TRIPP BULLETIN
VOL. 16 NO.1 SUMMER 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Publications

RESEARCH PAPERS

Data Recording Patterns and Missing Data in Road Crashes: Case Study of Five Indian Cities. Jha, A.N., Tiwari, G. and Chatterjee, N., 2018. *BMJ Journal, Injury Prevention, 24(2).*

Correlates of Fatality Risk of Vulnerable Road Users in Delhi. Goel, R., Jain, P. and Tiwari, G., 2018. *Accident Analysis & Prevention, 111, pp.86-93.*

Role of User's Socio-Economic and Travel Characteristics in Mode Choice between City Bus and Informal Transit Services: Lessons from Household Surveys in Visakhapatnam, India. Gadepalli, R., Tiwari, G. and Bolia, N., 2018. *Journal of Transport Geography.*

Estimation of PCE Values for Hill Roads in Heterogeneous Traffic Conditions. Gautam, A., Das, A., Rao, K.R. and Tiwari, G., 2018. *Transportation letters, 10(2), pp.83-91.*

Infrastructure Designs and Traffic Safety: The Road to Vision Zero. Tiwari, G., 2018. *International journal of injury control and safety promotion, 25(3):237-238* .

Perception of Potential Bus Users and Impact of Feasible Interventions to Improve Quality of Bus Services in Delhi. Suman, H.K., Bolia, N.B. and Tiwari, G., 2018. *Case Studies on Transport Policy, 6(4), pp.591-602.*

Safety of' the Vulnerable Road Users': Current Challenges and Need for a New Approach. Tiwari, G., 2018. *International journal of injury control and safety promotion, 25(1), p.1.*

Assessing the Impact of Black Spot Focused Policies On Traffic Safety. Bisht, L.S. and Tiwari, G., 2018. *Injury Prevention, 24(Suppl 2), p.A73.*

Estimation of Safety Performance Function with Limited Data on Highways. Malik, L., Jindal Shukla, G. and Tiwari, G., 2018. *Transportation Research Board (TRB), (No. 18-03318).*

Blackspot Identification and Cluster Analysis of Small Sized Indian Cities of Patiala And Rajpura. Dhanoa, K.K., Tiwari, G. and Malayath, M., 2018. *Transportation Research Board (TRB), (No. 18-01672).*

Factors Contributing to Motorcycle Fatal Crashes on National Highways in India. Naqvi, H.M. and Tiwari, G., 2018. *International journal of injury control and safety promotion, 25(3), pp.319-328.*

High Rate Failure Properties of Human Aortic Tissue under Longitudinal Extension. Gaur, P., Verma, K., Chawla, A., Mukherjee, S., Lalwani, S., Malhotra, R., Mayer, C., Ghosh, P. and Chitteti, R.K., 2018. *International Journal of Experimental and Computational Biomechanics, 4(2-3), pp.125-151.*

High Strain Rate Compressive Behaviour of Human Heart. Verma, K., Mukherjee, S., Gaur, P., Chawla, A., Malhotra, R. and Lalwani, S., 2018. *Int.onal J. of Experimental and Computational Biomechanics, 4(2-3), pp.152-174.*

Air Flow, Heat Transfer and Impact Study of Ventilated and Non-Ventilated Full-Face Motorcycle Helmet. Shishodia, B.S., Sikri, S., Sanghi, S. and Mahajan, P., 2018. *International journal of crashworthiness, 23(2), pp.124-133.*

Computational and Subjective Assessment of Ventilated Helmet with Venturi Effect and Backvent. Shishodia, B.S., Sanghi, S. and Mahajan, P., 2018. *International Journal of Industrial Ergonomics, 68, pp.186-198.*

Viscoelastic Properties of Recycled Asphalt Binder Containing Waste Engine Oil. Qurashi, I.A. and Swamy, A.K., 2018. *Journal of cleaner production, 182, pp.992-1000.*

Prediction of Density and Viscosity of Bitumen. Eleyedath, A. and Swamy, A.K., 2018. *Petroleum Science and Technology, 36(21), pp.1779-1786.*

Effect of Aging Level on Viscoelastic Properties of Asphalt Binder Containing Waste Polyethylene. Singh, P. and Swamy, A.K., 2018. *International Journal of Sustainable Engineering, pp.1-8.*

Interrelationship between Compacted Void Content Of Aggregates And Asphalt Concrete Properties. Swamy, A.K., Matolia, V. and Ramana, G.V., 2018. *Particulate Science and Technology, pp.1-9.*

An Energy-Based Approach to Characterizing Short-Term Aging Characteristics of Asphalt. Swamy A.K. and Qurashi, I.A., 2018. *Advances in Civil Engineering Materials, 7(2).*

Quantification of Uncertainty in the Master Curves of Viscoelastic Properties of Asphalt Concrete. Swamy, A.K. and Rema, A., 2018. *Advances in Civil Engineering Materials, 7(2).*

Probabilistic Approach to Characterise Laboratory Rutting Behaviour of Asphalt Concrete Mixtures. Singh, P. and Swamy, A.K., 2018. *International Journal of Pavement Engineering, pp.1-13.*

Site Amenities and Workers' Welfare Factors Affecting Workforce Productivity in Indian Construction Projects. Gupta, M., Hasan, A., Jain, A.K. and Jha, K.N., 2018. *J. of Construction Engg.and Management, 144(11), p.04018101.*

An Empirical Study on Performance Measurement Factors for Construction Organizations. Tripathi, K.K. and Jha, K.N., 2018. KSCE *Journal of Civil Engineering, pp.1-15.*

A Joint 3d-2d Based Method for Free Space Detection on Roads. Patra, S., Maheshwari, P., Yadav, S., Banerjee, S. and Arora, C., 2018, March. *In 2018 IEEE Winter Conference on Applications of Computer Vision (WACV) (pp. 643-652).*

Modelling Critical Success Factors for Sustainability Initiatives in Supply Chains in Indian Context Using Grey-DEMATEL. Luthra, S., Mangla, S.K., Shankar, R., Prakash Garg, C. and Jakhar, S., 2018. *Production Planning & Control, 29(9), pp.705-728.*

Service Capacity Coordination In It Services Supply Chain Prasad. S.K. and Shankar, R., 2018. *Journal of Modelling in Management, 13(4), pp.952-972.*

Network Redesign for Efficient Crowd Flow and Evacuation. L Taneja, NB Bolia, 2018. *Applied Mathematical Modelling; Volume 53, Pages 251-266*

Pedestrian Control Measures for Efficient Emergency Response Management in Mass Gatherings. L Taneja, NB Bolia 2018. *International Journal of Disaster Resilience in the Built Environment; Volume 9, ISSUE 3*

Speed - Density Functional Relationship for Heterogeneous Traffic Data: A Statistical and Theoretical Investigation. Hari Krishna Gaddam, K. Ramachandra Rao 2018. *Journal of Modern Transportation, https://doi.org/10.1007/s40534-018-0177-7*

Empirical Investigation of Multiclass Vehicle Behaviour under Heterogeneous Traffic Flow Conditions. Hari Krishna Gaddam, K. Ramachandra Rao 2018. *European Transport/Trasporti Europei, 68 (6).*

Continued on Page 4

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.

TRIPP BULLETIN
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
VOL 16 NO.1 SUMMER 2019

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 . 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 . 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.

A simple theoretical model that was developed which can be used to understand the finding of a road safety evaluation study. The basic understanding according to this model is that there are two causal chains which connect a road safety measure to its final outcome—engineering and behavioural. In the context of traffic enforcement, we are concerned with the causal chain through the behavioural effect. There are, therefore, two main theoretical strands based on which we can explain the effectiveness of traffic enforcement. First is the theory which explains why drivers correct their behaviour when an enforcement measure is implemented. Second is the theoretical basis which explains why that particular change in behaviour would lead to higher safety. For example, an enforcement measure targeting over-speeding would likely result in reducing the proportion of drivers driving above a certain speed limit. This is the behavioural effect of the enforcement. The final outcome i.e. number of crashes and accidents would then be dependent on the relationship between speed distribution and crashes.

The underlying theory which explains the effectiveness of different enforcement measures is called the 'deterrence theory', where deterrence is 'the omissions or curtailment of a crime from the fear of legal punishment. According to this theory the fear of punishment encourages potential offenders to comply with the law. The enforcement measure works not only by apprehending the offenders, which is often a very small proportion of all road users and in fact a small proportion of all offenders, but also by discouraging 'potential' offenders because of the perceived certainty getting caught .

"The principal opportunity for criminal law to be effective in reducing drunk driving is paradoxically, not by affecting the apprehended law violators, who stand within its power. Rather, it lies in affecting unapprehended individuals who are sensitive to the threat that, should they behave illegally. There are two types of deterrence, specific and general. Specific deterrence primarily focusses on punishing apprehended offenders and assumes that they will be deterred from repeating their offence in the future to avoid punishment. On the other hand, general deterrence focuses on the population in general and assumes that the threat of punishment will deter people from violating the law in the first place. The greater the perception of risk of punishment, the greater the likelihood that general deterrence will be effective. For an enforcement policy to be effective, it needs to ensure both types of deterrence are at work, so that a sanction not only impacts the individual who is being punished but also others who do not directly experience the sanction. The understanding of theoretical aspects that explain the effectiveness of enforcement measures is important to develop hypotheses for future application of these measures in different settings.

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 (Shults, Nichols, et al. 2004, Blais and Dupont 2005). 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?

The most common speed enforcement methods are point-based where vehicle speeds are detected at fixed locations on the road. With point-based speed enforcement methods, the drivers get familiar with locations of cameras and modify their behaviour only in the immediate vicinity of speed enforcement. Hence, innovative approaches were needed to make speed enforcement more effective. Average speed enforcement method was developed as an alternative to point-based method. This is also referred to as 'average speed section control', 'point to point', 'time over distance' cameras or section control or trajectory control (21, 24). This type of enforcement involves the installation of a series of cameras at multiple locations along a road section. The average speed of a vehicle over a section of a road is calculated by capturing its license plate number at more than one camera locations. In case this speed exceeds the posted speed limit, the vehicle information is communicated to a central unit. Almost all current installations throughout the world involve some degree of human verification to assess the validity of detected infringements. In such a system there are stopping sites for manual enforcement.

A review of the effectiveness of average speed enforcement methods was reported. 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.

here 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.

Red-light running results mostly in side-collision crashes which are more severe than other type of intersection crashes. In case there is a dedicated signal for the left-turning vehicles (in right-hand traffic), red-light running also results in head-on collisions. The implementation of red-light cameras (RLCs) is also associated with an increase in rear-end crashes resulting from drivers' tendency to apply break abruptly in order to avoid the fine. Since both the head-on and right angle crashes have higher severity than rear-end crashes, even if the number of crashes are cancelled out, the severity level of crashes is still likely to reduce with the implementation of RLCs.

Control of drivers under the influence of alcohol has a strong empirical justification. A meta-analysis demonstrates that there is no evidence of a threshold effect for alcohol. Alcohol gradually affects driving skills. There is no sudden transition from unimpaired to impaired occurring at a particular BAC level. A review from the US indicates that crash risk grows exponentially with increasing blood alcohol concentration (BrAC). The study shows that at low levels of alcohol (e.g., 0.03 BrAC) the risk of crashing is increased by 20 percent, at moderate alcohol levels (0.05 BrAC) risk increases to double that of sober drivers, and at a higher level (0.10 BrAC) the risk increases to five and a half times. At a BrAC of 0.15, the risk is 12 times, and by BrACs of 0.20+ the risk is over 23 times higher. Another meta-analysis concludes that "most skills which are relevant for the safe operation of a vehicle are clearly impaired by BACs of 0.05%, with motor functions being more affected than cognitive functions and complex tasks more than simple tasks. Generally, the results provided no evidence of a threshold effect for alcohol. There was no driving-related performance category for which a sudden transition from unimpaired to impaired occurred at a particular BAC level"

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

Elvik et. al 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 Koonstra et.al. published report 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 include 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 their results need 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, their data show 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.

This report commissioned by the DG for Mobility and Transport, European Commission, concluded that 20 to 28% of all road fatalities in the EU in 2012 could be attributed to drink-driving. This is a significant decrease from the 1980s when many countries reported share of alcohol related fatalities to be in the range 30 to 45%. The data also show that in some countries expert estimates of the share of alcohol related alcohol fatalities can be higher than the official statistics. Moreover, the definition of 'impaired' is different for each country. It ranges from 0.2g/l in Sweden to 0.5g/l in many countries and so a comparison of countries based on numbers of deaths from drink driving crashes is not really possible. There is general agreement that there was a significant reduction in the period 1980-2010 which can be attributed to stronger laws, vigorous enforcement, and changes in social norms which all contributed to the progress that has been made though not much change has been observed over the last decade.

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.

:- 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:
    - o Influence of road and infrastructure design on traffic violations and the difficulties of enforcement when designs are not adequate for the kind and volume of road users present.
    - o Critical/minimum levels of enforcement necessary for different traffic violations.
    - o Enforcement methods that would be cost effective in situations with high proportion of motorcycles and other vulnerable road users.

TRIPP BULLETIN
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
VOL 16 NO.1 SUMMER 2019

Continued from Page 1

Calibration of Non-Lane Based Macroscopic Continuum Model -a lying Global Search Algorithms. Hari Krishna Gaddam, K. Ramachandra Rao 2018. *Mathematics A lied in Transport and Traffic systems (MATTS), TU Delft, The Netherlands, 17-19 Oct 2018.*

Human Stampedes at Mass Gatherings: An Overview, Pedestrian and Evacuation Dynamics (PED-2018). Lakshmi Devi Vanumu, Laxmi Kant, K. Ramachandra Rao 2018. *Lund Sweden.*

Modelling Emergency Evacuation of Classroom with Different Age Profiles. Lakshmi Devi Vanumu, Aditya Arya, Hari Krishna Gaddam and K Ramachandra Rao 2018. Pedestrian and Evacuation Dynamics (PED-2018), *Lund Sweden*.

Driver Gap Acceptance Characteristics at Roundabouts and Meta-analysis of Recent Studies in India. Vaibhav Negi, Gaddam, H.K., K. Ramachandra Rao 2018. *Recent Advances in Traffic Engineering (RATE)-2018, SVNIT Surat, Aug, 2018.*

Identifying a Suitable Pedestrian Simulation Software – A case study on emergency evacuation of class room. Hemant Jain, Lakshmi Devi Vanumu, K. Ramachandra Rao 2018. *Recent Advances in Traffic Engineering (RATE), SVNIT Surat, August, 2018.*

Calibration and validation of pedestrian simulation parameters: a case study of classroom evacuation. Gaddam, H.K. Arya, A., Vanumu, L.D., Rao, K.R. 2018. *97th Annual Transportation Research Board (TRB) meeting, Washington DC., USA, Jan 7-11.*

Impact of low viscosity grade bitumen on foaming characteristics. SS Kar, AK Swamy, D Tiwari, PK Jain (2018). *Journal of the South African Institution of Civil Engineering*

Impact of recycled asphalt pavement on properties of foamed bituminous mixtures. SS Kar, AK Swamy, D Tiwari, PK Jain (2018). *Journal of Road & Bridge Engineering; VGTU; Vol 13 No 1 (2018)*

Regionalization of rainfall characteristics in India incorporating climatic variables and using self-organizing maps. S Chaudhary, CT Dhanya, AK Swamy (2018). *ISH Journal of Hydraulic Engineering ; Volume 24, 2018 - Issue 2*

BOOKS

Sustainable Approaches to Urban Transport. Mohan, D. and Tiwari, G. Eds. 2019. *Taylor & Francis Group.*

News

Randomized trials and self-reported accidents as a method to study safetyenhancing measures for cyclists—two case studies

A large number of studies show that high visibility in traffic is important in the struggle of getting the attention from other road users and thus an important safety factor. Cyclists have a much higher risk of being killed or injured in a traffic accident than car drivers so for them high visibility is particularly important. A number of studies have examined the effect of high visibility, such as reflective clothing, but most studies have been primitive, the data limited and the results very uncertain.

In this paper we describe the safety impact of increased visibility of cyclists through two randomised controlled trials: permanent running lights on bicycles and a yellow bicycle jacket, respectively. The effect of running lights was studied through a trial where the lights were mounted to 1,845 bicycles and 2,000 others comprised a control group. The bicycle accidents were recorded every two month in a year through self-reporting on the Internet. Participants were asked to report all cycling accidents inde pendently of severity to avoid differences between participants as regards to which accidents were reported. They reported a total of 255 accidents i.e. 7 accidents per 100 cyclists. The results showed that the incidence rate for multiparty bicycle accidents with personal injury was 47% lower for cyclists with permanent running light. The difference is statistically significant at the 5% level.

The effect of a yellow bicycle jacket was examined through a trial with 6,800 volunteer cyclists. The half of the group received a bicycle jacket and the other half comprised a control group. Both groups reported every month all their bicycle accidents independently of severity on the Internet. They reported a total of 694 accidents i.e. 10 accidents per 100 cyclists. The treatment group was asked each month if they carried the jacket on their last cycling trip. The results showed that on a random day the treatment group carried the jacket or other fluorescent cycling garment on 77% of their cycle trips. The incidence rate for multiparty accidents with personal injury was 38% lower than the control group. The difference is statistically significant at the 5% level.

The trials were not blind and it seems that the lack of blinding has influenced the level of the groups accident reporting. To address this bias we used a correction factor formed by the difference in the number of single accidents of the two groups.

The experiences with self-reporting of accidents via a web based questionnaire sent by e-mail with one respective two month intervals were very good; in both trials more than 80% answered all questionnaires whereas less than 2% did not answer, and the quality of the self-reported accident was considered high.

Harry Lahrmann, Tanja Kidholm Osmann Madsen, Anne Vingaard Olesen. Accident Analysis and Prevention 114 (2018) 17–24.

Establishment funds have been received from
Ministry of Industry, Government of India
Asian Institute of Transport Development, India
Tata Motors Limited, 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
MoUD Chair for Urban Traffic Safety
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

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

Phone: 91-11-26596361, 26596557
Fax : 91-11-26858703, 26851169
Email : ird11830@civil.iitd.ernet.in
http://tripp.iitd.ernet.in

TRIPP BULLETIN
VOL 16 NO.1 SUMMER 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Excerpts from two publications: A TRIPP BULLETIN INSERT

Air flow, heat transfer and impact study of ventilated and non-ventilated full-face motorcycle helmet

This work is an attempt to investigate the internal ventilation system of helmet for providing better thermal comfort to powered two wheeler (PTW) riders and to investigate the effect of vents on the safety aspect of helmet by performing front impact absorption test on ventilated and non-ventilated helmet. Head protection of two wheeler rider is very important issue and safety plays a key role in the motorcycle helmet research. As reported by Patel and Mohan, majority of the PTW riders (72%) complained that helmets cause discomfort due to heat in the summer months. Bogerd et al. have reported that wearing

full-face motorcycle helmet in uncomfortable conditions of high temperatures and high relative humidities can adversely influence the physiological and cognitive abilities of the rider, which may make a motorcycle rider less reactive and less attentive to threats while driving, indicating that redesigning of air ventilation system of helmet is of utmost importance for the thermal comfort of PTW rider. According to Bureau of Indian standard (BIS) 4151, the temperature in the space between the head and the shell should not rise inordinately. To prevent this, BIS4151 suggested that, ventilation holes may be provided in the shell to increase thermal comfort of rider. Since safety is the primary function of helmet, most of the helmet manufacturers suffer from a complete lack of fluid-dynamic guidelines for the design of helmets which can provide better thermal comfort to the PTW rider.

Pinnoji et al. conducted investigations on the helmet performance by conducting experiments on helmets with and without ventilating hole, they compared the experimental results with the computational fluid dynamics (CFD) simulation results, and observed that in the conventional helmet without ventilation, air velocities decreased in the beginning of helmethead gap and are almost constant at the top, where as in ventilated helmets air velocities in this gap are relatively lower on top and bottom of the gap compared to the centre as previously reported by Haider. Furthermore, they also analysed the orientation of the slot in the helmet; they provided slots to increase the mass flow of air in the helmet. They studied two slot orientations, at angle 30° to the horizontal and tangential to the head surface. They observed higher air velocities when the slot is tangential to the head, which lead to increased evaporation of the sweat from head in helmet providing thermal comfort to the rider. Mithun et al. suggested three vents in the front of helmet for enhanced air flow in the helmet. They also suggested that a small exhaust fan must be provided at the back of helmet for increasing air ventilation in the helmet. Raju et al. recommended a vent hole in the back of helmet along with the ventilating grooves in helmet for better removal of air form the air gap of helmet.

In our study, a three-dimensional (3D) computer aided drafting (CAD) model of full-face motorcycle helmet with and without vents has been designed in GAMBIT. Ventilated helmet is designed with three air vents in front of helmet. CFD simulations of air flow and human thermoregulations are performed in commercially available software ScTetra with standard wall functions, under steady state conditions. To understand the effect of helmet microclimate on the thermal comfort of rider, two sets of comparisons are done; first the effect of air inlet temperature on thermal comfort of rider is studied by comparing temperature and AT when rider is not wearing helmet with the temperature and AT when rider is wearing ventilated and non-ventilated helmet. Second, effect of increase of relative humidity in air on thermal comfort of rider wearing a ventilated helmet is studied. Since safety is the primary objective of helmet, so to ascertain the safety of ventilated helmet, front impact absorption test on ventilated helmet i performed. Results are then compared with the front impact absorption test on non-ventilated helmet to estimate the extent of damage caused to the ventilated helmet.

Air entered the domain with a velocity of 15 m/s at a temperature of 30°C and relative humidity of 50%. Head is considered as the source of heat (heat flux 104.6 w/m2) and sweat. Temperature and relative humidity are measured on the eighty points 1 mm away from head on central plane along the direction of flow. Simulations are repeated for different air inlet temperature up to 40°C, maintaining other inlet, outlet and boundary conditions unchanged.

For a rider wearing ventilated helmet, actual temperature is around 30°C in the major portion of head and it is around 32°C at the back of head. Similar trend is observed for AT distribution over head for a rider wearing ventilated helmet. AT in the front of head is around 23°C and it increases to 24°C at the back of head. For a rider wearing non-ventilated helmet, it is observed that actual temperature in the front of the head is in the range of 34-33°C and at the back of head is near to 32°C. AT in the front of head is around 27-28°C and decreases towards the back of head to around 25°C.

Results of CFD simulations and AT calculations indicate that ventilated helmets provide thermal comfort to rider only up to a temperature of 36°C. Which can be considered as a cross over temperature, beyond which if the air inlet temperature is increased, the microclimate in ventilated helmet becomes more and more uncomfortable for the rider as compared to non-ventilated helmet because above body temperature, air starts heating the head instead of cooling it, resulting in increase in AT heat index. Results were found in line with Steadman, who also suggested that when dry bulb temperature is increased, keeping other simulation parameters at base level, AT should increase. This increase in heat stress on rider with increase in air inlet temperature can be attributed to the decrease in temperature difference of head and air, due to which heat carrying capability of air decreases.

Weather conditions were recorded before each trail. The ambient temperature during the trials was in the range of 30-43°C and the relative humidity of the air was in the range of 30% 65%. The height, weight, age, sex and clothing of each rider were also recorded. Riders were asked to drive in three temperature conditions i.e below 36°C, between 36 and 38°C, and above 38°C (16 for each of the temperature range). Results of subjective human trials are compiled. 93% riders found ventilated helmet comfortable below 36°C and 7% riders did not find any difference between ventilated and non-ventilated helmet condition. In temperature range of 36-38°C, 80% riders found ventilated helmets comfortable. Only 17% riders found ventilated helmet comfortable beyond 38°C

Results strongly correlate the ventilation in helmets and the willingness of riders to wear helmets at higher temperatures. Results of subjective human trials are in line with our previous findings (through CFD simulations) that as the air temperature increase thermal comfort of the rider decreases.

This work is probably the first of its kind for predicting the thermal comfort of motorcycle rider wearing helmet, by coupling CFD and human thermoregulation. Results of CFD analysis are used to predict thermal comfort of rider wearing full face helmet. This work is significant because most of the manufacturers focus on safety aspect of helmet and provide vents in helmet shell randomly, without considering human thermoregulation and fluid dynamics of air flow in helmet microclimate. The study of the effect of temperature on thermal comfort of rider wearing helmets suggests that vents provide considerable cooling and thermal comfort to rider up to 36°C. Results also suggest that 36°C is a crossover temperature beyond which if the air inlet temperature is increased, the microclimate in helmet is not found comfortable for rider. The study of effect of increase in relative humidity of air suggests that as the relative humidity of air increases, AT increases and the thermal comfort of the rider decreases. So for providing better thermal comfort to the rider, good air ventilation in helmet is must. Front impact test on three ventilated helmets and one nonventilated helmet is done. Results are also compared with the experimental results of Pinnoji. The results of impact test indicates that the maximum value of the impact force on the helmet shell recorded for ventilated helmets are below that for non-ventilated or conventional full-face helmet. Results further indicate that the maximum acceleration of head form for the ventilated helmets is below that for non-ventilated helmet. Results indicate that ventilated helmet is safe to wear.

Bhagwat Singh Shishodia, Sandeep Sikri, Sanjeev Sanghi and Puneet Mahajan. International Journal of Crashworthiness, 2018 Vol. 23 No. 2, 124-133.

Continued overleaf

TRIPP BULLETIN
VOL 16 NO.1 SUMMER 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Excerpts from two publications: A TRIPP BULLETIN INSERT

Role of user's socio-economic and travel characteristics in mode choice between city bus and informal transit services: Lessons from household surveys in Visakhapatnam, India

Global trends like urbanisation, climate-change and deteriorating air-quality point towards the need to retain and enhance public transport usage in Cities. Emerging economies like China, India and Africa have a significant role in addressing these challenges since they have the maximum growth rate in urban population globally. India alone is expected to add 200 million urban inhabitants between 2014 and 2030. Given their lower incomes and vehicle ownership rates, a significant proportion of the users in these countries are dependent on public transport systems to perform their activities. While these countries have formal Bus and Rail based public transport systems, their availability and affordability hasn't kept pace with the increasing travel demands of their users. This further led to the emergence of 'paratransit' or 'Intermediate Public Transport (IPT)' systems which provide demand responsive transit services as opposed to the fixed route and schedule based services of the formal transit systems. Such paratransit services comprise of different vehicle types including three-wheeled auto rickshaws, four wheeled maxi cabs and mini buses which operate shuttle services along a few high demand routes. Therefore, an integrated analysis of user characteristics of both formal public transport and paratransit services is a necessary requirement to design comprehensive public transport policy and planning recommendations for Cities from emerging economies. The service attributes impacting bus users mode choice was studied the current characteristics of public transport users in Delhi and Mumbai respectively, but their analysis was restricted to the access and egress trips made by rail based mass-transit users.

The city of Visakhapatnam (also known as Vizag), a medium sized city located on the eastern coast of India, is taken as the case study. With a population of 1.73 million it is the largest city in the southern state of Andhra Pradesh. The current urban agglomeration of Visakhapatnam is spread over a vast area of 534 sq. km., of which the built-up area is only 166 sq. km. The city has a significant network coverage of both formal city bus services and informal shared taxi services. Fig. 1 presents the combined bus and paratransit network of Visakhapatnam overlapped with the land use developments around the network, along with a key map showing Visakhapatnam's location in the south-eastern part of India. Fig. 2 presents separate network maps for bus and paratransit services in Visakhapatnam.

The shared auto-rickshaw or three-wheeler services which act as the paratransit system in the city comprises of approximately 28,400 three wheeled auto-rickshaws with two variants of passenger carrying capacity: nearly half the fleet having a seated capacity of three passengers and the remaining half having a seated capacity of six passengers. The vehicles with capacity of three passengers typically operate as point to point taxi service while the ones with capacity of six passengers typically operate as shuttle services between fixed origins and destinations. These services operate along 18 high demand corridors across the city, with a cumulative network length of 91.3 km i.e. 15% of the arterial and sub-arterial roads of the city. The vehicles operating on these corridors are not bound to any fixed routes and operate across corridors in a demand responsive manner. They also do not have any designated drop off and pick up zones and as a result board and alight passengers at any point on the street. This further leads to reduced access and wait time for users as they can hail the vehicle anywhere along their operational corridor.

The city bus system of Visakhapatnam is owned and operated by the Andhra Pradesh State Road Transport Corporation (APSRTC). The bus system has a total fleet size of 670 standard urban buses operating across 133 bus routes assigned to four depots, out of which 83 routes operate entirely within the city limits while the remaining routes provide connectivity to the suburban areas. The bus system has a wider network coverage compared to paratransit, operating fixed route and fixed schedule services across 210 km of road network i.e. 76% of the arterial and sub-arterial road network. Table 2 provides a summary of the network characteristics of the bus and paratransit systems. Buses operate with a service motive, providing services for 16 h every day, while paratransit typically operates for 10 h a day i.e. during the morning and evening peak hours. The population of the city and the presence of competing formal and informal public transport systems make Visakhapatnam a representative case-study among the medium sized Indian cities with population between 1 and 5 million. Therefore, the findings from the city can offer learnings for integrated public transport planning in other such cities.

The article presents a comprehensive framework to understand public transport user behaviour in the context of cities in developing countries which are served by both formal public transport systems and informal paratransit systems. The methodology for data collection and analysis of public transport user characteristics and their mode-choice behaviour in such contexts is presented. Home-based interview surveys, which were identified as the best method to develop the activity diaries of transit users across modes, were carried out for the city of Visakhapatnam, India. The method helped in collected detailed travel behaviour pattern of users from various socio-economic backgrounds. However, it is to be noted that the method involves significant cost and effort in identifying a representative sample across the city and the data collection, owing to the manpower intensive process and the likelihood of poor response rate from households.

The detailed profile of user characteristics of the two public transport modes in the city i.e. the formal city bus system and the informal shared auto-rickshaw services that provide paratransit services were established. A comparative analysis of their characteristics revealed that most of the socio-economic and travel characteristics of city bus and paratransit users were significantly different. Such differences indicate that the two modes cater to separate sets of public transport users within the city, contrary to the popular perception that they are competing with ridership. Therefore, cities should recognise the key role played by paratransit in providing shared services closer to user groups that are not catered by the formal public transport systems like citizens from the lower-income groups and those having shorter trip lengths.

A binary logistic regression analysis was carried out to understand the trend and intensity of impact of various socio-economic and travel variables in determining the users' mode-choice. While most of the user characteristics are different for bus and paratransit, not all variables showed significant correlation in impacting their mode choice. Socioeconomic variables like gender, income and to a lesser extent-age were observed to have an impact on mode choice. All the travel time components i.e. access and egress time, waiting time and in-vehicle time have a significant correlation towards mode-choice. Within travel time waiting time is observed to be more important than in-vehicle time. Paratransit was observed to be the preferred mode for short trips while bus was the preferred mode for longer trips and trips where higher waiting times were acceptable.

The analysis indicates that the overall public transport mode share in the city can be maximized by minimising waiting time for users through operating the two modes such that they provide complimentary services catering to their specific set of users. This will imply moving away from the current planning perception of competition for ridership. Therefore, an integrated bus and paratransit network plan needs to be developed for the city such that bus services are optimized for longer trips and trips with higher wait times while paratransit provides high frequency services for the shorter trips.

The findings from the article can inform transit planning efforts in other developing countries with paratransit systems and cities in developed countries looking to develop demand responsive transit systems, although based on technology platforms. Future extensions of this work can consider comparing the Visakhapatnam data with user characteristics of other cities with similar public transport systems. Additionally, analysis of the operational characteristics of these modes and their governance frameworks can potentially provide insights into policy, planning and regulatory measures needed to integrate formal and informal public transport systems in Indian cities.

Ravi Gadepalli, Geetam Tiwari, Nomes Bolia. Journal of Transport Geography, 2018