TRIPP BULLETIN
VOL 16 NO.2 MONSOON 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Ph.D. Scholars *Current*

Role of informal public in small and medium Indian cities
Scholar: Aishwarya Sanjay Jaiswal

Transport, gender and climate change
Scholar: Akshima Tejas Ghate

Prediction of missing data in road accidents
Scholar: Alok Nikhil Jha

Multi objective optimization in construction project management
Scholar: Amit Chandra

Urban landuse and transport modeling
Scholar: Amit Sharma

Railway track pedestrian safety
Scholar: Darbamulla Saibaba

Pedestrian Safety near Crosswalks and Bus-stops: A case study in Delhi
Scholar: Deotima Mukherjee

Macroscopic modelling in heterogeneous traffic environment
Scholar: Harikrishna Gaddam

Material charcterization for blast loading
Scholar: Kanhaiya Lal Mishra

Evaluating the effect of highway geometric on the safety of national highways of India
Scholar: Laxman Singh Bisht

Pedestrian and crowd modelling
Scholar: Lakshmi Devi Vanumu

Externalities of urban freight transport: the case of Delhi
Scholar: Leeza Malik

Impact testing of helmet
Scholar: Manish Kumar

Simulation of hetrogeneous traffic at signalized intersections
Scholar: Mohit Kumar Singh

Private participation in metro rail projects in India: challenges and way forward
Scholar: Mukund Kumar Sinha

Integrated freight trip generation and mode choice model - case study Delhi
Scholar: Nilanjana De Bakshi

Transportation equity
Scholar: Nishant Singh

Characterization of aorta and diaphragm at high strain rate loading
Scholar: Piyush Gaur

Prediction of motor cycle - pedestrian crashes
Scholar: P Devendra Kumar

Human body finite element modelling
Scholar: Rajesh Kumar

Impact of transportation demand management strategies on pollution, congestion and mobility in Gurugram
Scholar: Ranjana Soni

Ph.D. Scholars *Continued*

Estimating post-crash accessibility to trauma care facility
Scholar: Richa Ahuja

Prediction of thoracic injuries of occupants in car crashes
Scholar: Sanyam Sharma

Ambulance Location Optimization for Enhanced Coverage and Survivability in Delhi
Scholar: Shayesta Wajid

Assessing the future of E-rickshaw
Scholar: Shiv Priye

Understanding pedestrian motion at mass gathering and evacuation process
Scholar: Tarapada Mandal

Crash safety of electric vehicles
Scholar: Thainigaivel Raja T

Ph.D. Scholars *Completed*

Study of the effect of geometric design features on capacity of hill roads
Scholar: Achyut Das

Establishing relationship between elements of highway engineering on crashes on national highways in India
Scholar: H.M. Naqvi

Human body model (thorax modelling and its validation)
Scholar: Khyati Verma

Mode choice initiators in public transport demand modelling
Scholar: Sandeep Gandhi

Framework to determine the level of service of urban bus systems - Case study: Delhi
Scholar: Sneha Lakhotia

Finite element Based Simulation of Abrasion trauma
Scholar: Wondwosen Ayelework Lakew

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.2 MONSOON 2019

Understanding the Complex City: Urban Design, Transport and the Health of Future Cities

Mark Stevenson
University of Melbourne, Australia

These questions and answers are based on excerpts from the 11th Annual TRIPP Lecture delivered by Mark Stevenson on 25th April 2019 at the Indian Institute of Technology in Delhi.

Can scientific methods be found or devised that would address the complex challenges presented by an increasingly digitised landscape?

Large-scale digital data has the potential for city residents to begin to understand the complex interaction of the various urban systems and to advocate for policies that support their health and well-being. It will also enable urbanists /scientists to move from traditional mathematical approaches (e.g., regression) to methods that can take full advantage of the complex relationships embedded in the collected data. Methods suitable to analyse these datasets include machine learning approaches, such as support vector machines and genetic algorithms and graph theory. Also, given the advances in computing power and emerging technologies, approaches such as artificial neural network methods have enormous potential to unravel the complex relationships inherent in large-scale data on cities allowing one to explore the complexity of urban form and transport systems on a population's health, for example.

"Urban systems in a city comprise an array of elements with varying relationships and interactions and a change in any part of the system will result in changes in associated elements in the broader environment. Therefore, cities are considered complex because various components of the system interact and change, and the change is not always observable by assessing the characteristics of an individual component, but rather by considering multiple levels and interactions". (2, p284)

A recent study that I undertook explored such complexity across multiple urban systems with an emphasis on land-use and transport systems and their effects on the health of city-residents in 6 cities namely, Melbourne, Australia; London, United Kingdom; Copenhagen, Denmark; Delhi, India; Sao Paulo, Brazil; and Boston, United States of America. Findings arising from the research highlighted the interaction between land-use and transport systems on population health. For example, when land-use was altered to increase population and building densities and at the same time increasing the diversity of a cities land-use (increased mixed-land-use) along with reducing average distances to public transit resulted in considerable reductions (between 13-19% in cardiovascular disease alone) in the burden of disease. The research highlighted what could be achieved if cities were able to plan or enhance current land-use such that it reflected a city of short distances, greater mixed use and at the same time, increased public transit and presided over a population transition to active transport using safe infrastructure.

The findings are similar to the city or urban typology illustration described below namely, that placing an emphasis on a 'compact city' design (a city of short-distances) influences the health of its citizens, and it also points to the need for increased efforts to understand the implications of compact cities not only in relation to health, but other urban systems including, housing, transport, energy and water.

How can dense cities designed on a human scale contribute to road transport safety?

A leader in designing cities at a human scale, Gehl developed the methods for prioritizing people in urban planning. Designing cities to human scale means designing cities for human use which improves the experience of people moving around and living in cities. To date, there are numerous examples of the human scale being ignored. An obvious example is the transport system itself. VannPashak writes about the irony of how a car's interior is designed at a human scale and yet the roads the car travels on (or the spaces outside of cars) is no longer hospitable to humans.

One important benefit however, of greater levels of urbanization is the increasing level of density in cities; densities with respect to population and building densities. As a consequence of increased densities, transport journeys are reducing in distance and cities are becoming more conducive to walking and cycling. Such a city is a human-scale city and importantly, one that is more sustainable. Current research is exploring density in cities as a way to deliver safe, sustainable and health future cities.

Can emerging technologies like (say) artificial neural network methods help us understand the inter-related complexities of urban health?

The answer to this question is a resounding yes. Resent research lead by Dr Thompson in our Transport, Health and Urban Design research lab has applied convolutional neural network modelling to understand various city typologies and how they may contribute to road trauma.

In this unique research, a total of 1667 cities from across the globe with populations exceeding 300,000 residents was identified from the 2015 United Nations world population prospect. A subset of these cities namely 689 cities from the Asia and Pacific region were the specific focus; comprising 40 countries ranging from Mongolia in the North, Pakistan in the West, New Zealand in the South and Fiji in the East. Map images from each city were obtained using a 2-stage approach. Details of the 2-stage approach are described in detail in a recent publication.

The convolutional neural network modelling was applied to the database comprising the map images for each city. The modelling was capable of identifying whether cities could be correctly classified based on the city design characteristics related to road transport. The following characteristics were obtained from the maps namely each city's road network and public transport networks. Other city design elements were also obtained namely, green and blue space. The model was calibrated using 2 stages that involved a supervised learning procedure namely a 'training' stage whereby the model learned which images were associated with which city, and a second stage which validated the performance of the model. During the validation stage, the model assesses the probability that the validation image comes from the map image of the actual city or from one of the remaining cities in the image dataset. In our earlier paper the validation stage was found to accurately classify images 86% of the time.

A graph-based analysis using the Force Atlas 2 algorithm was applied to the database comprising the 1.667 million map images and a spatially representative network graph was developed. The graph depicts cities that are grouped together meaning such cities are often confused for one another in the model and therefore they appear closer together in the graph. In contrast, cities that are not alike (based on the transport design features) are represented further apart.

The various city groupings were then assessed and described relative to the transport attributes of interest namely the road and public transport networks. To estimate the comparative risk of road injury posed by the transport network design of individual city types, we estimated the intensity of the road and public transport networks in each city by estimating the proportion of the pixel colour count for the respective urban characteristics for each city image.

Disease burden associated with road transport injury was estimated for each city within the various cluster types using data from the Global Burden of Disease (GBD) study. For comparative purposes, road traffic injury was reported as DALYs (Disability Adjusted Life Years) lost, which is a combination of the sum of the years of potential life lost due to premature mortality (YLLs) and years of productive life lost due to a disability (YLDs) per 100,000 people.

The findings identified nine global clusters of cities in which 1667 cities with populations greater than 300,000 population were classified. Refer to our publication for the details. The majority (64%) of low- and middle-income countries in the Asia-Pacific region fall within Clusters 1 and 2. These Clusters comprise cities predominantly from China and South Asia with many of the cities considered low- to middle-income. In contrast, cities from the high-income countries in the Asia-Pacific region namely, Japan, South Korea, Australia and New Zealand are classified in Cluster 6 – the Motor City and Cluster 8 (Intense city cluster).

The range between the urban cluster types with respect to the proportion of road networks allocated to city land-use is minimal (6.4% to 12.6%) with the Cluster Type – Intense, having the greatest proportion of road network. The urban cluster - Intense has land-use allocated to road networks that is two times greater than the urban cluster type with the lowest proportion of road networks namely, Large Blocks. Interestingly, two thirds of Asia-Pacific cities fall within the Cluster types Informal and Irregular which have only 6.8% and 6.9%, respectively, of the various cities land-use allocated to road networks; this is similar to the cluster with the lowest proportion of road network (Large Blocks with 6.4%). Public transport networks specifically rail networks, are most prevalent in the High Transit city cluster and the Motor City cluster. Both of these clusters have cities from high-income countries including those from the Asia-Pacific region namely, Australia, New Zealand, South Korea, Japan and Singapore.

A relationship was observed between road traffic injury and the proportion of road and public transport networks observed in the respective urban cluster types. Urban cluster types with both dense road networks (e.g., Clusters Intense and Cul de sac) and public transport (e.g., Clusters High Transit and Motor City) demonstrated lower rates of roa traffic injury. By contrast, urban cluster types that contained sparse road networks (e.g., Clusters Informal and cul de sac) have higher road traffic injury. This relationship was robust with more than 2.5 times difference in road traffic injury between the best performing urban cluster types (Clusters 5 and 6, High Transit and Motor City) and the poorest performing urban cluster city types (Clusters 1, 2 and 4 – Informal, Irregular and Cul de Sac).

Summary of Prof Stevenson's presentation

Observing unprecedented urban migration and with estimates that 70% of the world's population will reside in a city by 2050, the twenty first century is now considered the urban age. The greatest urban migration will occur in India, China and Nigeria; countries that account for 37% of the world's population. Over the 10 years to 2010 for example, 226 million Chinese residents migrated from rural to urban areas. Living in urban areas offers opportunities that are not available elsewhere including opportunities related to greater access to health systems, employment and recreational facilities. However, increased urbanization also means increased exposure to an array of health risks. The health risks associated with rapid motorization in urban areas alone, accounts for an estimated 1.35 million deaths per year due to road injury and 4.2 million deaths per year due to motor vehicle-related air pollution with particulate pollution (PM2.5, PM10) reducing average life expectancy by 1.8 years per person.

Motor vehicles have radically changed the shape and size of cities. In highly motorized countries such as the United States, Canada, Australia and New Zealand rapid motorization occurred after the 1950'sdue to expanding economies, available land upon which suburbs could be developed and opportunities to develop extensive infrastructure to facilitate mass transport for private motor vehicle use. However, the move to suburbs resulted in expanded city boundaries, low-density sprawl and cities divided into discrete areas linked by extensive local, arterial and highway road networks. Fast forward seventy years and private motor vehicles are no longer a transport solution but rather, an increasing health and planetary challenge, adding considerable complexity on how to build and deliver safe and sustainable transport in a rapidly urbanizing world.

The increasing complexity associated with the urban age is also confounded by the digital revolution which is poised to potentially introduce a new 'operating system' into a vast, well-established, and regulated urban model. For example, the advent of autonomous vehicles in the transport system may be potentially as disruptive as the invention of cars themselves. Similarly, the exponential growth in digital disruptors such as AirBnB and on-line property sales platforms that have internationalised housing demand, are making the current housing crisis even more acute, especially for younger people.

Finding solutions to these challenges is fundamental to the health of future cities. There is an urgency to embrace a diverse array of scientific methods which will facilitate interaction across the urban sciences, government and residents of cities alike. The solution will require better use of data, technologies and methodological approaches, to facilitate responsive yet stronger, decision making across urban systems. Such a strategy requires not just better, more dynamic, granular and accurate data but critically, transdisciplinary capacity-building among scientists, policy makers and practitioners to interpret and translate this data, for decision-making.

Cities around the world are dealing with an array of challenges including increasing population density, inadequate transport systems and increasing rates of non-communicable diseases that require comprehensive health system response. Cites are complex systems and to meet the major challenges of this century, cities will need to respond rapidly to accommodate the growing challenges they are confronting. Building cities that are sustainable, productive and that can respond rapidly to the health challenges is of utmost importance. As highlighted in this paper, by embracing transdisciplinary approaches, new methods and big data new insights to the complexity of twenty first century cities will be enabled. The insights will give direction on how to build, deliver services, and govern cities that embrace the 'human-scale' and hence, encourage sustainable, safe cities that are conducive to population health.

TRIPP BULLETIN
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
VOL 16 NO.2 MONSOON 2019

M.Tech. Projects

Completed

Pavement Design, Variability, Reliability, ME-approach pavement design
Student: Ajitesh Gupta
Traffic Safety Evaluation of Accident Black Spots on Expressways in India
Student: Amber Gupta
Identification of Hazardous location and corrective measures using iRAP (International Road Assessment Programme) methodology
Student: Ashif Hussain
Estimation of demand for remote parking location and scheduling of shuttle bus service
Student: Manas Adhikari
Evaluation of Impact of Traffic Calming Devices in Delhi
Student: Mohit Singla
Disaggreate Analysis of Accidents in Delhi
Student: Narendra Kumar
Time of the day choice of intercity air travel in India
Student: Pathan Mansoor Alikhan
Effect of Pollution on Travel Choice
Student: Prabhash Abhishek
Urban Freight Modelling for Sustainability - A Case Study of Delhi
Student: Pratyush Chaturvedi
Perspective of Paratransit Drivers Towards Electric Rickshaws
Student: Rajeev Ranjan
Multi-metric Exposure Assessment of Ultra fine Particulate Matter for Various Modes of Transportation in Darmstadt
Student: Sumit Shokeen
Feasibility of Taxi-Ambulance Service in the National Capital Territory of Delhi
Student: Vipul Mishra

NEWS

On the relationship between road safety research and the practice of road design and operation

How do the findings of road safety research affect the practice by which the road infrastructure is built and operated? The question is seldom asked. I discuss the complexities of the research-practice symbiosis in the light of two historical anecdotes. These allow me to point out several issues of concern. My general conclusion is that the relationship, as it evolved over time, is unpremeditated and occasionally dysfunctional. Issues of concern are the lightness with which decisions affecting road-user safety can be based on opinion that is unsupported by evidence, that such opinions can trump inconvenient evidence, that research findings can be willfully distorted or disregarded, that questionable results can be given a ring of consensual truth, and that the questions which research asks and what findings get published are at times influenced by external interest. In sum, the concern is that practice is not sufficiently evidence-based. Road users have a right to expect that decisions substantially affecting their safety take into account fact-based expectation of safety consequences. It is therefore time to endow the research-practice relationship with a premeditated and purposeful structure.

Ezra Haur (2019). Accident Analysis & Prevention, 128, 114-131.

Course Announcement

The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology Delhi, is organizing an eight day **"International Course on Transportation Planning and Safety"**. The course will be held in New Delhi, India, from **5 - 12 December 2019**. The course will have a common component for the first three days, followed by three parallel modules on Traffic Safety, Biomechanics and Crashworthiness and Prehospital Care and Trauma.

The course will be followed by a one day **Young Researcher Symposium**. The symposium will offer an opportunity to current doctorate students and recent graduates (graduated after 2017) working on different aspects of traffic safety to present and discuss their work with experts from all parts of the workd and to stimulate the exchange of ideas in the broad field of traffic safety.

Details of the course can be accessed from -http://tripp.iitd.ernet.in

Establishment funds have been received from
Ministry of Industry, Government of India
Asian Institute of Transport Development
Tata Motors, India
Volvo Research and Educational Foundations (VREF), Sweden

Endowments for perpetual Chairs
CONFER, India: TRIPP Chair for Transportation Planning
Ford Motor Co., USA: Ford Chair for Biomechanics and Transportation Safety
Ministry of Urban Development India: MoUD Chair for Urban Transport & Traffic Planning
MoUD Chair for Urban Transport and Environment
VREF: Volvo Chair for Transportation Planning for Control of Accident and Pollution

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

TRIPP BULLETIN
VOL 16 NO.2 MONSOON 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Framework to Determine the Level-of-Service of Bus Systems - Case Study: Delhi

Sneha Lakhotia, Excerpts from a Ph.D. Thesis

A TRIPP BULLETIN INSERT

Public transport (PT) forms the foundation of sustainable transport, as it aims to maximise accessibility and mobility options, and minimise externalities of transport sector (such as, pollution, energy, and congestion), with an emphasis on providing social equity. However, PT systems have to maintain a precarious balance between providing a reasonably good level-of-service (LoS) to the public and at affordable costs. The challenge also lies in providing a high LoS so as to encourage passengers who use PT out of choice, but also in striving to be affordable to the low-income population, who use PT primarily as captive users.

Transit Capacity and Quality of Service Manual (TCQSM) was developed by the Transportation Research Board in 2003. This has become one of the most widely accepted and adopted set of guidelines to assess PT LoS. TCQSM measures quality of service based on the following parameters— a) frequency of service, b) service span, c) access, d) passenger load, e) reliability, and f) travel time (TT). Frequency, service span, passenger load, reliability, and TT are the traditional determinants of the LoS offered by PT. Albeit the consideration of access is a constructive inclusion, it should be noted that its definition in the manual is restricted, as it doesn't include quality of access infrastructure, and ease in crossing streets to access PT stops.

Given that majority of the PT users predominantly walk to and from the stops, and further, there has been ample evidence established in research that pedestrian fatality rates are positively associated with increased bus usage, the risk faced by pedestrians and PT users is significantly higher. It is a critical issue which needs to be addressed as a foremost priority. Also, significant differences can exist in the objective PT LoS estimated and offered by the PT authorities and what is perceived by its existing and potential users, where PT authorities consistently have been shown to overestimate the LoS, as compared to the users.

Thus, three major lacunae have been identified in the field of current research pertaining to measuring the LoS provided by PT— a) lack of focus on safe access to PT stops, b) lack of focus on perceived measures (from passenger demand), and c) lack of focus on perceptions of existing and potential users. There is a need to address these research gaps, and to define a more inclusive framework to assess LoS provided by PT.

The primary objective of this thesis is to determine a framework to assess an inclusive LoS of urban bus systems. The secondary objectives are—

a)To identify relevant indicators which should be included to determine the LoS

b)To assess the relative importance of the different indicators comprising the LoS

Main conclusions

•It was observed that majority of the stops/links experienced low TTV but critically high HV

•This indicates that congestion or other traffic conditions are not largely responsible for high HV

•It further indicates that unrealistic schedules and low adherence of headways is responsible for critically high HV

•As HV is seen to show moderate positive correlation with boarding and alighting, it could be conjectured that accumulated passengers from possible bus bunching further exacerbate HV

•Congested links form corridors in many locations

•High-speed links are more isolated and scattered

•Thus, it will be easier to improve congestion due to identification of corridors

•The spatial disparity in access scores in tandem with income disparity highlights equity issues

•As majority of current bus users are captive users, belonging to primarily low-income areas, it is imperative to improve access conditions in low-income areas

•Significant clusterings of poor access scores were observed in north-west and east Delhi. However, since higher PT ridership was observed in east Delhi, this would be first priority

•For both the safety models developed, overall improved access was associated with lower risk

•Bus stops with higher risk of pedestrian fatalities common to both cases, were primarily located near high-speed segments and peripheral areas. These should be identified for interventions

•Longer routes were found to be associated with higher passenger volumes and lower coefficient of passenger exchange

•High frequency routes were found to be associated with higher passengers and lower coefficient of flow variation

•Thus, longer routes and high frequency routes perform more efficiently in Delhi, with high ridership and more even on-board passenger volumes making trips for the entirety of the route

•To improve bus service for current bus users, it is imperative to improve reliability and TT

•To induce mode-shift by potential users, it is imperative to improve lighting around bus stops

•Application of methodology to assess LoS of bus services to other Indian cities

•Extension of methodology to assess LoS of metro in Delhi

•Assessing underlying distributions for headways and travel times, and developing relevant parametric measures based on these

•Further investigation of bus stops and locations which show counter-intuitive performance or associations with other indicators

•Comprehensive and inclusive framework developed for assessment of LoS of urban PT

•Developing two-pronged strategy outline for identifying which parameter to improve and scenarios for how to improve the parameters

•Assessment of relation of pedestrian safety with quality of pedestrian access around PT stops

•Application of non-parametric measures of assessing reliability performance, presented along with rationale and proposed benchmarks for the same

TRIPP BULLETIN
VOL 16 NO.2 MONSOON 2019
TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Characterization of Human Heart and Lung Under Impact

Khyati Verma, Excerpts from a Ph.D. Thesis

A TRIPP BULLETIN INSERT

Road traffic injuries are the leading cause of death among the age group of 15-29 years globally. Though we usually think about occupants in vehicular crashes, in countries with increasing fleet size like in India, pedestrians are equally vulnerable. This has become an important aspect of vehicle safety research in the past few decades. The incidents of fatal injuries due to thoracic trauma are next to fatal head injuries. The chest is the most frequently injured region for AIS 3+ injuries in comparison to the other body regions for vehicle occupants, particularly those involved in offset frontal collisions. Thoracic impact can lead to the damage of soft tissues in the heart, lungs and aorta which can lead to sudden death of the occupant.

Predicting thoracic response in impact loading is complex as the region has a variety of tissues, with different material characteristics. Injury levels during various road crashes have been identified experimentally using post mortem human subject (PHMS), anthropometric test device (ATD's), finite element models and volunteers. Human body finite element model, when based on realistic geometry and bio-fidelic material properties, are useful in designing safer vehicles in order to reduce injuries and fatalities in crashes. Hence, material properties of the thoracic organs i.e. heart and lung are needed to predict the injury/quantify the injuries correctly in the crash simulation using FE models. The outcome of this thesis feeds into evolving bio-fidelic FE human body models, and developing safer vehicles which protect both the occupants and the vulnerable road users.

In the field of transportation and automotive safety, an anthropometric test dummy, multibody models and finite element human body models have been developed to understand kinematics and loading mechanism of the vehicle occupants during crashes and to decrease the risk of injuries by examining efficacy of alternate safety systems. Towards this, human body finite element models such as Human Model for Safety (HUMOS I and HUMOS II) by European Commission, the Total Human Body Model for Safety (THUMS) by Toyota Central Research lab, Wayne State human body model (WHMBS) by the Wayne State University and GHBMC model by the Global Human body Modelling Consortium are being continuously improved. Human body model scaling, based on anthropometric dimension and positioning, can be achieved using Position and Personalize Advance Human Body Models for Injury Prediction (PIPER) tool for injury prediction.

However, the accuracy of human body finite element models depends on precise reproduction of mechanical response of organs. Effective modelling of tissues has been limited by the known complexity of their biomechanical response, as they exhibits markedly nonlinear, inelastic, strain rate dependent and anisotropic characteristics with significant inter-subject variations and age dependent proprieties. Significant limitations in predicting the human body response in crash events using finite element human body model often arise due to limited data on the dynamic response of soft tissues. Also, the mechanics of soft tissues under impact loading conditions is not well understood yet. The experimental data that is available to develop constitutive models of soft tissues is limited and usually covers the range needed to predict physiological response. Efficient mathematical description of mechanical properties of soft tissues under impact, which cover their nonlinear, inelastic and anisotropic characteristics thus remains a limiting factor in the development of finite element human body models.

In automotive crashes, the occupant body is subjected to impact with the vehicle interior, often referred to as the secondary impact. In it, the impact energy is transferred from the interior of the vehicle to the occupant which decides the injury. The thorax region is more exposed than any other organ to injury during vehicle crash. The human thorax undergoes significant deformation in normal physiological activity and based on cadaver tests, injuries are correlated with excessive chest compression consequent to an impact. At speeds of deformation below 3m/s, rib cage damage and the risk of injury is correlated with the maximum compression of the chest during the event. A similar principle, based on kinematic measurements external to the body, has been applied to estimate injury to the heart and lung in compressive loading. Through deployment of HBM's, we aim to predict location of structural failure in tissues, taking into account intra-person and inter-person variation in tissue properties. Since the stress-strain response of soft tissues is known to depend on the loading rate, as a first step, we need an estimate of the loading rates of HBM material in typical automotive crashes.

To estimate range of strain rates, to which thoracic organs are subjected during crash, initial simulations were performed using the GHBMC model. The test setup for the simulation was based on Viano et al., (1989) for frontal impact and Shawn et al.,(2006) for side impact. The impactor velocity varied from 3m/s to 8 m/s. The strain rates observed in the heart and lungs went up to 309/s and velocity transfer to the organs ranged from 1.8m/s to 4.5m/s.

The existing HBM models have been validated against tests with wide range velocity impacts on post mortem human subject. The strain rate dependent response of soft tissue and correlation of predicted structural failure to injury probability remains a research need. Injury mechanism of ribs, being a bony structure, is well understood but the injury mechanism for soft tissues (heart, lung and great vessel etc.) has been more intractable due to variation in shape and location between individuals. Consequently, information available on the compressive properties of the lung and heart tissue is scarce. The objective of this research is to establish a material model for lung and heart which can be used in conjunction with explicit FE modelling to predict the incidence of traumatic soft tissue injuries in the thoracic region.

In order to develop a methodology to reproduce the behavior of the heart and the lung under impact, the need was felt to conduct compression experiments at varying loading rates. Quasi-static compressive test was needed to representing the physiological response of the tissue, and dynamic test data to characterize the tissue in strain rates up-to 200/s. This experimental data can then be used to develop a constitutive model relating the stress and strain response for the heart and the lung tissues, which is valid up to strain rates of 400/s.

Establishing strain rates, Quasi-static compression tests and dynamic impact test at varying loading rates were conducted on lung and heart tissue. Mechanical response and failure incidents in these tissues were recorded from these tests. To develop a reliable material model, compression tests were conducted on cadaveric samples a range of populations.