Bhavathrathan *Bhattiyil Kuzhiyamkunnath*

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Academic Profile

Singapore-MIT Alliance for Research and Technology — CREATE Way, Singapore

Postdoctoral Associate(Research Group: Future Urban Mobility) — *Nov '16 – Present*
Project: Improving the capability of *SimMobility* to incorporate urban freight movement

Indian Institute of Technology Bombay — Mumbai, India

Research Associate in Dept. of Civil Engg. (Specialization: Transportation Systems) — *Jul '16 – Oct '16*
Project: Analysing the red-light running behaviour at Mumbai's intersections

Indian Institute of Technology Bombay — Mumbai, India

Ph. D. in Civil Engineering (Specialization: Transportation Systems) — *Jul '11 – Jun '16*
Thesis: A critical state of multiple simultaneous disruptions on urban road networks

Indian Institute of Technology Guwahati — Guwahati, India

M. Tech. in Civil Engineering (Specialization: Transportation Systems) — *Jul '09 – Jul '11*
Thesis: Incorporating two-wheeler lane-sharing behaviour into macroscopic traffic flow models

University of Calicut — Calicut, India

B. Tech. in Civil Engineering — *Jun '03 – Jun '07*
Project: Survey, geometric design and structural design for a village road through a rolling terrain
Elective: Urban transportation systems planning

Research Exposure

During Postdoc: Urban Freight Transport, Commodity Flow, Establishment OD Synthesis

During PhD: Urban Road Networks, Network Resilience, Transportation Systems Optimization, Traffic Assignment, Critical Component Identification

During MTech: Traffic Flow Theory, Macroscopic Traffic Simulation, Heterogeneous Traffic, Numerical Schemes to Solve PDEs

Experience

Indian Institute of Technology Bombay — Mumbai, India

Teaching Assistant in Transportation Engineering — *Jul '11 – Jul '15*
Assisted in courses: Analysis of Transportation Systems, Transportation Engineering 1 & 2, etc.

Indian Institute of Technology Guwahati — Guwahati, India

Teaching Assistant in Civil Engineering — *Jul '09 – Jul '11*
Assisted in courses: Traffic Flow Modelling & Simulation, Urban Transportation Systems Planning, Engineering Drawing etc.

Royal College of Engineering and Technology — Thrissur, India

Lecturer in Civil Engineering — *Jul '08 – Jul '09*
Lectured on Transportation Engineering, Geotechnical Engineering, Engineering Mechanics. Guided a B. Tech. project on Alignment Design, etc.

Ramky Infrastructure Limited — Hyderabad, India

Junior Engineer, Planning — *Jul '07 – Jul '08*
Assisted project planning and scheduling activities of the Hyderabad Outer Ring Road Project.

Publications in Refereed International Journals

Published

1. Patil, G.R., and Bhavathrathan, B.K., "Effect of traffic demand variation on road network resilience", *Advances in Complex Systems* 19(1)(2016) http://dx.doi.org/10.1142/S021952591650003X

2. Bhavathrathan, B.K., and Patil, G.R., "Quantifying resilience using a unique critical cost on road networks subject to recurring capacity disruptions", *Transportmetrica A: Transport Science* 11(9)(2015) pp. 836 – 855, Taylor & Francis. http://dx.doi.org/10.1080/23249935.2015.1087230

3. Bhavathrathan, B.K., and Patil, G.R., "Capacity uncertainty on urban road networks: A critical state and its applicability in resilience quantification", *Computers, Environment and Urban Systems* 54 (2015) pp. 108 – 118, Elsevier. http://dx.doi.org/10.1016/j.compenvurbsys.2015.07.005

4. Chunchu, Mallikarjuna, and Bhavathrathan, B.K., "Analysis of the effect of two-wheeler lane-sharing behavior on macroscopic traffic flow modeling",*Transport* 29 (2) (2014) pp. 146 – 153 http://dx.doi.org/10.3846/16484142.2014.928788

5. Bhavathrathan, B.K., and Chunchu, Mallikarjuna, "Evolution of macroscopic models for modeling the heterogeneous traffic: An Indian perspective", *Transportation Letters* 4 (1) (2012) pp. 29 – 39 doi/abs/10.3328/TL.2012.04.01.29-39

Published in Elsevier Procedia

6. Sultania G., Bhavathrathan, B. K. and Patil G.R. "Analysing risk associated with multiple simultaneous disruptions on urban roads". *Transportation Research Procedia* (In Press) (2016)

7. Bhavathrathan, B.K., and Patil, G.R. "Analysis of worst case stochastic link capacity degradation to aid assessment of transportation network reliability", *Procedia-Social and Behavioral Sciences* 104 (2013), pp. 507 - 515 http://dx.doi.org/10.1016/j.sbspro.2013.11.144

Under Review

8. Bhavathrathan, B.K., Bhosale, M. and Patil G.R., "Two regimes of red-light-running at heterogeneous, saturated intersections: A field investigation in Mumbai, India", Revised version Communicated to *Transportation Research Record: Journal of the Transportation Research Board* in November, 2016

9. Bhavathrathan, B.K., and Patil G.R., "A weighted fictitious play algorithm to compute resilience of urban road networks", Communicated to *Journal of Computing in Civil Engineering (ASCE)* in August, 2016

10. Patil, G.R., and Bhavathrathan, B.K., "A game-theoretic approach to identify critical links on urban road networks", Communicated to *Computers, Environment and Urban Systems* in October, 2016

11. Bhavathrathan, B.K., and Patil G.R., "A method to optimally exercise predefined toll-slabs in congestion pricing", Communicated to *Economics of Transportation* in October, 2016

Under Preparation

12. Patil, G.R., and Bhavathrathan, B.K., "Impact of Adverse Climate on Road Network Resilience – A Case Study from Mumbai", Expected date of communication: November, 2016

Publications in Proceedings of International Conferences

International Conferences Held Abroad

1. Bhavathrathan, B.K., Bhosale, M. and Patil G.R., "Two regimes of red-light-running at heterogeneous, saturated intersections: A field investigation in Mumbai, India", Accepted for presentation*Transportation Research Board 96th Annual Meeting*, January 2017, Washington DC.

2. Bhavathrathan, B. K., and Patil, G. R., "Stochastic tolling to achieve long-run system optimum under tolerance-based probabilistic user equilibrium." Presentation at the *14th World Conference on Transportation Research*, July 2016, Shanghai, China. Available online at https://wctrs.conference-services.net/ viewfile.asp?sessionID=&abstractID=863926&conferenceID=3909&abstractName=paper

3. Patil, G.R., and Bhavathrathan, B.K., "A Game-Theoretic Model to Identify Critical Links on Urban Road Networks", *Transportation Research Board 95th Annual Meeting* 16-5213, January 2016, Washington DC. Available online at http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/264-1.2823590/16-5213-1.2981771/16-5213-1.2993251?qr=1

4. Bhavathrathan, B. K., Madhusoodhanan, C. G., Patil, G. R., and Eldho, T.I. "Climate change impacts on coastal urban road networks: A methodological approach." International Conference on Climate Change Innovation and Resilience for Sustainable Livelihood (*ClimDev15*), January 2015, Kathmandu, Nepal. Available online at https://smallearthnepal.files.wordpress.com/2014/06/proceeding.pdf

5. Patil, G.R., and Bhavathrathan, B.K., "Investigating the sensitivity of road network resilience to demand variability", *Transportation Research Board 94th Annual Meeting* 15-4173, January 2015, Washington DC, USA. Available online at http://docs.trb.org/prp/15-4173.pdf

6. Bhavathrathan, B.K., and Patil, G.R. "A critical state of multiple simultaneous link disruptions", *Transportation Research Board 93rd Annual Meeting* 14-4351, January 2014, Washington DC, USA. Available online at http://amonline.trb.org/trb-55856-2014a-1.823612/t-1134-1.870386/234-1.877005/14-4351-1.877014/14-4351-1.877018?qr=1

7. Bhavathrathan, B.K., and Patil, G.R. "Modelling network degradation using game theory- Optimal strategies at Nash equilibrium", *13th World Conference on Transportation Research*, July 2013, Rio de Janeiro, Brazil. Available online at http://www.wctrs-society.com/wp/wp-content/ uploads/abstracts/rio/selected/3076.pdf

International Conferences Held in India

8. Bhavathrathan, B. K., and Patil, G. R., "Identifying tipping-points of disruptions on urban road networks." Accepted for presentation at the *Transportation Planning and Implementation Methodologies for Developing Countries*, December 2016, Mumbai, India.

9. Bhavathrathan, B. K., and Patil, G. R., "Urban transportation demand management: A review of strategies, modelling frameworks, and case studies." *3rd Conference of the Transportation Research Group of India*, December 2015, Delhi, India.

10. Sultania, G., Bhavathrathan, B. K., and Patil, G. R., "Quantifying risk due to capacity uncertainty on urban road networks." *11th Transportation Planning and Implementation Methodologies for Developing Countries*, December 2014, Mumbai, India.

11. Bhavathrathan, B. K., and Patil, G. R., "Analysis of worst case stochastic link capacity degradation to aid assessment of transportation network reliability." *2nd Conference of the Transportation Research Group of India*, December 2013, Delhi, India.

12. Bhavathrathan, B. K., and Patil, G. R., "Modelling worst-operable-case on urban networks due to stochastic link capacity degradations." *10th Transportation Planning and Implementation Methodologies for Developing Countries*, December 2012, Mumbai, India.

Publications in Proceedings of National Conferences

1. Bhavathrathan, B. K., and Patil, G. R., "Investigating demand-sensitivity and establishing a generalized index of transportation network resilience." *Colloquium on Transportation Systems Engineering and Management*, May 2014, Kozhikode, India.

2. Bhavathrathan, B. K., and Patil, G. R., "Minimax optimization to analyze worst-case of transportation networks." *Recent Advances in Civil Engineering*, April 2013, Belgaum, India.

Teaching and Teaching-Assistance

Teaching

Royal College of Engineering and Technology *University of Calicut*

CE04 505 Transportation Engineering I (3 hours lecture and 1 hour tutorial per week)
CE04 504 Geotechnical Engineering I Module I (3 hours lecture and 1 hour tutorial per week)
CE04 308(P) Material Testing Lab II (3 hours practical per week)
EN04 107B Engineering Mechanics (B) (2 hours lecture and 1 hour tutorial per week)
Guidance: CE 808 (P) & CE 708 (P) Project, CE 707(P) Seminar, CE04 608(P) Mini Project

Teaching Assistance

Indian Institute of Technology Bombay *Mumbai*

CE 744 Analysis of Transportation Systems
CE 434 Traffic Analysis and Design
CE 415 Transportation Engineering II
CE 320 Transportation Engineering I
CE 328 Transportation Engineering Lab I

Indian Institute of Technology Guwahati *Guwahati*

CE 584 Traffic Flow Modelling and Simulation
CE 581 Urban Transportation Systems Planning
ME 111 Engineering Drawing

Professional Activities

Organizing Academic Events

Overall Coordinator (Students'), TPMDC '14: International Conference on Transportation Planning and Implementation Methodologies in Developing Countries (TPMDC 2014), IIT Bombay, Mumbai, December 10-12, 2014

Assisted in organizing UFT Workshop: An Indo-US workshop on Urban Freight Transport: A Global Perspective, Jointly organized by IIT Bombay and VREF Center of Excellence for Sustainable Urban Freight Systems, Rensselaer Polytechnic Institute, Troy, New York at IIT Bombay, April 9-10, 2014

Assisted in conducting IUT Meeting: Workshop on Transit-Oriented Development by Institute of Urban Transport (India) Western region Chapter at IIT Bombay, September 24, 2013

Assisted in organizing CE&QIP Course: Continuous Education (CE) & Quality Improvement Program (QIP) Short Term Course on Transportation Demand Modeling at IIT Bombay during June 17-21, 2013

Scientific Committee (Students') and Delegate Relation, TPMDC '12: International Conference on Transportation Planning and Implementation Methodologies in Developing Countries (TPMDC 2012), IIT Bombay, Mumbai, December 12-14, 2012

Assisted in organizing InTranse 2011: International Conference on Intelligent Transportation Systems (InTranSe 2011) jointly organized by IIT Bombay and Centre for Development of Advanced Computing (C-DAC) Thiruvananthapuram at IIT Bombay, October, 2011

Reviewing & Refereeing

ADB30 Committee of TRB: Member of the ADB30 (Transportation Network Modeling Committee) reviewer pool for Transportation Research Board Annual Meeting, Washington D.C., since 2014

Transportation Letters: Member of the reviewer pool for Transportation Letters: the International Journal of Transportation Research, published by Maney & J. Ross., since 2015

Journal of Urban Technology: Member of the reviewer pool for Journal of Urban Technology, published by Taylor & Francis, since 2015

CTRG: Member of the reviewer pool for Conference of Transportation Research Group of India, since 2013

TPMDC: Member of the reviewer pool for International Conference on Transportation Planning and Implementation Methodologies in Developing Countries, since 2012

Consultancy Projects

Vehicular Congestion and Emissions Analysis: Assisted in vehicular congestion and emissions analysis of a proposed township 'Rising City' in Mumbai. PI: Prof. Gopal R. Patil, IIT Bombay, October 2015

Professional Membership

MISTE: Life member, Indian Society for Technical Education, since 2008

Projects

Ph. D. Thesis

Submitted to Indian Institute of Technology Bombay

A critical state of multiple simultaneous disruptions on urban road networks: Roadways, the links of urban transportation networks, are susceptible to a variety of disruptions. Most disruptions are frequent non-severe ones like traffic incidents, snowing, flooding, road space reallocations, road space infiltrations, infrastructural failures, etc. Disregarding the cause, they may be viewed as multiple simultaneous disruptions on link-capacities. These disruptions cause capacity uncertainty on urban roadways and results in suboptimal operation and design. For most purposes, studies assume knowledge on patterns of disruption data, which in most cases are absent. The thesis analyses multiple simultaneous disruptions to establish a consequent *critical state* on transportation network. The problem is formulated in two perspectives: that of instantaneous levels of disruptions and of recurring levels of disruptions.

The critical state is modeled as the maximum irreducible system travel time (STT) with the demand being met. Game theory is employed and the situation is envisaged as a two-player zero-sum game—between a *friend* and a *foe*—on the network. A *minimax* optimization formulation is developed to find the critical state. It is also proved that it has a unique objective value.

The thesis proposes a novel method to quantify the resilience of urban road networks that are prone to disruptions. This is done by using the performance at the critical state. The thesis also proposes a method to identify critical links using the levels of degradation at critical state. A weighted fictitious play (WFP) algorithm is developed to efficiently solve the formulation on real-life networks. Frank-Wolfe algorithm with predetermined step-sizes is employed to calculate the best-response in the WFP algorithm.

Postdoc Project

At Singapore-MIT Alliance for Research and Technology

Improving the capability of SimMobility to incorporate urban freight movement *SimMobility* is a multi-scale simulator that considers land-use, transportation and communication networks along with individual choices and decisions at different levels of resolution: from detailed traveller movements to day-to-day and year-to-year travel and location choice decisions. It handles transportation demand, simulating agentsâĂŹ activity and travel patterns and capturing land-use and economic activity, with special emphasis on accessibility. The individual travel behaviour is modelled under an activity-based formulation where each agentâĂŹs daily life activities, their well-being, and its impact on the transportation system is simulated. All individual choices and decisions are modelled within a dynamic plan/action approach. This modelling approach allows a full integration of all individual choices and the reliable simulation of its impacts in the transportation system under future mobility scenarios. Currently, a new module is being developed to integrate freight generation and movements, thereby improving the capabilities of the platform.

M. Tech. Thesis

Submitted to Indian Institute of Technology Guwahati

Incorporating two-wheeler lane-sharing behaviour into macroscopic traffic flow models: The discipline of macroscopic traffic flow modelling is aged above half a century. However, models that could explain the coexistence of different vehicle classes on roadway started evolving only in the early years of the new millennium. These heterogeneous models are sufficient when the vehicles strictly follow the road markings. In countries like India, due to the presence of small-sized vehicles such as the two-wheelers and three-wheelers, it may be observed that the lane discipline is loosely followed. Here, even within a single lane, one can observe lateral interactions among bigger and smaller vehicles, in addition to the longitudinal interactions. Thus, should a model be of use in simulating Indian conditions, it inevitably has to incorporate the prevalent lateral interactions. Two-wheeler lane-sharing behaviour is a crucial lateral interaction that takes place in most of the Indian urban roads. This work is an investigation into probable modifications that can be done to existing multi-class models so as to improve their accuracy by incorporating the lane-sharing phenomenon and thus to better-simulate Indian conditions. This is being attempted by diminishing the densities that are given as input to the models. A density diminishing factor is proposed and methodology to calibrate the same is discussed. A correction required in the jam density values while simulating Indian conditions is also addressed. The proposals are validated by comparing the results from trial simulation runs with the observed data.

Extracurricular Project 1.

Interdisciplinary project taken up with Water Resources Engineering Group at IIT Bombay

Assessing climate change impacts on coastal urban road networks: Coastal urban regions across the world are highly vulnerable to climate change, and projections suggest that extreme weather events can intensify. On populous urban area, its implications on lifelines – of which transportation is vital – are manifold. Precipitation is a key climate variable that affects transportation, deteriorating its level-of-service. Urban road networks in precipitation prone zones, already operate at decremented roadway capacities. While routine operations remain unhindered due to precipitation-induced capacity deterioration, they do increase the system's total travel time. This unattributed menace of the present, thus poses a challenge for the future. The conventional transportation planning methods consider demand-increment, but neglect probable climate change impacts on capacities. This paper addresses this gap, introducing a methodology that analyses the risk involved in urban road networks due to climate change. We implement the methodology to assess the risk on Mumbai's over-utilized road network which is prone to high intensity rainfall.

Extracurricular Project 2.

Variable tolls to improve systemic costs

Stochastic tolling to achieve long-run system optimum under tolerance-based probabilistic user equilibrium: Even under a realization of the principle of user equilibrium (UE), a system optimal (SO) flow pattern is theoretically achievable by charging each user the marginal-cost that they inflict on each link. This philosophy has popularly attracted criticisms that can be chiefly attributed to the endogenous nature of tolls in the models. To address this issue, we present a model where the toll vector is exogenous, thus offering political flexibility. Here, an authority may predecide different acceptable levels of tolls on links, and exercise them stochastically to achieve a long-run SO, while ensuring that the difference among expected path costs will be minimum. A bilevel optimization problem is formulated and a solution methodology is suggested. We present an illustration involving a typical uptown-downtown expressway tolling problem, and establish the advantage of stochastic tolling over marginal-cost tolling.

Extracurricular Project 3.

Analysis of red-light violations at Mumbai's intersections

Red-light-running at heterogeneous saturated intersections: On the existence of two regimes and causal factors We present a red light running (RLR) analysis conducted at saturated intersections in the city of Mumbai, India, where the traffic is highly heterogeneous. Considering all vehicles, almost one in seventeen drivers are seen to be jumping red signals here. Unlike the RLR behaviour that has been hitherto reported from intersections elsewhere, a peculiarity observed here is that within a single red phase, there exist two distinguishable segments of RLR behaviour. We classify them into two regimes: Regime 1, just after the onset of red and Regime 2, just before the onset of next green. Around one-third of RLR events occur in Regime 1, and the rest in Regime 2. We fit different distributions on the time distribution of RLR events. The Kolmogorov-Smirnov (K-S) test suggests that exponential distribution fits best for RLR behaviours in Regime 1, and extreme value distribution fits for Regime 2, at all intersections. In addition to these two regimes, RLR at a lower rate is observed in the time period between these regimes, and normal distribution fits here. To analyse the causal factors of RLR behaviour in the two regimes, we develop models at a *mesoscopic* level, specific to vehicle-class and regime. While 'red to green ratio' and presence of policing proves to be relevant factors affecting RLR in both the regimes, 'relative time for which conflict area is free' affects RLR in Regime 2, but not in Regime 1.