TRIPP BULLETIN
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TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Research & Consultancy Projects

Simultaneous bus route network design and frequency setting in small and medium sized cities using evolutionary algorithm

Sponor: *Department of Science and Technology*

Project team*: K. R. Rao and Geetam Tiwari*

Objective: Bus Route Network Design (BRND) procedure is applicable for networks of real size in which many parameters need to be determined to reach an optimal solution. As a result, the meta-heuristic approaches, enables us to pursue reasonably global optimal solutions and deal simultaneous with the design of the bus route network. The main objective of this research is to systematically study the procedure of bus route network design in small and medium sized cities, which have different travel behaviours and development characteristics. A multi-objective network design model would be formulated considering passengers (users), operators and the government perspectives

Study of socio economic cost of road accidents in India

Sponsor: *Transport Research Wing, Ministry of Road Transport and Highways, Government of India.*

Project Team: *G.Tiwari, K.N. Jha and Saurabh Paul, TRIPP, IITD and Delhi Integrated Multi-Modal Transit System Ltd., India*

Objective: The objective of the research study is to develop a common framework that work as a tool to estimate the cost of road traffic accidents in India and undertake estimation of the socio-economic cost of road accidents for the country as a whole, in terms of loss of output, cost of medical treatment, damage to property, insurance and administrative and police cost etc. The study would be based on crash and post-crash information gathered from existing data sources in cities, state and national level; published and unpublished police records as well as primary data through survey and it should be built on the experience of the international best practices.

Development of a taxi-baed dispatcher-controlled EMS for low and middle income countries

Sponsor: *Department of Public Health, DBS, Chicago, USA*

Project Team: *K. Bhalla, G.Tiwari, D.Mohan and Nezamuddin*

Objective:Broad vision: Uber-like services are revolutionizing taxi services and other closely related transport/communication systems like product delivery. Our project aims to understand how these tools can revolutionize pre-hospital emergency care in resource-poor setting through the development and pilot testing of a taxi-based EMS system coordinated through a mobile App. - Trauma in LMICs a big problem- Need to strengthen EMS in LMICs. However EMS systems are expensive. This project aims to:

Aim 1: Establish the practical feasibility of implementing a dispatcher-controlled taxi-based EMS in LMICs

Aim 2: Use computational models to optimize response time and simulate health impacts of taxi-based EMS in Delhi

Aim 3: Build the capacity and partnerships to increase use of mHealth tools in EMS in LMICs

Urban traffic demand management strategies: Impact on congestion pollution and mobility (women scientist project of Ms. Ranjana Soni)

Sponsor: *Department of Science and Technology*

Project Team: *Ranjana Soni, G.Tiwari and Manoj M*

Objective: The aim of the current study is to analyse the Traffic Demand management strategies(ODD and EVEN,car free day) on pollution, congestion and mobility levels. The study will be carried out in Gurugram, haryana and will include observational studies to analyse the traffic speed data available from secondary sources (google congestion mapping) merging it with location specific primary surveys and using Geographical Information System (GIS) Arc/GIS 10 for spatial analysis.

Sustainable Development Goals (SDG) oriented planning and design for neglected cities and community participation

Sponsor: *International Association for Traffic Safety Science (IATSS), Japan*

Project Team: *Geetam Tiwari, Sudipto Mukherjee, Dinesh Mohan, Girish Agrawal*

Objective: The objective of this project is to provide guidance to three cities in India (population lessthan 1,000,000) for the following:

1. Identification of major traffic safety problems in the cities. (Documentation of travelpatterns and traffic safety issues). 2. Prioritization of possible interventions in consultation with local stakeholders. 3. Initiate discussion with local and state level stakeholders to integrate traffic and safety issues with sustainable development goals. 4. Publication of three city reports SDG and traffic Safety in cities.

Improving operational efficiency of bus systems and addressing data gaps in vehicular emissions management

Sponsor: *Shakti Sustainable Energy Foundation, India.*

Project Team: *Geetam Tiwari, K.R. Rao and M. Manoj*

Objective: The project focuses on the development of both, the robust data base and the data analytics tools for decision making at the policy level. Fleet characteristic data for passenger and freight vehicles at key highways, district roads and select cities is collected to inform policy initiatives aimed at regulating their emissions through vehicle scrappage, inspection and maintenance programs. Simple data analytics tools are being developed for State Transport Undertakings (STU) and City Transport Undertakings (CTU) to report on their performance, develop bus specifications and analyze the electronic Ticketing Machine Data. Additionally, the team is working to develop a State Urban Transport Policy framework focused on small and medium towns and integrating them in regional clusters through an efficient public Transport.

Simulation based preliminary study of lower extremity (LE) injuries caused by blast

Sponsor: *Defence Research Development Organisation (DRDO)*

Project team: *DK Dubey, A Chawla, S Mukherjee*

Objective:To study injuries incurred to the Jawans due to blasts.

Simulating LE blast injury using Finite element method to understand the blast injury mechanism.

a) The main deliverables would be the findings on the injury mechanism on the LE during blast.

b) Summary of the data available on blast injuries to the LE

Findings on the material models used for simulating the effect of blast on the LE and mathematical formulations used for simulating the blast & injury.

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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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Excerpts

WHAT AND HOW OF EFFECTIVE POLICE ENFORCEMENT?

Dinesh Mohan and Rahul Goel

Road traffic injury (RTI) reduction depends on interventions in institutional arrangements, road and environment design, vehicle safety features, post-crash care and ensuring safer road user behaviour by better policing systems. Regulation of traffic by police enforcement can be an effective strategy to reduce the public health burden resulting from traffic injuries (Peden et al. 2004, Elvik and Vaa 2004, Blais and Dupont 2005). As with many traffic safety interventions, the outcomes are not always as expected, and a weak theoretical foundation in traffic safety research makes it difficult to predict the effectiveness of different enforcement measures. For example, an increase in fixed penalties for speeding or jail terms for drinking and driving offences have not been found to be very effective deterrent measures in some studies (Elvik and Christensen 2007, SWOV 2013, Briscoe 2004, Criminal Justice Policy 2000, Li, Lawpoolsri, and Braver 2006, Wagenaar et al. 2007). Given the large variation in road designs and types of traffic mix, a given intervention is likely to have varying effects across different settings. Traffic enforcement measures can be costly, lead to additional workload for enforcement agencies and may involve additional costs in publicising these measures through various platforms. It is therefore important to assess whether a given enforcement measure, though seemingly beneficial in its intent, actually results in any reduction of delinquent behaviour of drivers and number of crashes.

In this paper we assess the evidence base of effectiveness of on-road enforcement measures by conducting a review of systematic reviews on this topic. In this review we focussed only on the objective police programmes or strategies and excluded the reviews which assessed the effectiveness of a traffic enforcement law. This is because in different settings across the world a law may translate to actual implementation on the road by varying degrees in terms of how soon it is implemented as well as its spatial coverage. In some countries, while a law may exist, but its implementation may be limited because police may think of it as less of a priority or because there is lack of capacity to implement it We will use this review to answer the following questions:

1)What are the different road safety enforcement measures for which evidence is available in systematic reviews and how current is this evidence?
2)What are the different limitations or drawbacks of different studies as reported by the systematic reviews and what are their implications on results?
3)What are the different factors which limit the generalisations of available evidence across different settings or across different types of modes?
4)What is the theoretical basis of different enforcement measures?

To find relevant studies, we used three main sources with a database of systematic reviews of road traffic injuries. These are The Handbook of Road Safety Measures (Elvik et al. 2009), Cochrane Injuries Review Group (https://injuries.cochrane.org/our-evidence) and Community Preventive Services Task Force (https://www.thecommunityguide.org/content/task-force-findings-motor-vehicle-injury). We also searched for the systematic reviews using the ancestry approach. We have not included any reviews published before 1990. Among the traffic enforcement measures, we found reviews covering four offences: speeding, red-light running, alcohol-impaired driving, and seat belt use. In some cases, we found multiple reviews for the same enforcement measure. For example, the review of red-light cameras by Aeron-Thomas and Hess (2005) has been updated by Perkins et al. (2017). The speed camera review by Wilson et al. (2006) published in 2006 (Cochrane Collaboration) was updated by Wilson et al. (2010) in 2010, and a study to update and expand the Cochrane systematic review, to provide a comprehensive account of the range of automatic speed enforcement strategies employed worldwide has been initiated by Steinbach et al. (2016). For effectiveness of speed cameras, we have also included a later contemporary review by Høye (2014) as it added value in terms of discussing some other facets that are missing from Steinbach's review.

A review of the effectiveness of average speed enforcement methods was reported by Soole, Watson, and Fleiter (2013) in 2003. The review concluded the following:

•In general, drivers show higher level of acceptance of average speed enforcement. The traditional camera-based measures using instantaneous speed are criticised on the grounds that drivers need to speed at certain points due to unforeseen reasons.
•The limited evidence suggests that average speed enforcement method may be more effective than instantaneous speed enforcement methods.
•Studies have found the implementation of this method is associated with the reduction in average and 85th percentile speeds, the proportion of speeding vehicles and speed variability. The approach has been specifically effective in reducing excessive speeding behaviour.
•In addition to reduction in speed, studies have also found considerable reduction in fatal and serious injury crash rates.
•There is lack of distance 'halo' effect resulting from average speed enforcement implementation. This means that reduction in speed and crash rates have not been found outside the area of enforcement. Therefore, this enforcement method should be used as complementary to the existing fixed and mobile speed enforcement methods.
•Studies suffered from multiple drawbacks because of which the evidence needs to be carefully interpreted. None of the studies used the control/comparison site. Other drawbacks include lack of driving exposure data and studies not accounting for regression-to-the-mean effect.

There is a strong theoretical understanding based on which effectiveness of average speed enforcement method can be explained. Reduction in excessive speeding behaviour has considerable implications for road safety given the exponential relationship between vehicle speed and crash risk

A systematic review of the effectiveness of red-light cameras by Perkins et al. (2017) concluded the following:

•RLCs can be effective in reducing red-light violations and some types of traffic crashes, particularly right-angle crashes, right-angle injury crashes, and total injury crashes.
•RLCs also appear to be linked to an increase in rear-end crashes which is likely a result of drivers abruptly breaking to prevent the offense.
•The presence or absence of warning signs did not appear to have an impact on RLC effectiveness.
•While a number of studies reported that spillover (or diffusion of benefits) occurred, the magnitude of this effect is not established.
•Studies are limited to four countries: USA, Canada, Singapore and Australia. The authors caution the use of this evidence in the UK since the intersections in the USA and Australia are much larger in size than the UK hence drivers may have greater feeling of openness and more likely to jump the light. Further, the speed limits across the settings are different which may also influence the likelihood of red light running.
•This review did not include studies which evaluated the effectiveness of red light cameras used both for red-light running as well as enforcing speed limit during the green.
•Due to the rarity of death or severe injury events, most studies use a combined measure of crashes and do not differentiate between the severity levels of crashes.

In some cases, additional time is given to yellow times and successful RLC programmes may include many on-site modifications such as red-light visibility, addition of warning signs, and amelioration of intersections geometry. This is clearly a case where engineering and enforcement measures are highly

interrelated or at least the relationship between the two can be established.

Evidence shows that an increase in the perceived risk of arrest appears to deter alcohol-impaired driving more effectively than increasing the severity of penalty after arrest and police patrol intervention increase the presence of police and the perception of being caught

Erke, Goldenbeld, and Vaa (2009) conducted a meta-analysis of the effectiveness of DUI-checkpoints. The review concludes:

•Crashes involving alcohol (or proxy measures of such crashes) are reduced at least by 17% and all types of crashes are reduced by 10-15%. Proxy measures of alcohol-related crashes include night-time or weekend night crashes.
•The largest reductions were found during the first 6 months of the DUI-checkpoint implementation, which may be confounded because the intensity of implementation may be much higher for short-term programmes.
•DUI-checkpoints in Australia result in the highest reduction in crashes indicating the Australian methods of booze buses and intensive publicity are highly effective. A similar approach when implemented in New Zealand also found large reductions, thus strengthening the evidence of their effectiveness.

•All the studies evaluating primary vs secondary law found primary seat belt law to be more effective than secondary law. The studies which reported fatalities as outcome, found median decrease of 8% higher among primary law states than secondary law states, though statistical significance of this estimate was not reported.
•Enforcement enhancement programs are associated with an increase in seat belt use (median 16 percentage points) and decrease in injuries.
•Based on the studies which carried out a follow-up of the enforcement enhancement programmes after they had concluded, there is evidence that the seat-belt use somewhat declined after the programs are ended.

Elvik et al. (2009) have reported meta-analysis of seat belt enforcement with no restriction to country and conclude the following:

•The results show the enforcement increases seat belt use by 21% during the enforcement period and by 15% afterwards.
•The covertness of the enforcement improves the effectiveness of seat-belt use. Greater effects have been found when checkpoints are not announced compared to when they are. This may be possible if the drivers think that they will fasten the seatbelts close to a checkpoint, and therefore, general compliance may be lower.
•The change in seat-belt usage rate is higher when the baseline rate is lower. A scatterplot of increase in usage rate versus the baseline usage rate shows a negative relationship between the two.

In 2002 Koornstra et al (Koornstra et al. 2002) published a report where they attempt to find a relationship between intensity of police enforcement and level of traffic law violation as an approach to get more insight about which enforcement level is needed in order to change road user behaviour and fatality risks. The results are shown in Figure 2 illustrated by belt wearing and drunk driving data on enforcement and violation levels in Sweden, the United Kingdom, and the Netherlands at that time. The authors cautioned that this curve needs to be validated with research results because of the complexity of that research when it comes to differentiating police enforcement efforts (combined with publicity) and the complexity of data-collection. To the best of our knowledge no serious efforts have been made to determine such curves for speed control, seat belt use, helmet use, DUI control and other violations for different modal shares in different countries of the world. What the curve does show is that percent law violation decreases as enforcement intensity increases and that enforcement levels have to be different for different types of violations. For example, the curve shows that in Sweden the enforcement levels needed for control of DWI and for enforcing seat belt use so that violations were limited to about 12 per cent, there had to be 250 checks per 1,000 driver license holders for DWI and 8 for seat belt use.

However, what is not clear is the level of enforcement that ensures a significant reduction in fatalities attributed to drinking and driving. At present, we do not have reliable studies available to inform us about the minimum level of enforcement that needs to be put in place in a cost-effective manner in low and middle-income countries. we do not have enough systematic reviews that assess the effectiveness of general deterrence policies on road safety that may have universal applicability. For the present, we have to rely on the studies that seem to point in a similar direction.

•Legislation and enforcement is effective when violations are visible and easy to detect.
•Stricter punishment not as effective as subjective perception of being caught.
•Severe punishment and laws sometimes reduce enforcement by police officials and conviction rates in courts
•There is little evidence that severe penalties reduce violations in traffic, including jail sentences given in isolation.
•Announcement of severe punishments can have a deterrent effect over a short period and the beneficial effect disappears over time.
•All violations that are not considered serious in terms of threat to life or wilful negligent acts endangering the community (serious injury or death), and those that do not require court judgement should have fixed penalties. Penalties for such offences should be in proportion to the ability of the defaulter to pay.
•There is an absence of studies that could provide guidelines on police enforcement for low and middle-income countries on the following issues:
oInfluence of road and infrastructure design on traffic violations and the need of enforcement or effectiveness of enforcement.
oCritical/minimum levels of enforcement necessary for different traffic violations.

There is a need to translate the results from car-based studies to settings where motorcycles and cyclists share the road space with cars. In such a context, what car-based studies refer to as property-damage only crashes may translate to higher severity crashes if the parties involved are cars/buses/trucks and vulnerable road users. This is the same for intersection crashes resulting from red-light running. The side crashes are often lead to high-severity crashes in case of cars. These will result in even higher severity injury crashes if between a four-wheeled vehicle hitting a motorcycle. It is possible that some of the enforcement measures which proved to be successful in car-based societies may lead to higher reduction in severity of crashes if not the number of crashes in contexts where vehicular mix consists of cars and a high proportion of vulnerable road users.

The reviews included focussed on answering multiple questions. The outcomes include both the compliance rate for the law that is being enforced as well as the crash rates. The first outcome indicates how effective enforcement measure has been to reduce the delinquent behaviour of the drivers that was being targets. The second outcome which includes various metrics of crashes indicates whether enforcement measure translates to reducing the crashes which is not always a given. For instance, red-light camera enforcement results in overall increase in the number of crashes because increase in rear-end crashes may offset the decrease in side and head-on crashes resulting from red-light running.

The reviews have not discussed the injuries classified by the road user types. This means that there is a potential for a revised review of the same studies to understand the effect of the enforcement measures on road users outside the cars such as pedestrians, cyclists and motorcycle riders.

Excerpts from the chapter "What and How of Effective Police Enforcement" in a forthcouming TRIPP publication "Transportation and Safety: Systems, Approaches and Implementation"

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Toward an integrated global transport and health assessment tool (TIGTHAT)

Sponsor: *University of Cambridge, UK*
Project Team: *Geetam Tiwari, M Manoj and Nezamuddin*

Objective: Lay the foundation for a modelling tool that can be readily applied to a wide range of urban settings based on readily available data. Health impacts will be modelled through the pathways of physical activity (PA), air pollution (AP), and road traffic injuries. In this project we will review the availability of data, plan future data mapping, and undertake three case studies to produce new estimates, to develop the model, and to understand which parameters our final result estimates are sensitive to. The longer term version is of a web based tool based on open source code that can be used by policy makers and practitioners to support urban planning. Such a tool should be easy to use, based on the best scientific evidence, and should allow for comparisons between settings

Audit the implementation of road safety directions by the states issued by the Supreme Court Committee on road safety

Sponsor: *Delhi Integrated Multi-Modal Transit System Ltd., India*
Project Team: *Geetam Tiwari, K.N. Jha, K. R. Rao and Dinesh Mohan*

Objective: The Supreme Court Committee on road safety sent directions to the states to implement various policy, institutional and infrastructure related measures in an effort to improve the standards of road safety and reduce accidents and fatalities. The study will cover all categories of important stakeholders/offices of potential road safety related representative bodies within given cities which will be identified in discussion with the client prior to undertaking the field activities. In this connection the consultants proposed to use both quantitative and qualitative techniques during the study to elicit information from potential road related representative bodies. In qualitative techniques, in-depth interviews and focus group discussions will be carried out to cover the identified road related representative bodies.

Human body FE model development for blast and impact

Sponsor: *Defence Research Development Organisation (DRDO)*
Project team: *A Chawla, S Mukherjee, DK Dubey, N Datla, JP Khatait*

Objective: To develop a methodology for developing, maintaining and manipulating the database associated with human body finite element models. Specific target shall be the Indian

a)Jawan, whose anthropometry shall be obtained and used so that the model can be used effectively for defense applications. The main deliverables from the project would be, Multiple Versions of IDM 50 FE model (50%ile Indian Defense

Services Male)

b)Sampling anthropometric data of defense personnel (collected with help from DRDO sources)

c)Full Body Medical Scans obtained from DRDO sources, Blast and Impact Modeling Methodology for FE HBM

d)Develop Tools for positioning and resizing the developed model, Validation data for the HBM under blast and other injuries.

Human body tissue characterization under blast, impact, and penetration

Sponsor: *Defence Research Development Organisation (DRDO)*
Project team: *A Chawla, S Mukherjee, DK Dubey, N Datla, JP Khatait*

Objective: The overall aim of this proposal is to characterize the mechanical response and injury of human body tissue under extreme wartime loads such as blast, impact, and penetration.

a)The developed understanding of the mechanical response and injury of the tissues will be used to develop FE models specific to Indian population.

b)The developed FE model can then be used for several purposes such as to estimate the injury and to develop injury mitigating

strategies.

Design of anti mine boots (AMBs) using finite elements simulations with human body model (HBM)

Sponsor: *Defence Research Development Organisation (DRDO)*
Project team: *A Chawla, S Mukherjee, DK Dubey, N Datla, JP Khatait*

Objective: This project aims at development of stable validated simulations of anti-mine boots (AMBs) testing in blast scenarios, and development of new design of AMBs.

a)Simulated Results of blast due to landmine on boots

b)Performance of AMB under specified conditions

c)Suggestions on re-design of current boots

d)Proposed further work in the redesign of boots will be delivered

Indicators of reliability and variability of BRTs/bus systems (INDIRA B)

Sponsors: *CEFIPRA (Indo French Centre for Advanced Scientific Research); Delhi Integrated Multi-Modal Transit System Ltd. (DIMTS)*

Project team: *Geetam Tiwari and K.R. Rao*

Objective: This project includes major interventions at two levels - product and process. The product involves use of Intelligent Transportation Systems (ITS) technology, for developing performance indicators for Bus Rapid Transit (BRT)/ bus systems. At the process level, the aim is to improve the operation of BRT by means of branching modules, dealing with new indicators in an existing management system exploiting an existing real time data acquisition system (AVLS).

The main outcome of this research is to develop a computer-based research tool consisting of different modules. This could be integrated into an operational platform for analysis and diagnosis of the quality of service of BRTS/bus systems lines in different operational uses.

Freight fleet characteristics data collection and analysis on highways

Sponsor: *Shakti sustainable energy foundation (SSEF), India*

Project team: *G.Tiwari, L. Malik, H. Jain, H. Rehman, R B Jupalli*

Objective: The objective of the project is to investigate the following aspects –

1)Collect fleet characteristics data of intercity freight vehicles to estimate the emission mitigation potential of various national policies that promote cleaner fuels and vehicles through scenario analysis.

2)Develop a robust SUTP framework primarily based on international and national practices and a case study of Punjab State.

3)To develop a webtool called 'TRIM4STU' for easy estimation of key parameters wrt operational efficiency for STUs.

4)To develop a preliminary Electronic Ticketing Machine (ETM) data analytics framework for critical operational parameters such as boarding-alighting, schedule, headway, and critical load sections, fleet utilization, etc for a typical bus system.

5)To develop data driven analytics for optimal bus fleet specifications and contractual process improvement for bus procurement by State Transport Authorities.

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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A TRIPP Bulletin Insert

Excerpts from a recently completed project *"Freight fleet characteristics data collection and analysis on highways (2017-2019)"*

According to the Ministry of Road Transport and Highways the freight vehicles in India have increased from a mere 0.082 million in 1951 to 9.34 million in 2015. Rapid growth of the road freight sector in India is expected to pose both opportunities and challenges for the country. Owing to India's economic growth the National Transport Development Policy Committee estimates that the "freight traffic may increase from around 2,000 billion net tonne kms (BTKM) in 2011-12 to between 10,500 to 13,000 BTKM by 2032, an increase by a factor of about 5-6 BTKM." However, the economic expansion as a result of increasing freight activities with air quality at stake will lead us to a precarious situation. Besides constituting a small proportion of total vehicular fleet, heavy duty vehicles and light duty vehicles share the highest contribution to the total air emissions and fuel consumption in India. This may be attributed to their lower fuel economy and higher annual mileage as compared to other vehicles. In view of the adverse energy implications, the harmful impact on environment and uncertainties related to future oil imports by freight vehicles, MoRTH has been formulating various policy interventions at the national level like scrapping of 20 year old vehicles, up gradation of fuel emission standards and planning of fuel economy standards.

In spite of the vital contribution of the road freight sector to the overall air emissions very little is said about their travel activities, their fleet characteristics (age distribution, fuel distribution, and technology distribution) and their fuel efficiency. These study have certain limitations such as many assumptions on freight characteristics (in absence of robust data) and thus impact the accuracy of freight-oriented policies on air emissions. In such conditions baseline fleet characteristics needs to be established and will thus aid in conducting a robust scientific analysis of the proposed freight policies.

At present the understanding of fleet characteristics in terms of age, annual mileage, fuel economy, fuel type etc. for the freight vehicles used for "inter-state" mobility on National Highways (NH) is already available. The freight fleet characteristics data is collected on major National Highways (NH-8, NH-3, NH-6 and NH-2) connecting the major cities of Delhi, Ahmedabad, Mumbai and Kolkata in the month of May 2016.

An interesting outcome of the NH freight fleet characteristics study is the presence of new freight vehicles for long distance transport. The age distribution obtained for heavy-duty vehicles on NH (gross weight greater than 3.5 t) includes 45.7% of vehicles in the age group 0–4 years, and only 9.2% of vehicles in the age group greater than 8 years. In the case of light-duty vehicles (gross weight less than 3.5 t), 71% vehicles are observed in the age group 0–4 years, and only 3.3% of vehicles in the age group greater than 8 years.

A necessary extension of the previous work to State Highways (SH) and Major District Roads (MDR) is taken up in this study. This is based on the rationale that the freight fleet characteristics observed on SHs and MDRs are quite different from that of National highways. It is probable that although freight vehicles plying on NH may be new, those plying on SH and MDR are likely to be older.

Taking into account the above facts, the primary focus of the present study is to investigate the following aspects:

(a) The analysis of freight characteristics on SH and MDR using both the driver responses and data retrieved from vehicle registration digital database called "VAHAN" (https://vahan.nic.in/nrservices/)

(b) The analysis of passenger characteristics on SH and MDR.

(c) The analysis of trip diary database to establish the annual kilometre travelled by different vehicle types.

(d) To examine whether the combined freight and passenger characteristics for NH, SH and MDR are sufficient for the estimation of the base line emissions.

(e) To estimate the total emission contribution by freight and passenger vehicles in 2017.

(f) Develop emission scenarios to understand the likely impact on the total emissions due to various policy interventions like introduction of BSVI, scrapping of aged vehicles policy and road freight vehicle kilometre travelled (vkt) reductions.

As an extension to the previous NH study, the present study makes an attempt to fill the following gaps and incorporate some improvements in the data collection methodology:

•To understand the variation in the freight fleet and passenger vehicle characteristics on different types of roads, surveys are conducted on SHs and MDRs lying within a 20 Km radius of the previously surveyed locations on National Highways. This is done to link and compare the current study results to the previous NH characteristics.

•The survey procedure in comparison to the previous NH study includes a new component where the trip diary of the entire day freight journey and passenger journey is captured. This will subsequently help us to understand the hours of their operation and calculate the annual km driven by different vehicle types

•The scope of using the vehicle registration e-database, "VAHAN", in estimation of age distribution is further explored.

•The current study includes the freight fleet characteristics captured on SH and MDR lying within 20 Km radius of previous phase NH locations. In comparison to NH the older fleet is observed to ply on SH and MDR. Further, survival rates comparison for the current study and survival rates established for various studies by urban emission.info necessitate the survey methodology to be extended to various cities. It is possible that the old fleets start plying within cities doing shorter trips.

•The use of the VAHAN database in establishing the age distribution of the vehicles is explored. The vehicle model year is useful to capture using the VAHAN database. However, only 50% of the total registration data collected is retrieved. Thus it is essential to aid the data retrieved through VAHAN by driver responses. Several issues such as mismatching vehicle type, fuel type, registration year (in the VAHAN and Survey database) was encountered. Thus, efforts are required in this direction to improve the robustness of the e-registration database.

•Trip diary surveys should be included as a part of the survey methodology. This helps to understand and cross check the odometer based annual mileages.

•As far as the policy implications are concerned, scrapping of the freight vehicles (greater than 15 years) is not going to reduce the emissions significantly. Rather introduction of BSVI emission standards should be in time implemented.

•The study has a few limitations: (a) The trip diary samples are few in number. A larger number of trip diary responses would be required to understand the operations of freight vehicles in India. The work can be extended to understand the efficiency losses encountered by freight vehicles in India. (b) The penetration of electric vehicles is not

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included in the emission projections and scenario. Thus, it is required to investigate in detail the market and societal response to the usage of electric vehicles in both passenger and freight transport. (c) The survey methodology is to be replicated in various cities so that the survival rates established by urban emissions.info are validated. A few attempts have been made to replicate the survey methodology in cities like Patiala, Bulandshahr, and Nanital. The analysis of the preliminary results for these studies are being processed. (d) The study work can be extended to understand the effect of fuel economy standards on the operations of freight vehicles. This is essential as there are no sound scenarios that capture the effect of the fuel economy standards on vehicle usage in India.

***Excerpts from a recently completed project**: "INDIcators of Reliability and Variability of bus systems (INDIRA-B)"*

This project includes major interventions at two levels – product and process. The product involves use of Intelligent Transportation Systems (ITS) technology, for developing performance indicators for bus systems. At the process level, the aim is to improve the operation of bus by means of branching modules, dealing with new indicators in an existing management system exploiting an existing real time data acquisition system (AVLS).

The objective is to assess some of the existing well known quality-of-service indicators, and to develop new ones. Performance indicators should be clear, easily understandable, and useful to the audience. The main outcome of this research is to develop a computer-based research tool consisting of different modules. This could be integrated into an operational platform for analysis and diagnosis of the quality of service of bus systems lines in different operational use. The applications will be tested in Delhi, and generic modules will be developed for other cities.

DIMTS (Delhi Integrated Multi-Modal Transit System Ltd.) has been managing bus operations of cluster buses in Delhi. The GPS data and AFC data available from Delhi cluster bus system will be used to develop various indicators which measure level of service of Bus system.

A multimodal platform, like ClaireSITI developed in France, is a research tool that allows accessing real-time and multi-sources transport information. All gathered multi-sources data are formalized through a generic data model. It includes a supervisory system which could be linked to any AVL system to provide both on-line and off-line performance analysis and diagnosis of the public transport operations. The ClaireSITI platform includes a supervisory system which is currently implemented in operational context in Toulouse and in Brussels with the STIB multimodal public transport operator (bus, metro and tram). This observatory gives both on-line and off-line performance analysis and diagnosis of the public transport operations.

Our objective in this research is to design a bus fleet "supervision cockpit" for both operators and public transport authorities. First, this project will set up the ClaireSiti platform on the Indian data; and second it will enrich its observatory with new relevant indicators. Performance indicators should be clear, easily understandable and useful to the audience. Four types of indicators are considered for measuring LOS for bus systems:

Operators are interested in maximizing revenue and minimizing operational expenses. While revenue maximizing is dependent on better fleet utilization-operational expenses are dependent on improved speed, minimizing fuel consumption, minimizing delays, minimizing crashes involving buses (compensation paid to the victims), minimizing bus break downs. These can be measured in terms of: 1- Expected system capacity, 2- Expected Operational or commercial speed (Km/h), 3- Average per bus stop and junction delay to a unit bus, 4- Number of fatal and injury crashes /100000 km of bus km, etc.

A module can be developed for the operators to monitor system wide performance and incident detection using GPS and AFC data.

Indicators that measure passenger preference are important for LOS measure. Passenger choice of using a bus system depends on these indicators. These can be measured in terms of: 1- Passenger speed or door to door travel time. 1-Waiting time and comfort, 2-Total walk distance for passengers in a one way trip, 3- Total delay to a unit passenger in a one way trip.

Passenger information system module can be developed to give information about bus arrival, expected journey time and access information around the origin and destination bus stops.

Knowing that, a disturbance on a vehicle has consequences on its successors and can disrupt the whole line over long periods. To avoid these disturbances, an accurate diagnosis of the sources and the impact of these disturbances situation are necessary. A special care will be given to these indicators within this project, giving rise to new relevant indicators of: 1- Reliability and 2- Indicators of Resilience

These can be measured by designing special indicators based on the variances of the different stochastic processes which model the flows.

Bus bunching is a consequence and after a cause for such kind of deviations from the schedules/headways. Using the metrics that identify bus bunching and algorithms to correct or minimizing the deviations, would be one of the indicators interesting tool.

What are the impacts of bus systems with consideration of Human as a traveller and as a customer? These can be measured in terms of: 1- Peak Bus Speeds (due to its impact on fatal crashes), 2- Potential for Shift from Private Transport – based on passenger travel time comparison between buses and private vehicles, 3- Potential for retaining existing public transport demand by improving the performance of current bus system, 4- Allowing universal access and barrier free mobility for primarily in terms of disabled friendly infrastructure and fleet.

The analysis of such indicators can deliver different services and utilities: enhance the passenger information in real time to include level of service inside the bus; identify locations prone to bus delays; identify black spot locations(locations experiencing repeated delays), the origin of these malfunction and some elements for enhancement.

DIMTS will participate at the test of the indicators usage and the evaluation of the impact of this new management practice on the organization and the overall performance of the bus system in the city. The evaluation tests will concern not only the efficiency of the indicators but also the supervision cockpit usability by operators and public transport authorities

ClaireSITI is a generic multimodal data model, and an analysis engine with functions, developed by IFSTTAR. It creates an interface which integrates diagnostics from the data providers and the service providers. A hierarchical interactive network graph is used to represent the multimodal transport system and nodes. A plethora of indicators are generated and supervised through this platform.