number palates could be eliminated.

IX. CONCLUSION

It is now clear from the studies that out of three aspects of robust design of road transport, the vehicle or cars are fairly designed for safety from all angles, except few cars coming in to the market without airbags. If the laws are made to punish suppliers selling cars without airbags, and if it is enforced without any infringement, we can say that the cars on the roads are designed for safety in all respects. There is a lesson to be learned from China, because she had achieved a massive reduction in traffic mortality within a decade, with massive investment in infrastructure. However, when it comes to the state of infrastructure and enforcement of provisions of laws to prevent drivers from violating the laws, there are lot of scope for improvement.

REFERENCES


