TRIPP BULLETIN
VOL 15 NO.2 MONSOON 2018
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Ph.D. Scholars *Current*

Study of the effect of geometric design features on capacity of hill roads
Scholar: Achyut Das

Transport, gender and climate change
Scholar: Akshima Tejaz Ghate

Context aware technology and systems
Scholar: Alok Nikhil Jha

Multi objective optimization in construction project management
Scholar: Amit Chandra

Urban landuse and transport modeling
Scholar: Amit Sharma

Accident reconstruction based study on motorcycle crashes
Scholar: Amrit Lal

Bus transit route network - aspects of design, optimization
Scholar: Bhamidipati Siri Aparna

Railway track pedestrian safety
Scholar: Darbamulla Saibaba

Pedestrian Safety near Crosswalks and Bus-stops: A case study in Delhi
Scholar: Deotima Mukherjee

Safety issues in project management
Scholar: Dilip A Patel

Macroscopic modelling in heterogeneous traffic environment
Scholar: Harikrishna Gaddam

Analysis of travel behaviour and impact of demand management interventions on non-captive bus users
Scholar: Hemant Kumar suman

Establishing relationship between elements of highway engineering on crashes on national highways in India
Scholar: H.M. Naqvi

Issues in human body FE modelling
Scholar: Kanhaiya Lal Mishra

Human body model (thorax modelling and its validation)
Scholar: Khyati Verma

Evaluating the effect of highway geometric on the safety of national highways of India
Scholar: Laxman Singh Bisht

Pedestrian and crowd modelling
Scholar: Lakshmi Devi Vanumu

Urban freight modelling
Scholar: Leeza Malik

Simulation of hetrogeneous traffic at signalized intersections
Scholar: Mohit Kumar Singh

Private participation in metro rail projects in India: challenges and way forward
Scholar: Mukund Kumar Sinha

Urban freight studies
Scholar: Nilanjana De Bakshi

Ph.D. Scholars *Continued*

Transportation equity
Scholar: Nishant Singh

Thorax model building and validation – diaphragm and aorta
Scholar: Piyush Gaur

Pavement materials
Scholar: Priyansh Singh

Finite element human body modelling direction
Scholar: P Devendra Kumar

Human body finite element modelling
Scholar: Rajesh Kumar

Understanding the urban environmental correlates of road safety : case study - Delhi
Scholar: Richa Ahuja

Mode choice initiators in public transport demand modelling
Scholar: Sandeep Gandhi

Finite element human body modelling direction
Scholar: Sanyam Sharma

Assessing the future of E-rickshaw
Scholar: Shiv Priye

Framework to determine the level of service of urban bus systems - Case study: Delhi
Scholar: Sneha Lakhotia

Understanding pedestrian motion at mass gathering and evacuation process
Scholar: Tarapade Mandal

Crash safety of electric vehicles
Scholar: Thainigaivel Raja T

Human body modelling requirements for vulnerable road users
Scholar: Wondwosen Ayelework Lakew

Ph.D. Scholars *Completed*

Modelling and risk assessment of heterogeneous traffic
Scholar: Gaurav Pandey

Road safety risk assessments of modern toll plazas and standardization of its geometric design
Scholar: Navdeep Kumar Asija

Measuring public health effects of urban transportation in Delhi
Scholar: Rahul Goel

Vehicle and crew scheduling optimisation of city bus systems
Scholar: S B Ravi Gadepalli

Impact of traffic control measures on speed and driver behavior in highway work zones
Scholar: Sumeet Gupta

The **Transportation Research and Injury Prevention Programme (TRIPP)** at the Indian Institute of Technology Delhi, is an interdisciplinary programme focussing on the reduction of adverse health effects of road transport. TRIPP attempts to integrate all issues concerned with transportation in order to promote safety, cleaner air, and energy conservation. Faculty members are involved in planning safer urban and inter-city transportation systems, and developing designs for vehicles, safety equipment and infrastructure for the future. Activities include applied research projects, special courses and workshops, and supervision of student projects at postgraduate and undergraduate levels. Projects are done in collaboration with associated departments and centres at IIT Delhi, government departments, industry and international agencies.

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Possible Futures of Vehicle Safety

Yves Page
RENAULT GROUP, Guyancourt, France

This paper proposes an overview of achievements in the safety benefits (lives extended and injuries mitigated) provided by current or close-to-market vehicle technologies. It also proposes to review some of the research and developments in future vehicle safety such as connected vehicles and automated driving. It finally discusses expected safety benefits, and potentials as well as barriers to a large dissemination of these current and future technology-based traffic safety measures.

As they are mostly foreseen in high income countries in the middle term, another type of revolution is needed in low and middle income countries for before these technologies can be put onto all global markets at a reasonable cost and contribute to the safety benefits of all road users. Frugal safety, coming from the frugal engineering concept, would be the recommended way to enable and accelerate this deployment.

As for vehicle safety technologies already on the market, they have proven to be highly effective in mitigating vehicle occupant injuries, and injuries of vulnerable road users. Secondary safety devices and basic driver assistance systems have been largely evaluated and the effectiveness of seat belts, load limiters, pretensioners, airbags, car structure, electronic stability control (ESC), emergency brake assist (EBA), and other such devices have been examined. Available results show that, for example, if all cars were Euro NCAP five stars and fitted with EBA and ESC, compared to four stars without ESC and EBA, injury accidents would be reduced by 47%, all injuries would be mitigated by 68% and severe + fatal injuries by 70% (Page et al, 2009).

Unlike secondary safety systems, ESC, ultrasonic park assist, cornering lights and manual speed limiters, most of the primary safety systems or advanced assistance systems (such as blind spot detection, lane departure warning, lane keeping assist, automated cruise control, night vision, high speed AEB, etc.) are not, or just poorly, deployed on the market. There are a few reasons for this. First, their maturity and their capacity to work well without too many counter effects are recent, technological barriers have been strong for a long time. They were launched first in luxury cars in the USA, Japan and Western Europe in the mid-2000's and democratization has started just a few years back. Secondly, these features are costly, in terms of unit price and also in terms of investment; and their deployment demands progress in cost reduction. Thirdly, their expected safety benefits are, to a certain extent, not really known. If it is now epidemiologically demonstrated that secondary safety features bring safety, as well as ESC, the positive effectiveness of not-yet largely deployed primary safety devices is only estimated and not yet proven, except for some of them like low speed AEB (Automatic Emergency Braking). Studies about effectiveness of these devices take into account the potential in saving lives of generic functions, but a lot is still unknown about the real-world usage and acceptance by drivers and pedestrians of these applications. As there are many variants of these features, and especially concerning the mode of restitution to the driver of the information, the alert, or the warnings, the genuine efficiency of each variant is still a mystery. Of course, in-house studies by suppliers and car manufacturers anticipate positive acceptance by drivers and have identified and countered possible counter effects. Of course, current research is evaluating their potential to safety and in covering real-world driver needs, but a large field of research is still open for their safety assessment in real-life.

Anyhow, the introduction of vehicle safety technologies is supposed to bring safety for a variety of road users and a variety of crash configurations. Of course, they will first be disseminated in high income countries but they will also be further disseminated, expectedly quickly, in the rest of the world under the pressure of customer demand, competition between vehicle makers as well as pressure from all kinds of New Car Assessment Programs, NCAP's (Latin NCAP in South America, Bharat NCAP in India, Asian NCAP in Asia, etc.) and more generally from Global NCAP, which federates NCAP's all over the world. This will be a first step in the globalization of existing or close-to-development vehicle safety technologies.

Actually connected technologies for safety and driving assistance systems in the current world of stand-alone technologies have 3 additional values:

•Improve the robustness of current systems by enhancing/duplicating capabilities & functionalities.

•Replace existing systems at a lesser cost.

•Add new functionalities to current ones and then expand the potential of coverage of various crash configurations and risk factors. For example, the EU-funded Drive C2X has selected 9 applications that are mainly safety related (most of them address the so-called 'risk awareness' issue, i.e. a crucial information needed by users and preventing them from a potential road hazard. The danger does not require an immediate action from the driver but requires an increase in attention and situation consciousness), but that can have also an impact on efficiency, mobility and the environment.

Furthermore, automated driving allows some kind of delegation of driving tasks from the driver to the system, from partial delegation (for example lateral control in congested traffic) to full automation (driver out of the loop or even out of the vehicle). Even though the technologies are not really fully reliable and robust, automated cars are largely experimented with in the US (and not only the much publicized Google or Tesla cars), in Europe and in Japan and are presented as the future of the automobile. These cars are expected to bring extremely large safety benefits when the technologies are mature and the driver errors eradicated.

Finally, frugal safety is a concept that helps in identifying ways to reduce dramatically the costs of technologies, both in the devices themselves and in the process to produce the devices and their integration in the vehicles.

Examples of vehicle-to-X technologies, automated driving functions and frugal safety devices illustrate our discussion about the promises of such technological revolutions. They are expected to highly contribute to crash and injury reductions to an extent never achieved by traditional safety measures so far.

Safety can be envisaged from several angles:

- Primary Safety, aims to prevent a harm. The difference between prevention and avoidance is a bit vague. Say, for the sake of simplicity, that any measure that targets attitudes and behaviors of road users as well as other players of road safety (in charge of design, maintenance and control of vehicles, road, road equipment and traffic management) are preventive actions, whereas measures that correct a driving situation which is critical or is about to be critical are avoidance measures. We do not elaborate here on the term 'precaution', which consists in taking measures against a new risk, unknown and not well-documented, which generally leads to very restrictive measures.

- Secondary Safety, aims to reduce the consequences of a harm (severity).

- Tertiary Safety, aims to bring the best and fastest care to victims.

- Quaternary Safety, aims to reduce the physical and psychological sequelae after a harm.

Therefore, vehicle safety consists of a series of measures which ensure, via a vehicle (or, nowadays, the so-called extended vehicle taking also into consideration the connectivity between vehicles or between vehicles and environment), automobile trips with minimum harm and external effects.

There are currently a few taxonomies of driving assistance systems. We propose 4 of them, according to the assistance type, according to the level of influence of the assistance and, according to the active or passive participation of the driver.

According to the assistance type:

•The assistance can be of a strategic type. It then targets the itinerary planning and the navigation. Navigation systems are typical examples of this type.

•The assistance can be of a tactical type. It targets the selection and the performance of the manoeuver adapted to the encountered situation. Blind spot help detection is a typical example of a tactical aid.

•The assistance can be of an operational type. It consists of controlling the vehicle trajectory. Emergency braking or electronic stability control are typical examples.

According to the assistance influence:

•In a first step, the assistance brings an information to the driver (e.g. an information about density of traffic or tire pressure).

•In a second step, the vehicle activates an alarm (for example a tone if the seat belt is not buckled up).

•The vehicle can also activate an enhanced information (a long and high tone if the belt is still not buckled up after a few seconds for example).

•The vehicle can perform a corrective action on the manoeuver (e.g. electronic stability control).

•The vehicle can, at last, take control, the driver being fully out the loop (automatic braking for instance).

According to the driver participation:

•Without driver intervention (for example automatic emergency braking)

•An assistance which takes part of the driving task (e.g. autonomous cruise control)

•A driving assistance under control, which accompanies an action by the driver (example: electronic stability control)

It is indeed difficult to establish a 'Top 10' rating of the most promising systems which for a few reasons [17]: Effectiveness studies are of 3 kinds: the ones which simulate the expected effectiveness of systems not yet or poorly on the market, the ones which observe the actual effectiveness of systems in the market according to their penetration rate in the fleet, and the ones which extrapolate the safety gains that would be observed if existing systems would be disseminated 100 % in the fleet. We thus have a problem of consistency among different estimates.

Whatever their types, available studies vary in the effectiveness indicators they use. It can be reduction in injury crashes, reduction in all kinds of crashes, reduction in fatalities, in severe injuries, in crash risk, in injury risk, taking into consideration (or not) the penetration rate, etc. (Possibly depending on accident or impact types such as loss of control, frontal impact, pedestrian collisions, etc.). As a consequence, they are not exactly comparable.

Similarly, methods and techniques of evaluation as well as simulation assumptions (noticeably concerning the use of driving aids by drivers) vary a lot too. Furthermore, some sensitivity studies establish effectiveness estimates depending on different values of a set of parameters entering into consideration to make the function work. Subsequently, effectiveness estimates might be quite different between variants of the same system.

Actually, numerous systems present numerous variants. Variants may concern the function itself: for example, a Lane Departure Warning can have different triggering thresholds, possibly selected by the driver, when the car is about to leave the lane, when it crosses the lane line, or long before crossing the line; or an AEB can detect only moving obstacles in the same direction, or can detect any kind of moving or stopped obstacles.

OEM's and suppliers continuously improve the systems, from time to time and new systems are continuously released. Therefore, the long list of functions and variants is always evolving. A Top 10 would shed the light on a few fashioned systems at a given time and possibly hide promising functions not properly analyzed yet. Moreover, some functions improve better than others overtime by, for example, extending their coverage (AEB against moving vehicle, than against stopped or fixed obstacles, than against pedestrians, at low speed and speeds) or by strengthening the technology (more reliable and therefore encompassing.

Primary, secondary or tertiary safety systems must not be considered in competition with one another but rather like different opportunities to solve similar problems. For example, an Intelligent Speed Adaptation System can reduce the driving speed, an automatic braking system can reduce the impact speed, a reinforced car structure combined with restraint system can be even better at lowering impact speed and an automatic crash notification can reduce intervention delays by rescue services. Rating them all in a Top 10 would mean ignoring their additive impacts.

If systems are sometimes complementary or additive, they are seldom fitted individually in a vehicle, which would demand the establishment of a Top 10 of the 'packages of systems' rather than a Top 10 of isolated functions. Given their high number, classifying hundreds of combinations or packages is impracticable.

To our knowledge, there is no unique Top 10, accepted by the scientific community as absolutely irrevocable.

Frugal engineering is the process of reducing the complexity and cost of a good and its production. Usually this refers to removing nonessential features from a durable good, in order to sell it in developing countries. It also refers to make cost reductions during the process of innovation, engineering, production and commercialization. There are many ways of doing this; the biggest challenge is to avoid producing bad products/services at low cost in bad conditions, which could have long-term negative effects on the brand, the whole economy and the safety/security of products.

Current examples of low cost safety systems can be found in smart phones, with a lot of free or cheap applications such as lane departure warning, drowsiness warning or forward collision warning, based on simple algorithm and the smart phone camera as sensor for example (or blood pressure sensor as another example). They do not prove efficient and cannot be considered as frugal engineering as they are often nomadic devices produced outside the OEM's world. A step forward would be to integrate frugal engineering as a basic paradigm for safety, so that it is for low-end cars which present nevertheless quite good levels of quality so far.

Automated vehicles, connected vehicles and frugal safety engineering are the three likely pillars for the future of vehicle safety based on technology.

Excerpts from a chapter in a forthcoming TRIPP publication: The Safe Way: State of the Art papers on Road Safety

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M.Tech. Projects

Completed

Prediction of air temperature for pavement temperature estimation
Student: Amit Kumar
Design of timetable for improved passenger comfort in Delhi metro yellow line
Student: Balarko Banerjee
Safety analysis of roundabouts and signalised intersections
Student: Brusava Kumar Swain
App based taxi and it's impact in New Delhi
Student: Kumar Kautilya
Emission calculation and characteristic analysis of vehicles on national highways in India
Student: Krisha
Intercity freight vehicle characteristics
Student: Manoj Kumar
Sustainable development goals focusing on travel and safety "evaluation and monitoring for small cities"
Student: Mohit Kohli
Rheological investigations of nano-modified binders
Student: Saqib Gulzar
Accessibility and safety of informal stops
Student: Sunil Kumar
Measuring performance for bus fleet operators
Student: Tanmoy Das
Estimation of driver character and PCE at roundabout
Student: Vaibhav Negi

NEWS

Road accidents involving bicycles: configurations and injuries

The main findings of the present research can be summarized as follows:
in most collisions, the bicycle impacted with a passenger car, followed by single accidents;
- the percentage of injured bicyclists was higher if the bicycle impacted with a heavy vehicle and decreased when the bicycle impacted with cars, two-wheeled vehicles, bicycles or pedestrians;
- a high percentage of injured and severely injured bicyclists in single accidents was observed;
- the most severe injuries were more frequently to the head and the extremities;
- the ten most frequent configurations represented about 60% of involved bicyclists and more than 60% of injured bicyclists;
- the five most frequent configurations represented 44% of involved bicyclists and 47% of injured bicyclists;
- accidents between a car and a bicycle with priority from a bicycle path alone represented almost 20% of involved bicyclists and more than 20% of injured bicyclists.

These results therefore suggest that injuries to bicyclists can be reduced through a better design of cars and heavy vehicles. Design measures include crash-friendly car fronts and side-underrun protection on lorries. Lorries could be made much safer for the other vehicle involved by the application of adequate protection around the vehicle, for example, side-underrun protection; such protection prevents the dangerous underrun of, for instance, bicyclists. Another important issue for reducing the number and severity of crashes with other vehicles is the visibility of bicyclists by means of lighting and reflecting devices. Bicyclists benefit from conspicuity aids such as armbands, light-coloured and retro-reflective clothing, and high-visibility helmets. In addition, bicycles should be equipped with front and rear lights and reflectors. Another relevant aspect is the importance of transportation infrastructure on bicyclist safety, in particular bicycle lanes: all ten of the most frequent configurations occur when the bicyclist is going or is riding outside the bicycle lane.

Chaira Orsi, Cristina Montomoli, Dietmar Otte and Anna Morandi (2017). International Journal of Injury Control and Safety Promotion, 24(4), 534-543.

Course Announcement

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is organizing an eight day **"International Course on Transportation Planning and Safety"**. The course will be held in New Delhi, India, from **November 29 - 7 December 2017**. The course will have a common component for the first three days, followed by three parallel modules on Traffic Safety, Biomechanics and Crashworthiness and Prehospital Care and Trauma.

The course will be followed by a one day **Young Researcher Symposium**. The symposium will offer an opportunity to current doctorate students and recent graduates (graduated after 2017) working on different aspects of traffic safety to present and discuss their work with experts from all parts of the workd and to stimulate the exchange of ideas in the broad field of traffic safety.

Details of the course can be accessed from -http://tripp.iitd.ernet.in

Establishment funds have been received from
Ministry of Industry, Government of India
Asian Institute of Transport Development
Tata Motors, India
Volvo Research and Educational Foundations (VREF), Sweden

Endowments for perpetual Chairs
CONFER, India: TRIPP Chair for Transportation Planning
Ford Motor Co., USA: Ford Chair for Biomechanics and Transportation Safety
Ministry of Urban Development India: MoUD Chair for Urban Transport & Traffic Planning
MoUD Chair for Urban Transport and Environment
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

Transportation Research and Injury Prevention Programme
Room MS 815 (Main Building)
Indian Institute of Technology Delhi
Hauz Khas,
New Delhi 110016, India

Phone: 91-11-26596361, 26858703
Fax: 91-11-26858703, 26851169
Email: ird11830@civil.iitd.ernet.in
http://tripp.iitd.ernet.in

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Public Health Effects of Urban Transport in Delhi

Rahul Goel, Excerpts from Ph.D. Thesis

A TRIPP BULLETIN INSERT

Road transport affects human health through three risk factors— injuries, air pollution, and physical inactivity (Dora and Phillips, 2000). Injuries are a result of road crashes, air pollution results from vehicular exhaust, vehicle wear and tear, and road dust re-suspension (Pant and Harrison, 2013), and increase in walking and cycling during travel reduces prevalence of physical inactivity (CMO, 2004). In addition to the three risk factors, transport also results in health effects due to noise, community severance, and the opportunity cost of transportation resource use (Woodcock et al., 2007). However, the evidence linking the three risk factors— injuries, air pollution, and physical inactivity— to health are strong (Woodcock et al., 2009), and hence these risk factors are most often studied in the context of transport (Doorley et al., 2015; Mueller et al., 2015).

Vehicular exhaust consists of various pollutants and, among them, particulate matter (PM) has been found to have the most potent effects on healh (Samet et al., 2000). Out of the total PM mass, the smallest particles i.e. PM2.5 (PM with aerodynamic diameter <2.5 μm), also known as fine PM, have been found to have the most adverse effects due to their ability to penetrate deeper into the lungs. The adverse effects include morbidity and mortality due to cardiovascular diseases (Brook et al., 2010), lung cancer (Pope et al., 2011), and acute lower respiratory infections in children younger than 5 years (Brauer et al., 2002). Evidence also links PM2.5 pollution with all-cause mortality (Dockery et al., 1993; Schwartz et al., 1996; Franklin et al., 2007). Once controlled for PM, independent effects of gaseous pollutants, such as carbon monoxide, nitrogen dioxide, ozone, have been found to be insignificant (Samet et al., 2000; Pope et al., 2002; Brook et al., 2010), except SO2 (Pope et al., 2002; Brook et al., 2010). As a result, PM2.5 is often used as an independent measure of air pollution for health impact estimates (Doorley et al., 2015).

Walking or cycling during travel contributes to physical activity of individuals. Epidemiological studies from various settings of the world have established a strong link between physical activity and health benefits. Walking and cycling during travel leads to health benefits in terms of reduced risks for cardiovascular outcomes (Hamer and Chida, 2008), type-II diabetes (Jeon et al., 2007), and all-cause mortality (Kelly et al., 2014). Also, these effects have been found to be independent of physical activity in other activity domains, such as leisure and work (Kelly et al., 2014).

According to Global Burden of Disease (GBD)–2010 study estimates, ambient PM2.5 pollution and physical inactivity are among the top ten risk factors of all deaths in India (IHME, 2013). The two risk factors result in various chronic diseases, and are estimated to be responsible for 630,000 and 440,000 deaths, respectively, contributing one in every 10 deaths in year 2010. During the same year, 134,000 deaths were officially reported in India due to road traffic crashes (NCRB, 2011), while GBD estimated the number of road deaths to be twice the official number (GRSF, 2014). Thus, the three risk factors combined contributed to more than one million deaths in 2010. All these deaths, however, are not due to transport alone. While road traffic injuries are wholly attributed to transport, PM2.5 pollution is contributed by multiple sectors, and physical inactivity is a result of inactivity in multiple activity domains.

It was found that almost one in every 10 deaths in Delhi for year 2014 are attributed to vehicular PM2.5 pollution and road traffic injuries, with pollution contributing 80% of those deaths. A similar number of deaths were estimated to have been prevented due to prevailing walking and cycling. Vehicular pollution death rate in Delhi is more than 15 times higher than GBD-reported death rate for the whole of India. The large difference occurs due to high motorisation rate as well as higher pollution levels in Delhi, compared to whole of India. The results highlight the importance of assessing transport-related health burden at local level.

In New York, the road traffic fatality rate is 3 per 100,000 persons (NYDMV, 2014), in Greater London, 1.6, (TFL, 2014), and in Amsterdam, it is 2 (iamsterdam, 2014). In Delhi, the death 178 rates are 4–6× higher than these three settings. Fatality risk per km for walking in Delhi is an order of magnitude higher than settings in the US and the Netherlands, while cycling is moerately higher (McAndrews et al., 2013; Teschke et al., 2013; de Hartog et al., 2010). Similarly, the PM2.5 concentrations in Delhi are, on an average, 10 times higher than the three cities. At such concentrations, high breathing rates during active travel makes active travel additionally hazardous. It was estimated that inhaled dose of PM2.5 during an hour of cycling in Delhi is higher than an entire-day dose inhaled by individuals in cities like London, New York, Tokyo and Amsterdam, as well as higher than an hour-long dose inhaled during biomassbased cooking. Clearly, active travel in Delhi has much higher combined risk due to injuries and air pollution than in high-income settings.

It should be noted that high magnitude of on-road pollution exposure occurs even when the onroad concentrations are only moderately higher (10-30%) than off-road or ambient concentrations. Thus, near-roadway sources contribute only a small fraction of the overall onroad concentrations. Instead, high exposure is a combined resul t of higher breathing rates during cycling (3× higher than at rest) as well as higher background concentrations (10× higher than clean high-income settings). Thus, higher exposure of pollution during travelling should be seen within the broader framework of overall air pollution problem and not from vehicular perspective alone, and the former is a result of multiple sectors in Delhi. Therefore, for reducing travel-related hazard of air pollution, policies aimed at reducing pollution from brick kilns, power plants, industries, and diesel generator sets are as important as the policies aimed at reducing vehicular pollution.

We also found that for individuals from car-owning households, the difference between their pollution exposure estimated from static and dynamic approach was negligible. However, this difference was much higher for individuals from households not owning a car, possibly as a result of their higher exposure during on-road travel. Even for those individuals, it was found that pollution exposure at residential location contributes more than 95% of overall day exposure of individuals. Thus, as long as the ambient pollution levels remain high in Delhi, the relative importance of on-road exposure will remain low.

It was found that the risk of travel-related pollution exposure, when expressed in terms of inhaled dose, is the lowest for cars and the highest for active modes, followed by PT which also involves walking for a part of the trip. Similarly, fatality risk of pedestrians is more than 30× higher than a car occupant and that of cyclists is 5× higher. This implies socio-economic 179 inequality of travel-related pollution as well as injury risk exposure, as those using cars in Delhi are likely to have higher socio-economic status than those using non-motorised modes or PT. In 2011, only 20% of the households in Delhi owned a car (Census-India, 2012) and, according to the travel survey conducted as a part of the thesis, less than 10% of the total trips in Delhi were reported to be travelled by car. The inequality of pollution exposure will be much less for high-income countries, such as the US and the UK, where 70% and 90% of all the households, respectively, own at least one car (Giuliano and Dargay, 2006).

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Modeling Traffic Flow and Fatal Crashes in Urban Areas

Gaurav Harishchandra Pandey : Excerpts from Ph.D. Thesis

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In some developed countries, microscopic simulation models have been used to evaluate geometric elements of roads, signal timings, frequency and capacity of public transit systems, impact of traffic policies on air quality, accident risk, toll plaza operation and even intelligent transportation systems. However, their use in developing countries is still limited due to difficulty in calibration and validation of model for non-lane, heterogeneous traffic conditions. In these conditions, fast and slow moving vehicles share the road space and hence the driver model becomes more complex as compared to developed countries where lanes are properly marked and vehicles maintain lane discipline. Also, owing to lack of infrastructure, the difficulty in collecting microscopic traffic characteristics such as lateral and longitudinal gaps, acceleration and deceleration properties etc. makes it even more difficult to calibrate and implement these models in developing countries.

Although there is a growing awareness among policy makers about the importance of modelling and simulation before implementation of transportation schemes, there is a need to evaluate the model microscopically and develop microscopic traffic flow models that can replicate traffic in developing countries. Also, there is a need to develop strategy for accurate measurement of traffic flow characteristics used in these models. Finally, various applications of these models can be explored to help improve the transport planning process. One such application is the use of micro simulation for determining intersection rate and hence crash risk. This approach appears promising as a micro-simulation model can be modified to account for any driving and site specific condition which may affect interaction rate. For example, simulation of lateral (along road width) driving of two wheelers while waiting for signal (phenomenon observed in developing countries in Asia) or simulation of lateral (along road width) driving of two wheelers while waiting for signal (phenomenon observed in developing countries in Asia) or simulation of work zones by creating road blocks inside model. This is not easy to accomplish in macroscopic models as the effects of small changes in driving or site conditions are averaged out due to aggregation. Hence, the use of microscopic traffic modelling for evaluating various custom traffic scenarios is increasing these days. This is especially true in the case of cellular automata models (CA) as it is simple rule based and its discretized characteristics allows for great flexibility in adopting various traffic conditions while being computationally efficient. But CA needs to be evaluated using microscopic characteristics as it has never been used for determining interaction rate under heterogeneous conditions.

Road crashes are going to be a major challenge in the coming decades especially for developing countries. However, if the correlation between fatal crashes and microscopic interactions between vehicular, traffic and geometric characteristics of the road are well understood, efficient and safer traffic policies can be devised. We believe that the amount of microscopic interactions between different types have an effect on the number of fatal crashes between them. Traditionally exposure is used as a measure to describe the total number of instances that could result in fatal crashes. Exposure can be defined in a number of ways but usually as total registered vehicles of any type or total vehicle miles driven by a vehicle type in the study area.

While these measures can be used to describe total number of instances that could result in fatalities and hence risk, they may not be accurate as not all registered vehicles of a given type have similar travel profile. This is because exposure for a given vehicle type depends on number of vehicles and average trip length for that type. Hence, if the total travel distance is used as measure of exposure, a bicycle sharing road space with other vehicle types would appear to face same risk as those using bicycle lanes but we know that dedicated bicycle lanes may significantly reduce the probability of crash between bicycle and other vehicles. Also, road geometry and driver behaviour vary between locations. So, for a given vehicle type and road length, some vehicles are at greater risk than others as risk is related to road geometry and driver behaviour. We believe that the interaction rate between locations. So, for a given vehicle type and road length, some vehicles are at greater risk than others as risk is related to road geometry and driver behaviour. We believe that the interaction rate between vehicle types may have better correlation with fatal crashes as compared to exposure. This is because interaction rate between two vehicle types is a result of traffic and driver characteristics such as vehicular proportion, occupancy on road, speed, overtaking and following tendencies etc. in the stream. Since many researchers have established relationship between traffic and driver characteristics and fatal crashes, the applicability of interaction rate between vehicle types for determining fatal crashes can be explored for better understanding of crash risk (Hauer, 1995; Oh et al., 2006; Kim et al. 2007 and many others). Vehicles are said to be interacting when their travel behaviour is influenced by the actions of other vehicles in stream. Some studies have defined interaction rate as number of overtaking and car-following events (i.e., discrete events) over a period of time on a stretch of road (Oh et al., 2006). But quantifying the interaction rate between two vehicle types is difficult and subjective. This is because interaction rate varies with traffic, driver and geometric characteristics. As the proportion of two vehicle types increases in the stream, the interaction rate between them also increases interactions between them. Various geometric features such as lane width, number of lanes, speed bumps, signal timings etc. and driver related factors such as aggressiveness may affect the interaction rate or number of car-following/overtaking events between two vehicle types. Since there are not many models that consider these effects and predicts interaction rate, most researchers have avoided exploring relationship between interaction rate and fatal crashes. This is especially true for heterogeneous traffic conditions where the researchers also need to consider non-lane discipline (staggered car-following) while determining interaction rate.

The study attempted to determine the effect of interaction rate between different vehicle type on fatal crash propensity. In this study the interaction rate between two vehicle types represents the number of vehicles observed to be overtaking/following per 1000 observed interaction between two vehicle types. Hence it can be assumed that interaction rate in this study is affected by driving characteristics in addition to traffic parameters such as flow, density and speed. We further believe that vehicular interaction rate used in the study would be a much better measure of exposure compared to conventional measures such as total registered vehicles or vehicle miles/time travelled. It may be difficult to measure interaction rate using video camera at the moment but steady increase in implementation of GPS devices in vehicles and/or improvement in video image processing would make interaction rate estimation quite easy in near future. While the use of conventional measures may be justified in the past due to data collection limitations, field conditions provide enough reasons to investigate more accurate measures of exposure for determining risk. On urban sub-arterial roads exposure between trucks and two wheelers would be much less than on arterial roads owing to the negligible share of heavy vehicles in stream. Similarly, on roads with exclusive lane for bicycles the exposure between bicycles and other vehicles would be much less. It can be assumed that exposure between bicycles and other vehicles would be much less. It can be assumed that exposure between different vehicle types depends on vehicular composition, lane configuration, vehicular density etc. on a particular road. Researchers (Carroll 1969; Cameron 1979) have defined exposures as the number of traffic events that may lead to crashes. The present study assumes that these traffic events to be overtaking or car-following events. Oh et al. (2006) tried to simulate exposure citing that exposure is equal to total time a vehicle pair spend following. Recently some researchers have tried to use CA micro simulation model for determining interactions between unconventional modes such as vehicles and pedestrians on crosswalks or ships in water-channels (Sun et., 2015; Chen et al., 2016). These approaches allow for more precise exposure estimates between the two vehicle types on a given road. This study also investigates the effect of macroscopic traffic characteristics such as speed distribution, flow, vehicular composition and density of vehicles on the propensity of fatal crash.