ANNUAL REPORT 2016
TRANSPORTATION RESEARCH GROUP

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1. OVERVIEW

The Transportation Research Group (TRG) was established at the University of Southampton in 1967 and has operated continuously since then. It sits within the Civil, Maritime and Environmental Engineering and Science Academic Unit (CMEES) which is part of the Faculty of Engineering and the Environment (FEE). TRG is located at the University's Boldrewood Innovation Campus where the £46 million National Infrastructure Laboratory is currently under construction (see below).

Artist's Impression of the National Infrastructure Laboratory at Boldrewood.

This report covers the research activities within TRG during the calendar year 2016.

TRG academic staff members during 2016 were:

- John Preston, Professor of Rail Transport and Head of TRG
- Nick Hounsell, Professor of Highways and Traffic
- Neville Stanton, Professor of Human Factors in Transport
- Tom Cherrett, Professor of Logistics and Transport Planning
- Mike McDonald, Emeritus Professor of Transportation Engineering
- Ben Waterson, Lecturer specialising in modelling and simulation
- Simon Blainey, Lecturer, specialising in rail transport and modelling.
- Ioannis Kaparias, Lecturer in transportation engineering.
- Bani Anvari, Lecturer, specialising in intelligent mobility
- Katie Plant, New Frontiers Fellow in Human Factors Engineering.

During this period we welcomed Dr Ioannis Kaparias and Dr Bani Anvari. Tom Cherrett was promoted to Professor Logistics and Transport Planning. We said goodbye to Dr Simon Box who left to join Tesla, California.

Research Staff in TRG during 2016 included Dr John Armstrong, Dr Craig Allison, Adrian Hickford, Fraser McLeod, Dr Aaron Roberts, Dr Alan Wong, Dr Kirsten Revell, Dr Alejandro Ortega, Alex Eriksson, Daniel Heikoop and Dr James Pritchard. We welcomed Dr Milan Lovric and Dr James Brown and said goodbye to Dr Jinan Piao. Their research activities are summarised in later paragraphs. **Technical Staff** supporting TRG included Dr Gavin Bailey, Karen Ghali and Daniel Fay. Melanie Hallford continued in her role as **Senior Administrator** for the Group, aided by the arrival of Kelly Carter, with Joy Richardson as administrator for Human Factors projects.

We have a number of 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 of TRL (Transport Research Laboratory); Professor Julian Hine of Ulster University 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 Terence Bendixson, Dr John Schoon, Dr Birendra Shrestha and Dr Mark Brackstone.

We also had over 30 students attached to the Group undertaking PhD or EngD (Engineering Doctorate) research in transport. In 2016, PhD degrees were

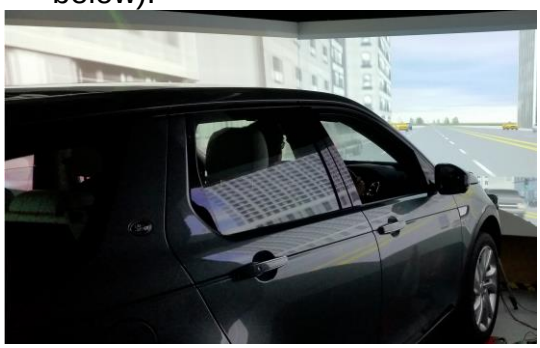
awarded to Anthony Velaquez, Victoria Banks, Ben Norton, Dae Soon Park, Joshua Price and Nicolas Rincon Garcia, with Richard McIlroy being awarded an EngD.

Postgraduate teaching continues to be an integral part of TRG activities, particularly the MSc in Transportation Planning and Engineering. Some 33 new students enrolled in September 2016, both full-time and part-time.

Overall, we have maintained a healthy portfolio of research in 2016, By the end of the year, our research grants and contracts had a total value of over £7 million, with over £4 million of this from EPSRC.

TRG facilities include:

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



The Southampton University Driving Simulator (Mark 2)

- The TRG Instrumented Vehicle (IV) for on-road trials and new garage facility in Building 185 of Boldrewood (see below).

The TRG Instrumented Vehicle.

- Our well-equipped 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.

- Our Outreach activities include demonstrations based on Scalextric and Model Train sets.

Outreach

In 2016, TRG was again very active in delivering high impact public engagement and outreach events, under the direction of Dr Ben Waterson (for Transportation Research) and Dr Alan Wong (for University Public Engagement events). This included:

- Helping to oversee the University's Science and Engineering Festival, which was attended by over 5,000 visitors from the region, and that included opening out the Boldrewood campus to the public for the first time, and providing effective transport links between this and the main Highfield campus, which also showcased our rail research activities through model train sets (see below);
- providing interactive transport research and related activities to

engage the public at the Cheltenham Science Festival, the Glastonbury Music Festival, BBC Countryfile, and the Winchester Science Centre;

- organising the first Southampton City independent TED talk event at the packed 300-capacity Berry Theatre in Hedge End, that showcased local science and humanities ideas;
- running Researchers' Cafés sessions for the University, which highlighted the research being conducted by early-career researchers and postgraduate students;
- acting as the Faculty Champion for the Three-Minute Thesis (3MT) Competition, to improve the science and research communications skills of postgraduate students.

TRG's Model Train Set at the University's Science and Engineering Festival.

2. EXTERNAL ACTIVITIES

The following sections summarise the range of external activities undertaken by TRG Academic Staff members in 2016:

John Preston:

- Member of the Commonwealth Scholarship Commission's Panel of Advisers.
- A member of the Netherlands Institute for Transport Policy Analysis (to March 2016).
- Member of the EPSRC Peer Review College
- External examiner for Masters level courses at Cardiff, Leeds and Newcastle Universities.
- Co-Chair (with Professor Ingo Hansen of the Technical University of Delft) of the World Conference on Transport Research Society's (WCTR) Rail Special Interest Group.
- Committee Member of the International Association of Rail Operations Research (IAROR) and the International Conference on Competition and Ownership in Land Passenger Transport.
- Lead on the Academic Response to the Rail Technical Strategy with respect to customer experience.
- Invited to give presentations to the Chartered Institute of Highways and Transportation (Southampton, 19 January) and Urbanet (Olso, 8 September).
- Co-author (with Xucheng Li) of the Rees Jeffreys 2016 prize for the best paper in ICE: Transport.
- Editorial Board Member: Journal of Transport Policy.

Nick Hounsell:

- Member of the Traffic management and Operations panel of the CIHT's Network and Infrastructure Management Board
- Member of the EPSRC Peer Review College
- Member of ITS EduNet, the European network for education and training in Intelligent Transport systems
- External Examiner for the Transport Masters Course at Napier University
- Academic reviewer of candidates applying for the Transport Planning profession (TPP) qualification
- Expert advisor to Monash University, Melbourne, Australia on a Public Transport priority research project, sponsored by the Australian Research Council (ARC)

Neville Stanton:

- Editor of the peer-review journal Ergonomics
- Member, Editorial Board, Theoretical Issues in Ergonomics Science
- Book series co-editor for Ashgate on 'Human Factors in Defence'
- External examiner for Bachelor and Master level degrees in Occupational Health and Safety at the National University of Ireland, Galway.
- Chair of the The Honourable Company of Air Pilots and the Air Pilots Trust Annual Aviation Safety prize
- Chair of the fourth International Conference on Human Factors in Road and Rail Transportation, 27-31 July, 2016, Orlando, USA.
- Chartered Engineer with the Institute of Engineering and Technology
- Chartered Psychologist with the British Psychological Society
- Chartered Ergonomist with the Institute of Ergonomics and Human Factors
- External expert advisor for Australian Research Council funded rail level crossing project, University of Sunshine Coast, Queensland, Australia.

Mike McDonald:

- Transport Research Foundation Fellow.
- Pao Yu-kong Professor at Ningbo University, China.

- Advisor to the EC WIKI project dealing with the implementation advice for transport innovations.
- Member of several professional and government committees and advisory bodies including the Research Councils.
- Significantly involved with the EC Transport Telematics programmes
- International recognition as an expert in Intelligent Transport Systems.
- Member of the Advisory Board the EC ESPRIT project, which is concerned with the implementation of autonomous vehicles.
- Council Member of the UK Transport Technology Forum, and is supporting MISTRAL in the development and assessment of its Swedish research programme in transport.

Tom Cherrett:
- Member of the i) U.S. Transportation Research Board's, Standing Committee on Urban Freight Transportation (AT025) ii) Editorial Board (Proceedings of the ICE: Transport Journal) iii) Logistics Research Network (LRN) committee iv) IET's (The Institution of Engineering and Technology) Transport Policy Panel.
- External Examiner; MSc Transportation Planning and Engineering course at Newcastle University (2015-2019).
- External Examiner; UG Logistics and Operations Management courses at Cardiff University (2017-2021).
- Invited witness to the Transport Select Committee's session on Urban Congestion 30/1/17.

Ben Waterson:
- Member of the Editorial Board for the Institution of Civil Engineers : Transport Journal

Simon Blainey:
- Secretary of the Royal Geographical Society's Transport Geography Research Group.
- Member of the Rail Research UK Association Executive Committee.
- Member of the EPSRC Associate Peer Review College.
- Co-author of journal paper which won the Lloyd's Science of Risk Prize 2016.

Ioannis Kaparias:
- Honorary Lecturer at the Department of Civil and Environmental Engineering of Imperial College London, with duties involving teaching and student project supervision
- Independent expert for the European Commission on research and innovation activities, acting as an evaluator of proposals and reviewer of running projects for the FP7 and Horizon 2020 programmes
- Elected member of the Executive Committee of the UK Universities' Transport Study Group (UTSG), acting as Honorary Treasurer
- Member of the US Transportation Research Board's Standing Committee on User Information Systems (AND20)
- Member of editorial boards: "Recherche Transports Securité" journal (NecPlus); IEEE Conference on Intelligent Transport Systems
- Co-editor of a special issue of the Transportation Planning and Technology journal, consisting of selected papers from the 47th Annual UTSG Conference

Bani Anvari:
- Contributed to the 8th International Conference on Pedestrian and Evacuation Dynamics, Hefei, China, 17 - 21 October, 2016.

Katie Plant:

- Associate member of the Chartered Institute of Ergonomics and Human Factors (CIEHF)
- Associate Editor for Human Factors and Ergonomics for Manufacturing and Services Industries journal

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. TRG's work is multi-modal and covers both passenger and freight transport, whilst also examining the extent to which information technology may act as a complement or a substitute for transport.

A focus of our research remains on Intelligent Transport Systems, with a growing portfolio of studies on Human Factors in Transport. We also undertake research on a number of other interrelated themes, including bus priority, 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 2016 within different topic areas. Research titles listed in **blue** represent contract (funded) research, whilst those in **green** are studies by Postgraduate Research students (PhD, or EngD).

3.1 Traffic Operations, Management and Control

Traffic Lights: Harnessing Distributed Control Intelligence
(WebScience Institute and CobaltOtter, November 2016-July 2017). *Contract holder:* Dr B. Waterson.

Modern urban traffic light control systems control thousands of traffic signals, but their core algorithms are based on first principles developed in the early 1980s. In many cases therefore they cannot reflect modern trade-offs between delays to different vehicle streams. While it is often shown that humans can out-perform current algorithms for a single road junction, the interactions between people controlling close proximity junctions where the decisions of one controller affect the situation faced by others, has never been formally investigated.

The Web enables users to experience issues from new standpoints, and researchers to understand how users respond in such situations, both individually and collectively. This project therefore creates a proof-of-concept of an interactive traffic simulation where road junctions are simultaneously and independently controlled by multiple humans in real time. Providing players with a bird's eye view of approaching vehicles enables them to experience the complexity of balancing everyone's needs at a junction, not just their own desires; analysing the red / green light decisions that they want to make in response to this view enables a better understanding of their priorities and what they perceive as a 'fair to all' system; and recording communications and interactions between users controlling adjacent junctions will form the basis of research into the next generation of real life traffic light control algorithms.

Monitoring and Evaluation of Managed Motorway Schemes (EPSRC and Mott MacDonald Ltd. EngD Studentship, from 2008 to 2016). Mami Jennifer Ogawa. *Supervisors:* Prof N.B. Hounsell (University of Southampton), R. Meekums (Mott MacDonald Ltd.)

Managed Motorway schemes aim to address congestion and improve Journey

Time Reliability (JTR) by utilising a set of advanced Intelligent Transport Systems applications to make as much use of the available capacity as possible. This research used substantial new databases from managed motorways to explore capacity, driver behaviour, lane utilisation and other features of managed motorways, including variants such as 'Through Junction running' and 'All-lane running'.

Optimising Urban Parking Operations (PhD studentship, from October 2011 to 2017) Chris Charles. Supervisors: Dr B.J. Waterson and Dr S. Box

The imperfect interactions between parking supply (spaces and costs), parking demand (durations) and parking behaviour (searching) create inefficiencies in the system that lead to traffic congestion, economic costs, increased pollutant emissions and increased frustration amongst drivers. Other transport sectors (most noticeably air travel) however have established strategies for optimally aligning supply and demand through web based 'pre-booking' systems.

This research is therefore considering the practical, environmental and economic consequences of operating an equivalent pre-booking style system for private car-parking in urban areas, addressing issues such as deterministic/stochastic durations of stay, search strategies of non-booked drivers, revenue optimisation, capacity utilisation and modal shift.

A pre-booking parking system arguably contradicts current sustainable transport policy as it potentially enhances the attractiveness of the private car to access the town centre. However, with a pre-booking system in place, it becomes evident to travellers when they will be unable to park their car close to their intended destination, encouraging mode shifts to public transport or trip-retiming effects. Prior knowledge of parking availability can therefore have a significant benefit on patterns of movement within urban areas and hence reduce the consequential economic and environmental costs.

Benefits with Changing Penetration of Autonomous Vehicles (part-time PhD student from February 2015). A. Graham *Supervisors:* Prof T.J. Cherrett, Prof N.B. Hounsell

Self-driving (autonomous) and connected vehicles are being developed at a pace in terms of automotive and sensor technology. But the deployment of them within a legacy fleet of conventionally driven vehicles is less clear. A specific problem is the trajectory of benefits – such as improved capacity – from zero penetration to full penetration. This project will research how benefits change over time with penetration of vehicles to produce guidance for traffic management systems.

Improving Automatic Incident Detection Algorithms (ESPRC and Siemens, PhD Studentship, from July 2016). Jonathan Evans. *Supervisors:* Dr B.J. Waterson, Prof T.J. Cherrett (University of Southampton), Dr Andrew Hamilton (Siemens).

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 will be created that can learn the patterns between the traffic state and context by analysing historical data. An AIDA with this insight will then be able to 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 Bus Operations and Priority

Exploring New Bus Priority Strategies at Isolated Vehicle Actuated (VA) Junctions (EPSRC, PhD Studentship, from October 2010). Bashir Ahmed. *Supervisors:* Prof N.B. Hounsell, Dr B. Shrestha

Priority to buses at traffic signals is very effective in improving bus speeds and reliability, thus improving passenger service quality and operational efficiency. Research in to priority strategies in Urban Traffic Control systems has been extensive in recent years, so this study has focussed on isolated traffic signals under Vehicle Actuated (VA) control, where little new research has occurred since the SELKENT study in London in 1987. The research has involved devising new control strategies for VA junctions taking advantage of new detection possibilities, and evaluating these strategies both mathematically and using the microscopic simulation model VISSIM.

The Improvement of Bus Networks Based on GIS Technology (PhD Studentship, from October 2013).Yuji Shi. *Supervisors:* Dr S.P. Blainey, Prof N.B. Hounsell,)

A fundamental way to solve today's urban traffic problems is to prioritize the development of public transport. However, today's bus networks are still not perfect. In the UK outside London, privatization and bus deregulation have contributed to some problems concerning bus network structure, fares, demand, and service quality. The aim of this research project is therefore to use Southampton as a case study to diagnose its current bus system, to find out its weak areas and problem lines, and to explore the corresponding improvement methods which could be applied. This service improvement problem is solved by making use of an optimisation technique, the tabu search algorithm, developed under the environment of ArcObjects for Java.

Evaluation of Bus Performance Using Advanced AVL Data: (PhD Studentship from Sept 2012), Mahesh K Dhakal. Supervisors: Prof N.B. Hounsell and Dr B. Shrestha)

Automatic Vehicle Location (AVL) data is used in bus transit for a number of reasons including performance evaluation. In London, this is available on 8,000 buses using their iBus system. A range of studies have been conducted in the past to evaluate bus performance, such as 'Headway Regularity' and 'On-Time Performance'. This research is focussing on Bus Journey Time *Variability* (JTV), an important performance measure in the Mayor of London's aspiration to provide consistent journey times for all road users. Research is also analysing passenger 'Excess Waiting Times (EWT)' – a key performance criterion currently used by Transport for London (TfL). In particular, the large databases across a number of bus routes are allowing correlation analyses to be undertaken between JTV and EWT, to assess the extent to which these performance criteria are compatible.

3.3 Energy & Environment

LSTF Case Study on Carbon Impacts and Congestion Relief (DfT, from

August 2013 to January 2016). A.J. Hickford, Dr A. Wong, K. Ghali, Prof I. Williams. *Contract Holder*: Prof J.M. Preston

This case study analysed the extent to which Local Sustainable Transport Fund (LSTF) schemes have an effect on carbon impacts and congestion relief across three UK regions, by using a longitudinal cohort survey, and building on experience gained from the iConnect project. TRG has been taking the lead in monitoring and evaluating the extent to which these schemes have reduced carbon emissions and/or generated modal shifts towards sustainable travel, including walking, cycling and public transport, working in partnership with Solent Transport, Transport for Greater Manchester, Leicestershire County Council and Loughborough University. Follow up travel and behaviour data was collected in 2014/15, and compared to previous baseline data as carried out in the five treatment areas (Rochdale, Hyde, Coalville, Eastleigh, Gosport) and also compared to similar surveys in three control areas (Wigan, Hinckley, Locks Heath). The results, which include complementary (secondary) traffic data and enriching qualitative focus group data from the respondents, have been reported and reviewed with the DfT, and are due for inclusion in their publications in 2017.

Centre for Sustainable Travel Choices

(Solent Transport and SCC, from September 2012 to August 2015, part extended to March 2016). Dr A. Wong, A.J. Hickford, K. Ghali *Contract Holder*: Prof J.M. Preston

The Centre is a partnership between Southampton City Council, the University of Southampton and Sustrans, that aims to promote local sustainable and active travel, whilst suppressing private car use. It oversees the work related to two Local Sustainable Transport Fund (LSTF) bids and a Better Bus Area Fund (BBAF) bid, with the University leading on the monitoring and evaluation of the physical interventions and travel behaviour change schemes. Follow up surveys of respondents' travel behaviour and attitudes in and around the City, and how they had been affected by the schemes were conducted by 2015, and compared against baseline information gathered by 2013, along with secondary data on traffic flows, measures of congestion and public transport usage, as well as other (external) survey data. The before-and-after results published in 2016 showed some encouraging changes in sustainable travel behaviour in terms of difference-in-differences in distances travelled, but the results were less than that originally anticipated at the outset. A follow up survey involving an MSc student conducting his dissertation was conducted in 2016, and the comparison with the previous years is due to be completed in the early half of 2017. In addition, a Horizon 2020 submission (Metamorphosis project) involving the City Council that looks at how car-oriented neighbourhoods can be transformed into children-friendly spaces achieving behavioural change and increase in the quality of life was submitted in 2016, and this has since been awarded.

Evaluation of thermal management emission abatement technologies on Southampton Buses

(Southampton City Council, from July 2015 to March 2016). Dr A. Wong, Dr D. Laila. *Contract Holder*s: Dr S. Box, Prof J. Preston

This research was funded by the Department for Transport's Clean Bus Technology Fund and was undertaken in conjunction with First Group. The performance of Selective Catalytic Reduction prior to fitment of thermal management technology was assessed using First Southampton's Route 7 buses as an experimental test bed, which involved tailpipe measurements using a

Horiba OBS 2200 Portable Emission Monitoring System and J1939 CAN data captured from the bus engines using a specially-adapted telematics unit. Before and after on-road trials were conducted over different vehicles, and the results showed some interesting findings in terms of the effectiveness in using Selective Catalytic Reduction for operational buses, which are being published in 2017.

Towards a Verifiably Robust Cycle Microsimulation Model (EPSRC DTC PhD Studentship, from October 2012). Chris Osowski. *Supervisor*: Dr B. Waterson, Dr S. Box

Quantitative tools are widely used to evaluate the effectiveness and value for money of schemes both before and after implementation. Tools for motorised traffic and pedestrians are widely available but this is not the case for cyclists. Additionally, the core behaviours of cyclists which would inform such a model are also poorly studied. This project aims to develop and validate a model for bicycles with the aim of enabling the modelling of interactions between bicycles and ultimately with other modes. Such a model would have application to shared-space and common highway scenarios and would form the basis of economic scheme evaluation tools.

Developing tools to determine the environmental impact of transport interventions (EPSRC and Southampton City Council, EngD studentship, from October 2012 to 2017). Matthew Grote. Supervisors: Prof I.D. Williams (Centre for Environmental Science), Professor J.M. Preston and S. Kemp (Centre for Environmental Science).

Road traffic is an important source of greenhouse gas (GHG) emissions and other air pollutants detrimental to air quality. These emissions are exacerbated in urban areas by the stop-and-go nature of congested traffic conditions. Therefore, when relevant authorities make decisions regarding changes to a transport system (transport interventions), quantifying the impact on emissions from road traffic is essential. The only practical method to quantify emissions at road network level (e.g. a city's road network) relies on Road Traffic Models (RTMs) to simulate vehicle movements, and Emissions Models (EMs) to calculate resulting emissions. Currently the EM options available to relevant authorities are simple models based on vehicle average speed that do not fully account for the impacts of congestion; or more complex models that do account for congestion, but are excessively resource intensive. This research is developing a new EM that can predict emissions from road traffic at network level, including the important influence of congestion, whilst avoiding the complexity that would render it impractical as a decision support tool for relevant authorities. A survey of Local Authorities has been undertaken in order to scope the new EM, induction loop data on vehicle traffic operations have been collated and data on over 500 GPS based driving cycles have been collected. A Practical Emissions Model for Local Authorities (PEMLA) has been calibrated and tested .Southampton City Council (SCC) is the industrial sponsor for this project, and the background to their involvement is SCC's ambition for Southampton to be a world-leading low-carbon city, and a desire to know how transport can contribute to realising this ambition.

3.4 Freight & Logistics

Freight Traffic Control 2050 (transforming the energy demands of last-mile urban freight through collaborative logistics) (EPSRC, from 2016 to 2019). F.N. McLeod, K. Ghali. *Contract Holder:* Prof T.J. Cherrett.

Freight transport currently makes up around 16% of all road vehicle activity in our cities and by 2030 the EU would like to see largely CO_2-free logistics systems operating in our urban centres. With van traffic predicted to increase by 20% in London by 2030, and slow uptake of electric or alternatively-fuelled goods vehicles, more radical strategies are needed to reduce the numbers and impacts of freight vehicles in our cities.

Working with some major parcel carriers in London, this project is examining the potential for closer operational collaboration between carriers to reduce urban traffic and energy demand whilst maintaining customer service levels, and evaluating to what extent such relationships can develop naturally within a commercial setting or whether a third-party 'Freight Traffic Controller' would be needed to ensure equitable distribution of demand across a city.

Delivery and Service Plan Project (Southampton City Council, from 2014 to 2017). Gavin Bailey, *Contract Holder:* Prof T.J. Cherrett

Assessments undertaken by Public Health England have indicated that up to 6% of all mortalities in urban centres may be attributed to poor air quality, recognising freight vehicles to be a major contributor to this. Ten Air Quality Management Areas (AQMAs) have been identified across Southampton where the air quality has fallen short of the minimum standard expected under EU Legislation. To address these issues, Southampton City Council has commissioned work from TRG to provide Delivery and Servicing Plans to public bodies and private businesses across these areas to help them re-appraise their delivery and servicing strategies to reduce freight impacts.

Delivery and Servicing Plans (DSPs) were developed by TfL as part of their Fleet Operators Recognition Scheme (FORS) to encourage businesses to consider the road network and air quality impacts of their vehicle logistics operations on the local environment. A DSP requires an independent audit of core goods and service activities using surveys, interviews and desk analysis of procurement and delivery records for a standard operating period. It then quantifies the daily freight and servicing activity (arrival times of vehicles by activity type, the duration of visits (loading/ unloading/ servicing), the recipient department and size and urgency of items). It also identifies the background to the procurement processes which lead to the generation of orders and freight activity.

To date, this project has engaged with and delivered DSPs for public organisations (NHS IoW and University Hospital Southampton, Southampton Solent University, University of Southampton) and private sector organisations such as DP World, ABP, Steve Porter Transport Group, Old Mutual Wealth and West Quay Shopping Centre. Notable ongoing works are as follows:

NHS Isle of Wight (IoW) Trust: The key recommendation for the NHS IoW Trust was the implementation of mainland consolidation for all goods-in, with an integrated delivery round to distribute medical supplies to the main hospital (St Mary's), and the outlying clinics on the island. The concept, which represents the first of its kind in the UK, is currently under negotiation, and would use the local council funded Sustainable Distribution Centre (SDC) located outside of Southampton City on the M271.

University Hospital Southampton NHS Trust: Following the DSP recommendations issued to the University Hospital Southampton NHS Trust (UHS), the University of

Southampton has provided continued support and research into the development of sustainable medical supply for the hospital, including: economic and environmental appraisals for the consolidation of medical goods, assessment of the benefits that could be achieved through the offsite location of outpatient pharmacy services, and usability assessments for hospital storerooms to identify key areas for improving the management of inventory.

The aim of these measures is the cumulative reduction of freight travelling to and from the hospital, thereby reducing the volume of vehicles on Southampton's urban freight network, and improving local air quality.

Sustainable Fleet Management: As part of ongoing internal DSP assessments at Southampton City Council a review of the council's vehicle fleet is being undertaken. This work seeks to audit the current utilisation of the council's vehicle fleet, and identify and appraise the use of electric vehicles for council services ranging from internal couriers, to parking wardens and service engineers. The expected output of this research is recommendations for adopting electric vehicles and related infrastructure to enable their implementation within specific areas of the council's fleet operations.

CITYLAB (EU Horizon 2020, from 2015 to 2018). F.N. McLeod. *Contract Holder:* Prof T.J. Cherrett.

The CITYLAB project is based on the concept of using cities as laboratories for experimentation in the area of goods transport. Southampton is one of seven cities testing various freight initiatives, along with Brussels, London, Paris, Oslo, Rome and Rotterdam. At the University of Southampton, our aim is to reduce the amount of freight transport that large municipal organisations generate through their purchasing of goods and services, by identifying opportunities for consolidation (e.g. of orders, suppliers, supply chains). One option is to use the Southampton Sustainable Distribution Centre at Nursling, operated by Meachers Global Logistics, as a consolidation point for incoming goods. We are also liaising with other local municipal organisations (e.g. Southampton General Hospital, Southampton City Council and Southampton Solent University) to investigate opportunities for joint procurement and consolidation to reduce environmental impacts. On-going work is looking at the scope for consolidating halls post to students living in halls of residence across the city and how consolidating pharmacy supplies might reduce transport impacts to hospitals.

Selection of Low Carbon Technologies for Heavy Goods Vehicles (EngD studentship, from October 2010, awarded 2016). Anthony Velazquez. *Supervisors:* Prof T.J. Cherrett, Dr B.J. Waterson, Mr P. Holdsworth (Martin Brower)

This research investigated the ways in which adopting various alternative vehicle, powertrain, fuel and refrigeration technologies could positively contribute to decarbonizing food logistics fleets. The work undertook economic, environmental, operational and technological appraisals to determine the optimal combination of low carbon technologies for more efficient fleet operation using the logistics fleet of a major UK fast food chain as a case study. More sustainable freight with vastly reduced carbon emissions could minimise costs, while at the same time improve energy security and waste management, mitigating volatility of fuel prices and other negative externalities of road haulage such as the impact of transport on global warming and air quality emissions.

Time-Dependent Vehicle Routing Problems for Flexible Logistics (PhD studentship sponsored by the Government of Colombia, from October 2013, awarded 2016). Nicolas Rincon Garcia. *Supervisors:* Dr B.J. Waterson, Prof T.J. Cherrett.

The vehicle routing problem (where, in the basic formulation, a set of N_v vehicles must be assigned to visit N_L locations with the minimum total route length) is one of the most widely studied theoretical problems in logistics. The basic formulation however is almost never applicable in reality and therefore over the years, many variations have been proposed, including for example capacity constrained problems for heterogeneous vehicle fleets, time constrained 'delivery window' problems which restrict the freedom of the schedules, and congested network problems which attempt to reflect time variant travel times between locations.

Unfortunately, despite this attempt to make theory better reflect reality, theoretical models are often poorly suited to especially smaller or atypical logistics operations as they do not reflect the real constraints imposed by unpredictable real life scenarios. This research developed improved implementations and approaches for better utilising existing algorithms.

Capacity and Demand Assessment Models for Container Ports (PhD studentship from January 2016). Manuel Buitrago. *Supervisors*: Prof J.M. Preston, Prof T. Bektas

This research project develops new maritime transport models to assess capacity and demand for container seaports in the United Kingdom. These consider competition both in terms of long- and short-haul maritime transport and in terms of hinterland transport within the UK.

The project helps to understand better the role that the UK's port system plays in global logistics networks. The geographical scope comprises initially the British ports. Nevertheless, the models will be applied in a later stage to the Hamburg–Le Havre range seaports, examining how they compete for traffic in heavily contested hinterlands.

In addition, demand side modelling will be used to determine supply-side responses within the system of systems modelling framework developed by ITRC-Mistral. Container throughput capacity will be assessed by considering navigation channels, berths, cranes, storage and onward links.

3.5 Future Technologies

SMArt CitIES Network for Sustainable Urban Futures (SMARTIES Net) (ESRC Newton Fund from May 2016 to April 2017) Contract Holder: Dr S.P. Blainey

This multi-institutional project, led by the University of Nottingham, brings together a team of academics and policy makers from the UK and India to create a Smart Cities Network which will develop future thinking and new approaches to increase the sustainability of selected cities in both countries. Through networking events, workshops and entrepreneur competitions it will focus on addressing the big issues faced by urban planners and governors including traffic congestion, affordable housing, the provision of accessible, resilient and future-proof infrastructure for clean water and sanitation, transport and energy, and waste management and recycling while ensuring all citizens have equal access to and participation in a city life which is safe, secure, inclusive, healthy and desirable. It aims to forge a sustainable community of researchers to develop innovative, future-proof and locally-acceptable solutions to the challenges faced by cities in India and the UK. TRG

is providing strategic transport modelling expertise to this network.

Incorporating a structured user-centred design process in mobile apps for transportation (Innovate UK and EPSRC under the KTP scheme, with City University London and Cubic Transportation Systems, from October 2016 to August 2017). *Contract Holder*: Dr I. Kaparias

Digital journey planning has become an important part of the travel experience. Increased proliferation of mobile devices, coupled with transport data being made available by authorities under an 'open access' model, has created a multitude of websites, apps, and technological platforms that are used by travellers. In particular the use of mobile apps is increasingly becoming a key component of mobility, with travellers and operators alike recognising their benefits in making trips quicker and more efficient.

Design research, naturally, is central to this trend, and has been recognised as an important means to improving customer experience. A widely used design approach in the computer science field is the so-called "User-Centred Design" (UCD), which places end-user needs, rather than engineering goals, as the starting point and as the central driver of system design requirements. UCD also defines an iterative process, through which these user needs can be embedded into both system functionality and user interface. When it comes to the development of transport mobile apps, however, examples of a structured, well-defined UCD process are rare, with the approach adopted usually being largely "ticket-oriented" and often prioritising system interoperability and the demands of numerous stakeholders over the needs of end-users.

The objective of this project is, hence, to create a mobile transportation app prototype within a structured and methodical UCD process in order to give user needs a more central role in the design. This approach holds the potential to make digital services, such as journey planning, more responsive to user habits and needs, as demonstrated in other domains such as healthcare and e-commerce. This in turn will make user interactions more efficient, benefitting the individual traveller, but also the transport system as a whole.

Green Adaptive Control for Future Interconnected Vehicles (G-ACTIVE) (EPSRC from March 2016 to February 2019). Dr C. Allison. *Contract holders:* Prof N.A. Stanton, Dr B. Anvari

The project targets a significant reduction in fuel consumption, CO_2 and NOx emissions in passenger and light duty road vehicles. This will be achieved by implementing new Energy Management control systems that are inclusive, predictive and adaptive.

CITYMOBIL2 (European Commission, from 2012 to 2016). Dr J. Piao, Contract Holder: Prof M. McDonald, Prof N.B. Hounsell

CityMobil2 was a European project under the Seventh Framework Programme for Research and Technological Development. It started in September 2012 and ran for four years. The main objective of CityMobil2 was to implement large-scale pilot platforms for technical and socioeconomic test and validation of automated transport systems (ATS) in urban environments by demonstration and evaluation in cities with different socio-economic conditions. During the project, large scale Demonstrations of ATS were carried out in Lausanne in Switzerland, La Rochelle in France and Trikala in Greece. These demonstrations also allowed CityMobil2 to undertake research focusing on technical, financial, cultural and behavioural aspects, as well as assessing ATS's potential effects on land use policies and how new systems

could fit into existing infrastructure in different cities. The project had 47 partners including local cites for demonstration, manufacturers of automated road transport systems, and academic/research institutions. TRG was mainly responsible for defining the evaluation process and for cross-site evaluation of the systems implemented– see: http://www.citymobil2.eu/

Transport Systems Catapult: University Partnership Programme **(**TSC from 2015 to 2017) Dr S Box, Dr A Wong, Dr B Anvari; Contract holder Prof N.B. Hounsell

The Transport Systems Catapult (TSC) set up a Universities Partnership Programme (UPP) in 2014/15, involving eight Universities actively working in Intelligent Mobility (IM) and who cover the different geographical regions in the UK. The University of Southampton is covering southern England and is undertaking three main activities: (i) *Knowledge Exchange: Seminars and Workshops:* Activities include workshops on knowledge exchange and transfer on IM involving staff from the University, the TSC and relevant industry players in the South of England (ii) *Knowledge Exchange through secondments:* This involves secondments of research staff and students to the TSC and potentially secondments of TSC staff to Southampton and (iii) *User needs for education and training in IM.* These activities are focusing on two of the TSC Business Unit themes – (i) Autonomous Transport Systems, with Southampton taking a leading role in maritime transport and (ii) Modelling, where one major activity at Southampton is the development of a traffic control testbed using open source software. The aim here is to support the evaluation of new traffic control strategies in traffic streams containing connected and autonomous vehicles. See www.tscatapult.org.uk

Designing public transport travel information that meets the travellers' information needs, according to the fourth rule of citizenship (EngD studentship from October 2013, sponsored by EPSRC and Southampton City Council). Amanda Haylett. *Supervisors:* Prof T.J. Cherrett and Dr G. Wills (Electronics and Computer Science)

In 1977, The National Consumer Council expressed that among the rules of citizenship, information provision must conform to two fundamental principles; (1) continuous access to information to assist in the decision making process and (2) the necessary support and advice that can convert that information into effective action. In line with this particular rule of citizenship, the aim of this research is to stipulate the best approach for satisfying this fourth rule. To do this the research will breakdown what travel information is, how it has developed in light of rapid technological advancement in delivery. Moreover, it will draw conclusions on how well we are meeting this fourth rule of citizenship through present day travel information provision techniques such as journey planners. The outcome of this research will be the production of specific travel information delivery standards to both ratify present day solutions, and improve future information delivery strategies.

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

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'. Though electric vehicles (EVs) currently 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.

Mitigating range anxiety and reducing energy consumption in drivers of electric vehicles (iPhD student from October 2015). R. Deacon. *Supervisors*: Prof N. Stanton, Dr K. Plant. Industrial sponsor: Jaguar Land Rover.

Range anxiety, or a driver's lack of confidence in an electric vehicle's ability to complete a specified journey, is considered to be the primary barrier to the purchase of battery electric vehicles (BEVs). However, most new BEVs have a range of 100 miles, whilst the average UK driver travels just 25 miles per day (National Travel Survey 2013). In order to reassure the motoring public, the driver requires accurate and user friendly feedback so as to be able to maximise the economy of the BEV, maximise range and boost user confidence. A series of studies are planned in the Southampton University Driving Simulator (SUDS) that will investigate a variety of different information presentation methods and their effects on driving performance. The project aims to test the effects of new driver interfaces that will be developed with the aims of reducing range anxiety and minimising energy consumption. It is expected that this project will help recognise the potential of BEVs in the development of Sustainable Infrastructure Systems.

Optimising Wireless Electric Vehicle Charging Locations (iPhD student from October 2015). L. 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 infinitely, dependent upon sufficient charging infrastructure. While much research has taken place examining the optimal location distribution of traditional (plug-in) charging points however, the optimal distribution of wireless charging infrastructure, both in isolation and in combination with plug-in systems has received little analysis.

This research therefore seeks to create a modelling framework that - given the inputs of a network, driver requirements and the infrastructure capabilities - can attempt to optimize the distribution of both wireless charging systems and plug-in charging stations within the network. The project also 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. The interaction environment between the driver, vehicle and infrastructure has been identified as the key component of

the system and achievable energy transfer efficiencies are dependent upon such aspects. Further exploration of these factors, both as individual entities and as a wider concept, will be undertaken to assess methods that can be applied, considering the global aim of maximising transfer efficiency.

Integrating Automated Vehicles Into The Transport Network (EPSRC CDT in NGCM Studentship from September 2015) Craig B. Rafter *Supervisors*: Dr B. Anvari, Dr B.J. Waterson. *Sponsors*: EPSRC and Transport Research Laboratory.

Recent government investment in driver-less car trials is accelerating us towards a future of greater automation in the transport network. As a direct result of this investment, investigating how transportation infrastructure can sustainably support high numbers of automated vehicles in the network is imperative.

Existing transportation infrastructure is designed around non-automated vehicles. This includes not just the road-space, but also the many thousands of traffic sensors, the control infrastructure (traffic lights, variable speed limits), the refuelling infrastructure and the integration between modes of transport (airports, train stations etc.). This research investigates strategies to redesign infrastructure to support automated vehicles and deliver improvements in sustainability.

This research considers scenarios ranging from low to high numbers of automated vehicles in the transportation network using computational modelling, and experiments on simulated and instrumented vehicles. Ultimately, the outcome of this research will be innovative new designs to transportation infrastructure - with a strong evidence base - that will support automated vehicles to maximize sustainability in the transport network.

Rocket trajectory prediction problems (PhD Studentship, from July 2014) Willem Eerland. Supervisors: Dr A. Sobester (Computational Modelling Group), Dr S. Box (Tesla Motors)

When it comes to accurately simulating a rocket's trajectory the simplest rockets can pose the greatest challenge. This is because unguided rockets are at the mercy of the atmospheric and small errors in their thrust and aerodynamics, making their trajectory highly uncertain. This sponsored project will involve combining six-degree-of-freedom aeronautical simulations with stochastic modelling, applied probability and pattern recognition to make predictions about trajectories. Models will be validated by flying test rockets as unguided rockets are a cheap and effective way of deploying sensors into the atmosphere. Balloon launched rockets can potentially reach very high altitudes at low cost. Also, some terrorists have access to simple unguided rocket based weapons. Military and civil law enforcement agencies require software tools to predict likely launch points for these weapons in order to protect important infrastructure, for example airports, military bases and Olympic stadia.

3.6 Rail

T2F: Track to the Future – Economic and environmental modelling (EPSRC Programme Grant from June 2015 to May 2020). Dr A. Ortega, Dr J. Armstrong. Contract Holders: Prof J.M. Preston, Dr S.P. Blainey.

This programme grant follows on from the previous research programme Track21 project, and will involve further research based on some of the key outputs from Track21, as well as addressing additional research questions with the aim of delivering improved

railway infrastructure performance. 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 will address 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 will involve 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 so far has focused on life cycle cost and carbon modelling of the installation of under-sleeper pads on two UK case study routes.

Developing Integrated Tools To Optimise Rail Systems (DITTO)

(RSSB, September 2014 to September 2017). Dr J. Armstrong, Dr S. Box and Dr B. Anvari. Prof C. Potts (Maths) and Prof T. Bektas and Dr A. Kovacs (Management). *Contract holder:* Prof J.M. Preston.

Building on the OCCASION project, DITTO is continuing the process of developing optimisation formulations, algorithms and processes that make better use of existing capacity without compromising service reliability. It is part of an industry wide initiative called FuTRO (Future Traffic Regulation) and is related to the development of in-cab signalling and the adoption of the European Rail Traffic Management System (ERTMS). It has the following four key components: (i) Development of optimisation tools that maintain safe operating conditions and do not exceed theoretical capacity limits. (ii) Quantification of the trade-offs between the provision of additional train services and the maintenance of service quality so as to develop working timetables that optimise capacity utilisation without compromising service reliability. (iii) Combination of dynamic data on the status of individual trains to produce an optimal system-wide outcome in real time. (iv) Use of Artificial Intelligence to examine tractable solutions to real-time traffic control.

It involves a consortium of three Universities (Southampton, Swansea and Leeds) and there is industrial support from Arup, Siemens Rail Automation and Tracsis.
The work at Southampton is focussed primarily on computer modelling. Analytical methods are being developed to calculate capacity utilisation indices and relate these to the propagation of delays, with encouraging initial results. These will in turn be used to optimise train timetables using a stochastic version of the job shop scheduling algorithm, which is being developed in parallel. A dynamic simulation model, Tracula, developed by the University of Leeds and based on their car following model, Dracula, will be used to adjust train running speeds in real time. This micro-simulation will be linked to a macro-assessment of the network, based

on solutions to the Multi-Commodity Network Design Problem.

These tools will be combined in public domain software called OnTrack developed by Swansea University which will also incorporate safety analyses. The results in terms of the dynamic rescheduling of trains will be compared with what train signallers/dispatchers do in real situations. For road traffic, such expert controllers often outperform existing algorithms. In such cases, machine learning tools can be used to produce new algorithms which can outperform human controllers over an extended period. This will be tested in the rail context.

Very Light Rail Shuttle Between Dudley's Tourist Attractions (RSSB from June 2016 to January 2017) Contract holders: Dr M J Fernandes De Pinho Lopes, Dr S Blainey, Prof J Preston, Prof W Powrie, joint with University of Warwick and industrial partners.

This research project is undertaking a feasibility study for a Very Light Rail shuttle service connecting three tourist attractions in Dudley: Dudley Zoo, the Black Country Museum, and the Dudley Canal Trust visitor centre. The project is being undertaken in conjunction with the University of Warwick and several industrial partners, with the study covering all aspects of scheme construction and operation. If constructed, this would be the first UK application of a number of technologies associated with Very Light Rail systems.

Improving Customer Experience While Ensuring Data Privacy ('DICE') (EPSRC, September 2016 to August 2019. Dr J. Pritchard. *Contract holder:* Dr S.P. Blainey, joint 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.

A New Station Demand Forecasting Model for Wales (Welsh Government, January 2015 to August 2016). *Contract holder:* Dr S.P. Blainey.

Building on previous rail demand forecasting research undertaken at TRG, this project involved the recalibration of 'trip end' rail demand models previously developed for England and Wales, making use of Geographically-Weighted Regression. As part of this process the models were also extended to take into account the destinations served by trains from local stations in the forecasting process. Following calibration the new models were used to produce passenger forecasts for a range of proposed new railway stations across Wales.

Understanding Passenger Loadings and Providing Better Information (Govia Thameslink Railway (GTR), November 2016 – December 2018) Dr J. Pritchard, Dr K. Revell. *Contract Holder:* Prof J.M. Preston

This project builds on the earlier RRUKA funded work looking at the use of passenger loading data to influence behaviour and mitigate crowding. It is funded as part of Future Rail's TOC'15 initiative.

On the basis that providing better crowding data to passengers seems desirable, the first aim is to identify the most suitable data sources for counting passenger numbers. A range of data sources have been obtained, which vary in terms of accuracy, cost and other practical limitations (for example, not all sources can be read in real-time), and work is ongoing to assess their relative merits. It may be that an optimal solution is found by using some combination of the available data sources.
The second aim is to develop the methods used to accurately predict passenger loadings from the data available, developing algorithms and working with GTR's appointed third parties to ensure that they can be implemented.
The final aim is to determine how best crowding information should be presented to the travelling public and to implement a small-scale trial in order to further assess the benefits.

Integrating data sources to enhance the experience for passengers with special needs through privacy aware mobile applications (RRUKA, September 2015 to November 2016). Dr J. Pritchard. *Contract holder:* Dr S.P. Blainey, joint with University of Surrey and Loughborough University

The project explored issues related to the provision of personalised journey information for rail passengers through mobile applications for both customers and station platform staff. Specifically, it: 1) examined from a human perspective what specific problems are experienced by passengers with special needs and/or disabilities when they are making rail journeys, particularly where disruptions occur; 2) assessed how different data feeds from ATOC, TfL, and Network Rail could be used to provide integrated personalised journey information for particular passengers; 3) identified ways in which the location of a particular passenger on board a train can be determined, in order to optimise the provision of personalised information and passenger assistance services; and 4) explored the trade-offs between data privacy and an improved, personalised rail journey experience. As part of this work prototype apps were produced to demonstrate the passenger localisation methods investigated during the project.

The Use of Passenger Loading Data to Influence Behaviour and Provide an Improved Experience for Passengers and Operators alike (RRUKA, October 2015 –November 2016) Dr J. Pritchard. *Contract Holder:* Prof J.M. Preston

This project, undertaken in partnership with Govia Thameslink Railway (GTR), used Stated Preference survey methods to understand how rail passengers might respond to information provided about crowding levels. Crowded trains can adversely affect the experience of rail passengers. They can also cause practical issues for train operators, especially if slow boarding and alighting at stations makes it hard to maintain tight dwell times. It is thought that some of these issues can be mitigated by providing better information to passengers and encouraging them to make different travel choices as a result. At one level, the choice of carriage on a particular train is important – by spreading passenger loading more evenly throughout a train, it may be possible to reduce the number of instances of overcrowding. At another level, the choice of train itself is important. If passengers can be encouraged to travel on alternative, more lightly loaded, services this will also help to mitigate some of the problems. An increasing number of data sources for

monitoring train loading are becoming available, including on-train systems which can estimate the number of passengers in a given carriage. Methods of communicating with passengers are also becoming more sophisticated, with an increased use of real-time information systems and a high proportion of smartphone.

The main aims of this project are to prove that it is feasible to mitigate crowding by improving information provision and influencing passenger choice, and to understand how such information should best be presented.

Improving Quality of Rail Service in Kuala Lumpur, Malaysia (PhD Studentship, from October 2008). Siti Nurbaya Ab Karim. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey

Passenger Boarding and Alighting surveys have been undertaken to gauge optimal headway, optimal fleet size, optimal vehicle capacity and optimal pricing based on an economic optimization approach. The number of *KTM Komuter* train sets required has been examined using the ROMAN-D software based on both the actual and design operating service frequencies. As a result, a better *KTM Komuter* Working and Public Timetable has been identified. The key results of the O-D surveys depicted that there were high possibilities for the integration of Non-Motorized Transport (NMT) and Public Transport (PT) with mode splits of 21% walk and 40% PT for access and 39% walk and bicycle and 32% PT for egress. Descriptive analysis resulted in the corresponding access-egress walk distances for the commuters who walked to and from the rail stations (892 m and 623 m). The corresponding mean access and egress travel distances including PT were 15.0 km and 13.1 km, respectively. The resulting values of the Generalised Journey Time were high suggesting the importance of these determinants in deterring passengers from choosing *KTM Komuter* as a main mode of transport. For the results of the Attitudinal surveys, both the overall service quality and level of service were mostly rated as being fair by the *KTM Komuter* passengers. Improving parking facilities, increasing train efficiency, people services and space comfort were the main components in the KOMIQUAL models that best defined high quality *KTM Komuter* service among *KTM Komuter* users.

It was found that the number of *KTM Komuter* passengers per hour for seven time periods differed widely. The optimal fleet size, optimal vehicle capacity and optimal pricing resulted in two categories of peak period for Inbound services, namely 0630 – 1230 and 1630 – 2130 and these should be designed with the fleet sizes of 28 and 21 sets respectively. Three categories of peak period for Outbound services were noted, namely 0630 – 0930, 1000 - 1300 and 1600 – 2100 and these should be designed with the fleet sizes of 28, 26 and 33 sets respectively. A capacity of up to 249 seats per set, including standees, should be provided for Outbound services 1600 – 2100. By contrast, a capacity of up to 161 seats per set, including standees, should be provided for Inbound services 0630 – 1230. The optimal price is estimated to be RM1.83. This is slightly lower than the average fares per boarding from 2008 to 2013 ranging from RM1.90 in 2011 to RM2.40 in 2013. It is suggested that new *KTM Komuter* fares for the Klang Valley sector should be structured based on the current operating cost per day per passenger-km of RM0.21.

These models produced optimised service patterns (train frequency and capacity) and fares. A practical operating service headway should be 10 minutes during 0500–1630 hours and 15 minutes during 1630–2235 hours for both ways. This will provide an economically

efficient operation and an adequate quality of service.

Modelling Railway Station Choice Using Geographical Information Systems (GIS) (PhD studentship, from October 2014). Marcus Young. *Supervisors:* Dr S.P. Blainey, Professor J.M. Preston.

This project will explore the factors that influence railway station choice decisions made by passengers, and apply this improved understanding to update methodologies used in the planning of new and existing railway services and networks. Station choice is often treated in a fairly simplistic manner in industry demand forecasting methodology, with access and egress distance usually the only influencing factors considered and passengers assumed to choose the nearest station to the ultimate origin or destination of their trip. However, recent research suggests that the choice of station is a far more complex process than this, with many other interrelated factors potentially involved.

Social Total Costs Associated With The Development of High Speed Rail Using Saudi Arabia as a Case Study (PhD from September 2016). Hamad Almujibah. Supervisors: Professor J.M. Preston, Dr S.P. Blainey.

The main aim of this research is to understand how the total social costs of high-speed rail (HSR) can be minimised with objectives of determining total operator cost, total user cost and total external cost for different demand levels. Moreover, other objectives will be included such as comparison of total social costs of HSR with other modes (classic rail, coach, car, and airplane) and determining of an appropriate HSR network for Saudi Arabia. The system in Saudi Arabia is used as a particular case-study and will be compared with different systems and models. The research will involve questionnaires and use of data from Saudi Arabia (regarding its existing rail network), helping to understand issues of costs and demands, and making comparisons with developed systems in different countries.

Improving Pre-trip Information About Transfer-involved Rail Routes (PhD from October 2013). Yiwei Guo. *Supervisors*: Prof J.M. Preston, Dr S.P. Blainey.

With the development of information and communications technology, rail passengers' experience of punctuality and reliability relies increasingly on the available passenger information.

Although passenger information is viewed as an important influencing factor on customer experience and rail patronage, the quality of the pre-trip information about certain transfer-involved, delay-sensitive routes (called 'critical routes') is often disregarded due to the limitations of current technologies. On the one hand, the accuracy of pre-trip timetable information is prone to train delays and cancellations. On the other hand, real-time disruption alerts contribute little to the pre-planning of the transfer activities involved in a given journey and the relevant activities before and after the journey.

This research explores the possibility of improving rail passengers' experience of punctuality and reliability by improving the pre-trip information about these transfer-involved (critical) routes. A methodological framework is proposed that incorporates the identification of critical routes in a given railway network, the adjustment of the pre-trip information about the identified critical routes, and the evaluation of the potential effect of these adjustments on passengers' experience of punctuality and reliability. A case study of Britain's passenger rail system is being conducted, and the empirical results illustrate the efficiency

and effectiveness of the proposed methodology.

3.7 Transport and Infrastructure Policy

Multiscale Infrastructure Systems Analytics (MISTRAL) (EPSRC Programme Grant from January 2016 to June 2020). Dr M. Lovric, Mr A.J. Hickford, Dr J. Pritchard. *Contract Holders:* Prof J.M. Preston, Dr S.P. Blainey, Prof R. Nicholls, joint 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 our NISMOD system. ITRC's vision is for complex infrastructure decisions to be guided by our systems analysis ability. 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 to inform their National Needs Assessment.

Work at TRG is focusing on enhancing the transport models developed during ITRC phase 1. This centres on developing an integrated framework covering capacity, demand and risk, and incorporating a network-based representation of the British transport system. The scope of the model will also be extended to cover key international linkages. Tasks include generating a base year OD matrix for Great Britain, parameterising transport interventions and policies for inclusion in the model using the best available evidence, constructing a flexible network-based national transport model, developing meta-models or emulators to represent local transport within this model, and integrating risk and resilience modelling into the wider framework.

TRG staff members are also involved in other MISTRAL work, aiming to adapt and apply the systems-of-systems infrastructure assessment capabilities to other locations including developing countries, rapidly developing city-states, and post-conflict, post-disasters contexts. Together with researchers from Oxford University, and in collaboration with the United Nations Office for Project Services (UNOPS), a series of open-source analysis tools known as NISMOD-Int is being developed for the application of evidence-based decision making to developing countries. The initial focus has been on the infrastructure needs of Palestine, and a 'fast-track' report will be completed during the first half of 2017.

A Comparative Assessment of Modal Shift Policies in the Passenger Sector in Korea. (PhD Studentship from September 2011, awarded 2016, funded by the Korean Government), Dae-Soon Park. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

The Marco Polo Programme in the EU was launched in 2003 to stimulate modal shift from trucks to trains or ships. There may be potential for similar Modal Shift Policies (MSPs) in the passenger sector. This research focussed on the questions: 'What is an effective MSP from the car to public transport in the passenger sector in South Korea?', 'What is the best combination of MSPs?', and 'What factors influence the transport mode

choice of commuters?" The main MSPs considered were: a commuting cost subsidy for public transport users, additional parking fees for car users, and congestion charges for car users.

In order to investigate the relative effectiveness of these policies, stated preference data were obtained from 767 respondents, who work in the Gangnam area of Seoul, through an online survey that took place in early 2013. A full factorial design was used for the purpose of the survey to estimate the main effects and interactions without correlation. Various binary standard logit models with alternative-specific and generic covariates were developed to identify the effectiveness of MSPs and understand what factors affect people's mode choice decisions. In order to overcome limitations of standard logit by allowing for random taste variation, mixed logit models are also developed. In addition, through various models both without and with interaction terms, the modal shift effects of the combined MSPs, as well as a single MSP, are compared. According to the change of allocation ratio of two combined MSPs (e.g. subsidy 0% : parking 100% → subsidy 10% : parking 90%), the market share of travel mode was also evaluated to understand interaction terms. This research offers numerical evidence of negative modal shift synergy effect for combinations of the three MSPs.

With a view to forecasting the modal shift effects of socio-economic groups and a more deep understanding of the characteristics of each group, segmentation methods were used. An equity impact analysis of MSPs has been conducted to obtain the Compensating Variation Per Person (CVPP). In addition, the ratio of the CVPP to the average income of each income group is calculated to judge whether each MSP is a progressive or regressive policy. The expenditure and revenue of MSPs are calculated. In addition, how revenue from MSPs should be spent in order to achieve a better transport system is considered.

Integrated Vulnerability Assessment of Transport Networks in Seoul Capital Area, South Korea. (PhD Studentship from September 2014, funded by the Korean Government), Wonman Oh. *Supervisors:* Prof J.M. Preston, Dr S.P. Blainey.

Transport networks can be unavailable suddenly due to natural disasters or intended attacks, even though transport networks are ubiquitous infrastructure in a modern society. Suspended transport networks may cause a considerable travel cost from the perspective of the whole society as well as an individual traveller. The primary purpose of this research is to assess the vulnerability of public transport networks with integrated analysis between railway systems and road networks in the Seoul Capital Area (SCA), Korea. Reflecting personal preferences to transport modes and routes in disrupted Seoul Metropolitan Railway Systems (SMRS) through an online survey, an integrated impact of a disruptive event on SMRS both SMRS and the adjacent road networks will be identified. Furthermore, this research will suggest management strategies to increase resilience of the transport networks in the SCA and to recommend a guideline to travellers in disrupted situation.

Low cost, Infrastructure Free Forms of Indoor Localization (PhD Studentship, from January 2012 to 2017) Shashank Gupta
Supervisors: Dr Simon Box, Prof R. E. Wilson (Bristol University)

Despite innovative research in indoor positioning, it is still not in the mainstream. In trying to trace the reasons, we identify two main reasons: (1) An indoor positioning application may require aisle-level precision (2) While

such precision is attainable with pervasive radio based systems – Wi-Fi, however they come at a prohibitively high cost, mostly in the form of meticulous (signal) calibration. Therefore, this research aims to develop a self-contained low cost infrastructure free form of indoor positioning solution.

Recently smartphones have redefined the notion of mobile computing platforms. Ever improving features of affordability, ubiquity, and portability, increased sensory and computational power along with low power consumption fuelled by readily available batteries, have opened up a number of interesting applications. One such application is location based application. Therefore, this motivated us to use smartphone for our research. Primarily this research will investigate the techniques/algorithms that can assist in locating the position of the pedestrian based on the contextual information collected by several sensors in the smartphone.
Moreover, this research will also be aimed to understand the movement pattern of the pedestrian. The smartphone's sensory signals would be collected and analysed. Various machine learning algorithms would then be employed to identify whether the pedestrian is walking, running, jogging, standing, going straight, turning, etc. based on the collected sensory signals - accelerometer and heading measurements.

Road Infrastructure Requirements and Funding for Intelligent Mobility and Low Carbon Transport (part-time PhD from January 2014) Katherine Tegerdine. *Supervisors*: Prof N.B. Hounsell and 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:

- 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;
- Analyse and understand the cost and revenue implications of these road transport scenarios on Governments and road users;
- Explore and develop new ways of funding transport infrastructure, including new ways raising the revenue required to fund the scenarios presented, whilst identifying the impacts of this on all concerned;
- Make recommendations to Governments on transport infrastructure funding requirements and revenue raising options and implications, on the basis of this research.

A Dynamic Analysis of the Economic Impacts of a Major Port on its City, South Korea (PhD studentship funded by the Korean Government, from September 2015) Jongjoon Song. *Supervisors:* Prof J.M Preston, Dr S. Blainey.

This research aims to get a better understanding of the dynamic changes over time in terms of the economic impacts of the port industry; especially, major container ports in South Korea. To be specific, this research focuses on the changes in the relationship between the proportion of the container traffic handled in a major port and the economic impacts on its city over time. In order to evaluate the economic impacts of major ports (Busan, Gwangyang, Incheon, and Ulsan), this research

compares the annual performance of gross value-added (GVA) and GVA per worker among regions at the level of the metropolitan city or the province during 25 years from 1990 to 2015. Shift-share analysis is applied to show the relative changes among 4 major ports and its cities compared to other 12 cities or provinces. Furthermore, this research will analyse the statistical significance of the economic contribution of major container ports with the econometric model based on the augmented Solow's growth model by Mankiw et al. From the results, this research will suggest the major characteristics in terms of the economic contribution of port industry and supply several recommendations for port policy in South Korea.

Transport Planning in Port Cities (PhD studentship sponsored by the Education Endowment Fund, Republic of Indonesia, from September 2016). Aditya Tafta Nugraha. *Supervisors:* Dr B.J. Waterson, Dr S.P. Blainey.

With the exception of modern specifically created 'superports', most of the world's major ports are located at the heart of urban areas (indeed the growth of the surrounding city is often a result of the port location). While such proximity to an urban area enables the plentiful supply of workers and accommodation facilities for travellers through the port, it also provides large challenges to enable ports to handle increasing throughput of goods and travellers without overloading the likely already congested urban transport system. This research therefore seeks to review port-city situations around the world, to investigate issues such as constraints on port operations, impacts on urban traffic networks, best practices on port-city transport scheduling, operation, and coordination, as well as the consequences for the economic benefits of port-city prosperity.

3.8 Human Factors

i-VISION (EU, from October 2013 to October 2016). Dr K. Plant *Contract Holder:* Prof N. Stanton

The i-VISION project aims to support the design and validation of aircraft cockpits, through the exploitation of knowledge-based immersive virtual reality technologies. During the development of the i-VISION platform, it would be of primary focus to facilitate the knowledge existing in several individual components of the cockpit, using a semantic approach for developing the virtual environment. A range of simulation issues will be addressed including:

- Analyse connections between elements of the cockpit in respect to various operating conditions and procedures.
- Visualize the operator's workflow. Analyse the frequency and allocation of tasks within the cockpit.
- Augment virtual cockpit with semantic annotations. Add intelligence and knowledge to the VR-based simulation of cockpit operations. Virtual objects should be more than a set of faces and vertices. Need to go beyond the current state of scene-graphs, where only geometries exist and no knowledge.
- Create a virtual scene-graph as a knowledge data-base. Currently no logical or functional knowledge exists behind virtual objects.
- Consider the special simulation requirements of different operation conditions (e.g. landing, extreme weather, and increased air-traffic).

The project working cycle will be based on a closed loop between the human pilot, the modern virtual aircraft cockpit interfaces and the operating conditions.

Human Factors of Highly Automated Driving (HF Auto) (EU Marie Curie ITN from June 2014 to June 2017) Alex Eriksson, D Heikoop. *Contract holder:* Prof N. Stanton.

The main concern is that with highly automated driving, the human operator becomes a supervisor rather than a manual controller, introducing out-of-the-loop problems such as deskilling and loss of situation awareness. Difficult Human Factors questions will have to be answered, such as: how to present the operators with the right information? what are the effects on accident risk and transport efficiency, and who is legally responsible?

TASCC: Human Interaction: Designing Autonomy in Vehicles (HI:DAV) (Jaguar Landrover/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. Our project will answer these questions by using Human Factors methodologies to model driver behaviour for level 3 semi-autonomous vehicles, then studying a wide range of drivers with different driving experience in simulators, or test-tracks and in road going vehicles.

During the course of the research the Universities of Cambridge and Southampton will be working closely with JLR engineers to ensure that the UK remains at the forefront of technological innovation in vehicle automation. We will have answered the questions about how drivers will react to this new technology and how best to design the driver-automation interaction. The success of vehicle automation design will be on designing appropriate interactions and interfaces that support the driver. Our research will be essential to that success.

Future Flight Deck Technologies (Innovate UK (formally TSB) from 2014-2016) Dr K. Revell. Dr C. Allison. *Contract holder:* Prof N.A. Stanton

This project aims to develop new pilot-centred interface technologies to improve situation awareness, decision making and improve the availability of aircraft in adverse weather. A further major objective is to develop novel system architectures which will allow for the safe and expedient operation of commercial aircraft with a reduced number of crew.

Comet (BAE Systems from 2014-2017). Dr A. Roberts, D. Fey. *Contract holder:* Prof N. A. Stanton

Command team's face the challenges of increasing amounts of data coupled with more automated systems and reduced manning. The future of effective decision making in these teams will be dependent upon high quality empirical evidence from well-controlled experimental studies with high statistical power that can clearly demonstrate the benefits and pitfalls of new team structures, allocation of system functions, ways of working, communication media, interfaces, job aids and work design.

Encouraging Eco-driving with Multisensory Feed-forward and Feedback Information (EngD studentship sponsored by EPSRC and Jaguar Land Rover, from October 2011, awarded 2016). Rich C. McIlroy. *Supervisors:* Prof N.A. Stanton, Prof J.M. Preston.

The way in which a car is driven has a significant effect on the amount of fuel that is used. Given the issues of the over use of resources and the emission of large volumes of carbon dioxide (and equally damaging pollutants), the aim of this project is to encourage energy-

conserving driving behaviours through the design of an in-vehicle information presentation system. While there have been a number of studies investigating the use of visual tools to help drivers save fuel, with varying success rates, each of these tools carry with them the issue of visual distraction. Considering that usage of the accelerator and decelerator pedals is a haptic task (i.e. of or relating to the sense of touch), can we provide information haptically to guide the driver's behaviour? To address these questions, a driving-simulator based study is planned that will make use of variety of different information presentation methods, including visual, auditory and haptic information, and all combinations thereof. Theoretical justification and design rationale find basis in the principles of Ecological Interface Design, an approach to design rooted in Gibsonian ecological psychology.

Human Factors in the Design of Traffic Management Systems (EngD studentship from October 2011, awarded 2016). Joshua Price. *Supervisors:* Prof N.A. Stanton, Dr B.J. Waterson (University of Southampton), Mr I. Snell (Siemens).

This research project investigates the potential benefits a human factors design approach can have when applied to the development of the next generation of traffic management systems. The systems used by Traffic Management Centres to manage congestion were assessed in the early stages of the project using Event Analysis of Systematic Teamwork (EAST) based on observational data. Focus was then shifted to the specific tools used to validate SCOOT controlled traffic signals, with Cognitive Work Analysis (CWA) used to assess the existing textual tool and develop a graphical alternative. The project's final stages are concerned with testing this new design empirically.

Automatic Cars are Safer and more Efficient (EPSRC and Jaguar Land Rover Ltd. EngD studentship, from October 2011, awarded 2016). Victoria Banks. *Supervisors:* Prof N. Stanton, Prof J.M. Preston, Mr D. Robertson (Jaguar Land Rover Ltd.)

With systems design plagued by criticism for failing to adequately define the role of the human operator within the system as a whole, there is lasting concern amongst the Ergonomics and Human Factors community that automated sub-systems in driving may contribute to safety concerns rather than overcome them. Failing to acknowledge the role of the driver in an automated vehicle system may lead to undesirable behavioural adaptation as a result of inadequately controlling for the changing role of the driver within the control-feedback loops. Adopting a systems-theoretic approach, this project aims to address the issues surrounding task sharing between the driver and automated subsystems by analysing the interaction that takes place within the driving system at different levels of automation in a simulated driving environment.

Application of a Systems Approach to Driver Distraction from In-vehicle Technology (EngD studentship sponsored by EPSRC and Jaguar Land Rover from October 2013). Katie J. Parnell. *Supervisors:* Prof N.A. Stanton and Dr K. Plant (University of Southampton) and D. Thomas (Jaguar Land Rover Ltd.)

Technologies are increasingly entering road vehicles, offering secondary functions alongside the primary driving task. The variety of activities available to the driver are multiple, however their nature of being available to the driver while on the move also make them likely to have adverse effects on driver safety. The presentation of information on in-vehicle interfaces requires careful

consideration by manufacturers in order to prevent advances in technology from having adverse effects on driver safety. A systems approach is applied to the issue to identify all elements within the road transport system that play a role in developing and allowing the presentation of information that could be potentially distracting to the driver. Rather than focusing blame on the driver, as is the traditional approach, this project assesses the broader elements within the socio-technical system that facilitate driver distraction. This hopes to bring a novel approach to the issue and highlight elements higher up in the causal chain that play a part in distraction related incidents through facilitating technology use in vehicles.

Latent Error Detection & Recovery in UK Naval Aircraft Maintenance (PhD funded by Royal Navy from October 2013). Commander Justin Saward. *Supervisors:* Prof N.A. Stanton, Prof J.M. Preston

Human error is the most significant factor in aircraft accidents for both military and civilian aviation organisations. A task carried out in error creates a latent condition that can result in a future undesirable outcome if the error is not detected later. Detection of typical latent errors, post-task completion, has been observed amongst UK naval air engineers and is reported to be a result of some seemingly spontaneous recollection of past activity. Despite an extensive literature review, the nature and extent of this phenomenon is not understood fully and appears to be an under-researched area; causes of error and proximal error detection having been researched widely. To research this phenomenon, the systems view of human error has been combined with a multi-process approach to post-task latent error detection (LED). Early findings suggest that distributed cognition across the entire socio-technical system may be influential and that time, location and systems cues appear to account for LED amongst naval air engineers who have experienced the phenomenon. Since the concept of human error has broad applicability, it is anticipated current research will benefit the wider community interested in safety resilience using a systems approach to minimise the consequences arising from latent error.

Who's in control? Lessons from human-human interaction applied to Human Computer transfer of control (PhD funded as part of HFAuto - Human Factors of Automated Driving PITN-GA-2013-605817 from June 2014). Alexander Eriksson. *Supervisor:* Prof N.A. Stanton, Dr S Box

This work will develop a human-machine interface (HMI) supporting the operator of the future highly automated vehicle. The interface shall intuitively guide the operator during platooning and transient manoeuvres such as joining or leaving a platoon, lane changes and merging. The new HMI shall support human-to-vehicle instruction (setting and changing of automation modes and driver preferences) as well as multimodal (e.g. visual, haptic, and auditory) vehicle-to-human semantic information and status feedback (e.g., about automation status, change of automation mode, and environmental information like road infrastructure and surrounding vehicles) during highly automated driving.

4. TRANSPORTATION RESEARCH GROUP PUBLICATIONS

2016

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