



5th Conference of Transportation Research Group of India

CTRG- 2019

Scientific Report of 5th CTRG

18 – 21

December 2019

Noor-Us-Sabah Palace

Bhopal, India

5th Conference of Transportation Research Group of India

18 - 21 DECEMBER, 2019

Scientific Report of 5th CTRG

ORGANIZED BY



Transportation Research Group of India



MANIT Bhopal

Preface

We are pleased to present the scientific report of the 5th Conference of Transportation Research Group of India (CTRG), held during 18th to 21st December 2019 at Noor-Us-Sabah Palace, Bhopal, India. The conference was organized by Maulana Azad National Institute of Technology (MANIT) Bhopal and Transportation Research Group of India (TRG).

The objective of the conference is to provide a unique forum in India, for the interchange of ideas among transportation researchers, educators, managers, policymakers from all over the world, with the intention of covering all modes and sectors of transport (road, rail, air, and water; public and private; motorized and non-motorized) as well as all levels (urban, regional, inter-city, and rural transport) and for both passenger as well as freight movement. At the same time, to also address the transportation related issues of; safety, efficiency, economic and social development, local and global environmental impact, energy, land-use, equity and access for the widest range of travelers with special needs etc. CTRG was first held in December 2011 at Bangalore, India and since then is being organized biennial.

The report covers the highlights of the conference as well as the report of each Workshop that was conducted during the conference. The idea of the workshop was to highlight and develop the agenda for transportation research, capacity building, and collaboration for next 2-3 years based on the present situation and needs of the country. We hope that transportation researchers, educators, managers, and policymakers will be able to utilize the outcomes of these workshops, to develop their activities and action plans in the near future.

Date: July 28, 2020

5th CTRG Team

Acknowledgement

We wish to acknowledge all the distinguished speakers, authors, and registered delegates for contributing to and supporting 5th CTRG and making it a grand success, especially in terms of quality and standard. We are also grateful to the Chair and Co-Chair of each workshop for collating the ideas that emerged in their respective workshop and devoting time and energy in preparing the succinct workshop reports, which are included in this conference report.

Date: July 28, 2020

5th CTRG Team

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Message from the Chair (Scientific Committee)

We received an overwhelming response since the day the first announcement of the 5th CTRG went online (November 30, 2018). We received a total of 449 abstracts under the nine different themes of the conference. A total of 416 abstracts were shortlisted and the corresponding authors were invited to submit their full papers. A total of 252 full papers were finally submitted. After the first stage of full-paper review, the corresponding authors of the provisionally accepted papers were asked to re-submit the revised paper along with a detailed response to the reviewers' comments. Subsequently, the final decision on acceptance/ rejection was taken on each of these manuscripts. Thus, a total of 202 papers were finally selected for presentation (oral or poster) in the 5th CTRG. For both abstract review as well as full paper review, the review processes were conducted in a double-blind manner, and also at least two review reports were necessary before proceeding to take a decision on any given abstract or full paper.

We tried to maintain stringent and rigorous review standard throughout. This would hopefully make the proceedings of our conference as a distinct one. This was possible to achieve only because of the tremendous support provided by the members of scientific committee. We are also thankful to all the reviewers who have submitted their detailed and thoughtful review reports. We also thank all our keynote speakers who have graciously accepted our invitation, and enriched our conference. Thank you all.

I would like to thank each of the Chairs of the individual themes, who have worked tirelessly throughout this journey - and many a times within a very short time-span available. I would like to express my special thanks to Prof. Akhilesh Kr. Maurya for helping me out with everything related to the review-portal management system and also for his valuable advice time-to-time. I also would like to thank Prof. Ashish Verma, Prof. Pradeep Kr. Agarwal and Prof. Siddhartha Rokade for extending their help and support during the entire process.

Thank you.

Animesh Das
(Chair, Scientific Committee, 5th CTRG)

Conference Themes

Theme-A: Pavements and materials

This theme will focus on all aspects of material characterization, analysis, design, construction, evaluation and maintenance of pavement structures. The topics include (but not limited to) characterization of conventional and innovative pavement materials, pavement material modelling, pavement recycling, stabilization of pavement layers, low volume roads, composite pavements, preventive and preservation techniques, rehabilitation, pavement instrumentation, performance monitoring, pavement deterioration modelling, forensic investigations, analysis and design of bituminous, concrete, composite and other kind of pavements, life cycle cost analysis, pavement maintenance management system, pavement drainage, airport pavements and railway track etc.

Theme-B: Traffic flow theory, operations and facilities

The theme will focus on the understanding of vehicular traffic operations on different types of facilities (e.g. expressway, arterial) as well as designing of these facilities in order to provide mobility in an efficient, reliable and safe manner. The topics include (but are not limited to) traffic operations, traffic control and management, traffic flow theory and modelling, operational effects of road geometry, signals and signs, traffic simulation, design of traffic facilities like roadways, intersections, toll-plazas, parking lots, transportation network analysis and optimization, real-time traffic data collection and analysis, vehicle dynamics, applications of trajectory data in modelling, design and operation of road transportation systems, connected and autonomous vehicles etc.

Theme-C: Transport planning, policy, economics and project finance

This theme will focus on transport policy, economics and project finance. The topics include (but are not limited to) pricing strategies, public-private partnership, user impact of multimodal transport projects, project evaluation, cost-benefit analysis, performance measures and related resource management strategies, policy analysis, interaction with political, socio-economic and physical environment, transport as a means for economic development, social equity, transport education and driver education etc.

Theme-D: Travel behavior and transport demand

This theme will focus on research on travel demand forecasting and travel behaviour that aims to obtain a detailed understanding of how much, where, how, when, and why people travel. The Topics include (but are not limited to) travel demand management, spatial analysis of travel patterns, determinants of travel behaviour, data collection methods for capturing travel demand, activity-based travel demand models, tour, stop and trip generation models, destination and mode choice for developing economies, route choice and assignment for heterogeneous traffic networks, valuation of travel time, cost and reliability, role of service quality and subjective factors like

attitude/perception on travel choices and demand, endogeneity in travel choice dimensions, dynamics in travel decisions, alternatives to utility maximization framework, etc.

Theme-E: Environment (including energy) and sustainability in transportation

This theme will focus on the sustainability issues in transportation. The topics include (but are not limited to) the concept of sustainability in transportation and the contemporary issues, transportation land use, socio-economic impacts of transport projects, issues related to energy, public health, safety, and short, medium and long term transport related climate change impact, asset management, green design and construction, ecosystem and land surface degradation, case studies of best practices, effective institutions and governance etc.

Theme-F: Transportation safety and security

This theme will focus on safety and security issues related to transportation with various modes, such as highway, railway, waterway and aviation. The topics include (but are not limited to) crash data collection, analysis and modelling, analysis of transportation policy and planning for safety and security, adaptation of user behavior and human factor in transportation safety and design improvements, safety evaluation of devices, treatments and infrastructure design, effectiveness of control systems, operation and maintenance strategies, construction practices, adopted technologies and management techniques related to safety and security of transportation network etc

Theme-G: Transport and mobility networks (including public transportation, freight and logistics)

This theme will focus on efficient planning and design of transport and mobility networks including public transportation, freight and logistics. The topics include (but not related to) multimodal transport systems, transport data and analytics, big data and transport modelling, planning, implementation, operation and management of all forms of urban and regional public transit systems, transit demand estimation, transit capacity and level of service, impact assessment of transit and policy issues, public transport and demand responsive systems, smart mobility and quality of life, transport accessibility, mobility and transport for elderly and disabled persons, smart city network design, traffic assignment, freight demand modelling, city logistics systems, freight traffic management, intermodal freight transport, application of technologies in freight transportation etc.

Theme-H: Emerging travel technologies (ITS and IOT)

This theme will focus on all aspects that come under the broad umbrella of technological advances in transportation. The topics include (but not related to) connected and autonomous vehicles and modelling, technology enabled models of mobility services related to passenger and freight transportation, technology enabled multi-modal integration, intelligent transportation systems,

robotics, artificial intelligence and augmented reality in transportation, computer vision and image processing for transportation applications, big data analytics for transportation, V2X communication in transportation, internet of things in transportation etc.

Theme-I: Other transportation modes (including NMT) and pedestrian

This theme will focus on various modes of transportation like air, water, rail and roads (including non-motorized transport) and pedestrian movement. The topics include (but not limited to) aviation system planning, control and management, aviation economics and forecasting, port, harbour and fleet services, marine operation and safety, railway system planning, design, operation and management, rail-road operation and safety, all aspects of pedestrian and (bi/tri) cycle including activity models and facilities design and evaluation for their safe, comfortable and efficient movement etc.

Details of Workshops

1. Workshop-A: Sustainable Transport

Chair – M. Parida, IIT Roorkee

Co-Chair – A. Jaiswal, MANIT

Description of theme : Economic policy & planning, transport project evaluations in multimodal environment, transport impacts, public transport planning, and strategies for inclusive mobility including NMT, socio-economic impacts of transport projects, project financing, project management and smart mobility options etc.

2. Workshop-B: Transportation Modes, Planning & Demand Forecast

Chair – Prasanta Sahu, BITS Hyderabad

Co-Chair – Manoj M., IIT Delhi

Description of theme : Demand forecast for passenger & freight movements, multimodal network design, land use transport integration, spatial interaction models, travel behaviour choice models, freight network equilibrium models, activity based models, routing and scheduling, logistics, harbour and fleeting services, container & truck terminal planning, application of planning softwares, urban rapid transit system operations and management of the urban & regional transport systems etc.

3. Workshop-C: Traffic Systems Analysis

Chair – S. Arkatkar, SVNIT Surat

Co-Chair – Gowri A., IIT Tirupati

Description of theme : Human factor analysis, traffic flow behaviour, traffic safety and geometric design improvements, design of traffic facilities, development of application of intelligent transport systems, travel time reliability for transit operations, corridor and area traffic coordination systems, user perceived level of service, inclusive design of intersections & transfer stations, efficacy analysis of safety measures and its economics, real time traffic data collection and analysis and vehicle dynamics etc.

4. Workshop-D: Highway Materials & Pavement

Chair – Ransinchung G D R N, IIT Roorkee

Co-Chair – Nikhil Saboo, IIT BHU

Description of theme : Characterization of conventional & non-conventional highway materials, their performance assessment, pavement analysis & design, performance analysis, long lasting pavements, green highways, porous pavements, composite pavements, pavement response and rehabilitation and pavement maintenance etc.

Conduct of Workshops

- a) All the workshops will be of 1.5 hours duration and will be organized in parallel during a dedicated time slot during the conference.
- b) All the conference delegates will be distributed among the parallel workshops based on their preferences (obtained at the time of registration at conference venue) as well as based on maintaining a good mix of academic, industry, field/government professionals, foreign delegates, and students for each workshop.
- c) The parallel workshops will be an important part of the conference, as they will help build the tangible output of the conference in terms of report of each workshop that will be prepared by Chair and Co-Chair of each workshop. The draft version of these reports will be presented in the Valedictory/Closing Session of the conference by Chair/Co-Chair of each workshop.
- d) The workshop reports will not only help build the work agenda for TRG (towards fulfilling its vision, mission and objectives) but will also give direction to transportation research and capacity building needs in India for the next 2 to 3 years. The idea is that the collective wisdom of many learned delegates attending the conference should be utilized to provide right direction to transportation research and capacity building needs in India.

Workshops Guidelines

- a) The following deliverables are expected from each workshop pertaining to its theme:-
 - a. Research issues/topics that needs to be addressed in immediate future i.e. next 2-3 years.
 - b. Capacity building/training/education issues/topics that needs to be addressed in immediate future i.e. next 2-3 years.
 - c. Collaborative opportunities on research/capacity building issues (as identified above) with industry, field/government organizations, and other countries.
 - d. Any specific major project(s) that needs special attention.
- b) The discussion in each work should stay **absolutely focused on workshop topic and absolutely ON-TIME**
 - a. Some overlap with other workshop may be inevitable but needs to be minimized.
 - b. Chair/Co-Chair guide discussion towards meeting deliverable targets
 - c. The workshop participants should not stray or get caught up discussing a specific localized issue or project
- c) The following is the suggested format for the workshop:-
 - a. First 0.5 hour: Initial deliberation/presentation by Chair/Co-Chair to give initial feed for discussion, open discussion and deliberation
 - b. Next 1.0 hour: Deliberate and suggest recommendations with respect to the theme of the workshop and under each category of expected deliverables.
 - c. Recommendations - Bullet-wise points giving specific and crisp recommended actions and strategies pertaining to the topic of the workshop.

- d) WORKSHOP REPORT (about 5 PAGES) – **to be compulsorily submitted by first half of 21st Dec. 2019**
- a. Page 1-3: Summarize workshop discussion, workshop description, issues raised, needs identified, etc.
 - b. Page 4 & 5: Recommendations pertaining to the theme of the workshop.
 - c. Maximum 5-6 slide presentation in Valedictory/Closing Session on the recommendations of each workshop by either Chair or Co-Chair.

Report of Workshop-A: Sustainable Transport

Chair – M. Parida, IIT Roorkee

Co-Chair – A. Jaiswal, MANIT Bhopal

- The workshop covered the following major themes:
 - ❖ Economic policy and planning
 - ❖ Transport project evaluations in multimodal environment,
 - ❖ Transport Impacts,
 - ❖ Public Transport Planning, and
 - ❖ Strategies for inclusive mobility including NMT,
 - ❖ Socio-economic impacts of transport projects,
 - ❖ Project financing,
 - ❖ Project management, and
 - ❖ Smart mobility options etc.
- The major objective of the workshop is Capacity building/ training/ education issues/ topics that needs to be addressed in immediate future i.e. next 2-3 years.
- The discussion started at 3.30 pm with the Chair (Prof. Manoranjan Parida) guiding discussion towards deliverable targets.
- The workshop participants are students, researchers (both scientific and academic), and industrial experts.
- Major participants include
 - ❖ Mr. P. L. Bongirwar, Advisor, L&T,
 - ❖ Dr. P.K. Agarwal, Professor, MANIT Bhopal
 - ❖ Dr. Rajat Rastogi, Professor, IIT Roorkee
 - ❖ Dr. Debasis Basu, Assistant Professor, IIT Bhubaneshwar
 - ❖ Dr. Samson Mathews, Professor, NIT Trichy
 - ❖ Dr. Kamini Gupta, Senior Technical Officer, CRRI-CSIR, New Delhi
 - ❖ Mr. Sidhardha Rokade, Associate Professor, MANIT Bhopal
- Initial deliberation/presentation by Chair/Co-Chair was given as initial feed for discussion, open discussion and deliberation for 30 mins.
- The presentation addressed the following issues with respect to each theme of the “Sustainable Transport” workshop
 - ❖ Basic principles of sustainable transport
 - ❖ Contributions of livable streets to sustainability
 - ❖ Avoid/shift/improve approach fro sustainable mobility
 - ❖ Proliferation of E-Vehicles
 - ❖ Understanding the choice of technology and appropriate public transport system
 - ❖ Street design for non-motorized transport (NMT) mobility
 - ❖ Technology for disabled people movements

- ❖ Bike-sharing facilities in various parts of the world (Ex: Shanghai, Tokyo, Pune)
 - ❖ Off-street parking technology
 - ❖ low-energy intensive parking spaces/facilities
 - ❖ Smart parking facilities (Ex: Srinagar)
 - ❖ ITS applications as next era for public transport systems
 - ❖ Integrated traffic management systems etc.
 - ❖ Studies on Walkability and Transit Oriented Development
- After the presentation of the Chairperson, the discussion was open for the next 1.0 hour to Deliberate and suggest recommendations with respect to the theme of the workshop and under each category of expected deliverables.
 - Pertaining to the topic, Mr. P.L.Bongirwar raised the issue of subsidized fare structure to sustain adequate public transport ridership. The discussion looked at the topic as a burning issue in the existing public transport systems (MRTS and BRTS) of Indian cities like Mumbai, Delhi, Ahmedabad, and Pune. PPP project mode, complex transport systems, suburban housing and policy constraints were found to be major factors that affect subsidized fare structure and ridership loss. Further, organization of unified transport authority within a city, static and dynamic advertisements within public transport systems were suggested as feasible solutions to sustain the loss.
 - A participant solicited the situation of imbalance (Ex: overcrowding) between demand and supply of public transport systems. He also added to the discussion about road space allocation and traffic congestion in cities like Delhi. On this note, Prof. Rastogi opined that we need to look at the driver behavior and lane discipline of vehicle movements and space allocation on the basis of composition of traffic stream.
 - Reduction of lane width is another addition to the discussion. As observed in the Pune and Hyderabad, the capacity has been abruptly increased with a reduction in lane width. For example, provision of 11m lane width on flyovers in Hyderabad. Restriction of lane width from 8.5m to 7m in Pune urban roads. Prof. P. K. Agarwal felt that the future studies should focus on geometric standards of urban roads. The Chair mentioned about the practice of reduced lane width in Barcelona and other Smart Cities. Reduced lane width can further enhance safety in urban areas.
 - Further, question raised on design of geometric instruments for cities like Bhopal, Pune etc. which has greater composition of two-wheeler vehicles. Provision of separate/dedicated two-wheeler lanes was continued in the discussion. The chairperson, Prof. Parida has mentioned the case of dedicated two-wheeler and cycle tracks in the Shanghai city and its success in mitigating traffic congestion. Street design as an exercise is useful while protecting the rights of slow moving/pedestrian movements.
 - Prof. Rastogi added to the discussion, on the problems of pedestrians/ cyclists due to discontinuity in the urban streets of Pune. Prof. Rokade mentioned the disutility of well-designed cycle tracks in Bhopal context. The question raised on the measures to attract cyclists/non-motorized users. Prof. Basu felt that the demand estimation of bicycle usage is essential before designing bicycle network. The will power of government agencies in

implementing bicycle tracks play major role in the usage of cycle tracks. The encroachment along cycle tracks are found to be major issues that need to be addressed.

- Prof. Basu said that it is essential to identify the catchment areas around transit stations/bus stops where people are willing to walk/cycle. The NMT facilities must be designed based on the walkability within the catchment areas. He also mentioned that the catchment areas need to be segmented based on existing walkability levels on the basis of findings of an Imprint research project undertaken by him.
- Prof. Parida (Chair) raised a token on Smart Mobility, E-Vehicles and vehicle sharing (Ola, Uber etc.). Prof. Rastogi felt that there must be a feasibility study in the Indian context on the provision of 100% E-vehicles in urban areas. The provision of E-vehicles must be at a smaller scale. It would be feasible to shift two-wheeler to E-vehicles than cars, particularly in Indian cities.
- Prof. Parida (Chair) opine that the long-term operation of BRTS is questionable, unless a feedback study on the success/failure of BRTS is done after implementation. Adding to it, Dr. Bivina mentioned the failure stories of Delhi and Surat BRTS due to the lack of motivation of authorities on traffic management and regulation on the BRTS corridors.
- A participant of IISc Bangalore raised certain issues related to the topic. Some bullet tokens are attractiveness of public transport systems, absence of scientific studies backing the NUTP framework, Confining E-Vehicles to two-wheelers, target-based transport systems.
- At a final note, Prof. Basu addressed the importance of revealed preference data in developing travel demand models instead of stated preference data.

Recommendations of the Workshop

- The following major recommendations for the next 2-3 years:
 - ❖ Development of a method to work out the fare structure for public transport systems
 - ❖ Provision of reduced lane width and its impact
 - ❖ Capacity enhancement with the dedicated two-wheeler lanes
 - ❖ Continuity in the bicycle/walking tracks and other important design elements
 - ❖ Understanding the factors influencing cycling/walking track usage
 - ❖ Identification of catchment areas around transit stations based on walkability
 - ❖ Analysis on the Shift of two-wheelers to E-vehicles
 - ❖ Analysis on the absence/presence of traffic regulation and management for BRTS lanes
 - ❖ Performance evaluation studies on existing BRTS at a national scale
 - ❖ Travel demand modeling based on RP Data and comparing it with SP based models

Report of Workshop-B: Transportation Modes, Planning & Demand

Forecast

Chair – Prasanta Sahu, BITS Hyderabad

Co-Chair – Manoj M., IIT Delhi

Description of theme : Demand forecast for passenger & freight movements, multimodal network design, land use transport integration, spatial interaction models, travel behaviour choice models, freight network equilibrium models, activity based models, routing and scheduling, logistics, harbour and fleeting services, container & truck terminal planning, application of planning softwares, urban rapid transit system operations and management of the urban & regional transport systems etc.

Since certain sub-themes were interrelated the chairs decided to club the respective themes and proposed three broad themes for discussion. They are:

- Passenger demand analysis and forecasting
- Freight demand analysis and forecasting
- Public transport operation and management

A. Passenger demand analysis and forecasting

The following points were highlighted by the participants in the broad areas of passenger travel demand, transport policy, behaviour modelling and demand forecasting.

- Move to advanced travel demand forecasting models with rescheduling possibility. Forecasting for 24 hrs rather than modelling peak hour demand.
- Development of household travel survey database similar to NHTS. Explore the potential of mobile phone data for travel demand analysis.
- Promotion of accessibility-based demand analysis
- Integration of land use and transport planning and development land use transport models.
- Development of socio-economic evolution models for explicit inclusion in travel demand forecasting, especially for disaggregate demand analysis.
- Explore other behavioural models for demand forecasting – e.g., disutility minimisation / regret minimisation approach

Research issues/topics that needs to be addressed in immediate future i.e. next 2-3 years.

- Development of data repository for advanced travel demand modelling.
- Explore the Potential of mobile phone generated data for travel demand modelling
- Explore the possibility of spatial transferability of travel demand models to minimise model development cost. Case studies are welcome.

Capacity building/training/education issues/topics that needs to be addressed in immediate

future i.e. next 2-3 years

- Training professionals, researchers and academicians for household travel survey data collection, data analysis and transport modelling.
- TRG-I may initiate training programs – survey design, data collection, etc. – with the help of international experts.

Collaborative opportunities on research/capacity building issues (as identified above) with industry, field/government organizations, and other countries.

- Collaboration with IATBR for special sessions on travel behaviour and demand forecasting in CTRGs.
- Collaboration with NSO, Census of India, Google, and mobile network service providers for travel demand data.

Any specific major project(s) that needs special attention.

- Development of household decision-making framework to explicitly model long-, medium-, and short-term mobility decisions in Indian settings.

B. Freight demand analysis and forecasting

The following points were highlighted by the participants in the broad areas of freight demand analysis forecasting.

- Model are hand count in India
- Data unavailability
- Modelling framework
- Limited research base in India on freight transportation
- Issues in last mile connectivity

Research issues/topics that needs to be addressed in immediate future i.e. next 2-3 years.

- More focus on developing freight demand models
- Developing data collection framework
- Demand-supply chain configuration

Capacity building/training/education issues/topics that needs to be addressed in immediate future i.e. next 2-3 years

- TRG-India may initiate training programs – survey design, data collection, etc. – with the help of experts.

Collaborative opportunities on research/capacity building issues (as identified above) with

industry, field/government organizations, and other countries.

- Collaboration with freight operators

Any specific major project(s) that needs special attention.

- Development freight demand models at regional/city/state levels.

C. Public transport operation and management

The following points were highlighted by the participants in the broad areas of public transport demand, operations, and management.

- Poor LOS of bus-based PT systems in India
- Safety concerns female passengers
- Incompatibility with passenger OD
- Lack of good routing and stopping policies
- Inadequate vehicle and line capacity despite demand for travel
- Lack of adoption of ITS and traveller information systems
- Change in perceptions and lack of awareness of people

Research issues/topics that needs to be addressed in immediate future i.e. next 2-3 years.

- Development of stop-level ridership forecasting models
- Studies and policies to alley safety concerns of 'transport-disadvantaged' sections of the society

Capacity building/training/education issues/topics that needs to be addressed in immediate future i.e. next 2-3 years

- Training program for transit agencies – data collection, data analysis, safety analysis, and optimisation and operations management

Collaborative opportunities on research/capacity building issues (as identified above) with industry, field/government organizations, and other countries.

- Industry academia integration - Collaboration with bus manufactures
- Academic collaboration with successful transit operations – e.g., Bogota BRTS, Paris metro
- Research studies with UMTA, DIMTS, BMTTC, etc. to name a few

Any specific major project(s) that needs special attention.

- Development of an integrated demand, schedule, and routing model for a transit agency and its field implementation

Report of Workshop-C: Traffic Systems Analysis

Chair – S. Arkatkar, SVNIT Surat

Co-Chair – Gowri A., IIT Tirupati

Description of themes

The workshop on Traffic Systems Analysis was conducted during 3:15 to 5:00 pm on 21st December 2019. The following themes were discussed in this workshop:

Human factor analysis:

Human Factors are one of the major casual factors for traffic crashes due to Unsafe Driving Behaviors of several important traffic maneuvers at mid-blocks, roundabouts, junctions and intersections of different road classes.

- a. Light vehicle drivers (Taxi/car/motorized two-wheelers/motorized three wheelers).
- b. Heavy Vehicle Drivers (Bus/Truck)
- c. Pedestrians

This may be addressed by studying/researching on:

1. Impact of human factors and functional characteristics of location on walking speed at various facilities including crosswalks, un-signalized and signalized intersections.
2. Driving simulator studies: demographic factors, distractions, perception, work load, alcohol consumption, etc.

Traffic flow behavior:

The following aspects were described under this theme:

- a. Development of Trajectory Data for Investigating Vehicle Behavior in Mixed Traffic Environment
- b. Developing and Calibration of Vehicle Following Models Using Trajectory Data Under Heterogeneous Traffic Conditions
- c. Examining Microscopic and Macroscopic Traffic Flow Parameters at Diverging Section On Multilane Urban Roads in India
- d. Study of Vehicle Following Behavior Under Heterogeneous Traffic Conditions.
- e. Methodology for Simulating Heterogeneous Traffic on Expressways, National Highways and Arterials of Developing Countries
- f. Calibration of Traffic Stream Models on High Speed Urban Roads
- g. Effect of variation in road geometry and traffic schemes on Traffic operations of roads
- h. Development of fundamental traffic flow diagrams and modelling traffic flow using data from smart data collection technologies.
- i. Theoretical/rule-based approaches for developing traffic flow stream models

Traffic safety and pedestrian facility design improvements

The following aspects were described under this theme:

- a. Gap Acceptance Based Safety Evaluation Of Urban Midblock Crossings Under Mixed Traffic Environment
- b. Evaluation of safety of margin of pedestrian at mid-blocks in India.
- c. Pedestrian Critical Gap Estimation Methods at uncontrolled Mid-block Crosswalks and signalized intersections.
- d. Developing proximal safety indicators for assessment of un-signalized intersection.
- e. Developing of warrants for Pedestrian facility control
- f. Pedestrian Safety Evaluation for Unprotected Mid-Block Crossings Under Mixed Traffic Conditions.

Geometric Design of roadway facilities

The following aspects were described under this theme:

- a. Developing performance based geometric design under mixed traffic environment for varying terrains and roadway conditions.
- b. Developing Safety Warrants For Urban/rural un-signalized intersections Under Mixed Traffic Environment
- c. Design of near-saturated or over saturated signalized intersections.
- d. Developing warrants for design of Toll Plazas in India.
- e. Safety in design of minor intersections on rural roads in India.

Development of application of intelligent transport systems

The following aspects were described under this theme:

- a. To derive macroscopic and microscopic traffic parameters using wireless sensors under Heterogenous Traffic Conditions.
- b. Wireless sensor for traffic and transit data collection
- c. Open source GTFS (General transit feed specification) static and real-time data.
- d. Road to vehicle communication equipment
- e. Vehicle Detection sensors
- f. Pedestrian detection sensors
- g. Demand Actuated Traffic Signals
- h. Safe driving support system at the ITS proving ground
- i. Right turning collision prevention system on high speed highways
- j. Examining the driverless future.
- k. Extraction of micro-level traffic characteristics using image processing technique under heterogeneous traffic

Travel time reliability for transit operations

The following aspects were described under this theme:

- a. Bus Travel Time Reliability Using GPS-Based Bus Trajectory Data Under Mixed Traffic Conditions.
- b. Exploring short term bus travel time prediction methods under mixed traffic conditions
- c. Concept of Reliability Cost.
- d. Impact of service reliability on bus ridership.
- e. Evaluation of reliability of frequency based services

- f. Impact of service reliability on user perceived congestion.
- g. Dynamic Transit trip assignment to enhance transit system reliability.

Corridor and area traffic coordination systems

The following aspects were described under this theme:

- a. Framework for coordinated signal control design for Indian traffic condition
- b. Traffic control design for areawide dispersion of concentrated congestion regime to increase overall system efficiency.
- c. Traffic movements based on systemwide traffic demand.
- d. Framework for areawide congestion measurement.
- e. Inclusive design of intersections & transfer stations

User perceived level of service

The following aspects were described under this theme:

- a. Impact of on-street parking on pedestrian perceived level of service on Sidewalks.
- b. Examining factors affecting Perceived Quality of Bus Service
- c. Assessing Satisfaction Levels Of Bus Users And Monetizing their Travel Time
- d. Determination of pedestrian level of service for stairways at suburban rail station in developing countries
- e. Quantification of Level-of-Service Index for Bus Routes in Developing Countries

Efficacy analysis of safety measures and its economics

The following aspects were described under this theme:

- a. Framework to quantify socio-economic impact of road accidents
- b. Evaluating the effects of the road safety system
- c. Benefit cost analysis of the road safety system
- d. Other direct and indirect methods of economic analysis
- e. The relationship between safety research and practice is often not very functional. The empirical research through before/after or with-without studies are encouraged.

In response to above description above discussion points were deliberated:

Traffic Data collection/automation

- Absence of automated tools for trajectory extraction (semiautomatic traffic data extractor is available)
- lack of reliable crash data
- accident data is available in local language
- no open access TRAJECTORY data

Calibration/validation of traffic stream/simulation models

- Macroscopic parameters are used to validate microscopic models
- Simulation should not be used as an optimisation tool due to its limitations
- Too many parameters demand cumbersome procedures of calibration
- Two-dimensional models are not thoroughly considered by researchers

No much multidisciplinary research in India

- Absence of mechanism/policy on data repository
- Lack of scientific crash investigation at affected locations
- Lack of road condition/pavement surface data (correlation with crashes)
- Evaluating the effectiveness of traffic calming measures at critical locations
- Research works related to vehicular pollution parameters (emissions/ noise)

In response to these issues there is a strong need to work on the following aspects:

- Automated tools for trajectory extraction (deep learning, machine learning techniques)
- National level data repository
- Open access TRAJECTORY data
- Multi-institutional collaborative research
- GTFS Realtime for transit operation
- Wireless (Bluetooth/Wi-Fi) sensors
- Image processing for vehicular traffic/pedestrian data extraction and analysis.
- Automatic number plate detection system.
- Road Instrumentation for better traffic monitoring
- Crash data corresponding to geometric features and cause analysis
- Evaluation of safety warrants
- Proactive safety assessment based warrants development for Vehicular and Pedestrian Traffic and other VRU's (indicators, thresholds and indices)
- Revisiting Design Methodologies and reliability/consistencies (performance based mid-block/intersections, overall roadway geometry)
- Research to implementation - Ground implementation of safety and traffic calming measures on urban and rural roads

Future Research Directions:

- Instrumented vehicles(naturalistic driving data)
- Development of high quality trajectory data
- Geometric design and safety evaluation
- 2-Dimensional traffic flow models
- Data driven models
- Open source simulation model
- Big data analytics (ITS, IoT)
- Smart mobility, smart city applications
- Autonomous vehicles (multidisciplinary research)
- Crowd dynamics at public facilities and events
- Incorporating user perception into research
- Traffic calming measures

Report of Workshop-D: Highway Materials & Pavement

Chair – Ransinchung G D R N, IIT Roorkee

Co-Chair – Nikhil Saboo, IIT BHU

Broad Agendas Covered

The workshop was opened to discussion on the following broad areas:

- a) Binders
- b) Bituminous Mixes
- c) Pavement Quality Concrete

A) Binders

The discussion in the domain of asphalt binders included various views on the existing binder grading system and use of modified binders for construction of pavements.

Participants from PMGSY raised few problems which they have been facing with the viscosity grading of binders. They were of view that the penetration grading system was simple and could be evaluated at site labs in contrast to viscosity measurements which requires specialised technician and equipment. In an era where lots of research are being carried out in the area of rheological characterisation and grading of binders, a gap exists in the knowledge transfer between academia and field Engineers. It was concluded that in absence of standard protocols, viscosity grading as per IRC 37 2013 should be followed for characterisation of asphalt binders. It was felt that the field Engineers should be trained more about the advanced testing methods and its importance in characterisation of asphalt binders.

Another discussion was initiated by one of the participant from Industry, regarding the use of polymer modified binders in DBM layers and its recyclability. No standard guidelines exists in India which talks about the recyclability issues associated with polymer modified binders. It was resolved that, through voluntary participation, TRG can initiate compilation of international literatures on the aforementioned problem. The compiled document can be used by stakeholders for convincing sponsoring agencies on the use of PMB and other modified binders in the binder course of flexible pavement.

B) Bituminous Mixes

The main topic of discussion was related to the use of perpetual pavement in Indian roads. Again, no standard guidelines exist for the construction of perpetual pavement in India. In absence of previous data and guidelines, it is a challenge for contractors and consultants to take up large projects. Perpetual pavement, which is a full depth asphalt pavement is designed by limiting the tensile strain lower than 70 microstrain at the bottom of bituminous layer. Perpetual pavement has been extensively researched in other countries and such experiences can be utilized in India too. The issues related to the use of concerned gradation for such layer, a literature review is required wherein different gradations use in other countries can be compared with the Indian gradations such as DBM/BC. These gradations, with minor

changes, if required, can be adopted for the construction of perpetual pavement in India. Use of reclaimed asphalt pavement materials in HMA was another topic of discussion. Industry, in absence of technical know-how, is facing problems related to the performance of high RAPM HMA. It was clarified that Asphalt Institute guidelines and NCHRP report should be strictly studied for appropriate mix design of RAPM HMA. Use of RAPM upto 25% is simple. Use of higher percentages will require understanding of blending charts and changes in mix design required. Moreover, the mixing plants should have appropriate facilities for to handle RAPM materials separately. An immediate research on the blending of RAPM binder and virgin binder is required for developing fundamental guidelines on the mix design of RAPM HMA.

C) Pavement Quality Concrete

Most of the discussion in the domain of PQC revolved around the use of RAPM in PQC. Few researchers working in the same domain shared their result with the audience. It was decided that based on the laboratory results few test sections should be constructed to see the performance of RAPM inclusive PQC. The need of the hour is to develop standard mix design procedures for the use of RAPM in PQC. This will build confidence among the stakeholders for adopting such new technologies.



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