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

Research & Consultancy Projects

Development and field testing of panic switch based safety device for cars for aiding womens safety

Sponsor: *Ministry of Electronics and Information Technology*

Project team*: Anoop Chawla*

Objective: To develop a safety device for the passengers (especially female passengers) travelling in Cabs and Taxis. The device is expected to be in the form of an SOS / panic button which, when invoked would transmit an SOS signal to a set of predefined locations. The system will be a combination of software and hardware providing an infrastructure for safety of passengers (especially female passengers) commuting in invoked informing concerned agencies, providing them with the relevant vehicle data including location. The data, in full or in part, can be transferred to remote locations which will be handed over in standard format to police authorities.

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.

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 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 BRTS/bus systems lines in different operational use.

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

Consulting services to audit the implementation by the states of directions 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.

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

Consulting Services for 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.

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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.

Excerpts

PRINCIPLES FOR DEVELOPMENT OF SAFER RURAL HIGHWAY SYSTEMS FOR CONDITIONS PREVAILING IN LOW AND MIDDLE-INCOME COUNTRIES

Geetam Tiwari

There is a broad range of factors affecting road traffic crashes. These factors are usually related to traffic and road characteristics, drivers and other road users, vehicles, and environment. Traffic characteristics (such as traffic flow and speed) and road characteristics (such as road geometry and the quality of infrastructure) might affect road accidents. Factors which seem to have a strong correlation with traffic crashes are discussed in the following section.

Speed is an important factor affecting road accidents both in terms of accident occurrence and severity. It seems reasonably safe to assume that increased speed would mean that the accidents that have occurred would be more severe, if other factors (e.g., environment and vehicle design) remain the same. A Large number of studies have shown this by both Newtonian physics and empirical data. Between speed and the number of accidents, most of the studies suggest that increased speed is associated with more accidents or higher accident rates. The effect of change in speed on road safety has been extensively investigated by Nilsson who employed before-after studies in Sweden using the Power Model. It was found that changes in the number of accidents (or accident rate) can be associated with the changes in speed according to a power function. Positive associations between changes in speed and accidents were found, though the magnitude depends on types of accidents (e.g. fatal and injury). Similarly, Rune Elvik undertook an extensive evaluation on the effect of speed on accidents again using the Power Model. They concluded that there is a causal relationship between changes in speed and changes in road accidents. In addition, it has been speculated that it is the dispersion of vehicle speeds (i.e. speed variance rather than speed itself) that affects the accident frequency. Lavefound that the fatality rate was strongly associated with speed variance rather than average speed, thus it was argued that speed variance caused safety problems instead of speed itself. A later study (Davis, 2002) however argued that such a claim of "variance kills" may be subject to ecological fallacy. Therefore there remains the question of the role of speed variance in road safety.

The relationship between traffic density and accidents has been investigated in a few studies, often using other variables to represent density, for example Volume by Capacity ratio (V/C). Examination of the hourly accident rates (per million vehicle kilometres) and the V/C ratio on a US interstate highway showed that the relationship follows a U-shaped pattern and accidents involving injury and fatalities tended to decrease while the V/C ratio increases. Results of investigation of single and multi-vehicle highway accident rates and their relationship with traffic density while controlling for land use, time of day and lighting conditions on two lane highways found a negative exponential relationship with density (volume/capacity ratio), meaning that the accident rate is the highest at low V/C ratio.

A freeway segment study based analysis on the relationship between accident, density and the V/C ratio found that both density and V/C ratio have an overall inverse relationship with the number of accidents (per year per km). Accident-density and accident-V/C relationships were also examined according to different accident categories such as total, single-vehicle, and multi-vehicle accidents. It is found that there is a U-shaped relationship for total and single-vehicle accidents but a positive relationship for multi-vehicle accidents.

Generally mixed relationships have been found between density and safety in the literature, depending on the measurements of density and types of accidents. Clearly this is an area that has been studied less and as such further research is required.

Studies of international literature of how countries have improved their safety performance over the years, shows a multitude of potential explanations. Researchers have developed benchmarking methodologies to learn from international comparisons. This is a difficult task due to the presence of confounding factors. Fred Wegman states "It is, to the best of our knowledge, fair to say that no country has a full explanation of the progress made. However, it is also fair to say that our knowledge and understanding of why countries made progress has increased significantly over the last few decades".

In the last few decades traffic safety measures have been focussed on the following:

- Improving human behaviour (speed, alcohol, seat belts, and helmets) through legislation, enforcement, and campaigns.
- Safer infrastructure through planning and design.
- Safer vehicles through better crashworthiness, active vehicle safety, and vehicle inspections.

We examine these interventions in the context of theories of safety science to understand what role different interventions may have on safety consequences. It has been a tradition in road safety to analyse road safety data for understanding why crashes occur, which factors influence risks, and what determines crash severity, and based on this understanding, to arrive at reliable conclusions on how to prevent them most effectively and efficiently. We call this a data-driven approach. In this approach, we derive priorities by using crash data, background data, exposure data, and data of safety performance indicators. This is what the researchers call a scientific method and evidence based interventions. However, there has to be a fundamental vision or theory which drives what data should be collected and what should be evaluated. For example, if the theoretical understanding is that driver error causes traffic crashes and driver training can reduce traffic crashes the data collection process focusses on collecting driver related data and modelling impact of driver characteristics and knowledge about driving rules. If the theoretical understanding is that driving behaviour is influenced by the road and traffic characteristics, then road geometry and traffic characteristics (operating speeds, traffic volume, type of vehicles) are modelled for controlling traffic crashes.

J. Stoop, de Kroes, and Hale provide a detailed discourse on safety science in general and its application to transportation safety. They highlight the development of three basic notions as the cornerstones for safety science as a scientific discipline, no matter what domain it is related to: interdisciplinary, problem-solving orientation and systems approach.

Interdisciplinary is a first necessary condition to deal with complex phenomena that exist in reality: such phenomena cannot be reduced to paradigmatic notions within one scientific domain. However, a decomposition of their complexity is a prerequisite for unravelling their control laws, properties, relations, variables and performance indicators.

Problem orientation: Achieving consensus on a common problem definition is considered a second prerequisite for a scientific approach of safety. Interdisciplinary discourses may result in controversies and rivalries, up to the level of schools of thinking. It also may lead to individual antagonism, defining minorities as dissenting voices in a homogeneous scientific community.

Systems approach: While an interdisciplinary approach may provide coverage of broad issues on which a variety of actors, disciplines and stakeholders may have achieved consensus, resolution of the problem and enhancement of the actual safety level of performance to the required level requires a third necessary condition: the application of a systems theory. Systems theory facilitates in structuring a complex reality. A decomposition in elements, components, aspects and relations provides oversight and coherence across levels and entities that interact with each other. Putting events in the context of systems in which they operate, requires a distinction between event and system, similar to a patient and the health system or a convict and the judicial system. While accidents should be prevented for the sake of their unacceptable consequences, the object of research for safety interventions is at the systems level

Perrow has discussed some fundamental properties of complex systems in terms of tight and loose coupling between different elements and non-linear interactions between elements, and therefore, the need for building systems which do not depend on user or operator alone to ensure safety. Traffic crashes present an excellent example of complex systems, uncertainties and nonlinear interactions between human beings, vehicles and the road environment. This makes a strong case for moving away from focusing on the errors that road users make to concentrating on road and vehicle designs that can reduce the propensity and severity of crashes. Safety science has had a major influence on the traffic safety theories in the last fifty years.

R. Elvik et al. have discussed two important road safety theories that are related to engineering and human behavioural effects. Road safety measures could affect road safety by influencing relevant factors through engineering effect and behavioural adaptation. This suggests that engineering and human behaviour related factors are two important sources of risks. For example, road lighting improves visibility (engineering effect) but road users tend to be less alert (behavioural adaptation). Most factors can be related to either engineering or human behavioural effects. Vehicle related factors can also be explained through engineering effects. For instance compared to cars, large trucks have unique characteristics, most notably high gross weight, long vehicle length, and poor stopping distance, which can be associated with different levels of risk.

Many other safety theories can be explained based on the engineering and behavioural theories. For instance, drivers can modify their behaviour based on what they see on the road ahead of them (e.g. increasing speed or reducing attention), especially when the lower risk is brought about by a road design countermeasure. Physiological theory may be related to both engineering and behavioural theory to some extent. For instance it was suggested that drivers are more likely to fall asleep or feel bored on straight, monotonous, dual carriageway roads with little traffic. In this case, drivers changed their behaviour on certain types of road (e.g. straight and monotonous roads); and on the other hand, road engineers could alter the road environment in order to reduce driver boredom. However, in some cases fatigue or boredom are linked more to the characteristics of the person themselves rather than engineering or behavioural adaption. For instance, it was found that individuals with a higher level of anxiety may be more likely to feel fatigue. In addition, some groups of people (e.g. older people) are inherently more vulnerable than others, thus more likely to be involved in an accident or to be more seriously injured if an accident occurred.

Safety science has influenced the traffic safety interventions in HICs, primarily leading to the emergence of safe systems approach in The Netherlands and Vision Zero in Sweden.

Vision Zero accepts, as a basic starting point, that human beings make conscious and subconscious mistakes. That is why accidents occur, and the safety work must in the first instance be directed at those factors which can prevent accidents leading to death and serious injury. Accidents in themselves can be accepted, but not their serious consequences.

According to Vision Zero, the principal cause as to why people die and are seriously injured is that the energy to which people are exposed in a traffic accident is excessive in relation to the energy that the human frame can withstand. Vision Zero is, among other things, based on the research that the famous American road safety expert William Haddon conducted in the 1960s. Knowledge of energy and tolerance has to a great extent served as a basis for the development we have seen of the passive safety characteristics of vehicles and for the development of different protection systems such as child safety seats, helmets, seat belts, etc. One important consequence of Vision Zero as a general policy for safety work is that the view of knowledge which has served as a basis for the development of a sub-component in the road transport system, namely the vehicle, also has become a general principle for the entire road transport system.

According to Vision Zero, it is not the individual road-user who has the ultimate responsibility but rather the so-called system designers. The responsibility for safety is thus split between the motorists and the system designers (i.e. infrastructure builders and administrators, the vehicle industry, the haulage sector, taxi companies and all the organizations that use the road transport system professionally), on the basis of the principles that:

- The system designers have ultimate responsibility for the design, upkeep and use of the road transport system, and are thus responsible for the safety level of the entire system.
- As before, the road-users are still responsible for showing consideration, judgment and responsibility in traffic and for following the traffic regulations.
- If the road users do not take their share of the responsibility, for example due to a lack of knowledge or competence, or if personal injuries occur or for other reasons that lead to risk, the system designers must take further measures to prevent people from being killed or seriously injured.

In Vision Zero, the responsibility for safety is a chain of responsibility that both begins and ends with the system designers. Sustainable safety approach of The Netherlands is based on similar principles. Fred Wegman has noted that:
"There are two good reasons why the traditional approach (working on reducing "spikes in distributions") will become less effective and efficient in countries with mature road safety policies. The first reason lies in the fact that serious road crashes will occur as long as we leave the inherent unsafe conditions in road traffic untouched: the inherent risks come from a combination of the physical vulnerability of the human body and the levels of kinetic energy in crashes (a combination of speed and mass). These inherent risks also stem from the fact that the road transport system cannot be designed from the perspective of the human being as long as it fails to defend against human errors and offenses that can result in crashes. Because of this, we are almost fully dependent on how well drivers, riders, and pedestrians perform their tasks. It is remarkable that, while the road transport system puts its faith in individual driving skills, the rail system and the aviation system are designed from a safety perspective—and even well-trained professionals like train drivers and airplane pilots are only allowed to operate under rather strict conditions. A second good reason lies in the fact that our traditional policies have become less effective and efficient. Traditional interventions dealing with reducing relatively high risks are in the process of coming to the ends of their life cycle, suggesting that they may be subject to the law of diminishing returns. In the Netherlands, these two underlying reasons have triggered a paradigm shift and resulted in the development of Sustainable Safety, the Dutch version of the Safe System approach."

Given the understanding from traffic safety theories of the last fifty years, the systems approach and Vision Zero, we can propose some basic principles which can form the corner stones for developing safe highways in LMICs.
Safe systems approach has three key principles :

- Principle 1 Recognition of human frailty
- Principle 2 Acceptance of human error
- Principle 3 Creation of a forgiving environment and appropriate crash energy management.

Current highway standards for geometric design of highways can be reviewed in the context of these three basic principles. Principle 1 and 2 must recognize that highways in LMICs will have presence of NMVs and pedestrians along with motorized traffic. Principle 3 becomes the operational principle for setting appropriate speed limits for ensuring a forgiving environment for all road users. Pedestrians will make mistakes in judging the possible risk in the system whereas, drivers can make mistakes in adopting an appropriate speed.

Excerpts from the chapter
"Principles of Development of Safer Rural Highways Systems for Conditions Prevailing in Low and Middle Income Countries" in a forthcoming TRIPP publication **Transportation and Safety: Systems, Approaches and Implementation**

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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

Traffic Management Plan for Nainital Town

Sponsor: *Nagar Palika Parishad, Nainital, Uttarakhand*
Project Team: *Geetam Tiwari, Dinesh Mohan and K.N. Jha*
Objective:I.Design strategies for Traffic management for Nainital town
II.Estimate parking demand for next five years .
III.Analyse current traffic circulation in the city and estimate traffic circulation requirement in the next five years .
IV.Develop short term implementation strategies (1 year) and medium term strategies (3 years) to address traffic circulation in Nainital.

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.

Safety Audit of Yamuna Expressway

Sponsor: ***Jaypee Infratech Limited***
Project Team: *G.Tiwari, K.R. Rao, K.N. Jha and S. Mukherjee*
Objective:The study will cover complete 165 km stretch of Yamuna expressway including the entry exit ramps, toll booths and all facilities along the corridor.
Specific objectives are:
1.Identify geometric deficiencies in the Yamuna Expressway alignment including the entry exit ramps, toll booths and all facilities along the corridor with respect to traffic safety and suggest corrective measures.
2.Identify deficiencies in signage marking and road side barriers on the YE corridor with respect to traffic safety and suggest corrective measures.
3.Identify high crash locations based on last three year traffic crash data along the corridor and suggest measures to reduce traffic crash risk on these locations.
4.Suggest measures to improve speed compliance along the corridor.

NEWS

Studying critical pedestrian behavioral changes for the safety assessment at signalized crosswalks

Although the pedestrian speed has been discussed in the literature, previous studies mainly focused on the average walking speed. This paper presents important suggestions for understanding pedestrian maneuvers in detail from a safety viewpoint. Sudden pedestrian speed changes are important events that may significantly contribute to the severity of pedestrian–vehicle conflicts since drivers cannot easily expect them. The developed pedestrian speed profile model can contribute to the representation of realistic conflicts with vehicles. This can be utilized to estimate the pedestrian-vehicle conflict risk as a part of traffic simulation for safety assessment, by integrating with other maneuver models of vehicles and pedestrians. Another application can be a real-time information provision to vehicles to alert the risk of hazardous conflicts. Such system is expected to be useful not only for drivers but also for the development of avoidance maneuver modeling of autonomous vehicles.

It is also important to mention that the proposed methodology can be used to identify proper crosswalk layout that minimizes acceleration/deceleration events. Moreover, it can be used to adjust pedestrian clearance interval (adaptive signal setting) by detecting pedestrians and estimating the needed crossing time considering the possibility of behavioral changes.

Wael K.M.Alhajyaseen, MihoIryo-Asano (2017), Safety Science, Vol. 19, Pages 351-360.
https://doi.org/10.1016/j.ssci.2016.09.002

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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 work in progress: "Improving operational efficiency of bus systems and addressing data gaps in vehicular emissions management (2017-2019)"*

Economic efficiency of cities and well-being of urban inhabitants are directly influenced by the pattern of mobility. If the growing automobile dependency is not prevented, increased travel distances and the car centric urban form and infrastructure can lock up enormous amount of carbon and pollution that will make sustainable growth difficult in the future. In this context equity based inclusive mobility planning assumes even greater significance.

Currently there is significant scope to improve the intra-city and intercity bus and freight operations which can result in large scale emission reduction by way of decreased usage of emission intensive means like private vehicles and higher operating performance due to adoption of upgraded technology.

Hence IIT Delhi's interdisciplinary Transportation Research and Injury Prevention Programme (TRIPP), with support from Shakti Sustainable Energy Foundation is working on a two pronged approach, in the ongoing study:-

1.Developing Fleet characteristic data base for passenger and freight vehicles
2.Promoting Bus based Public Transportation in Indian context.

1. Developing Fleet characteristic data base for passenger and freight vehicles

Inadequate information is available for in-use passenger and freight vehicles for estimating fuel efficiency performance, annual mileage, vehicle age, emission standard, etc. This is limiting the implementation of key MoRTH policy initiatives aimed to regulate their emissions through vehicle scrappage, inspection and maintenance programs. These policy interventions are weakly supported by rough estimates instead of robust scientific analysis.
Following observations are based on the learnings from the project while assessing the freight vehicles characteristics along the major national highways and key connecting roads of SH and MDR /ODR.
In-use HDVs consume approximately 55 percent of the country's total diesel and contribute up to 65 percent of carbon dioxide emissions from the transport sector, besides constituting a small proportion of total vehicular fleet. This may be attributed to their lower fuel economy and higher annual mileage as compared to other vehicles. However there is very little information available about their fuel efficiency performance, annual mileage, vehicle age, emission standard, etc. There is need to collect primary and secondary data to analyse the usage characteristics of HDVs, LDVs and also the emission mitigation potential of various policies that promote cleaner fuels and vehicles.

The 24-h classified volume counts, 48 hour intercept OD Survey data was collected in two phases for the freight fleet : (a) Freight fleet characteristics on National Highways NH-8, NH-3, NH-6 and NH-2 covering North India connecting major cities of India like Delhi, Ahmedabad, Mumbai and Kolkata (May 2016). (b) Freight fleet characteristics on State Highways and Major District Roads, lying within a 20km radius of the previously surveyed locations on National Highways. (c) Trip diary of the entire day freight journey is captured to subsequently understand the hours of their operation, crosscheck the annual kilometer results obtained from the odometer readings and route details wrt type of roads. (d) scope of using the vehicle registration e-database, "VAHAN", in further analysis and crosschecks.

A total of 393 and 4921 O& D samples were collected for light-duty and heavy-duty vehicle, respectively, in phase 1 at National Highways. The results of the first phase of the project indicated the presence of newer fleet for long distance transport. 46% and 71% of the fleet lies in the age group of 0–4 years for heavy and light-duty vehicles respectively. Only, 4% and 1% of heavy-duty vehicle and light-duty vehicle are greater than 10 years old, respectively. The average annual mileage of 51,000 km and 30,000 km are observed for heavy and light duty vehicles, respectively. The fuel economy for diesel-run light-duty vehicles ranges in between 11 km/l and 13 km/l, whereas, for heavy-duty vehicles, it is in the range of 3 4 km/l.

A total of 1074 and 1582 origin and destination samples are collected for freight vehicles on MDR and SH, respectively. Similarly, a total of 2857 and 3938 origin and destination samples are collected for passenger vehicles on MDR and SH, respectively.

Results show that older fleet ply on SH and MDR in comparison to that on NH. The highest proportion of the older fleet in case of both heavy duty and light duty vehicle is observed to be plying on SH. In case of MDR for heavy-duty vehicles 23% of vehicles in the age group greater than 10 years. In the case of light-duty vehicles on MDR, 12% of vehicles in the age group greater than 10 years. The age distribution obtained in case of SH for heavy-duty vehicles includes 28% of vehicles in the age group greater than 10 years. In the case of light-duty vehicles on SH, 16% of vehicles in the age group greater than 10 years.

As suspected, the freight fleet characteristics observed for State Highway and Major District Roads might be quite different from that of National highways. The observations of the vehicle age distribution thus justify the need for estimating representative survival rates for SH and MDRs. On-going work includes the investigation of using the vehicle registration e-database "VAHAN", in further analysis and crosschecks and the analysis of trip dairy data to retrieve the operation hours of the freight fleet. Subsequently, nationwide fleet emission calculations are to be performed.

2.Promoting Bus based Public Transportation in Indian context.

Ideally, bus planning and operations should be a data driven exercise based on transport demand assessment together with careful analysis of service needs, preferences and expectations of the users. However, the bus operators lack the technical capacity to collect and analyse data to effectively plan their services by judiciously deciding number and types of buses based on the size and category of cities. Hence the proposed project developed data driven decision tools to arrive at the optimal bus fleet, its procurement guidelines and robust scheduling for efficient transport operations.

Task I - Data Management Practices In Bus Companies

Bus based public transport is the backbone of road based mobility in our country. Currently, there are 53 STUs owned and regulated by respective state governments. Out of 53 existing STUs in India, 24 are corporations, 7 come under municipal undertaking, 9 are run by government departments, and 13 are government companies. With overall fleet utilization of 89.5%, roughly 1.25 lakhs buses were on road daily covering 15.5 billion revenue-earning kms carrying more than 6.8 crore passengers per day.

The average buses held by STUs and average buses on road and total number of passengers carried have increased during 2013-14 while, fleet utilization, passenger km offered, average occupancy ratio and passenger km performed has declined marginally. To avoid this trend, ASRTU needs a tool which can evaluate the fleet data collected by different STUs. And provide the solutions which can help STUs for better performance of their fleet.

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4 case study cities - Mathura and Meerut in U.P. State and Patna and Gaya in Bihar have been studied to understand the current data management practices in Bus companies. The study included qualitative surveys of the depots along with detailed interviews and data logs to understand collection, maintenance and utilization of data by city bus service providers. An analysis of 'State Transport Undertaking Profile and Performance' and 'Review of the Performance of State Road Transport Undertakings (SRTUs)' over a period of 4 years i.e. 2009–10 to 2013–14 shows that -

1. STUs are accountable for funds they receive from central and state governments, hence, they maintain their performance data in terms of capital investment, revenue, fleet and capacity utilization and maintenance. Public bus operator's prime focus is to improve financial performance of the system rather than as a basic service to the society.
2. Indicators that measure user benefits and benefits to the society at large such as punctuality, reliability, comfort, safety, security and emissions are not measured or poorly reported.
3. Less than 20% data is in digitial format. In general, data is rarely used for operations, planning and decision making (Manual data entry – 82% in logbooks and spreadsheets and partially in ERP software).

Additionally, Webtool for reporting bus related Key Performance Indicators (KPI) periodically at depot level is being developed for ASRTU.

As a first step towards the development of this tool, depots categorization basis area of operation, i.e. Urban and Rural (consisting of both intercity and Mofussil services) for all Hilly and Plain states, was developed. Following this secondary data and existing reports on evaluation of STU indicators were reviewed. This assessment was used to compile a list of indicators to be accommodated in the tool and used in the performance evaluation of STU. These indicators were categorised as passenger, operator and societal. In the other dimension, they were categorised as indicators which are useful for evaluation by ASRTU (or at the National Level comparison between STUs), at the STU level (comparison between depots) and at the depot level (comparison of performance parameters with other depots or past years).

In the following step, input data required for all indicators was identified and segregated into data input at depot level (by individual depot managers) and data input at STU level (by STU managers). All formulas for estimation of indicators, their input and output units was finalised. Additionally, output type for use by different stakeholders was finalised. For example, at National level, comparison of all (or selected) indicators between STUs are useful, or a selected indicator between all STU's or indicators of a STU across past years (time series or trend analysis).

In the final step of the study, the above defined methodology for analysis, evaluation and comparison in the tool is being converted to a web-based version, titled as 'Trims4STU'. The forms for data collection at STU and depot level are currently being finalised and the same shall be shared with STU and/or CIRT for testing and dummy data collection. Following this the alpha version of website shall be shared with stakeholders to gather feedback on user-friendliness and appropriateness.

It is envisaged that the data collected, sorted and presented by this web-based tool will provide insights for improvement and decision making for planning action by individual STUs. Additionally, it will also help ASRTU develop benchmarking for different indicators, allowing comparative evaluation, and setting practical targets for improvement. This web tool will also ensure data availability to a larger audience including students, academicians and researchers, encourage research which will have potential to benefit STUs, which shall in turn help make bus based public transport more attractive to commuters, attracting higher patronage.

Task II – Develop Framework For Electronic Ticketing Machine (ETM) Data Analytics

Due to ineffectiveness of State run Urban Public Transport Authorities to cater to large demand, commuters are shifting to alternate modes of transport. A tedious exercise entailing large data analytics is must to strengthen and effectively distribute Public transport system to provide a safe, time and cost-effective journey to the commuters.

A one-month (Nov 2017) Electronic Ticketing Machine (ETM) data has been collected from Meerut City Transport Service Ltd. (MCTSL) as sample. The data collected from Meerut city contained 50 routes of varying lengths and overlapping stations. The initial phase was to segregate the routes based on route numbers and check availability of data. The routes are classified based on the length of route and frequency of travel based on the available depot schedule. These classifications are High frequency short route (HFSR), High frequency long route (HFLR),Low frequency short route (LFSR) and Low frequency long route (LFLR). Next step of the algorithm involved comparison of assigned depot scheduled bus numbers and actual running busses to observe discrepancies. This allows one to observe the actual fleet utilized with accuracy to individual bus numbers.

Efforts are to identify various performance indicators which can be easily measured for operation planning from the ETM data. Few performance indicators such as seat availability and passenger –km travelled, Level of service (LOS) provided to the commuters has been analysed. Other indicators such as understanding the boarding and alighting along the route, utilization co-efficient, feet utilization, co-efficient of passenger exchange, indicators based on time and fixing of a schedule based on actual use is also being estimated.

The initial phase is to convert the available ETM data into a common format, remove unwanted information from the data. Routes containing at least three weekends were taken into consideration as there has to be a representation of variability in commuter usage (roughly 70%). The routes are then divided into separate files based on route number thereby avoiding confusion of overlapping routes. Certain observations were made namely missing data, overtaking of busses and inconsistent ticket timings.

For the creation of validation data in the case of programme a sample route is selected. Route 16 is selected for this purpose, a HFSR based on its depot schedule. The Depot details for the route is studied and a comparison is made with actual busses running the route over the study period. Percentage of assigned fleet utilized is determined.

The programming is underway where a python front end and a database analysis language - SQL is working as a back end of the program. SQL is used by large data handling organisations thereby making it a best solution for handling the current data analysis requirement of Transport sector.

The next step in the algorithm picks the first ticket timings at each bus stop which corresponds to the arrival time of the bus at the particular stop. Daily trip details of bus at select route is plotted. These provide the user with actual trips done per bus per day.