ANNUAL REPORT 2020
TRANSPORTATION RESEARCH GROUP

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1. OVERVIEW

The Transportation Research Group (TRG) was established at the University of Southampton in 1967 and is part of the Faculty of Engineering and Physical Sciences.

TRG is located at the University's Boldrewood Innovation Campus where the £46 million National Infrastructure Laboratory (NIL) was completed in May 2019 (see below).

Professor Tom Cherrett became Head of the Group in August 2020.

National Infrastructure Laboratory at Boldrewood

This report covers the research activities within TRG during the calendar year 2020.

TRG academic staff members during 2020 were:

- John Preston, Professor of Rail Transport
- Neville Stanton, Professor of Human Factors in Transport
- Tom Cherrett, Professor of Logistics and Transport Management

- Ben Waterson, Associate Professor, specialising in modelling and simulation
- Simon Blainey, Associate Professor, specialising in rail transport and modelling
- Ioannis Kaparias, Lecturer in transportation engineering
- Katie Plant, Lecturer in human factors engineering
- Shahram Heydari, Lecturer in Transportation, specialising in safety.

Research Staff in TRG during 2020 included Dr John Armstrong, James Brown, Adrian Hickford, Fraser McLeod, Dr James Pritchard, Dr Kirsten Revell, Dr Aaron Roberts, Dr Alan Wong, Dr Vicky Banks, Dr Rich McIlroy, Dr Matt Grote, Dr Marcus Young and Leonie Webster. During the year we welcomed Rachael Wynne, Katie Parnell, Matthew Webster, and Jed Clark and said farewell to Leonie Webster, Dr Aaron Roberts, James Brown, Professor Neville Stanton and Dr Kirsten Revell.

Their research activities are summarised in later paragraphs. **Technical Staff** supporting TRG included Karen Ghali, Daniel Fay, Kiome Pope and Joy Richardson. During the year, we welcomed Sophie Hart and said farewell to Karen Ghali.

Melanie Hallford continued supporting the Group in her role as **Senior Administrator** for the Department.

Mike McDonald continues as Emeritus Professor in Transportation Engineering and Nick Hounsell and Neville Stanton as Visiting Professors. We have a number of other Visiting Professors and Research Fellows who contribute significantly to the Group. These include Professor Jianping Wu, Tsinghua University; Professor

Pengjun Zheng (Dean of the Faculty of Maritime and Transportation Engineering) at Ningbo University in China; Professor Alan Stevens (formerly of TRL); Professor Mike Browne (Professor of Industrial and Financial Management & Logistics), University of Gothenburg; Professor Johan Woxenius (Professor of Industrial and Financial Management & Logistics), University of Gothenburg; Professor David Jeffery; Dr John Walker; Dr John Schoon, Dr Shahjahan Miah, Professor Paul Salmon, Iain MacGregor, Dr Antonio Velazquez Abad, Dr Bani Anvari Dr Birendra Shrestha, Stephan Zieger, Dr Alejandro Ortega-Hortelano, Dr Md. Shamsul Hoque, Dr Hans Eriksson, Cdr Justin Saward, Dr Leonie Webster, Christopher Parnell, Dr Aaron Roberts, Dr Jisun Kim, and Oliver Davey.

We also had over 30 students attached to the Group undertaking PhD or EngD (Engineering Doctorate) research in transport. In 2020, PhD degrees were awarded to Jonny Evans, Farah Alkhalisi and Craig Rafter.

Postgraduate teaching continues to be an integral part of TRG activities, particularly the MSc in Transportation Planning and Engineering. We continue to offer three pathways through the course, offering students a choice of specialising in Infrastructure, Behaviour or Operations on either a full time or part time basis, and 19 new students enrolled in September 2020 – with 9 starting in January 2021.

Overall, we have maintained a healthy portfolio of research in 2020. By the end of the year, our research grants and contracts had a total value of over £10 million, with over £4 million of this from EPSRC.

TRG facilities include:
- SUDS (Southampton University Driving Simulator), located in Building 176 at Boldrewood and equipped with a Land Rover Discovery (see below).


The Southampton University Driving Simulator (Mark 2)

- The TRG Instrumented Vehicle (IV3). Following a successful bid to the University's 'Delivering Innovation to the Next Generation (RESOUNDING) Fund' in 2019, a plug-in hybrid Toyota Prius was procured and is currently being fitted with a variety of sensors that will support a range of basic and applied on-road research.

TRG Instrumented Vehicle (IV3)

The IV3 and an instrumented bicycle (iBike) for on-road trials, are hosted in the garage facility in Building 185 at Boldrewood.
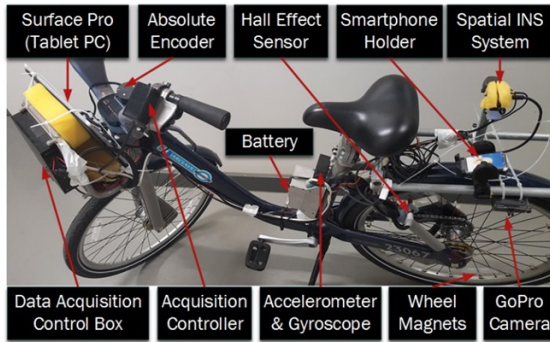
The TRG Instrumented Bike

- Our transport data analysis facility, located in Building 176, Boldrewood.

- ComTET – A command teamwork experimental test bed for submarine control rooms, located in Building 21, Highfield.

The ComTET Submarine Control Room Simulator

Outreach

Unfortunately public engagement and outreach activities were severely curtailed during 2020 due to the Covid-19 virus, including the cancellation of a major conference on 'Creating the Child-friendly City' featuring Mikael Colville-Andersen, the author, urban designer and founder of Copenhagenize, and Sir Stephen Holgate, the MRC Clinical Professor of Immunopharmacology who gave evidence at the inquest into the death of Ella Kissi-Debrah, the London school-girl who died partly due to air pollution.

Some minor engagement activities have moved on-line during the course of 2020, although it is hoped that they may resume in a 'new normal' form during the latter part of 2021.

2. EXTERNAL ACTIVITIES

The following sections summarise the range of external activities undertaken by TRG Academic Staff members in 2020:

Tom Cherrett:
1. Member of the U.S. Transportation Research Board's, Standing Committee on Urban Freight Transportation (AT025).
2. Member of the Editorial Board, Proceedings of the ICE: Transport Journal.
3. Member of the Logistics Research Network (LRN) committee.
4. Member of IET's (The Institution of Engineering and Technology) Transport Policy Panel.
5. External Examiner; UG Logistics and Operations Management courses at Cardiff University (2017-2021).

John Preston:
- Member of the EPSRC Peer Review College.
- External examiner for Masters level courses at Cardiff and Leeds Universities.
- Chaired the 15th World Conference on Transport Research Rail Special Interest Group sessions at Mumbai 26-31 May.
- Committee Member of the International Association of Rail Operations Research (IAROR) and the International Conference on Competition and Ownership in Land Passenger Transport.
- Member of the Future Traffic Regulation Optimisation (FuTRO) Project Control Board and the Vehicle/Train Control and Communications Systems Interface Committee.
- Editorial Board Member: Journal of Transport Policy and member of the Scientific Committee of the World Conference of Transport Research Society.

Neville Stanton:
- Associate Editor, IEEE Transaction on Human-Machine Systems.
- Member, Editorial Board, Theoretical Issues in Ergonomics Science.
- Member, Editorial Board, Safety Science.
- Book series editor of "Transportation Human Factors" with CRC Press.
- Chair of the Honourable Company of Air Pilots and the Air Pilots Trust Annual Aviation Safety prize.
- Chartered Engineer with the IET
- Visiting Professor at the University of the Sunshine Coast, Queensland, Australia
- Visiting Professor at Tsinghua University, Beijing, China

Simon Blainey:
- Member of the Governance Board for the Data Analytics Facility for National Infrastructure (DAFNI.)
- Member of the EPSRC Associate Peer Review College.
- Senior External Examiner for MSc, BSc, DipHE and CertHE courses in Railway Operations Management, Glasgow Caledonian University.
- Member of the Editorial Board for the Journal of Transport Geography
- Member of Steering Group for development of Transport for the South East's Future Mobility Strategy and Action Plan
- Guest Lecturer at Department of Geography, Ghent University

Ioannis Kaparias:
- Honorary Lecturer at the Department of Civil and Environmental Engineering of Imperial College London.

- Independent expert for the European Commission on research and innovation activities, acting as an evaluator of proposals submitted to the Horizon 2020 programme
- Member of the US Transportation Research Board's Committee on "Human Factors of Infrastructure Design and Operations" (ACH40) (formerly "User Information Systems" (AND20))
- Member of the US Transportation Research Board's Committee on "Pedestrians" (ACH10)
- Deputy Editor-in-Chief of the IET Intelligent Transport Systems journal (Institution of Engineering and Technology)
- Member of the Scientific Committee of the 9th Symposium of the European Association for Research in Transportation (hEART 2020), 3-4 February 2021, Lyon, France (virtual)

Katie Plant:
- Chartered Member of the Chartered Institute of Ergonomics and Human Factors

Shahram Heydari:
- Member of the editorial board of Analytical Methods in Accident Research.
- Collaborative member of the Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT)
- Member of the Network of Excellence in Air Quality at Imperial College London

3. RESEARCH

TRG research fits within a view of transport as a socio-technical system capable of delivering sustainable outcomes, but also with the potential for unsustainable outcomes if the interactions between transport technology and society are not adequately addressed. We are particularly interested in how society shapes, and is shaped by, technological developments in transport. This requires an interdisciplinary approach involving the engineering and physical sciences, along with the social sciences and humanities. In particular, we bring together traffic engineering, transport economics and human factors with TRG's work being multi-modal, covering both passenger and freight transport.

A focus of our research remains on Intelligent Transport Systems, with a strong portfolio of studies on Human Factors in Transport. We also undertake research on a number of other interrelated themes, including energy and environment, freight and logistics, future technologies, rail and transport economics and policy.

The remainder of this report summarises TRG research activities ongoing in 2020 within different topic areas. Research titles listed in **blue** represent contract (funded) research, whilst those in **green** are studies by Postgraduate Research students (PhD, iPhD or EngD).

3.1 Traffic Operations and Safety Management

CRoss-modal Intervention To Improve Cyclist Awareness Levels (CRITICAL) (Road Safety Trust October 2019 – April 2021) M. Webster, J. Richardson, Dr R. McIlroy. *Contract Holder:* Dr K.L. Plant

Cyclists are disproportionately represented in accident statistics; for every 26 car drivers killed or seriously injured per billion vehicle miles, 1,011 pedal cyclists are killed or seriously injured. Typical cycling accidents include the motorist emerging into, or turning across, the path of the cyclist and cyclists' riding off the pavement into the path of a vehicle or making right turns into the path of a vehicle. These dangerous interactions can be understood from the perspective of incompatible situation awareness therefore different road users interpreting the same road situation differently.

The research will use a Cross-Modal training approach, where different road users receive training on how another road user interprets the road situation and behaves in different situations. Car drivers will be trained on how a cyclist interprets the road situation and how might they behave, i.e. what it is like to be a cyclist and cyclists will be trained on how a driver interprets the road situations and how they might behave, i.e. what it is like to be a driver.

The project has been split into two elements a theoretical and practical course. The theoretical side aims to enhance your competency and teaches drivers and cyclists theory-based content about the opposite road user group from three components; knowledge (what we know about something), skills (our physical abilities to perform a task) and attitudes (the beliefs we hold). The practical course aims to achieve similar goals to the theoretical course but instead, the driver and cyclists are given first-hand experience of the opposite road user group. So, drivers will be taught how

to be a cyclist by a fully qualified instructor supplied by our project partner CyclingUK and the cyclists will be placed in the driving simulator room (SUDS) and given the opportunity to drive a range of scenarios involving common driving interactions.

By the end of the project, two cross-modal training programmes will have been developed and longitudinally evaluated to understand the resilience of the training interventions. After the project, it is intended that these programs will be available to relevant stakeholders to roll out as a legacy of the project.

STARS: Socio Technical Approach to Road Safety. NIHR Global Research Group on Global Road Safety (National Institute for Health Research, August 2017 to July 2020) Dr R.C. McIlroy**.** *Contract Holders:* Prof N.A. Stanton, Dr K.L. Plant, Prof J.M. Preston, Prof. C. Deakin (Medicine), Prof P. Roderick (Medicine).
Extended to July 2021. *Contract Holders:* Prof N.A. Stanton, Dr K.L. Plant, Dr R.C. McIlroy

Low- and Middle-Income Countries (LMICs) see more than twice as many road traffic fatalities (per head of population) compared to high-income countries. Whilst these countries represent 82% of the global population, they are home to only 54% of the world's registered motor vehicles. The overall goal of our Global Health Research Group (GHRG) is to reduce the number and severity of road accidents in LMICs through our underpinning philosophy of "local solutions for local problems".

The original GHRG had the University of Southampton collaborating with a least developed country (Bangladesh, via Bangladesh University of Engineering and Technology), a low-income country (Kenya, via Strathmore University), a lower-middle income country (Vietnam, via National University of Civil Engineering), and an upper-middle income country (China, via Tsinghua University). Following a successful bid for a 12-month extension to the project, two new project partners have also been included: Ecuador, via the Universidad de las Americas in Quito; and Brazil, via the Pontifical Catholic University of Rio de Janeiro.

During the first three years of the project, four research streams were undertaken: (1) a large cross-cultural comparison survey to explore traffic risk perceptions, attitudes to road safety, and pedestrian behaviour; (2) Accimaps as a systems-based method for road traffic collision analysis, using the findings to develop systems-based safety recommendations; (3) a naturalistic 'think aloud' study with country-specific road users (e.g., moped riders in Vietnam, cyclists in the UK) to enhance our understanding of road-user decision-making processes fro; and (4) the installation and use of driving simulators in the LMIC partner institutions to test the effects of proposed interventions on driving behaviour. Additionally, during year three, whole-system analyses using the STAMP methodology were undertaken. The extension period, year four, has seen driving simulation work continue, and is also seeing the development of systems-based collision report forms, drawing on systems analyses undertaken in years one to three. Questionnaire work undertaken in the original partner countries is being extended during year four through dissemination in Brazil and Ecuador.

Optimizing Social Utility for Demand Responsive Shared Transport (DRST)

(Ph.D. Studentship from September 2019), Fawzan Alfawzan. Supervisors: Dr B.J. Waterson, Dr S. Blainey

Shared mobility services should result in more carpooling, ride splitting, public transit, and other modes and services which do not increase VMT, shared mobility would contribute to enhancing the performance of the transit system. Even though there are social and environmental benefits to such a shared transit system, such as congestion mitigation or emission reduction, user's self-interest is the primary motive for participate in ridesharing. Indeed, it is unclear whether the new forms of Demand Responsive Shared Transport (DRST) systems can derive the same benefits to the transportation system. This project will investigate the potential for cost-sharing strategy induces sustainable ridesharing services that improve mobility, reduce VMT, and enhance social welfare.

Cost-sharing rules for successfully organizing ridesharing for one O-D pair may not be reliable and effective for large scale adaptation. Thus, when considering dynamic ridesharing apps in general networks, different cost-sharing strategies should be presented for several shared services. Given our current level of understanding of ridesharing, we can point to some considerable critical concerns for ridesharing services which include:

- The impacts of different subsidy/incentive strategies on travellers' mode choices and the design of appropriate subsidy strategies.
- Ridesharing efficiency index and other mechanisms that assess the penetration of ridesharing and encourage ridership.
- Ridesharing impact on social welfare: how fares might be structured to distribute additional social benefits to riders, other groups, or more broadly.

Developing a Traffic Flow Controlling Method using Autonomous Vehicles to Dissipate Congestion on Motorways

(PhD Studentship from September 2019), Hassan Abu Saq. Supervisors: Dr I. Kaparias, Dr B.J. Waterson

Reducing congestion is a key challenge for any road transport system operator. Traffic congestion is estimated to cost the UK around £7.9 billion per year (with drivers spending an average of 178 hours per person per year in traffic congestion). Congestion also leads to more acceleration and deceleration of the vehicles, which results in greater fuel consumption and higher pollutant emissions. As it is now widely recognised that building new roads can only offer short-term relief to the problem of congestion, efforts have more recently shifted to the solutions in the domain of technology. Current techniques for controlling the traffic flow and for reducing and dissipating congestion include predominantly infrastructure-based systems, such as Variable Speed Limits and Lane Advisory Information. However, these techniques have limitations, in particular as concerns static control and lack of adequate enforcement, which often reduce their effectiveness. This project attempts to overcome these limitations by investigating whether alternative dynamic control approaches using autonomous vehicles (driverless cars) could be more effective.

Development of Travel Time Estimation Models: Consideration of Link Geometry for Korean Motorways

(funded by the Korean Government, PhD Studentship from September 2016), Sungbae Yoon. *Supervisors:* Prof J.M. Preston, Dr I. Kaparias.

Link cost functions have been used to estimate travel time depending on the assigned traffic flow. Current models include free-flow travel time (FFTT) and road capacity in order to cover various link characteristics. However, both values have uncertainties in two aspects: measurement and spatial transferability.

The aim of this study is, therefore, to develop feasible travel time estimation models that can replace existing approaches with FFTT and road capacity. Three statistical methods for modelling were introduced in this study: ordinary least squares (OLS) linear estimation, generalised least squares (GLS) linear estimation and nonlinear least squares (NLS) estimation. The case study of 72 Korean motorway sections was implemented based on the empirical traffic data from ITS and geometric data from design drawings.

This study concludes that new types of travel time estimation models with geometric features (without FFTT and road capacity) can replace current models. The application to transport appraisal shows that the newly developed model has a significant impact on the feasibility of transport projects by changing the total benefit compared to current Korean models.

Improving Automatic Incident Detection Algorithms (ESPRC and Siemens, PhD Studentship, from July 2016). Jonny Evans. *Supervisors:* Dr B.J. Waterson, Prof T.J. Cherrett, *Industrial*

Sponsor: Dr Andrew Hamilton (Siemens). Awarded 2020

Incidents are events that disrupt the normal flow of traffic, such as vehicle impacts, breakdowns, illegal parking/unloading and emergency roadworks. They cause significant costs to road network users in the form of delay, vehicular damage, air pollution and personal injury.

Automatic Incident Detection algorithms (AIDAs) have been developed to analyse traffic data and inform users of potential incidents on the road network. However, many AIDAs fail to differentiate between an incident, and recurring congestion (e.g. from major events or rush hour). This project seeks to improve AIDAs by understanding the context surrounding the traffic data.

A machine learning algorithm has been created that can learn the patterns between the traffic state and context by analysing historical data. An AIDA with this insight can then raise alerts to Transport Operators more quickly and with less false alerts, ultimately aiding in mitigating the consequences of incidents on the road network.

3.2 Energy & Environment

Centre for Sustainable Travel Choices
(DfT Access Fund, through SCC in conjunction with British Cycling, Cycling UK, Hampshire County Council and Sustrans, from April 2017 to March 2020, with bid extension to March 2021). Dr A. Wong, A. Hickford, K. Ghali; *Contract Holder*: Prof J.M. Preston.

The Centre (CSTC) is a partnership that works with the City Council and the wider region to promote local sustainable travel,

walking and cycling, whilst suppressing private car use. This project continues on from the collaborative work originated through the Local Sustainable Transport Fund, with TRG leading on the monitoring and evaluation of physical interventions and travel behaviour change, as well as advising and supporting Southampton City, Eastleigh Borough and Hampshire County Councils in developing an active travel culture that enriches lives, provides realistic travel choices, and tackling the pressing air quality problem in the region. Significant progress has been made on encouraging modal shift along the major 'cycle-to-work' corridors as promoted through the DfT Access Fund, to complement the now established city-wide cycling freeways and quietways in the Southampton Cycle Network (SCN), and in preparations for 'Active Travel Zones' to be established in St. Denys (which includes Portswood) and in the Polygon (around Bedford Place), with more areas planned from 2021: https://transport.southampton.gov.uk/activetravelfund.

Support has also been given to Southampton City Council during the year on developing their Green Transport Recovery Plan, following the outbreak of Covid-19 and the effects this had on people's travel movements and subsequent mode shifts. Recent focus has also moved towards projects associated with the DfT's Transforming Cities Fund in 'Connecting Southampton', which includes: (1) the development of 'rapid bus corridors' linking Southampton with Hythe and Totton to the West, Bishopstoke and Eastleigh to the North, and Woolston, Thornhill and Bursledon to the East; (2) a new 'Park and Ride' scheme close to the M271 in the West, which will provide services to Southampton General Hospital and (at weekends) into the City Centre; and (3)

an enhanced multi-modal interchange at Southampton Central Station.

The CSTC will also be leading the monitoring and evaluation of projects associated with the Future Transport Zone in the wider Solent Transport Region, which started towards the latter half of 2020, including Mobility-as-a-Service (MaaS) trials, Growing 'Solent Go', e-Scooter trials, and bike (and e-bike) share schemes.
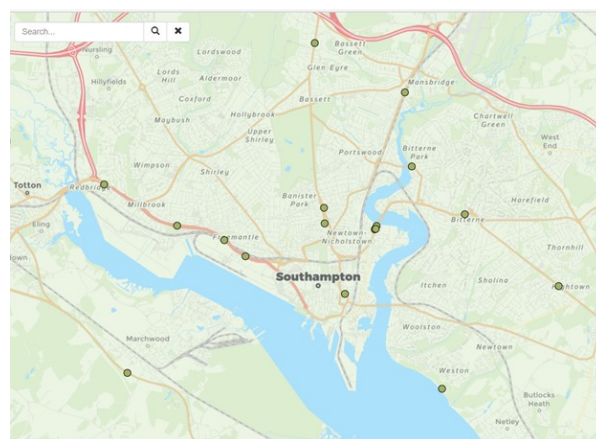
The CSTC Monitoring/Evaluation area in Southampton, showing real-time data points (courtesy of SCC/Drakewell, 2021)

Decarbonising Transport through Electrification (DTE) (EPSRC Network+ Grant. September 2019 – August 2022). *Contract Holder:* Prof. J.M. Preston.

This network is led by Prof L. Cipcigan of Cardiff University and also includes Birmingham, Bristol and Cranfield Universities. The DTE Network+ brings together academia, industry and the public sector to address the challenges limiting the current implementation of an electrified, integrated transport system across the automotive, aerospace, rail and maritime sectors. The DTE Network+ will explore drivers for change within the transport system including technological innovation, individual mobility needs and economic requirements for change, alongside environmental and social concerns for sustainability and consider

the role, social acceptance and impact of policies and regulations to result in emissions reduction. It will adopt and integrated whole system approach that will address short, medium and long-term time-frame challenges, using a multi-layered approach that considers vehicles and technology, charging infrastructure, the supply of electricity and smart mobility. An inception meeting was held in early 2020 and some seed-corn funded research projects have been initiated. For more details see: https://dte.network/

Centre for Re-Engineering for Electric Mobility (RE4EM) (Faculty of Engineering and Physical Sciences, January 2020 to December 2021) *Contract Holder:* Prof. J.M. Preston with Prof. A. Cruden (Energy Technology Group) and Prof L. Wang (nCATS – National Centre for Advanced Tribology at Southampton). *Intern:* Sharifah Syed Ihsan.

With the climate emergency high on the global agenda, and many nations planning to prohibit the sale of new diesel and petrol cars within the next two decades, there is an urgent need for progress towards cleaner transport systems – in particular, electrified systems. This Centre of Excellence will accelerate the pace of change through advances in energy storage technology, the development of digital tribology to optimise electric vehicle (EV) components, the redesign of human–machine interfaces and a systems approach to infrastructure planning RE4EM's approach involves re-engineering existing infrastructure and vehicles to deliver a more sustainable, interconnected transport system, with a focus on road transport as well as the transition to electric rail, air and sea transport systems. Work to date has involved the development of a landscape

document and databases of researchers and research projects. For more details see: https://www.southampton.ac.uk/re4em

3.3 Freight & Logistics

Southampton Delivery and Servicing Plans (Southampton City Council, from September 2020 to March 2021). Dr M. Grote. *Contract Holder*: Prof T.J. Cherrett.

The aim of the Southampton Delivery and Servicing Plans (DSPs) project is to conduct DSPs on organisations located in and/or around Southampton for Southampton City Council (SCC) via a sub-contract arrangement with the Transport Research Laboratory (TRL). A DSP is a flexible plan to minimise the costs, impacts and number of deliveries and servicing visits to an organisation, and is developed through an audit of the current situation, analysis of the audit's results, and the formulation and implementation of a plan-of-action. DSPs are widely seen as an effective method to reduce (*inter alia*) harmful emissions from delivery and servicing vehicles, and SCC's desire to improve air quality in Southampton is the background to the project.

The project consists of two DSPs. The first involves the Bedford Place area of Southampton where improvements have been made aimed at creating a more pleasant and attractive atmosphere, and at creating additional space for businesses in the hospitality industry to operate safely outdoors in response to the COVID-19 crisis. As part of these improvements, a scheme was implemented in August 2020 to pedestrianise the area. The DSP is investigating the changes in delivery and

servicing activities for the businesses affected by the pedestrianisation scheme, and quantifying the associated impacts on factors such as delivery and servicing vehicle-kilometres (vkm) and emissions.

The second DSP involves the High Street area of Ryde on the Isle of Wight where funding has been obtained for regeneration over the next four years. As part of this regeneration, a scheme was implemented in July 2020 to pedestrianise a section of the High Street. Similar to the first DSP, the second DSP is investigating the changes in delivery and servicing activities for the businesses affected by the pedestrianisation scheme, and quantifying the associated impacts on factors such as delivery and servicing vkm and emissions.

Understanding Freight Decarbonisation Investment Decisions (EPSRC (Decarbonising UK Freight Transport), from 2020 to 2021). *Contract Holder:* F.N. McLeod.

This project aims to identify the main factors that influence investment decisions for different actors in freight transport by road, rail or sea. This will be achieved through online focus group interviews with key stakeholders, including fleet owners, freight operators, freight trade associations, professional bodies and those making investment decisions within the public sector. These interviews will contribute to generate a multicriteria decision analysis (MCDA) framework that will enable the quantification of changes in the relative significance of these factors for each sector over time. This study will also research the relationships between these factors and internal freight decarbonisation targets, and it will identify the alignment between these and climate emergency, energy and transport

policies. Our project partner in this 5-month study is TRL.

Southampton Delivery and Servicing Plans (Southampton City Council, from September 2019 to August 2020). Dr M. Grote. *Contract Holder:* Prof T.J. Cherrett.

The project consisted of four DSPs. The first involved a survey of deliveries by Carnival UK's (CUK) local suppliers to Meachers Global Logistics' (MGL) warehouse facilities in Southampton prior to consolidation for delivery to CUK's cruise ships at the dockside. The possible benefits of a milk-round collection service operated by MGL as an alternative to supplier deliveries were investigated, including the potential for shared fleet operations utilising spare capacity in SCC's electric van fleet to provide vehicles for the milk-round.

The second DSP investigated the possible benefits of installing parcel collection points (e.g. Amazon Lockers) on University campuses, consolidating the delivery of personal parcels and reducing the incidence of failed deliveries. The analysis was based on the results of a survey of online shopping habits of staff and students at the University of Southampton (UoS).

The third DSP was based on the same staff/student survey and considered the potential benefits of implementing a consolidated delivery service for student resident in University Halls. The service involves students using a local logistics firm (MGL) as the address for delivery of their online orders, which are then consolidated for delivery to Halls, thereby reducing delivery vehicle traffic to Halls.

The final DSP concerned SCCs special needs transport service for schools in Southampton, investigating the

opportunities for, and possible benefits from, implementing a plan to provide the transport service utilising schools' minibuses or spare capacity in SCC's own vehicle fleet.

FLIPGIG (Digitally transforming deliveries and collections in the gig-economy: fairer and more sustainable last mile parcel logistics) (EPSRC, from 2019 to 2021). F.N. McLeod. *Contract Holder:* Prof T.J. Cherrett

Gig-economy couriers form an integral part of many last-mile logistics operations, but the industry has come under increasing scrutiny due to concerns about poor working conditions. The project has identified inefficiencies and perceived unfairness relating to unpaid time and low pay, biases to using motorised vehicles, hiring too many people for the work available, which can lead to hazardous working conditions as couriers take risks to earn a living. We are now developing algorithms and dynamic models to optimally balance fair work with job availability and service level, while choosing the most sustainable transport mode for delivery, while empowering gig-economy couriers to better meet their personal working preferences. Project website: http://www.flipgig.org/

Multi-Modal Shared Logistics in an Urban Setting – Unlocking the Potential of the NHS Same Day Delivery Network (PGR student, from October 2019) Andy Oakey. *Supervisors*: Prof T.J. Cherrett, Dr A. Martinez-Sykora, Prof J.P. Scanlan.

The demand for same day deliveries is ever growing, whilst journey times in urban areas continue to worsen as a result of increasing congestion. Typically,

little thought is given to logistics in urban planning, nor the environmental burden faced by everyday deliveries. Transfer to more sustainable practices across multiple, cleaner transit modes can help to relieve some of these pressures.

This research aims to investigate the potential for a shared multi-modal logistics fleet to operate across many applications in an urban and peri-urban environment, using NHS same day delivery systems in the Solent region as case studies.

This includes: the transfer of diagnostic specimens for analysis from GP surgeries to hospitals, as well as between hospitals, ad-hoc and emergency blood stocks from Southampton Blood Centre to recipient hospitals, cytotoxic medicines for cancer treatments to hospitals, and localised pharmacy medicine deliveries. Multiple modes will be considered, taking advantage of each mode's beneficial traits, e.g. fast and direct transport by drone, short range urban transport by cycle courier, or longer distance and heavy transport by LGV. The selection of vehicle type, as well as the interaction between the platforms will be key to the development of this system. Consideration of the cargo type will also be particularly important in the medical setting of this research.

To optimise the use of these vehicle assets, an allocation system will be developed, considering factors such as time criticality, cost, and routing restrictions. In the NHS setting, improving delivery timescales is a key target. Across all of the case study elements, there is potential to create knock-on savings across the NHS, improve quality of care, and save lives.

To further improve the sustainability of multimodal fleets, this research will consider how such a fleet could be shared by multiple parties in a collaborative partnership.

Restructuring the Supply Chain to Better Serve Rural Farmers: A Case Study of Thailand's Mango Supply Chain (PGR student, from October 2017) Korawit Fakkhong. *Supervisors*: Prof T.J. Cherrett, Prof J.M. Preston, Dr Antonio Martinez-Sykora (external).

In this study, the research addresses one of the Thai Government key goals related to its food production policy; namely, to create a more inclusive operating environment for rural farmers to improve their transport efficiency and ensure that they can remain competitive. Original primary data were gathered on the production of mangoes by rural farmers across Thailand and used to develop the business-as-usual logistics case along with alternative operating scenarios using range of collaborative logistics options. The Clarke and Wright saving algorithm was used to quantify the benefits of different operating scenarios involving (i) farmer sharing vehicles through a farmer's co-operative, and (ii) a 3rd party vehicle to make milk-round collection. In addition, an important aspect of the collaboration is to decide on how to share the benefits, and how the transportation cost should be distributed fairly among the group of farmers. To investigate these issues, two different cost allocation methods were used – proportional based on volumes and stand-alone cost and the Shapley value methods based on co-operative game theory.

Demand Forecast and Capacity Appraisal of the United Kingdom Lift-on Lift-off Container Ports System (SMMI PhD studentship from January 2016). Manuel Buitrago. Supervisors: Prof J.M. Preston, Prof T. Bektas (University of Liverpool).

The maritime sector is of the utmost importance for the United Kingdom's economy. Great Britain relies heavily on the use of sea-borne transport for most of the freight commodities. Airfreight is mainly used for high-value and time-sensitive products and the capacity of the Channel Tunnel railway is constrained. For bulk and containerised commodities, which usually present a lower value density and higher volume, maritime transport is the only feasible option. As a result, up to 96% of the volume of all UK import/export trade flows use the UK ports. Roll-on roll-off (ro-ro) and lift-on lift-off (lo-lo) container terminals are essential to accommodate container flows. Besides, amongst lo-lo terminals, the UK also needs a certain deep-water capacity to be able to cater for ultra-large container ships (ULCS) that are deployed to the main maritime route that links the Far East with Northern Europe. Ensuring the availability of enough spare deep-water capacity has become even more important on the eve of Brexit.

Apart from enabling the trading capability of the nation, the ports are crucial for the UK's economy in, at least, two other important ways. Efficient ports increase the competitiveness of the UK economy, reducing dwell times and facilitating trade. Secondly, ports generate important spill overs. These include value generation, creation of jobs and the formation of clusters and industrial poles.
The UK container port system has experienced profound change since the 1980s. The system underwent a change

in two dimensions. Firstly, all major UK container ports are privately-owned, after a privatisation wave during the 80s and 90s. Secondly, the container traffic is concentrated in just three major ports of the south-eastern coast of the UK, which handle more than 70% of the total yearly throughput.

This research project develops new models to assess capacity and demand for the lift-on lift-off container seaports in the United Kingdom. The evolution of the UK container port system has been analysed. Besides, the system capacity has been analytically appraised using a system of systems approach.
An aggregate forecast of the demand for lo-lo container traffic of the United Kingdom system of container ports has been calculated up to the year 2050, using econometric models that incorporate economic growth and the cost of energy as predictors. Several scenarios have been incorporated to reflect the uncertainty and the potential disruption caused by the future UK-EU relationship. Finally, the forecast traffic is allocated to the individual UK containers ports by means of a ground-breaking Lotka-Volterra dynamic competition model.

This research presents insights to decision-makers to base port policy on evidence and informs crucial strategic investment decisions for government and industry alike. This PhD provides a rationale to substantiate where and when to invest in capacity expansion. Finally, the results can be used to signpost risks to the port system, in terms of congestion, loss of traffic and vulnerability of the port infrastructure network.

3.4 Future Technologies

Examination of the Effects of New Transportation Technologies and Business Models on Urban Structure
(PhD from January 2019). Paraskevi Sarri. Supervisors: Dr I. Kaparias, Prof J.M. Preston

New technologies and business models in transportation will change the way people travel in the future. New technologies such as autonomous, connected, electrical or low emission vehicles and business models like schemes like Mobility as a Service or car sharing, have been researched intensely. The last time that urban mobility had faced such evolution was in 1885 when Karl Friedrich Benz created the first car that could be powered by an internal combustion engine. Since then the car has been the most important component of urban and interurban transportation around the world because it has opened economic opportunities to the population but also it has significantly increased the speed of travelling.

Predicting the impacts of these technologies in everyday life is necessary at this point. Land use and Transportation Interaction (LUTI) models are an appropriate tool of modelling for the assessment of many kinds of new technologies, business plans and also combination of these and not just in a one- dimensional way. Providing predictions is a practice that is deeply linked to science and is an integral part of the design of urban systems around the globe. In order to integrate new technologies and business models in LUTI models, it is inevitable that the internal mathematical structure of LUTI models has to change and become more adaptable. To achieve this using multidisciplinary models and various

mathematical relationships that relate transportation, location and land use characteristics is essential describe and analyse urban systems. More specifically, the DELTA LUTI model has been chosen in this project, as it has been deemed appropriate due to its strong theoretical foundations.

The results of such a study come from both the urban models but also other aspects, such as transportation models and data from new technologies, thus they can be beneficial for both the individual and the society in general. Here it is important to mention that some of the results that have occurred from analysis in this project were accepted for presentation from the 9th Symposium of the European Association for Research in Transportation. New technologies such as autonomous vehicles, can bring sustainability to mobility solutions in the future and thus being able to predict the impacts of them can prevent possible policy and planning mistakes. The new and more versatile to new technologies framework can be used as a tool for both urban design and transportation planning and engineering.

Exploring Person-based Signal Control Paradigms in Urban Road Networks (PhD from January 2018). Zongyuan Wu. Supervisors: Dr B.J. Waterson, Dr B. Anvari (external).

This project aims to understand the benefits of adopting extra occupancy information obtained from connected vehicles in control strategies. In particular, the research focuses on investigating impact of considering occupancy delay reduction rather than vehicle delay reduction for achieving person-based metrics. The report reviews existing urban signal control strategies, points out their drawbacks and highlights that they neglect the priority of high occupancy vehicles. This research proposes an Adaptive Person Based Signal Control Algorithm (APBSCA) to minimize person delay by exploring all phase combinations and feasible signal plan strategies at isolated urban intersections. The control system has been improved and extended to be coordinated in large road network scales. The different coordination levels of APBSCA have been tested in simulation to understand how information communication degree affect the performances of proposed algorithms. The research builds evaluation frameworks for coordinated APBSCA in large scale case study with variety traffic demand levels and penetration rates, incorporates multi-modal vehicles and pedestrians into algorithm for control system enhancements. The current research attempts to improve the behaviours of control system in low penetration rate situations where lack of connected information for both vehicular data and occupancy data.

Addressing the New Reality of Vehicle Automation in Highway Design (sponsored by the EPSRC Sustainable Infrastructure Systems CDT, iPhD studentship from September 2017). Hameed Jehanfo. *Supervisors:* Dr I. Kaparias, Prof J.M. Preston.

It is estimated that by 2025, the global intelligent mobility market will be worth £900bn per year, with fully autonomous vehicles predicted to hold a 25% market share in the automobile industry by 2030. The UK has signalled its resolve to be prepared for this transport shift by launching the Centre for Connected and Autonomous Vehicles (CCAV) in 2015 with the sole objective to "keep the UK at the forefront of the development and deployment of [CAV] technology",

investing more than £250m into 70 research and development projects from 2014 to 2018, and enacting the Automated and Electric Vehicles Act 2018, which provides bespoke insurance for CAVs accidents. Yet, the government acknowledges that the existing roads – which have been design and constructed using standards developed for conventional vehicles - are unfit for CAVs. But developing a new approach to road design for CAVs must be supported by adequate research to avoid uneconomical over-designs or under-designed highway infrastructure which fail prematurely. An optimised whole-life cost (WLC) design solution is required to achieve a balanced approach.

A key component in whole-life cost analysis is the physical road infrastructure, of which the structural pavement forms a major constituent. Current pavement designs are deliberately conservative due to two main factors. Firstly, the lane distribution models of manual trucks on multi-lane highways are indeterminate. However, the lane choice of CAVs can be more precisely controlled, reducing uncertainty in pavement fatigue loading. Secondly, wheel channel positions of manual trucks within the lanes follow a normal distribution function, which moderately concentrates the wheel loads, very much unlike the zero (high wheel load concentration) or uniform wander (no wheel load concentration) models of connected autonomous trucks (CATs).

Investigations into relationships between CAVs and engineering aspects of road design are scarce. Although there is some activity in the area of pavement analysis for CATs, none provides a whole-life optimised solution for highway re-design. Also, the range of pavement materials is limited to flexible asphalt

concrete, which restricts the ability to compare the deterioration impact of CATs on different pavement construction systems. Finally, the existing studies do not account fully for the effect of lane widths on pavement deterioration in their analysis.

The core aim of this research is to find highway design solutions for CATs that optimises the WLC of the highway infrastructure. This will be achieved by analysing the pavement failure effects of CATs as the main focus, and then extending the work to incorporate the highway engineering variables (such as lane configuration and widths), that significantly impact on pavement deterioration.

Based on a conceptual motorway link, multiple scenarios will be generated and analysed, and then costings integrated to produce an optimal highway infrastructure design model for CATs. The research will formulate a new WLC optimisation technique which can be used to produce a model for designing highways for CATs.

Electric Vehicle Drivers and their Use of Digital Media (part-time PhD, from December 2013). Farah Alkhalisi. *Supervisors*: Dr B.J. Waterson, Prof T.J. Cherrett. Awarded 2020

Promoting the use of renewable-source fuels has greater potential to reduce transport-related carbon emissions in the short to medium term than changed traveller behaviour, especially given doubts that Western Europe has reached 'peak car'. Although electric vehicles (EVs) currently only account for around 1% of new cars sold in the UK, they are intended to play a key role in meeting the objectives of the 2008 Climate Change Act. Strategies to counter barriers – both

technical and cultural - to EV purchase or adoption are therefore clearly necessary.

Transport users, cyclists and walkers are increasingly using digital technologies such as social media platforms, smartphone apps and crowd-sourced databases to overcome infrastructural shortfalls; for car-sharing; and for intermodal transport. Little is known, however, about the extent to which EV drivers could be similarly using digital resources related to, for example, location of public charging points; scheduling and remote monitoring of their cars' charging; or technical data and information-sharing. This research therefore attempts to understand the relationships between electric vehicle drivers and digital media.

Optimising Wireless Electric Vehicle Charging Locations (iPhD student from October 2015). Luke Hutchinson. *Supervisors*: Dr B.J. Waterson, Dr B. Anvari. *Industrial Sponsor*: Transport Research Laboratory.

Wireless Power Transfer offers a viable means of charging Electric Vehicles (EV) whilst in a dynamic state, mitigating issues concerning vehicle range, the size of on-board energy storage and the network distribution of static based charging systems. Such charge while driving technology has the capability to accelerate EV market penetration through increasing user convenience, reducing EV costs and increasing driving range indefinitely, dependent upon sufficient charging infrastructure. Yet, the detailed vehicle interactions of both users and non-users of a dynamic charging system has received little analysis.

The project intends to identify the potential of the dynamic charging situation, how it could be implemented

into the existing charging infrastructure, and the issues that could be encountered during deployment. This research has seen the development of both traffic and energy models to analyse various deployment scenarios and to understand the limitations of taking laboratory prototype systems to full scale deployment. Whilst the traffic modelling has involved both microscopic and macroscopic simulation, the development of instantaneous energy consumption, power transfer and emission programs were significant contributions of the research. The study concludes with the necessary tools to quantify the optimisation of deployment scenarios.

Integrating Connected Vehicles into the Transport Network (EPSRC CDT in NGCM Studentship from September 2015) Craig B. Rafter *Supervisors*: Dr T.J. Cherrett, Dr B. Anvari. *Industrial Sponsor*: Transport Research Laboratory. Awarded 2020

Connected intelligent transport systems contain a wealth of data accessible to traffic signal controllers. However, algorithms that use data from a connected environment do not fully exploit the potential of this new data source. Instead, traffic signal controllers rely on speed and position data to supplement data from infrastructure. This research aims to understand which data that are available from connected vehicles are useful for traffic signal control in urban environments. Vehicle positions and speeds fit well into our current understanding of traffic theory, but more abstract data such as passenger counts and stop frequencies may offer new ways to optimise traffic signal controllers to reduce traffic delays.

This research shows how data connected vehicles can be exploited to improve

urban traffic signal control, and how using connected vehicle data differs from traditional sources. The outcomes of this research have a significant impact on the implementation of connected intelligent transportation systems and policy for the transportation industry.

3.5 Rail

NISMOD-TRD – Developing Applications of the ITRC-NISMOD Transport Model (EPSRC IAA, July 2020 to July 2021). A. Hickford. *Contract Holder:* Prof J.M. Preston.

This project aims to establish and develop relationships between the transport modelling and strategies team in TRG and national, regional and local transport bodies, promoting the application of ITRC's NISMODv2 Transport model. The model has had relatively limited exposure to planners and strategic decision makers, and this project will initially develop collaborative relationships with the National Infrastructure Commission (NIC), Hampshire County Council (HCC) and Solent Transport. Building on previous work with the NIC, the new modelling capabilities of NISMOD-Tv2 will be used to examine future options for the GB strategic road network, including an assessment of the impact of DfT's Road Investment Strategy on congestion, journey times and emissions. More locally, transport options for future developments in Southampton, Portsmouth and the wider Solent Transport and Hampshire regions will be investigated, to assess the impacts of currently planned strategic objectives and determine possible pathways to meet such objectives, together with a comparison of the NISMOD-Tv2 model

outputs and HCC's Sub-Regional Transport Model (SRTM).

Providing Improved Information to Rail Passengers & Understanding the Value of Data Privacy (EPSRC IAA, June 2020 to June 2021). Dr J. Pritchard. *Contract Holder:* Dr S.P. Blainey

The overall aim of the project is to work with the Rail Delivery Group (RDG), via secondment of a TRG researcher to RDG, to develop improved passenger information systems and services which may require the use of personal data. This will help ensure that the rail industry (and ultimately society) benefits from previous EPSRC-funded research into the value placed by travellers on information provision and data privacy. The project will also sustain and enhance the relationship between the University of Southampton and rail industry bodies (notably RDG), building on the University's role in the UK Rail Research and Innovation Network (UKRRIN). Work during the secondment will be focused in two main areas. The first will involve developing a framework for evaluating the benefits of improved information provision and service enhancements, which properly takes in to account the importance of data privacy and the willingness of passengers to provide any necessary data. Secondly, the TRG researcher will work with the Rail Delivery Group as they develop new passenger information systems, focusing particularly on assessing the suitability of additional data sources for incorporation in such systems.

Assisted VSTP (Very Short Term Planning) (Bellvedi/Tracsis for RSSB from July 2020 to May 2022). Dr J Armstrong. *Contract Holder*: Prof J.M. Preston.

Timetable planning for Britain's railways is a long-term process, starting over a year prior to the twice-yearly introduction of new national timetable. Alongside the longer-term term timetable planning (LTP) process, there is also a requirement for the short- (STP) and very short-term planning (VSTP) of passenger and freight trains in the days and hours prior to their operation, in response to changes in demand and operating circumstances, including operational disruptions. The short timescales available for STP and, especially, VSTP services currently precludes their full validation, introducing performance risks and the likelihood of sub-optimal infrastructure, rolling stock and traincrew resource allocation. TRG is assisting Bellvedi/Tracsis in the development of an improved VSTP system, focussing on the identification of robust VSTP train paths and the development of improved contingency plans in response to operational disruptions.

Causal Self-Evident Reactionary Delays (CACI for RSSB from February 2020 to July 2021). Dr J Armstrong. *Contract Holder*: Prof J.M. Preston.

When trains on Britain's railways are delayed by three minutes or more, the causes of these delays are investigated and, where possible, each delay is attributed to a cause category and code, and is allocated to one or more incidents that ultimately caused the delay. Delays fall into two broad categories: direct or primary delays, where a train is delayed directly by an infrastructure or rolling stock failure or some other cause, to which the delay is allocated; and reactionary or secondary delays, where a train is indirectly delayed by another delayed train.

The delay attribution (DA) process is time- and resource-consuming, and prone to error, inconsistency and dispute, and would benefit from the automation of the attribution process for those reactionary delays whose causes can be determined directly and unambiguously from the data available from the signalling system, and are thus causally self-evident. TRG is supporting CACI Ltd. on this RSSB-sponsored project, reviewing the current DA process in Britain alongside international research and practice, and conducting industry stakeholder engagement to ascertain the nature of the current DA system, its shortcomings, and opportunities and aspirations for improvement. The findings of the review and consultation processes have been presented to RSSB and the project steering group representing the wider railway industry, and provide the basis for ongoing option development. TRG are also supporting CACI in the process of developing, reviewing and calibrating the automated DA algorithm.

IntelliDwellTime (RSSB from November 2019 to June 2020). Dr J. Pritchard and staff from GeoData Institute. *Contract Holder:* Dr S.P. Blainey.

This project was undertaken in partnership with Porterbrook, Elastacloud and Abellio Scotrail as part of the RSSB Data Sandbox+ programme. It built on modelling and visualisation work carried out during a previous project on 'Predicting and Mitigating Small Fluctuations in Station Dwell Times'. The project collated and analysed on-train monitoring data from the Scotrail fleet and used this to create a pre-commercial product capable of understanding and predicting variations in train performance which are likely to cause dwell time exceedances. This should help to reduce delay minutes and thus increase the cost-

effectiveness of fleet operation. Southampton's role centred on data integration, modelling and visualisation for the software product.

T2F: Track to the Future – Economic and Environmental Modelling (EPSRC Programme Grant from June 2015 to May 2021). Dr J. Armstrong, Dr M.A. Young, G. Rempelos. *Contract Holders*: Prof J.M. Preston, Dr S.P. Blainey.

This programme grant follows on from the Track21 project (2011-2015) and involves addressing additional research questions with the aim of delivering improved railway infrastructure performance, as well as further research based on some of the key outputs from Track21. As train frequencies and speeds continue to increase over time, railway track is being more intensively used, which leads, in turn, to increased maintenance requirements. Combined with the urgent need to reduce the railway system's costs and environmental impacts, this places great pressure on railway infrastructure operators. Alongside this, it will also be necessary to mitigate the impacts of climate change on railway track systems, with coastal railways potentially particularly vulnerable in this regard.

In order to help the rail industry tackle these challenges relating to track maintenance and performance, T2F is addressing three key research challenges. The first is to develop low maintenance and long-life track systems with optimised use of materials. The second is to design crossings and transitions so as to optimise vehicle behaviour and consequently maximise the service life of trains, and the third is to develop an integrated approach to the design of low-noise and low-vibration track. TRG's contribution to the project involves the calculation of the economic

and environmental impacts of such interventions. This involves working in partnership with Network Rail (with whom the University of Southampton has a Strategic Partnership), and with other T2F researchers at the universities of Southampton, Birmingham, Nottingham and Huddersfield. Work has focused on life cycle cost and carbon modelling of the installation of under-sleeper pads and the use of fibre-reinforced ballast and on comparing ballasted and non-ballasted track systems. TRG are currently developing (in partnership with the Institute for Sound and Vibration Research) a more accurate and spatially detailed socio-economic assessment of changes in noise and vibration from railway track systems using GIS to combine and process a range of datasets. A generalised socio-economic assessment methodology for track system interventions based on data ontologies is also being developed in conjunction with researchers at the University of Birmingham.

Improving Customer Experience While Ensuring Data Privacy ('DICE') (EPSRC, September 2016 to February 2020). Dr J. Pritchard. *Contract Holder:* Dr S.P. Blainey, jointly with University of Surrey, Loughborough University, and Royal Holloway University of London.

This project is investigating the trade-offs rail passengers might face between data privacy and improvements to the customer experience. Particular attention is paid to passengers with special journey requirements and to future ticketing systems. Research areas include: the development of an effective trust framework to enable customer control over data privacy; the development of data aggregation techniques which aid the provision of an improved customer experience without compromising data

anonymisation; testing the applicability of these frameworks and techniques to potential future ticketing solutions; developing use case scenarios for systems to improve the rail customer experience; and assessing the demand and environmental impacts of providing an improved customer experience enabled by these systems.

Our initial focus, working mainly with the team from Loughborough, was on analysing a set of customer complaints in order to ascertain the factors which can lead to a degraded customer experience, and understand how individual context can make a difference. This helped build up a picture of where the potential trade-offs between data privacy and customer experience might lie. The second phase of our research involved carrying out on-train stated preference surveys on the Great Western Railway Network to assess the trade-offs passengers are prepared to make between provision of personal data and an improved journey experience during times of disruption.

Data-Driven Robust Timetabling (RSSB from November 2019 to October 2020). Dr J Armstrong, S. Zieger (Visitor from RWTH Aachen University). *Contract Holder*: Prof J.M. Preston.

Britain's railways carried a record number (1.759bn) of passengers in 2018-19. As traffic grew on the network prior to the Covid pandemic, it became increasingly challenging to operate trains punctually, as even a small initial, or primary, delay to one train could quickly cause knock-on, secondary delays to other services, and delay and congestion could spread rapidly across the network as a result (punctuality has improved with the reduction in passenger demand and train services because of Covid, but is likely to deteriorate again if and when demand

and traffic growth resumes). The industry thus faces the potential twin challenges of providing capacity to accommodate traffic growth, while operating the additional services punctually and reliably. Primary delay levels remained fairly constant in recent pre-Covid years, while secondary delay increased and formed approximately 70% of recorded delays. Unattributed, small delays (less than three minutes) made up approximately 35% of all delay, and need to be better understood, both in terms of their causes and as a source of larger, secondary delays.

This project investigated the timetabling process and the relationship between the timetable and the rules underpinning it and the resulting performance in terms of train punctuality. It identified statistically significant relationships between planned dwell and running time values and punctuality for individual stations and route sections. These relationships were then used to predict the performance of train services over longer route sections, with encouraging results. This process and the findings obtained can be used to identify the sources and causes of small, timetable-related primary and secondary delays, which can in turn be used to modify the timetable planning process to reduce and eliminate these delays. This will improve the punctuality and reliability of train services, making better use of the available network capacity and, where possible, providing the certainty needed to introduce additional services without causing delays to existing trains.

Research on High-speed Railway Network Capacity Utilisation & Optimisations (Funded by China Scholarship Council, PhD from September 2020). Jiaxi Li. *Supervisors*: Prof J.M. Preston, Dr J. Armstrong.

Rail transport, with its eco-friendly effects and high carrying volumes, creates strong economic linkage among cities and is a valuable solution to commuting crowds and other travel for most countries. However, what troubles railway operations throughout the world, no matter whether the railway is a high-speed system or not, is the increasingly intensive capacity utilisation of railway infrastructures in some busy areas, in peak periods, or both. This causes a gap between train service supplies and travel demands.

Capacity utilisation indices, based on timetable compression, were first developed for plain track and more recently have been developed for nodes (junctions and stations), including work at the University of Southampton. However, they are rarely developed for networks. Building on previous works by the student in undergraduate and postgraduate research, the initial focus will be on optimising capacity utilisation for the China High Speed Rail Network, the largest high-speed railway network in the world, serving a complex Origin-Destination Passenger Flow structure.

In this research, several parts will consist of an optimisation framework of railway network capacity utilisation to achieve a balance between a train operation structure (TOS) (the time distribution of a certain number of train lines) and a highly efficient capacity utilisation of a high-speed railway network. The transferability of the analytical framework and assessment method to classic rail services and the interaction between high speed and classic rail service will be examined, possibly adopting a case study of High-Speed 2 in the UK and its interaction with classic rail services provided by the West Coast Partnerships.

For the next coming decades, a new major railway network is less likely to be built, while the transport demand keeps growing in the world. In this case, effectively improving the capacity utilisation of a railway network, mainly by optimising TOSs, will be railway companies' common choice. As it has mentioned above, a network level research will be one of the rare research topics despite a long history of railway capacity study, and it would greatly support the scheduling efficiency of railway timetabling departments guided by the research.

A Comparative Assessment of Intercity Transport Technologies: A Saudi Arabian Case Study (PhD from September 2016). Hamad Almujibah. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

With increasing urbanization worldwide, passenger demand for inter-urban travel has grown and the development of new transport technologies is needed, such as High-Speed Rail (HSR), Magnetic Levitation (Maglev) and Hyperloop. This thesis undertakes a comparative assessment of these three intercity transport technologies in terms of their service characteristics. The aim is to identify the most suitable transport mode with the lowest average social and operator cost for an identified corridor under the level of demand that is forecast.

The comparative assessment method comprises four models. The first is the Spreadsheet Total Cost Model (STCM), which focuses on calculating the social and financial costs according to the vehicle characteristics and unit costs of each of the transport technologies studied. It includes operator cost, user cost, external cost and, hence, social cost

and average social cost. Second, a Demand Forecast Model (DFM) is developed to forecast travel demand for HSR flows. This model includes parameters such as the population along the corridor, Gross Domestic Product (GDP) per capita, generalized journey time, percentage of unemployment and number of years since the lines opened. The third model is a Stated Preference Model (SPM) to examine the choice of Hyperloop over other modes of transport and to gain an understanding of how decisions are made when people are faced with several transport alternatives. The fourth is the Elasticity of Demand Model (EDM) to determine existing mode flows in terms of generalized journey time, including by conventional rail, air, car and bus.

The Riyadh–Dammam corridor in Saudi Arabia is used as a case study in which to apply the comparative assessment method proposed by this thesis to examine High Speed Ground Transportation (HSGT). The aims are to determine the most suitable transport modes in terms of level of service and total social and operator costs, and to forecast passenger demand. In this case study, Hyperloop appears to be the best next-generation high-velocity HSGT, since it has the lowest average social cost (ASC) of €67.7 per passenger in 2030, compared to €103.3 for HSR and €100.2 for Maglev due to its lower capacity, which leads to a high hourly service frequency.

Streamlined Train Travel: Assessing and Reducing Door-To-Door Journey Times Associated with New Rail Infrastructure (funded by the Turkish Government, PhD Studentship from September 2018) Emine Tugba Yazici. *Supervisors:* Dr S.P. Blainey and Dr M.A. Young

There are many reasons for investment in high-speed rail (HSR), such as increasing transport capacity, enhancing network, supporting mode shift from air travel to HSR, but often one of the primary reasons for promoting HSR investment is a reduction in journey time. While HSR services are usually able to achieve a reduction in on-board time between major centres, not all HSR services are necessarily successful in achieving reductions in door-to-door journey time. Therefore, this research reviews high-speed rail routes and their stations around the world to investigate factors affecting the door-to-door journey time such as station connectivity, accessibility, location, HSR route alignment and service operation. Then, with the assessment of the existing applications, for the future HSR construction, a guideline will be provided to help transport planners on the provision of HSR services in a way which maximises the potential journey time benefits.

An Assessment of Reforms to Optimise the Railway Organisation in Saudi Arabia (PhD from April 2018). Sultan AlSaedi. Supervisors: Prof J.M. Preston, Dr S.P. Blainey.

The Saudi government has started to reform its railway industry by following the international trends in railway reform. The initial stage of railway reform that has occurred was the ownership reform when the government created a new railway company, Saudi Railway Company (SAR), for the North-South Railway project rather than constructing and operating this project under Saudi Railway Organisation (SRO) responsibility. The reforms also involved privatising Haramain High-Speed Rail (HHSR) under a build-operate-transfer (BOT) contract with a Saudi-Spanish

alliance. Most recently, there has been a merger in which SRO assets have been transferred to SAR. Despite these reforms, the railway's industrial organisation can be seen as not fully developed compared to the other industries. In addition, the rail infrastructure is not yet fully developed. The current rail network has a total network-line length of 4,580 km, and the planned rail projects will expand the network up to 9,900 km by 2040. Therefore, the aim of the research project is to determine the optimal organisation of rail services in Saudi Arabia that has not fully developed its rail network. Moreover, the project assumes different forms of railway reform to achieve the optimisation.

The railway reform can be described as any changes in the rail policies, investment plans and the structure of the rail industry. Practically, the railway reform can be clustered in three blocks based on country experiences. The first block is the regulation reform, which aims to introduce different forms of competition, to impose different levels of economic regulation, to create regulatory bodies, etc. The second block is the structural reform, where the railway organisation is restructured horizontally and/or vertically in two models. A vertical separation model is a form of separating the rail infrastructure from train operation. A horizontal separation model is a form of segregating passenger from freight rail services and/or regional division. The last block is the ownership reform, which takes a form of explicit privatisation or deregulation of the rail market.

To deliver the assessment, the project sets three measures to select the optimal railway organisation. The first measure is the technical efficiency, which aims to identify the most railway reform option

that can maximise production technology. The second measure is the cost efficiency, which aims to select the optimum railway reform that can achieve cost minimisation. For these two measures, the project will develop a benchmark by using the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The last measure is the socioeconomic efficiency, which means that different forms of railway organisation will be assessed with respect to welfare economics. It should be noted that the project has selected 32 countries from Europe, the Middle East, the Central and East Asia between 2000 and 2017 with a maximum of 439 observations. At the end, the project will draw some conclusion and recommendations regarding the rail policies, and these recommendations will be validated by interviewing the railway industry experts.

A Whole Life Carbon Model for Railway Track System Interventions
(EPSRC and Network Rail Sustainable Infrastructure Systems iPhD from January 2018). Georgios Rempelos. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

The UK's rail network consists of approximately 20,800 miles of track and estimates suggest that the volume of maintenance and renewal required results in approximately 430,000 to 934,000 t CO_2 per annum. This project aims to develop a cost and carbon emissions model framework for railway track systems, covering the whole life of the infrastructure. The model will be capable of modelling the impacts of a wide range of track system interventions, including the full range of engineering solutions developed during the Track21/Track to the Future (T2F) research programmes. In essence, this

project aims to produce a framework which will work as an analytical tool to better understand the carbon footprint of today's rail industry and, subsequently, assist the decision-making process for both minimising CO_2 and realising sizeable financial/social benefits. The results from this work are purposed to be fed into a wider Cost Benefit Analysis (CBA) framework, in order to objectively assess different track interventions qualitatively and quantitatively at a macro level and subsequently assist stakeholder decision-making.

Presently, the project is focussed on analysing a range of future track systems, but in order to establish the extent to which these are an improvement over existing ones, it is necessary to undertake a whole-life environmental appraisal of their relative performance. Aside of the environmental externalities of the infrastructure, the project attempts to provide a link between both cost and carbon, examining prospective trade-offs between the upfront and the on-going financial and environmental externalities throughout the useful life of these structures. Of particular interest are potential performance comparisons between different optimised ballasted track forms with interventions developed during Track21/T2F.

Work so far focussed on individual life cycle cost (LCC) and carbon foot-printing studies based largely on existing embodied carbon factor databases such as the 'Bath Inventory of Carbon and Energy', the 'Rail Carbon Tool' by Rail Safety and Standards Board (RSSB), and a rail industry-specific software, VTISM. In detail, this includes a streamlined LCA study to evaluate and compare the lifecycle Greenhouse Gas (GHG) emissions

associated with the four most common sleeper types present in the UK rail network. This work is now extended with a focus on LCC and GHG emissions modelling of optimised ballasted track forms (e.g. fibre-reinforced ballast, under sleeper pads, twin-block sleepers, composite sleepers, re-profiled shoulder track, and finer ballast gradings, etc.) through route-based case studies. To do that, a methodology, based on relative settlement was proposed to adapt the results of laboratory tests into a suitable parameter for input into VTISM.

Future work will extend the proposed framework to include other costs/revenues and externalities, with the overall aim of developing an integrated methodology for investigating the potential of different interventions to reduce both LCC and externalities of ballasted track. This is important as it could provide new perspectives for targeting lifecycle enhancements, as well as better aid project and policy decisions.

The Project Economics and Management of Railways in the Middle East (PhD (Part-time) from October 2018). Fawad Munir. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

The focus of this research is the "Investment choice" of establishing a modern rail, and other transport, networks in the Gulf region. From a recent open source literature (www.meed.com) and media review (Gulf News) it emerges that almost all Gulf Cooperation Council (GCC) authorities are seeking alternatives to state investment in major transport projects. An example of this could be the ambitious yet hugely delayed GCC rail project. It is unclear if, or how, an investment model has been considered in the strategic decision of the GCC rail network, but it seems that any

such studies have only been done at a rudimentary level. It is argued by Harry Markowitz that stock investors with sufficient computational resources can be compared with government bodies and client organisations and therefore it is feasible to assume that portfolio theory can either be utilised prior to the investment decision or soon after the feasibility study and decision to go ahead with one or the other project. Therefore, in the context of GCC rail projects, this research will draw parallels with the investment portfolio theory and look at alternative models such as Public Private Partnerships (PPPs).

At first, a comparative and parametric study for existing economic models of long-distance railways and/or Metro in modern western countries may be carried out. This will provide a benchmark for comparison with the current GCC practices. Then this study would critically analyse financial studies of GCC region railway projects regarding their investment policy.

The study will provide recommendations, a framework and a model for transport infrastructure investment. This study will be useful for government organisations and other stakeholders for investment choice for a new railway network. Additionally, this research work can also recommend on existing networks in order to establish network wide polices of freight and passenger movement, for a viable business case.

3.6 Transport and Infrastructure Policy

DAFNI Champion (STFC, July 2020 to April 2021). A Hickford. *Contract Holder:* Dr S.P. Blainey.

DAFNI (Data and Analytics Facility for National Infrastructure) represents an £8 million investment from the UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC) to provide infrastructure systems research capabilities and enhance the quality of modelling and other research outputs. DAFNI aims to improve the efficiency, reliability and sustainability of infrastructure through better sharing and use of data, exploitation of simulation and optimization techniques, and engagement with stakeholders through visualisation.

There are five main projects (across seven universities) associated with the DAFNI Champion programme. The responsibilities of DAFNI Champion for the University of Southampton and TRG are threefold: identify potential future users of DAFNI, and host discussions and presentations with particular groups and individuals to promote the facility within the Engineering department and further afield; advocacy for the facility within the wider transport research community across the UK via the Universities' Transport Study Group (UTSG – www.utsg.net), to try to determine the key requirements from a facility such as DAFNI, and how might it be appropriate for transport research generally; and user feedback as the ITRC NISMODv2 modelling suite is incorporated into DAFNI's capabilities.

Pathways to Decarbonise Transport in England's Economic Heartland (EEH, March to May 2020). A Hickford. *Contract Holders:* Dr S.P. Blainey, Prof J.M. Preston, jointly with University of Oxford.

Outputs from the NISMOD transport model were used to investigate the effects of population change on travel demand, and the subsequent impact of different sets of options, or 'Pathways', to

help achieve the net-zero carbon target for transport in EEH by 2050. The challenging target implies a substantial change in the vehicle fleet towards zero-emission vehicles, coupled with technological solutions to improve both vehicle efficiencies and the use of the road and rail networks, and promoting behaviour change of drivers and passengers to reduce the number and nature of motorised trips in the region. Each of the alternative 'Pathways to Decarbonisation' focuses on a specific approach to change the way that people travel in the future: 'Highly Connected', involving increased use of digital communications and embedded technologies in the transport network; 'Adapted Fleet', consisting of rapid technological development (and electrification) of the vehicle stock; and 'Behaviour Shift' toward more intensive use of fewer vehicles achieved through road pricing and education measures. The measures and interventions contributing to each Pathway change travel demand. Road pricing measures help to reduce demand, while our assumptions regarding autonomous vehicles provide higher road capacities, so more vehicles can use the same road network, resulting in higher flows. Population growth adds continuing pressure to the transport network, and levels of congestion are expected to increase as population grows. The mix of interventions could help reduce the overall demand on the transport network, but it will require significant effort through governance, legislation and public will to affect such large-scale changes.

Decision Support Systems for Resilient Strategic Transport Networks in Low Income Countries (FCDO, July 2020 to July 2022). A. Hickford, Dr M.A. Young. *Contract Holders:* Dr S.P. Blainey,

Prof J.M. Preston, jointly with University of Oxford.

This project forms part of the FCDO High Volume Transport research programme, and will involve developing and delivering what will be (to the best of our knowledge) the first multi-state transport infrastructure decision support system in a developing context. The system will aim to support investment decisions and option selection for long distance strategic land transport projects by providing a fast and consistent methodology for comparing the advantages and disadvantages of different project options. As well as covering infrastructure investments, the system will be sufficiently flexible to also allow assessment of changes to the management and operation of long-distance road and rail systems. The project is working at national and international scales, modelling the road, rail and port networks in Kenya, Tanzania, Uganda and Zambia, with a particular focus on strategic freight network development. Initial work is focusing in two areas. Future scenarios for strategic transport networks are being developed covering both exogenous factors such as population and economic development and endogenous factors including infrastructure changes and advances in transport technology. The project is also assembling datasets to represent the transport infrastructure networks across the case study region and the usage of these networks. These datasets and scenarios will form the basis for developing a methodology for calculating sustainability metrics associated with potential transport schemes, including carbon emissions, local air pollution, network resilience and safety. A comprehensive network resilience assessment will be carried out, including the identification of locations

which are exposed to climate hazards and quantification of the risk to transport networks at these points. Finally, the project will build a web-based tool to allow transport stakeholders to explore future scenarios, navigate trade-offs between different sustainability goals and compare transport investments and policies.

Metamorphosis (EU Horizon 2020, in partnership with SCC, from June 2017 to May 2020, and extended with the EU to October 2020). Dr A. Wong. *Contract Holder*: Prof J.M. Preston.

This H2020 project consisted of 13 consortium partners, including seven city authorities in the UK and Continental Europe, who committed to transforming parts of their neighbourhoods from being car-orientated to child-friendly and community-oriented spaces. The partner cities and neighbourhoods comprised a wide variety of demographic and location areas, and each worked with an academic or enterprise partner leading different strands of the project, to help improve local quality-of-life and the physical and mental well-being of their citizens. The seven cities comprised
(1) Graz, Austria; (2) Meran, Italy;
(3) Munich, Germany; (4) Tilburg, Netherlands; (5) Alba Iulia, Romania;
(6) Zurich, Switzerland; and
(7) Southampton, UK, with TRG leading on the 'user analysis and involvement' work package involving all partners, as well as supporting the City of Southampton in local implementations. Each partner city has implemented a series of trials to encourage more 'child friendly neighbourhoods', to show what can be achieved, and expanded on the availability of community shared space, play streets, living laboratories, crystallisation points, and other public space interventions. Benefits include

improved/integrated planning to promote walking and cycling (and sustainable travel generally), instead of using the car, and providing innovative approaches to local urban design, which engages local children and adults as stakeholders and participants in the development and build process, as well as enabling and simplifying city planning procedures for the implementation of child-friendly neighbourhood measures and activities, e.g. as implemented in Southampton. TRG has also provided a systematic review of the interventions and measures that have been applied through different local case studies in the cities, as well as in the development of Implementation 'Fact Sheets' that provide useful indicators for the effort required, impact and cost.

As part of the project, Southampton has benefited from the implementation of several 'School Streets' schemes, beginning with St. John's School in the Old Town, and semi-permanent trials underway during 2020 at Freemantle Academy, St. Mary's Primary, Shirley Junior, Shirley Infant, and Mansbridge Primary Schools. Trial street closures and local community interventions were also implemented in the neighbourhood of Sholing, which resulted in greater levels of walking and cycling, particularly to the local community hub and Valentine School, and reduced car use.

TRG also played a major role in developing the EU CIVITAS 'Four Neighbourhood' Projects conference (online) in October, to share ideas for developing sustainable mobility in local neighbourhoods and communities, which built on the EU INEA/CIVITAS cluster workshop for effectively 'co-creating' urban mobility schemes the previous year.

Example measures and activities implemented as part of Metamorphosis to create child-friendly neighbourhoods

UKCRIC Strand C: Data Analytics Facility for National Infrastructure (DAFNI) (EPSRC from April 2017 to March 2021). *Contract Holder:* Dr S.P. Blainey, jointly with eleven other universities.

DAFNI is a major UK facility which aims to advance infrastructure research. Based at Science and Technology Facility Council (STFC Harwell), DAFNI will host national infrastructure datasets and provide a complex system science driven platform for modelling, simulation and visualisation. These capabilities will be underpinned by the high throughput data interconnectivity and integrated high performance computing facilities required for multi-scale infrastructure system modelling, linked with a unique national infrastructure database. DAFNI will be implemented and tested over the four-year period from 2017 to 2021, enabling significant new advances in infrastructure research and facilitating access to tools and methods capable of addressing real-world challenges at a range of scales. It will therefore provide world-leading capability to support UK research, business and government in infrastructure systems analysis, modelling, simulation and visualisation. The University of Southampton is one of 12 partner institutions overseeing the

delivery and management of the programme, with the university's input being provided by representatives from TRG. As part of the DAFNI programme a virtual reality facility is currently being installed on the Boldrewood Campus which will facilitate a range of research into human-transport interactions.

Multiscale Infrastructure Systems Analytics (MISTRAL) (EPSRC Programme Grant from January 2016 to June 2020). Dr M. Lovric, A.J. Hickford. *Contract Holders:* Prof J.M. Preston, Dr S.P. Blainey, Prof R. Nicholls (Energy and Climate Change), jointly with six other universities and industrial and government partners.

MISTRAL is phase 2 of the Infrastructure Transitions Research Consortium (ITRC), expanding the scale and reach of the NISMOD (National Infrastructure Model) system. ITRC's vision is for complex infrastructure decisions to be guided by systems analysis. Using the pioneering tools developed by the ITRC team, decision-makers are able to visualise and assess how all of their infrastructure systems are performing, help to pinpoint vulnerabilities and quantify the risks of failure. The tools are capable of performing 'what-if' analysis of proposed investments and exploring the effects of future uncertainties, such as population growth, new technologies and climate change. A key feature of the ITRC projects has been a high level of engagement with industry and government, and the modelling tools produced as part of ITRC and MISTRAL have been used by the National Infrastructure Commission, Oxford-Cambridge Arc and England's Economic Heartland among others. Results for these studies have been disseminated widely and have generated interest from a range of stakeholders.

The transport model developed by TRG has undergone further development. The model is centred on building an integrated framework covering capacity, demand and risk, and incorporating a network-based representation of the British transport system, and base year OD matrix for Great Britain. Work is ongoing to incorporate NISMOD onto DAFNI (Data and analytics Facility for National Infrastructure).

ACHILLES (Assessment, Costing and Enhancement of Long-Life, Long-Linear Assets) (EPSRC Programme Grant, July 2018 to December 2022). Dr J. Armstrong. *Contract Holder:* Prof J.M. Preston.

ACHILLES is led by Newcastle University and also includes universities at Bath, Durham, Leeds and Loughborough, as well as the British Geological Survey. TRG is working closely with the Infrastructure Group at the University of Southampton. ACHILLES is focussed on long-linear assets that are critical to the delivery of services over long distances such as road and rail embankments and cuttings, pipeline bedding and flood protection structures. TRG's work will provide economic forecasting and decision support at the network level. More specifically, a model of Whole Life Costs of interventions is being developed and the social costs of service disruptions examined. Risks and uncertainty will be considered using Monte Carlo Simulation within a Bayesian hierarchical structure. A fast track analysis of road and rail infrastructure on the London – Bristol corridor is being undertaken.

Comparative Economic Assessment of Urban Transport Infrastructure Options in Low- and Middle-Income Countries (PhD Studentship, from April 2017, funded by the Vietnamese Government and Faculty of Engineering and Physical Sciences), Minh Tam Vu. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

Powered two wheelers (PTWs) are dominant in mixed traffic environments in developing countries and in particular in East Asia. Furthermore, significant increases in PTWs and Demand Responsive Rapid (e.g. Taxi and Uber) in urban areas pose a challenge to planning authorities and policy makers. A popular solution is to invest in urban public transport (PT) schemes such as Bus Rapid Transit (BRT), Urban Rail Transit (URT) and Monorail. However, many investments in PT have been ineffective. Additionally, there seems to be very little evidence on evaluation methods of motorcycles, cars and public transport to analyse feasibility of a new PT mode. Hence, the main aims of this thesis are to (i) Analyse the feasibility of new PT technologies in mixed traffic environments with a dominance of PTWs; and (ii) Identify the most cost-effective mixed transport system.
To achieve these aims, the research develops a comparative economic assessment for comparing public transport technologies, Demand Responsive Transit and private transport for a local transport corridor. The comparative economic assessment is integrated from four models: Social Cost Model, Incremental Elasticity Analysis Model, Incremental Multinomial/Nested Logit Model and Microscopic Simulation Model.

The completed assessment was applied to compare the existing mixed transport situation and twelve transport infrastructure options with the introduction

of new PT technologies (Bus Rapid Transit, Elevated Metro and Monorail) replacing the whole or part of the existing bus services; and with or without a congestion charge scheme for private transport on the chosen corridor in Hanoi, in terms of three criteria: average social cost, total general demand and PT share. The results show that five options with Bus Rapid Transit or Monorail can be feasible because of lower average social costs. In addition, the Monorail option partially replacing the existing buses in conjunction with a congestion charge scheme might be the optimal alternative based on the three criteria above. Transport planners and decision makers can draw on the findings of this thesis.

Future Funding for Highways (part-time PhD from January 2014) Katherine Tegerdine. *Supervisors*: Dr I. Kaparias, Prof N.B. Hounsell, Dr S.P. Blainey.

The overall aim of this research is to devise and recommend one or more practical and acceptable methods for funding road transport in the UK, in the short/medium term future, given progress towards intelligent mobility and a low carbon transport system. More specific objectives to achieve this aim are to:

1. Evaluate road transport scenarios up to 2050, reflecting all important trends in traffic growth, vehicle composition and characteristics, infrastructure changes, technological developments, legislation, societal changes and so on;
2. Analyse and understand the cost and revenue implications of these road transport scenarios on Governments and road users;
3. Explore and develop new ways of funding transport infrastructure, including new ways of raising the

revenue required to fund the scenarios presented, whilst identifying the impacts of this on all concerned;
4. Make recommendations to Governments on transport infrastructure funding requirements and revenue raising options and implications, on the basis of this research.

Objectives 1 and 2 have been completed, with research currently focussing on objective 3.

Modelling Land Use and Transport Evolution in Port Cities (PhD studentship, from September 2016) Aditya Tafta Nugraha. *Supervisors:* Dr B.J. Waterson, Dr S.P. Blainey.

The urban morphology is a complex system characterised by self-organisation where interactions of multiple agents produce emerging patterns on the urban form. Additional complexities in port cities arise from the port-urban relationship which could either benefit or cause tensions for each other. Most urban cellular automata (CA) models simulate land-use evolution through transition rules with consideration of multiple factors representing the local interactions. Calibration of such models could be seen as a process to measure the effect of each factor. Due to the complexity of the calibration process of urban land use and transport interaction (LUTI) models based on CA, manual methods are often preferred. This, however, limits the insights on urban interactions to a few explored settlements and in turn prevents applications for planning in other port-urban contexts.

This research, therefore, sought to improve the calibration method of LUTI models based on CA and contributed to a better understanding of the dynamics

between port and urban system by quantifying generalizable interactions between urban agents from a wide range of port-urban settlements. This research also illustrated how these interactions in a simulation model can allow long-term impact predictions of planning interventions.

A paper of this research has been awarded the Smeed Prize at the UTSG conference in 2020 for best student paper and presentation.

3.7 Human Factors

Open Flight Deck (OFD) (Innovate UK from March 2017 – March 2020) Dr K. Parnell, R.A. Wynne. *Contract Holders:* Dr K.L. Plant.

Next generation civil aircraft require a step change in the capability of the flight deck to deliver new operational scenarios in a more transparent way. Flight deck technology will need to incorporate the latest developments in computing platform, Human-Machine Interface (HMI), crew aids and pilot interaction technologies. The aim of the Open Flight Deck project is to develop an open, accessible and standardised avionic platform for the flight deck which can support the introduction of such technologies, new software applications and peripheral devices. With the flight crew remaining central to aircraft operations, the project also seeks to develop new crew aids that can both optimise crew workload but also improve situational awareness to extend safe aircraft operations. Further it also seeks to integrate new and existing applications to add functionality, simplify the flight deck, reduce error potential and harness big data opportunities. Working with GE Aviation, BAE Systems, Rolls Royce and

Coventry University, Human Factors expertise is provided in the design and evaluation of these future flight deck innovations.

TASCC (Towards Autonomy - Smart and Connected Control): Human Interaction: Designing Autonomy in Vehicles (HI:DAV) (Jaguar Land Rover (JLR)/ EPSRC, April 2016 to April 2020). Dr K.M.A. Revell, James Brown**. *Contract Holder:* Prof N.A. Stanton

Cars that can drive themselves have been predicted for some time, but they are nearly with us. Highly automated vehicles are likely to be on public roads within the next ten years. The largest gap in our understanding of vehicle automation is how drivers will react to this new technology and how best to design the driver-automation interaction. This project aimed to answer these questions by using Human Factors methodologies to model driver behaviour for level 3 semi-autonomous vehicles. It studied a wide range of drivers with different driving experience in simulators, and in road going vehicles.

During the course of the research the Universities of Cambridge and Southampton worked closely with JLR engineers to ensure that the UK remains at the forefront of technological innovation in vehicle automation. Experiments were carried out to identify how drivers react to this new technology, and provide data on how best to design the driver-automation interaction. Following an iterative design process, an HMI was developed to provide appropriate interactions and interfaces that support the driver.

ComTET2b (Dstl from 2019-2020). Dr V. Banks, Dr J. Clark, D. Fay, K. Pope, S. Hart. *Contract Holders:* Prof N.A. Stanton, Dr K. Plant

The Command Team Experimental Testbed (ComTET) project is a body of work that aims to examine current and future ways of working in submarine control rooms. ComTET2b builds upon its predecessors (ComTET1 and ComTET2) in providing evidence-based recommendations from well-controlled experimental studies to demonstrate the benefits and pitfalls of new team structures, allocation of system functions, ways of working, communication media, interfaces, job aids and work design. The ComTET2b team continue to explore new avenues of work including the investigation of optimal deployment, operation and utilisation of data derived from unmanned underwater vehicles by command teams.

Understanding Informal Rules of the Road and Incorporating this Knowledge into a Communication System for Autonomous Vehicles (PhD Studentship from September 2020): Peter Youssef. *Supervisors:* Dr B.J. Waterson, Dr K. Plant.

With autonomous vehicles (AVs) likely to be on our roads in the next few decades, drivers will become passengers in their vehicles. As such, a growing area of research has developed looking at how these vehicles will interact with human road users. This is due to concern that AVs will not have the capabilities to properly communicate their intentions to other road users, with explicit communication techniques, such as eye contact and gestures, no longer a feasible option. A common school of thought to remedy this problem, is to investigate how road users currently communicate with each other, so that new Human-Machine Interfaces (HMIs) can be better designed in order to replace the existing communication modes. As such, this PhD will begin by looking at how different users communicate with each other in cooperative situations to convey their intentions.

Decision Making in Human Machine Teaming (funded by Thales, PhD from September 2020), Kirsty Lynch. *Supervisors:* Dr K.L. Plant, Dr V.A. Banks and Dr J. Downes.

Accountable decision-making has become specific concern of Thales for operators of Maritime Autonomous Systems (MAS), as decision-making is a key aspect in the safe operation of MAS and the role of the operator has changed significantly due to the introduction of an autonomous system. This PhD project will explore accountable human decision making in human-machine teams, as there is a concern that humans could adopt a position of 'social loafing' (leaving the machine to do all the work). Alternatively, they might do all the work taking over from the machines at every possibility due to lack of appropriate trust. In an ideal situation, human-machine teams would lead to social facilitation, whereby the performance of both humans and machines is optimized. In this instance, human operators will only take control from machines when it is beneficial to do so.

The template of accountable decision making will be used to derive principles for the design of human-machine teams and will include considerations such as task type, trust, workload, and situation awareness. An experimental environment will be constructed to enable exploration of accountable decision making, in which the factors such as number of machine agents, task allocation and workload can be manipulated to discover the effects on decision making. From the results of these experiments a set of design guidelines for MAS decision support

systems will be developed for Thales to implement in their design process of MAS, to support decision-making in human-machine teams.

Training Implications for Drivers of Automated Vehicles (funded by Institute of Advanced Motorists RoadSmart and the Engineering and Physical Sciences Research Council, from September 2019), Siobhan Merriman. *Supervisors:* Dr K.L. Plant, Dr K.M.A. Revell.

Automated Vehicles are expected to bring a huge number of benefits to society. These include improved safety (fewer accidents and traffic law violations), efficiency, and mobility on the road; however, these benefits will only be realised if drivers are trained in how to use them.

When AVs are introduced onto the market, the driver's role will change from an active role of vehicle manoeuvring and control to a passive role of supervising and monitoring the vehicle and the road environment and only intervening (manually controlling the vehicle) when required (e.g. when the automation fails or reaches its limitations). However, the research literature and recent AV collisions suggest that these tasks are challenging for drivers to perform well. For example, in The United States of America, there have been five high-profile collisions involving Automated Vehicles and in the investigations that followed, the driver's inattention to the driving task, the road environment and the operation of the vehicle, their lack of response to the imminent collision and their complacency and over-reliance on the automation were identified as significant causal factors. Therefore, driver training is required to ensure drivers have the appropriate skills to perform their role as a 'co-driver' of an Automated Vehicle.

Most manual driver training programmes are based on the IPSGA (Information, Position, Speed, Gear and Acceleration) system of vehicle control. However, as the nature of the driving task will change when Automated Vehicles are introduced onto the market (see above), a new driver training programme needs to be developed. This PhD project will attempt to address these issues by designing, developing, testing and validating a new training programme for drivers of Automated Vehicles.

Applying a Sociotechnical Systems Approach to Improve Cycling Road Safety and Increase Cycling Participation (funded by Southampton University, from October 2018), Matthew Webster. *Supervisors:* Dr K.L. Plant, Prof N.A. Stanton.

Cycling provides many benefits, such as increased physical health, a positive contribution to the economy and reduction in air pollution. Despite this, cycling still is involved in a constant battle to be seen as a positive activity amongst the media and non-cyclists and cyclists too. On top of this, a huge gender divide with the majority of cyclists being male creates a struggle to ensure that infrastructure is inclusive towards women. Furthermore, the low participation levels of younger children riding a bike to and from school within the UK is considerably small when compared to the Netherlands (2.5% vs 30%). Finally, the number of cycling accidents throughout Britain is worryingly high being around 18,477 in 2016, this number made up around 8% of all modal accidents within the UK which, when comparing the number of cyclists against vehicles, highlights a need for change.

This research begins to tackle cycling by treating it as a system and taking a

sociotechnical approach, by researching into social (News, Social media, Neighbourhoods, Peoples views), technical (legislation, economic, accessibility), hardware (Signs, potholes, roads, cycle lanes, theft/safety) and organisational (Government, Council, Schools, Emergency Services) features of cycling to create a safer cycling Britain and increase participation across all levels of cycling, ages, and gender.

In time this research hopes to join forces with other organisations such as British cycling, local governments and high-profile company's and public figures involved within cycling to allow a stronger reach and implementation of interventions to be tested and improved to allow them to be as effective as possible and provide a strong set of recommendations that can ultimately be used and applied within the UK.

Ready to Take Back Control – Assessing the Optimal Way to Monitor Driver States Using a Variety of Cognitive and Psycho-physiological Methods (funded by Jaguar Land Rover, PhD studentship from October 2017) Sylwia Kaduk. *Supervisors:* Prof N.A. Stanton, Dr A. Roberts.

Automation offers the potential to mitigate or reduce the risks related to driving. However, there are also some new challenges for drivers related to semi-automated driving. Two phases of semi-automated driving that raised concerns of the researchers were a period of automation that requires a monitoring activity from the driver and the take-over of manual control following the automated mode. Topic: the aim of this doctoral dissertation was to propose models of the driver state monitoring in semi-automated vehicles and present data on the psychophysiological changes occurring during the semi-automated driving, as well as the circadian effect on semi-automated driving and driver state monitoring. Methods: fifty-two participants were recruited to the experiment on semi-automated driving. They participated in two experimental sessions day-time session (9 a.m.- 1 p.m.) and a night-time session (10 p.m.- 2 a.m.). They went through the experimental scenario simulating semi-automated driving with phases of manual driving, automated phase, take-over and manual driving. During the experiment their psychophysiological functions were recorded with following measures: electrooculography, electromyography, electrocardiography, respiration belt, electrodermal activity device, oximetry for the pulse and blood oxygenation, their voice was recorded for the acoustic voice analysis, saliva was collected for the hormonal analysis, and four questionnaires were collected at different stages of the experiment. Additionally, electroencephalography was recorded; however, its' analysis was not included in this dissertation. Results: two predictive models were proposed to predict performance after take-over and attention during automation. Analysis of the time-course of the semi-automated driving suggested a decrease of the driving performance after automation associated with increased sleepiness, increased fatigue, decreased readiness to take-over and decreased mental workload. Some physiological changes suggested mental underload. Comparison of the circadian phases resulted in multiple physiological, behavioural and cognitive changes. Conclusions: physiology can be used to predict the driver's performance in semi-automated vehicles; however, the proposed models are not ready to be implemented in the cars. Automation creates a risk for driving safety due to mental underload. Sleepiness and fatigue

present the largest risk for automation monitoring, while suboptimal mental workload and arousal for the safety of the take-over. Circadian phase affects the psychophysiology and performance of the driver; however, the direction of the effects requires further investigation.

Designing Interactions in Automated Vehicles: The Application of Communicative Concepts to Generate Novel Solutions (funded by Jaguar Land Rover as part of the TASCC: Hi:DAV project, PhD studentship, from January 2017) Jediah Clark. *Supervisors:* Prof N.A. Stanton, Dr K.M.A. Revell.

In automated vehicles that require a human driver to be present, the transition of control (whether planned or unplanned) marks a profound vulnerability in the driving-system. As drivers remain 'out-of-the-loop' for an extended period, issues such as loss of 'situation awareness' may occur. Virtual assistants have been proposed as a solution to such issues. However, how and what to present to the driver during these transitions remains unclear, and issues such as safety, usability and user-trust must be considered. This PhD project concluded in July 2020 and provides novel user-interaction solutions that address these issues through iteratively generating design concepts and testing them experimentally. By doing so, a well-considered and refined design has been provided to facilitate the transfer of control between human and automation during automated driving. Further, several design recommendations are provided such as what information should be transmitted, how the user can gain access to more information and how can the interaction be physically designed. The project aims to assist in the design process for modern automated vehicle user-interaction in both industrial and

academic settings, whilst developing our understanding of how natural communication can be applied to technology.

Optimising Steering Wheel Based Controls in Motorsport (PhD (part-time) from October 2017). James W H Brown. *Supervisors:* Prof N.A. Stanton, Dr K.M.A. Revell.

The interfaces of cars within the higher echelons of motorsport are highly complex as a result of the need to be able to maximise performance. However, there are multiple known instances of driver errors occurring, costing them time and, in some cases, loss of control of the vehicle, due to interface design issues. Motorsport is both high-risk and high-cost and drivers are frequently exposed to high cognitive and physical workloads. This combination of factors represents a significant challenge in terms of interface design. Identifying and prioritising the primary usability aspects relevant to racing drivers aids the definition of the unique problem domain. The subsequent application of Human Factors methods to the specific area of steering wheel-based controls aims to optimise control locations, attributes and layouts. This project hopes to generate a hybridised methodology for the creation of idealised interface designs within motorsport. The production of prototype steering wheels based on the methodology's outputs allows experimental testing and validation. The project output should additionally provide insight into the generic design of complex interfaces in high risk/high cognitive load scenarios.

Alternative Safety Management Techniques for Air Traffic Management (funded by NATS, PhD from September 2017). Craig Foster. *Supervisors:* Dr K.L. Plant, Prof N.A. Stanton.

Air Traffic Management (ATM) exists to support the safe and expeditious flow of aircraft through the world's airspace. However, safety in ATM presents unique challenges due to it being a complex and highly coupled socio-technical system of systems. Despite this, ATM has achieved an ultra-safe level of performance. However, ATM is undergoing unprecedented change and a number of new challenges face the industry. New regulations and regulators, new technologies, changing roles for the human, the desire to reduce the environmental impact of air travel and a demand for further cost efficiencies and commercialisation could all affect the ATM industry's commitment to safety. Against this backdrop, ATM needs to ensure that how safety is understood and managed remains appropriate and safety data continues to deliver information about how safe the operation is and provide an alert to changing risks to inform action. This PhD examines the challenges that arise from the way safety is currently thought about in ATM and considers recent advances in safety science as providing an alternative approach which focusses on successfully harnessing the adaptations present within complex socio-technical systems. A review of the safety literature identifies a need to further elaborate how organisations are to practically apply these emerging ideas within the context of an industry which is characterised by standardisation, procedures and regulation.

Whilst the introduction of new technology presents challenges to safety it also presents an opportunity to marry this alternative safety management approach with the use of data generated from the delivery of the ATM service to better understand the adaptations that produce safety. The PhD is expected to explore and contribute to research in this area and bridge the gap between grounded safety theory for complex socio-technical systems and novel techniques for understanding data generated by humans adapting whilst doing work in safety-related domains.

Maritime Command and Control Human-Machine Interaction (sponsored by DSTL and BAE Systems, PhD (part-time) from 2014). Daniel Fay.
Supervisors: Prof. N.A. Stanton, Dr A. Roberts.

Future maritime control rooms will be tasked with handling increased data with potentially less crew. User interfaces have evolved to meet current requirements, but this iterative process has propagated legacy design paradigms that may be unsuitable for future requirements. A new design paradigm for user interfaces may be required to maintain effective performance. Ecological Interface Design (EID) is being explored as a theory-based approach to design new interfaces. Novel user interfaces will be designed and tested to assess their applicability for future maritime command and control.

The Problem of emergence in Sociotechnical Systems: Exploring Individual and Group Dynamic Risk Analysis (DRA) in a Military Diving Fatality (Funded by the Royal Navy, PhD from January 2018) Mark Sanderson. Supervisors: Prof N.A. Stanton, Dr K.L. Plant

Workplace safety risk management utilises both static and dynamic methodologies. While the former is conducted prior to an event or activity, the latter is customarily performed live and in the moment. Where the preparatory risk

assessment is routinely completed by the management or organisational specialists, the onus for dynamic risk analysis rests predominantly with the worker undertaking the activity. Previous research identified seven factors common to DRA and subsequently established a network model. These factors have now been applied to a recent UK military diving fatality through a deductive thematic analysis. Although the post-mortem attributed the cause of death to an undiagnosed heart anomaly, the case illustrates the necessity for DRA in even the most well prepared of activities. The case shows how and where the knowledge of the DRA factors could have helped in coping with the emergent risks. It also offers wider utility and reveals how they could also be used in considering risk in advance of an activity or when reviewing events post-incident.

Ultimately, it is important not to perceive the DRA factors as just another set of rules to be applied. Rather, they complement existing safety management systems and represent considerations to be used when analysing dynamic risk.

4. TRANSPORTATION RESEARCH GROUP PUBLICATIONS 2020

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