TRIPP BULLETIN
VOL 17 NO.2 MONSOON 2020
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Ph.D. Scholars *Current*

Role of Intermediate Public Transport in Indian cities
Scholar: Aishwarya Sanjay Jaiswal

Transport, gender and climate change
Scholar: Akshima Tejas Ghate

Prediction of missing data in road accidents
Scholar: Alok Nikhil Jha

Urban landuse and transport modeling
Scholar: Amit Sharma

Traffic flow modelling
Scholar: Anamika Yadav

Effect of oxidation on engineering, rheological and viscoelastic properties of asphalt
Scholar: Anjali Balan L

Incorporating uncertainty issues in flexible pavement design framework
Scholar: Aswathy Rema

Residential self-selection and activity travel behaviour
Scholar: Chetan Nagesh Doddamani

Railway track pedestrian safety
Scholar: Darbamulla Saibaba

Surrogate Safety Measures For Traffic Safety Assessment
Scholar: Debashis Ray Sarkar

Pedestrian safety near crosswalks and bus-stops: A case study in Delhi
Scholar: Deotima Mukherjee

Methodology for prediction of pedestrian injuries under different motorcycle-pedestrian impact scienarios
Scholar: Devendra Kumar

Management of sustainability risks in freight transportation systems
Scholar: Divya Choudhary

Material charcterization for blast loading
Scholar: Kanhaiya Lal Mishra

Formulation of energy absorption model to estimate the pre-impact speed of motorcycle invlved in a crash on Indian roads
Scholar: Kuldeep Singh

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

Impact testing of helmet
Scholar: Manish Kumar

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

Evaluating public private partnership in urban rail in India
Scholar: Mukund Kumar Sinha

Pedestrian safety perception in Built environments
Scholar: Neba C Tony

Ph.D. Scholars *Current*

Integrated freight trip generation and mode choice model - case study Delhi
Scholar: Nilanjana De Bakshi

Transportation equity
Scholar: Nishant Singh

Accident Prediction Modeling of priority junctions at inter-city urban highways
Scholar: Parveen Kumar

Characterization of aorta and diaphragm at high strain rate loading
Scholar: Piyush Gaur

Prediction of motor cycle - pedestrian crashes
Scholar: P Devendra Kumar

Optimization framework for transitioning to electric bus system for New Delhi
Scholar: Pranav Gairola

Human body finite element modelling
Scholar: Rajesh Kumar

Impact of transportation demand management strategies on pollution, congestion and mobility in Gurugram
Scholar: Ranjana Soni

Estimating post-crash accessibility to trauma care facility
Scholar: Richa Ahuja

An empirical study on sustainable procurement in the construction industry
Scholar: Santu Kar

Prediction of thoracic injuries of occupants in car crashes
Scholar: Sanyam Sharma

service characteristics and infrastructure design for e-rickshaws in Delhi
Scholar: Sourav Das

Development of a predictive model to assess the performance of a construction worker through skill development training
Scholar: Sparsh Johari

Ambulance location optimization for enhanced coverage and survivability in Delhi
Scholar: Shayesta Wajid

Assessing the future of E-rickshaw
Scholar: Shiv Priye

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

Crash safety of electric vehicles
Scholar: Thainigaivel Raja T

Performance measurement in sustainable freight transportation
Scholar: Vijayta Tukaram Fulzele

Landuse transport integration
Scholar: Vishal Rai

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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An excerpt from: ROAD SAFETY IN INDIA: STATUS REPORT 2020

Dinesh Mohan[1], Geetam Tiwari[1] and Kavi Bhallal[2]
[1]IIT Delhi, India and [2]Chicago University, USA

• According to official statistics 1,51,417 persons were killed and 469,418 injured in road traffic crashes in India in 2018. However, this is probably an underestimate for injuries,as not all injuries are reported to the police.

• The number of cars and motorised two-wheelers (MTW) registered in 2016 was 30.2 and168.9 millions respectively. The official registration data over-represent the number of vehicles in actual operation because vehicles that go off the road due to age or other reasons are not removed from the records. The actual number of personal vehicles on the road is estimated to be 50%-60% of those mentioned in the records.

• The extent of underreporting of road traffic deaths in India is not well understood. Global Burden of Diseases, Injuries, and Risk Factors Study, estimated that in 2017, 218,876 deaths (95% UI 201,734 to 231,141) due to road injuries occurred in India. A National Burden Estimates study estimates RTI deaths in 2017 in India to be 275,000. These two estimates are 45% and 82% higher than the MoRTH number.

• Police data should not be used for studying the epidemiology of non-fatal road traffic injuries (RTI) in the country. The official estimate of non-fatal RTI in 2018 was 469,418 which probably underestimates injuries requiring hospitalization by a factor of 5 and all injuries by a factor of 20.

• Over the last two decades the burden of road traffic injuries in India has increased, while the number of those affected by infectious diseases has declined. In 1990, road traffic injuries were the 16th leading cause of health loss, and 10th in 2016.

• Country income level cannot be taken as excuse for inefficient data collection systems and it is possible for countries like India to set up professionally managed data collection systems that give a reasonably accurate estimate of RTI fatalities.

• Lack of finances does not necessarily mean that a society has to have absence of safety on the roads. We cannot depend on growth in national income alone to promote road safety. It will be necessary to put in place evidence based national safety policies to ensure improvements in traffic safety.

• The numbers and proportions of different road users killed and injured as mentioned in MoRTH reports are erroneous and cannot be used for any analysis.

• Tables dealing with causes of road traffic crashes should not be used for any analysis or policy making.

• This situation can only be improved by MoRTH with a complete revamp of the data collection systems in collaboration with the Ministry of Home Affairs and establishment of a professional data and analysis department. Analysis of data at national level

• The total number of deaths in 2018 was 10 times greater than in 1970 with an average annual compound growth rate (AACGR) of 6%, and the fatality rate in 2014 was 5.2 times greater than in 1970 with an AACGR of 3.9%.

• The only way the decline of RTI fatalities can be brought forward in time is to institute evidence based India-specific road safety policies that are more effective.

• The Indian official estimates of pedestrian fatalities are extremely low compared to independent researchers' estimates (~15% vs ~35%), therefore, official estimates for all other modes will also be wrong.

• The error in the official reports regarding types of road users killed probably arises from a wrong coding of the victims' status and the procedure needs to reviewed carefully and revised.

• It is not known why the involvement rate of children (<18 years) and the elderly (>59 years) in India is lower than that in the USA when a large number of children walk, cycle and travel on overloaded vehicles to school in India. Reasons for these differences need further study.

• Compared with the situation in 2015, the total number of deaths in 2018 decreased by more than 10% in 5 states and union territories, was 10% higher or lower in 16 states, and increased by more than 10% in 11 states.

• Fatality rates per hundred thousand persons in 2018 increased in fifteen states and union territories and reduced in fifteen.

• Since RTI fatality rates in states and union territories do not seem to be influenced strongly by location in the country (culture) it suggests that state RTI fatality rates may be more influenced by infrastructure availability, vehicle modal shares, road design, and enforcement.

• Much more attention will have to be given to street and highway designs and enforcement issues that have an influence on vulnerable road user safety than current practice of focussing on motor vehicles as has been the practice up to now. This will require a great deal of research and innovation as designs and policies currently being promoted do not seem to be having the desired effect in improving road safety. Urban safety

• In 2018 the average fatality rate for all fifty million plus cities combined was 14.6 per 100,000 persons which is 30% greater than the national average of 11.2. For 33 cities where the data can be compared between 2006 and 2016 only 15 recorded a decrease in fatality rates. For most of them the decrease was less than 30%. This is quite an alarming situation, as in a third of the cities the death rate increased by more than 50% in a period of 10 years.

• Compared to 2015 the number of deaths in 2018 increased by more than 10% in 19 cities, remained about the same in 15 cities, and decreased by more than 10% in 15 cities.Significant reduction in number of deaths was seen in large cities (> 5 m population): Bengaluru, Chennai, Delhi, Hyderabad and Mumbai. The reasons for these reductions are not known. It is possible that increases in traffic congestion is leading to decreases in vehicle speeds may have contributed to this.

• Eight cities with 50% higher rates than the average for all cities in 2018 (greater than 22 fatalities per 100,000 persons): Agra, Allahabad, Gwalior, Jabalpur, Meerut, Patna, Raipur and Vijaywada.

• Ten cities with 50% lower rates than the average for all cities in 2018 (less than 7 fatalities per 100,000 persons): Ahmedabad, Amritsar, Hyderabad, Kannur, Kochi, Kolkata, Mumbai, Pune, Srinagar and Surat.

• It is not possible to explain the causes of these increases and decreases in the city fatality rates as they do not have any correlation with the size of the cities or their location in India.

• The proportion of vulnerable road user (pedestrians, bicyclists and motorised twowheelers) deaths in the nine cities range between 84% and 93%, car occupant fatalities between 2% and 7%, and occupants of three-wheeled scooter taxis (TSTs) less than 5% per cent, except in Vishakhapatnam where the proportion for the latter is 8%.

• An interesting feature emerging from this analysis is the involvement of MTW as impacting vehicles for pedestrian, bicyclist and MTW fatalities in cities. The proportion of pedestrian fatalities associated with MTW impacts ranges from 8 to 25 per cent of the total.

• MTW and pedestrian deaths are relatively high at 20:00-23:00 when we

would expect traffic volumes to be low. Surveys done in Agra and Ludhiana suggest that due to lower volumes vehicle velocities can be higher at night, adequate street lighting is not present, and there is very limited checking of drivers under the influence of alcohol.

• Occupant fatalities per vehicle decrease in the following order – TST:MTW:Car.

• Following countermeasures need to be given priority in cities: Safe pedestrians paths and crossing facilities, speed control by traffic calming measures like raised pedestrian crossings, change of road texture, rumble strips and use of roundabouts. Intercity highways

• National Highways comprise only 15% of the total length of roads in India but account for 33% of the fatalities. Fatality rate per km of the road is the highest on NH with 0.67 deaths per km annually and this fact should be the guiding factor in future design considerations

• Expressways had a length of only 1,000 km in the country in 2014 but a high death rate of 1.8 per km per year. This should be a cause for concern

• A majority of those getting killed (68%) on highways in India comprise vulnerable road users

• Data from three highway segments from 2009-2013 show a similar pattern. Pedestrian and MTW proportions are very high except on six-lane highways where the proportion of truck victims is much higher.

• Trucks and buses are involved in about 70 percent of fatal crashes in both rural and urban areas. This is again very different from western countries where there are significant differences in rural and urban crash patterns.

• On 4-lane divided roads head-on collisions comprise 19% of the crashes. Divided 4-lane roads are justified on the basis that these would eliminate the occurrence of head-on collisions. The fact that this is not occurring means that many vehicles are going the wrong way on divided highways. This is probably because tractor and other vehicles go the wrong way when they exit from roadside businesses and the cut in the median is too far away.

• Rear end collisions (including collisions with parked vehicles) are high on all types of highways including 4-lane highways. This shows that even though more space is available on wider roads rear-end crashes do not reduce. This is probably due to poor visibility of vehicles rather than road design itself. Countermeasures would include making vehicles more visible with the provision of reflectors and roadside lighting wherever possible.

• Following countermeasures need to be experimented with: physical segregation of slow and fast traffic, provision of 2.5m paved shoulders with physical separation devices like audible & vibratory pavement markings, provision of frequent and convenient underpasses (at the same level as surrounding land) for pedestrians, bicycles and other nonmotorized transport, and traffic calming in semi-urban and habited areas.

• Safety would be enhanced mainly by separating local and through traffic on different roads, or by separating slow and fast traffic on the same road, and by providing convenient and safe road crossing facilities to vulnerable road users.

• India despite having the distinction of being the second most populous country contributed only 0.7% published articles on road traffic injuries worldwide.

• When normalized for population levels in 2011, India's output appears poor in comparison with both Brazil and China. The gap between India and China has widened considerably in the past decade.

• The number of papers from China per-person per US$ per-capita income are more than three times greater than that from India in all areas. This means that if we want to catch up with China in ten years with their present levels of productivity, we will have to grow at more than 10 per cent per year.

• A review of peer reviewed papers on road safety published from India indicated that only about one-third of them included statistical analysis and modelling.

• Road traffic injury research output is still subcritical in India and not enough original research findings can be used for India specific policy making for the future. International knowledge base

• Imposing stricter penalties (in the form of higher fines or longer prison sentences) will not affect road-user behaviour significantly. In general, the deterrent effect of a law is determined in part by the swiftness and visibility of the penalty for disobeying the law, but a key factor is the perceived likelihood of being apprehended on the road and sanctioned.

• Driver or pedestrian education programmes by themselves usually are insufficient to reduce crash rates. The only effective way to get most motorists to use safety belts and motorcyclists to wear helmets is with good laws requiring their use and strict enforcement.

• Use of seatbelts and airbag-equipped cars can reduce car-occupant fatalities by over 50%.

• Use of daytime running lights on cars shows a reduction in the number of multi-vehicle daytime crashes by about 10–15%. Similar results have been confirmed for the use of daytime running lights by motorcyclists.

• Traffic-calming techniques, use of roundabouts, and the provision of bicycle facilities in urban areas provide significant safety benefits.

• A great deal of additional work needs to be done on rural and urban road and infrastructure design suitable for mixed traffic to make the environment safer for vulnerable road users. This would require special guidelines and standards for design of, (a) roundabouts, (b) service lanes along all intercity highways, and (c) traffic calming on urban roads and highways passing through settlements.

• Reserve adequate space for non-motorized modes on all roads where they are present.

• Notification and enforcement of mandatory use of helmet and daytime headlights by two-wheeler riders.

• Traffic calming in urban areas and on rural highways passing through towns and villages.

• Construction of service lanes along all 4-lane highways and expressways for use by lowspeed and non-motorised traffic.

• Removal of raised medians on intercity highways and replacement with steel guard rails or wire rope barriers.

• Modern knowledge regarding pre-hospital care should be made widely available with training of specialists in trauma care in the hospital setting.

Development of street designs and traffic-calming measures that suit mixed traffic with a high proportion of motorcycles and non-motorized modes.

- Highway design with adequate and safe facilities for slow traffic.
- Pedestrian impact standards for buses and trucks.
- Evaluation of policing techniques to minimize cost and maximize effectiveness.
- Effectiveness of pre-hospital care measures.
- Traffic calming measures for mixed traffic streams including high proportion of motorised two-wheelers.
- Establish National Board/Agency for Road Safety
- Establish a special central department for coding and recording all fatal crash data. The data so collected should be anonymised and made available publicly for analysis.
- Establish safety departments within operating agencies.
- Establish multidisciplinary safety research centres at academic institutions.

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Ph.D. Scholars

Completed

Performance of freight transportation: A study on people, planet and profit
Scholar: Devendra Kumar Pathak

Macroscopic modelling in heterogeneous traffic environment
Scholar: Harikrishna Gaddam

Externalities of urban freight transport: the case of Delhi
Scholar: Leeza Malik

M.Tech. Projects

Completed

Open Transit Data-Development of Bus Transit System Control Measuresign
Student: Anjali Tarar

Identification of Homogeneous Sections in Pavement Network
Student: Harshit Gupta

Rheological Characterization of Bituminous Binders Modified with Nano Particles
Student: Kausik Pahari

Estimating SDG Targets for Traffic Safety in Small Cities
Student: Md Afroz Khan

Development of CMF for 4 Lane Highway
Student: Mekuanint Getnet Hunegnaw

Access Trip Characteristics to Delhi Airport
Student: Sudeep Kumar Mishra

Feasibility of Electric Buses for Urban Operations
Student: Sushant

NEWS

The reader's attention is invited to the special issue of "International Journal of Injury Control and Safety Promotion, vol. 27 No. 1 March 2020"

1. Global road safety: a well-travelled road? *Mark Stevenson and Kavi Bhalla*
2. Preventing motor vehicle crash injuries and deaths: science vs. folklore lessons from history. *Brian O'Neill and Dinesh Mohan*
3. Dealing with existing theory: national fatality rates, vehicle standards and personal safety. *Dinesh Mohan and Brian O'Neil*
4. Opportunities to reduce road traffic injury: new insights from the study of urban areas. *Mark Stevenson, Jason Thompson, Jasper S. Wijnands, Kerry Nice, Gideon Aschwanden, and Haifeng Zhao.*
5. What can we learn from the historic road safety performance of high-income countries? *Kavi Bhalla, Dinesh Mohan and Brian O'Neil*
6. Progress in pedestrian safety research. *Geetam Tiwari*
7. Speed in a high-speed society. *Christer Hyden*
8. Safety of motorized two-wheeler riders in the formal and informal transport sector. *Maria Isabel Gutierrez and Dinesh Mohan*
9. Driver education: how effective? *Brian O'Neil*
10. Prehospital trauma care evolution, practice and controversies: need for a review. *Mathew Varghese*
11. How much would low and middle-income countries benefit from addressing the key risk factors of road traffic injuries? *Kavi Bhalla, Dinesh Mohan and Brian O'Neil*
12. ICoRSI's comments on WHO's draft global targets for road safety risk factors. *Independent Council for Road Safety International*

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 Road Safety Audit, Biomechanics and Crashworthiness, and Road Construction Safety"**. The course will be held in New Delhi, India, from **01 - 15 December 2020**. The course will be available with an option for **online participation** from **01-05 December 2020** and require mandatory "**in person participation**" from **06-15 December 2020**. Participants in the Road Safety Audit module will get a "Road Safety Auditors Certificate" after fulfilling the requirements as recommended by the Indian Road congress (IRC).

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

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Externalities of urban freight transport

Leeza Malik, Excerpts from a Ph.D. Thesis

A TRIPP BULLETIN INSERT

The study of traffic impacts by freight vehicles in urban areas has been a growing interest globally in the past few decades. As the number of private cars outweighs the number of freight vehicles, the primary focus of sustainable development policies initially, was on passenger transport. However, recognizing the importance of freight transport in urban transport issues, cities around the world have shifted their focus to the inclusion of freight transport in urban transport planning. On the one hand, urban freight transport is essential for economic growth and global competitiveness. On the other hand, the urban freightmovements are recognized with various nuisances like congestion, pollution, accidents and noise(Beuthe et al., 2002; Dablanc, 2007; Behrends, Lindholm and Woxenius, 2008).

Even though the freight activities have made consumer's life easier, it has made the task strenuous for the city authorities to manage the negative impacts of the growing freight load on urban roads. Thus, contrary to dominant passenger-centric policies, new interests and advancements on data-driven freight policy-making decisions and choices have been witnessed(Dablanc, 2009; Giuliano et al., 2015; Gonzalez-Feliu, Goodchild and Guerrero, 2016; Schaefer et al., 2017,Browne et al., 2018).The work in present thesis dealswith in-depth exploration of urban freight movement and regulatory pricing measures in context to Indian Capital City Delhi.

The negative impacts of the vehicular movementare associated with costs, generally termed as the "external cost". External cost refers to the cost which is borne by others but not by the user himself. Road usersignore the cost of the negative impacts which they impose on other travellers and thus, make inefficient travel decisions. The external costs are not accounted for in market transactions and thus are an example of market failure. Thus, it is observed that these external costs are internalised through pricing policies. Internalisation of the costs helps to reach optimum market equilibrium and the road users who value the benefit from travelling more than the cost, actually use the road facilities. Moreover, the calculation of the external cost also helpsto investigate the cost-benefit analysis of investment in transport infrastructure and policies.

The present thesis work primarilyfocuses on the following four aspects—1.Estimation of freight and passenger flow with limited data resources.2.Quantification of the external costs (congestion, accident and emissions) imposed by freight and passenger vehicles on the society. 3.Assessmentof societal benefit of time restriction policy.4.Determination of optimal charges for freight and passenger vehicles based on the marginal external cost.The scope of the present work is limited tomorning peak (8 am to 11am) and off-peak (11 am to 2 pm) hours in context to Delhi.The chosen peak hour coincideswith the prohibited time for goods movement in Delhi (8am to 11am).

The time restriction for freight vehicles varies with the type of roads, areas and commodity carried.The chosen peak hour coincideswith the prohibited time for goods movement in Delhi (8am to 11am). The time restriction for freight vehicles varies with the type of roads, areas and commodity carried.Therefore, morning peak hour with time windowsdoes not necessarily mean the absenceof freight traffic on the road.The first objective is related to the preparation of prerequisites of total flow and vehicle-Two kilometre travelled by freight and passenger vehicles separately for peak and off-peak period. It is to be noted that freight vehicles alone are not accountable for all negative impacts of congestion, accident and pollution. The externalities are imposed by passenger vehicles as well. Delhi road space is shared by a very heterogeneous mix of traffic. It includes passenger mode of transport like car, two-wheelers, three-wheelers, buses and non-motorised vehicles. Freight vehicles include heavy commercial vehicles and light commercial vehicles. Evaluation of any policy intervention demands to look at both freight and passenger vehicles as a system. It is likely possible that even if the freight vehicles are banned in the system, the externalities imposed by passenger vehicles movement are enough to negate benefits of freight restriction policies.Therefore, the results of passenger vehicles for all the objectives are reported along with the freight vehicles for comparison purposes. Moreover, the inclusion of passenger vehicles further aids in comprehending the overall perspective of Delhi's transport system. After that, the total and marginal theory of congestion cost, accident cost and environmental cost are applied. Next, three external costs imposed by freight and passenger vehicles are aggregated to understand the proportion of various cost imposed on society. Further, thebenefit of banning freight vehicles is evaluated for the peak period. Finally, multiple scenarios are developed to propose the optimal level of freight and passenger flow in Delhi. Based on the best scenario, the optimum charge for both freight and passenger vehicles are further evaluated.

The following key conclusions can be drawn—·Initially, freight and passenger flow is estimated.Freight vehicles contribute to 4% and 8% of total VKT (passenger +freight) travelled in peak and off-peak hour. With respect to peak hour, in off-peak hour LCV VKT increasesby 63% and HCV VKT increasesby 50%.·Random Forest machine learning models are found to perform better in comparison to other developed direct demand models.The study results suggest that Leave-Out-Location validation strategy should be preferred in comparison to Leave-Out-Time validation strategy in the case of variables exhibiting temporal characteristics. ·Sensitivity of the Multi-Modal ODS results run for short time intervals by using three different variations of the seed/target matrix is carried out. It is observed that when performing Multi Modal ODS model for short time intervals the estimates of total trips produced/attracted can be uniformly distributed across each inter-zonal matrix cells. Second, the use of the null matrix may leadto the overestimation of the VKT and thus should be used cautiously.·

The benefit of morning freight time restriction policy is assessed by the aggregation of three external costs.Completely restricting the freight vehicle movement may only lead to the reduction of total cost by 17% and30% for peak and off-peak hour respectively.·The maximum societal benefit is achieved when both passenger and freight vehicles are charged. A total external cost reduction of 88% and 84% is estimatedfor peak and off-peakperiodrespectively.·The charges for freight vehicles range from 55 Rs./vkm for LCV and 73 Rs./vkm for HCV in the peak hourAlso, for off-peak hour freight charges range from 48Rs./vkm for LCV and 61Rs./vkm for HCV.

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Higher Order Continuum Modelling Methodology For Non-lane Based Heterogeneous Traffic Environment

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Hari Krishna Gaddam, Excerpts from a Ph.D. Thesis

A comprehensive modelling methodology has been proposed to represent the traffic behaviour in non-lane based heterogeneous traffic environment. As an initial step, the research focuses on evaluating existing single regime models using two criteria. One is fitting empirical speed-density data and the other is about properties of fundamental diagrams. Limitations of the existing speed-density models in satisfying all the mathematical properties of fundamental diagrams encouraged us to develop new speed-density functional forms. The new speed-density functional form along with the developed conservation of momentum equation will be helped in predicting the traffic flow patterns in non-lane heterogeneous traffic stream more accurately. An improved two-sided lateral gap car following theory and statistical inferences from field data are used in developing a new non-lane based heterogeneous continuum model. To capture the complex vehicular interactions, the proposed model considers class specific lateral separation distance factor, frictional clearance term and density dependent disturbance propagation speed which are absent in other non-lane continuum models. The lateral separation distance factor represents the overtaking behaviour of vehicles on both sides of the leader, frictional clearance term represents the effect of slow moving vehicles on traffic stream. The proposed model is able to replicate complex traffic phenomenon such as local clusters, phantom traffic jams and dissipation of queues etc. Further, the proposed model is effective in supressing traffic jams even at high density conditions compared to other continuum models. Analytical results proved that new model improves the stability region of traffic flow thereby increases the throughput of traffic stream. The current research presented two classical and evolutionary optimization algorithms such as hybrid search and generalised pattern search to find model parameters for non-lane based heterogeneous traffic present on urban arterials in India. Performance of these algorithms have been compared with other commonly used global search algorithms such as genetic algorithm and simulated annealing. The robustness of proposed model in representing the real traffic behaviour is validated using traffic accident evaluation and platoon dispersion characteristics of vehicles.

Following are the main conclusions drawn from this study: Empirical v-k relationship of heterogeneous traffic observed on urban arterials revealed some interesting facts: (i) Dependence of speed on density is diminished as density approaching zero i.e. $v(k)k—>0$=0 and this non-dependency region is very small compared to that of homogeneous traffic case. Generally the length of this region is a function of number of lanes, type of facility and composition of vehicles. (ii) Capacity of the stream is observed to be very high due to the effective utilization of road width (this behaviour possibly attributed to non-lane discipline and presence of small sized vehicles). (iii) Large variation in highway capacity values can be seen in q-v and q-k plots. This variation in capacity is observed due to vehicle composition and their respective selection of speeds. (iv)Large deviations (non-linear behaviour) can be observed in the q-k curve at congested region. This behaviour is attributed to varying vehicle dynamics and their selection of safety headways. As a first attempt for Indian traffic conditions, some of the behavioural parameters such as kinematic wave speed (cj) and saturation flow parameter (λ) are determined using empirical observations. The typical value of the parameter cjis -12.42 km/h and the value is less than that of homogenous traffic case (Del Castillo and Benitez 1995). Jam density values for given facilities are difficult to estimate and they approximately vary between 700-800 Veh /km. The saturation flow parameter value depends on kinematic wave speed and jam density. Several static and dynamic properties of flow-speed-density relationships were set out and applied to study equilibrium models. It is to be concluded that none of the existing functional forms satisfy all the properties. Two new speed-density functional forms are proposed. It is observed that both the proposed models satisfy numerical accuracy and the fundamental diagram properties. These new forms would be able to improve the model predictions especially in continuum traffic modelling when coupled with dynamic speed equations.

An improved two-sided lateral gap car following theory and statistical inferences from field data are used in developing a new non-lane based heterogeneous continuum model. To capture the complex vehicular interactions, the proposed model considers class specific lateral separation distance factor, frictional clearance term and density dependent disturbance propagation speed which are absent in other non-lane continuum models.The analysis shows that the two-sided lateral gap parameter does not affect traffic flow when density is low. It is because vehicles do not interact with each other at low volume condition and they intend to travel at their desired speed without interruption. On the other hand, when vehicular density becomes large, the capacity of traffic stream increases with increase of two sided lateral gap value. Further, as density approached jam density, the effect of a two-sided lateral gap on fundamental diagram diminishes. It is due to less freedom for the vehicles to manoeuvre and they are forced to travel at the same speed. The neutral stability condition is obtained through linear stability analysis and it is observed that two-sided lateral gap in the model improves traffic stability. Further, non-linear analysis at neutral stability line is carried out using KdV-Berger equation and one of the travelling wave solution is also obtained. The model's ability in representing local cluster effect and local break down effect was also studied using a suitable numerical scheme and boundary conditions. The model was able to replicate complex traffic phenomenon such as local clusters, phantom traffic jams and dissipation of queues etc. Further, the proposed model is effective in supressing traffic jams even at high density conditions compared to other continuum models. Analytical results proved that new model improves the stability region of traffic flow thereby increases the throughput of traffic stream. However, lateral separation distance does not have any effect on performance of traffic flow when density exceeds 0.07 veh /m. For non-lane traffic flow, the stable density regions are identified k0<0.07&k0>0.09 whereas the unstable density region is 0.07<k0<0.10. The characteristic range of density such as stable, metastable and unstable states for non-lane based traffic system can be considered for future research. Model parameters are estimated using different optimization algorithms. The algorithms such as Genetic Algorithm, Hybrid search, Generalized Pattern Search (GPS) and Simulated Annealing are compared and tested for data collected on urban arterial located in Delhi, India. The results show that GPS algorithm is found to be more consistent, accurate and fast compared to others. In future, the validity of the model parameters and algorithm will be tested for data collected on other arterial sections.