University of Nottingham
UK | CHINA | MALAYSIA

University of Nottingham
UK | CHINA | MALAYSIA

Transport, mobility and cities

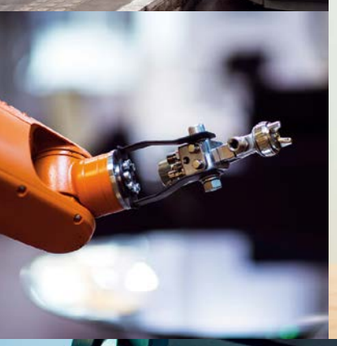
A comprehensive guide to capabilities

Find out more:

TMC@nottingham.ac.uk

nottingham.ac.uk/research/groups/tmc

Published November 2018. FRM322473



Contents

Foreword

The University of Nottingham is at the forefront of smart transport and mobility innovation within a Future City context. Our activity spans the whole University, and includes the Faculty of Engineering and the Schools of Computer Science, Psychology, Philosophy, English, History as well as the Business School. Through this strong and established internal network we share knowledge, learning and data to develop holistic solutions across the transport, mobility and cities domains.

Future transport modes within our future cities will require new forms of physical, civic and digital infrastructure to enable mobility. These must be designed in new and innovative ways, using smart materials, urban planning principles and be citizen-centric to promote healthy, productive living environments. Journeys within and between cities will be seamless, with integrated ticketing where transport information and modes are based on intelligent systems and data. Travel within the city will be resilient with smart and multiple modes of transit supported. To realise this future, innovators, academia and government will need to work together in order to transcend traditional silos. Implementing solutions will require understanding and acceptance within industry and wider communities.

In January 2018 the University of Nottingham was the second of only six universities to sign a Deep Academic Alliance with the Transport Systems Catapult – a three year framework for a strategic relationship.

Over the last year, the University of Nottingham and the Transport Systems Catapult have worked in close partnership to articulate Nottingham's existing research capabilities across transport, mobility and cities, and define how we can work with national and international stakeholders to deliver value through a number of propositions.

Drawing on teams across the University, this activity has been led by myself – a specialist in positioning and navigation technologies and leader of our Transport Research activities, Sarah Sharples – a Professor in Human Factors, Intelligent Mobility research leader and non-executive board member of the Transport Systems Catapult and Dr Lucelia Rodrigues – an expert in environmental design and sustainability and Future Cities research leader. Our multi-disciplinary leadership team has enabled a truly integrated approach to developing our world-leading expertise in this diverse area.

This Capability Statement presents breadths of expertise at Nottingham and creates a strong, visible platform for Transport, Intelligent Mobility and Smart City research and innovation.

Professor Terry Moore
Director of the Nottingham Geospatial Institute

Professor Sarah Sharples
Professor of Human Factors and Pro-Vice-Chancellor for Equality, Diversity and Inclusion

Dr Lucelia Rodrigues
Associate Professor, Sustainable and Resilient Cities Lead

Our research themes and partner collaborations

This document outlines the capabilities and skills of Transport, Mobility and Cities at Nottingham. It captures the breadth of our expertise and acts as a guide around areas in which we are actively seeking collaboration or can offer expertise.

- Architecture, Culture and Tectonics Research Group
- Automated Scheduling, Planning and Optimisation Research Group
- Buildings, Energy and Environment Research Group
- Centre for Additive Manufacturing
- Centre for Environmental Geochemistry
- Centre for Structural Engineering and Informatics
- Composites Research Group
- Computer Vision Lab
- Estates Department – Sustainability
- Energy Technologies Research Institute
- Fluids and Thermal Engineering Research Group
- George Green Institute for Electromagnetics Research
- Horizon Digital Economy
- Human Factors Research Group
- Institute for Aerospace Technology
- Intelligent Modelling and Analysis
- Laboratory for Urban Complexity and Sustainability
- N/Lab
- Nottingham Business School
- Nottingham Centre for Geomechanics
- Nottingham Geospatial Institute
- Nottingham Transportation Engineering Centre
- Power Electronics, Machines and Control Research Group
- Propulsion Futures Beacon
- Resilience Engineering Research Group

About smart transport and mobility innovation

By 2025, the global Intelligent Mobility market will be worth

£900bn

which corresponds to about 1% of the projects global GDP

Source: Intelligent Mobility: a Global Market (Transport Systems Catapult, 2016)

By 2025, the UK faces a potential skills gap of

742,000 people

in the Intelligent Mobility sector

Source: Transport Systems Catapult (Intelligent Mobility Skills Strategy 2016)

By 2020, the Smart Cities market is projected to grow to over

$750bn

an increase of 20% per year since 2015. Europe is currently the largest market at almost $130bn

Smart City Strategies: A Global Review (Future Cities Catapult, 2017)

Place

The movement of people and goods cannot be separated from their specific physical and social contexts. By focusing on the place, our work situates transport within the complex socio-economic geography of urban systems at different scales, from the siting and urban design of physical infrastructure, the form of cities themselves, through to the urban modelling of entire national networks.

We also undertake research on many key aspects impacting on, and integrated with, geospatial engineering and science, utilising a diverse range of scientific disciplines including geodesy, remote sensing, engineering surveying and GIS.

Successful places support attractive, smart multimodal transport options, and are an integral part of healthy, sustainable cities.

Collaborations

Engineering | Architecture and Built Environment | Geography | Computer Science

Theme leads

Dr Nicole Porter
Architecture, Culture and Tectonics, Faculty of Engineering

Dr Chris Hill
Nottingham Geospatial Institute, Faculty of Engineering

Example project

SMART Campus

The University has opened up its campus to enable students, academics and businesses to examine and evaluate user behaviours and to trial smart concepts including bike and car share schemes and an active travel dashboard.

We have focused on the understanding of campus and user patterns by analysing positional data in conjunction with evidence gathered through interviews and focus groups. This will lead to a more efficient inter-campus bus service with demand-led provision being the end goal. We are working in partnership with Atkins and Nottingham City Council to explore how learning and innovation from the University's Smart Campus can be scaled up across the wider urban area.

Capabilities

Source: The 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UN DESA)

Urban planning and design for health

Capabilities in this area include the study of health-based metrics and design criteria is conducive to both indoor and outdoor environmental quality. This change in quality can be measured through physical, physiological and psychological well-being in the differing environments. The area of environmental science and psychophysics focuses on the quantitative and qualitative study of the relationships between people and their perception of the environments that they inhabit. The current research activities in this area focuses on the human physical and physio-psychological response to different stimuli and how this can shape responses to the built environment. This research moves the design and planning away from the 'one size fits all' approach that currently exists, to a more tailored approach which recognises the difference between individuals.

Mobility and connectivity

Our research in this area focuses on the development of sustainable, safe, responsive and resilient spaces. Our capabilities help to ensure that these areas are enjoyable places to work and study, through the use of digital technologies and innovative use of open data. This can help to ensure that mobility and connectivity are enhanced and are available to as many users as possible.

We are able to use the University campus as an extension of our research in this area. The University of Nottingham campus in many ways serves as a small city – it has both residential and office areas, its own transport and health services, retail outlets, sports facilities, car parking, security, waste collection and energy generation network. We have used our campus to complement our research into this area and enhance our capabilities into mobility and connectivity. The campus is an ideal vehicle to observe, test and evaluate user behaviour and can trial Smart City initiatives, which can then be scaled up to advance and improve urban environments.

Integrated urban models

The capabilities in this area include the sustainable and smart development of transport infrastructure which identifies ways to invest in sustainable development that embraces innovation and new technology. This process supports a healthy society and respects the environment which is vital for the future development of urban models. This framework can also provide a more sustainable method of managing transportation infrastructure including assets such as road and rail.

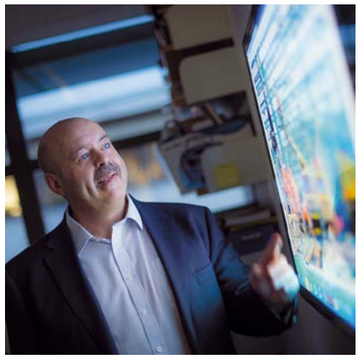
Our capability in driving this systems-led approach will help shape an integrated, intelligent, safe, environmentally conscious and accessible transport network for future cities.

The development of modelling methods, including transport models – in which we have an in-depth knowledge – will help to shape future sustainable urban living through improved planning and prototyping.

Place-based solutions

The University's expertise in the analysis, understanding and development of place-based solutions draws upon expertise in architecture, urban design, urban planning and landscape design. This enables us to provide a multi-disciplinary approach to our research that can emphasise the uniqueness and importance of place in our understanding of both existing places – and also with the development of new places within our urban and rural environments.

Our philosophy in the creation of place-based solutions centres around the celebration of and creation of unique places that are connected, accessible, diverse and inclusive. The focus of our research is therefore always upon understanding people and communities to enable this work to feed into the development of meaningful and place-specific solutions.



Urban design scale

The University of Nottingham has a long history and strong international reputation for its expertise in the research and practice of urban design. Supported by a large PhD group and strong masters programme research strengths include the varied scales and contexts within which urban design operates. Our expertise and capabilities range from the revitalisation of historic and heritage-rich urban environments to the regeneration of brownfield sites.

Research in this area focuses upon identifying the unique tangible and intangible qualities of urban environments and the interpretation of these to create meaningful solutions that enable the sustainable evolution of these places. In doing so we draw upon qualitative and quantitative research methods to provide data and evidence that can underpin creative proposals.

Geointelligence, location based services and positioning accuracy

The University's expertise in geointelligence includes: spatial analysis, positioning, tracking and prediction, data collection technologies, sensor-webs and spatial data infrastructures. Traditional research in this area tends to focus on defence and intelligence, but our capabilities stretch wider and involves the collection, analysis, integration and management of geospatial data. Our expertise in this area ensures that we then interpret this data to make inferences about the world around us to answer specific questions.

The dynamic and precision mapping research that is carried out at Nottingham is able to provide low-cost positioning and sensing technology which when integrated through advanced processing and fusion algorithms, can produce high quality, real-time dynamic map data. This map data can be constantly updated to allow users to take advantage of the most up to date information.

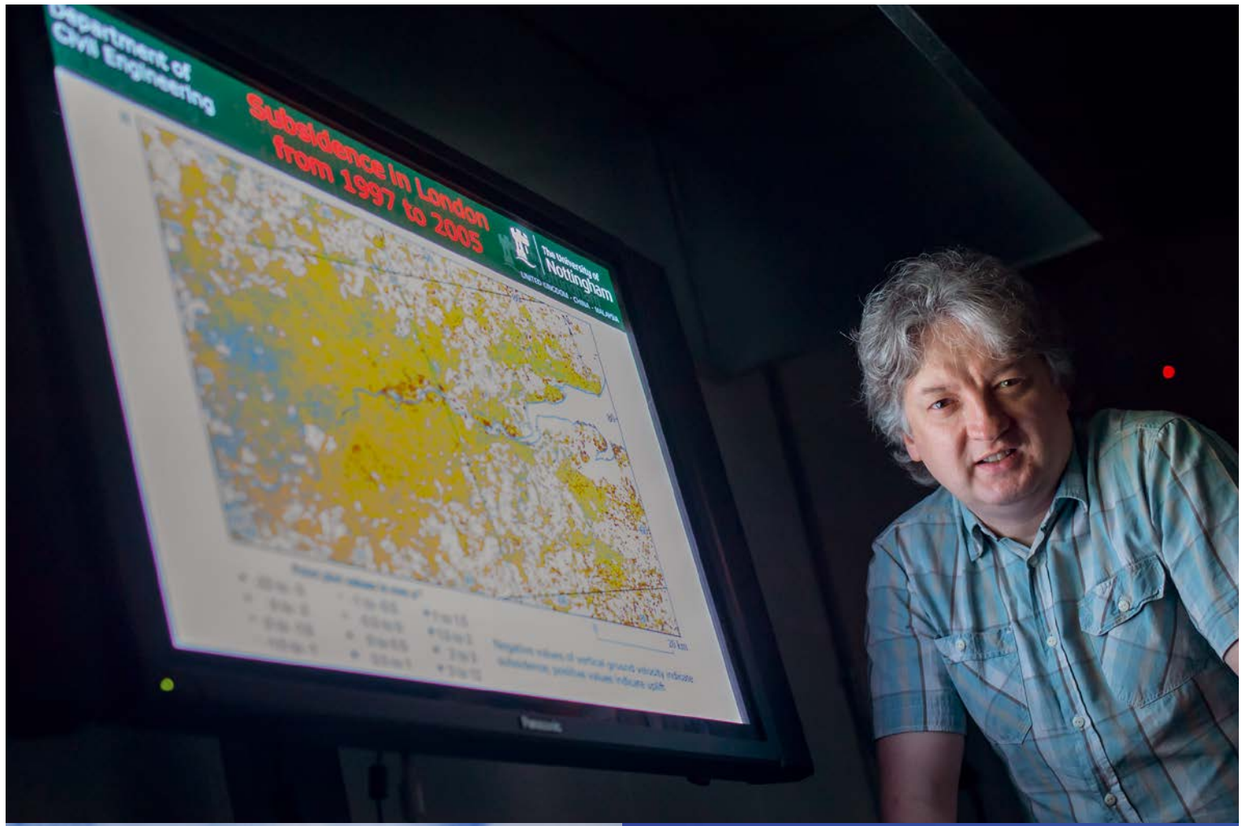
GIS and earth observation, positioning and navigation technologies

The University of Nottingham's world-leading expertise in this area includes the research and development into low cost, high-precision GNSS receivers and the subsequent commercialisation of these technologies. Our capabilities are becoming increasingly diverse and range from the fundamental science to a wider engineering and environmental focus. This includes network- based GNSS RTK, Precise Point Positioning (PPP) software receiver engineering and mobile phone applications – to imagery and communications-based positioning and navigation.

Research and development is also carried out into ubiquitous positioning and navigation technologies which will be vital in creating efficient and resilient future urban and transportation models.

University of Nottingham Campus and Estates

The University's Estate Office works closely with its academic community to ensure our campuses are living, breathing examples of good practice. We support innovation, projects, long-standing teaching programmes and aim, together, to create a living laboratory where we test, try and enable new technologies. Examples include the Creative Energy Homes, hydrogen refuelling station, electric charging technologies, innovative architecture and energy technologies.



The University of Nottingham has a long history and strong international reputation for its expertise in the research and practice of urban design.

People and goods

Citizen and user centric approaches are essential in the design of any transportation or city system. As well as occupying various roles, we can also think of people in the transport system in various ways – as physical beings (for example, where we might have concern for passenger comfort or safe lifting amongst railway track workers) – as thinking beings called on to make complex decisions about either their own mobility or that of others (for example, air traffic controllers) – feeling beings with attitudes, preferences and needs, and as members of teams or less well-structured groups that must coordinate their efforts.

Key concerns in this area include improving efficiency, ensuring the safety of all people throughout transportation, better understanding of changing and varied mobility needs and understanding of the role of people as a key component within increasingly complex transportation systems that are already operating at the edge of their performance envelopes. Digital and 'Big Data' offer great potential in terms of providing information that can be used to improve transport networks, providing better and more timely information to operational decision makers and creating new approaches to personal mobility (for example, Mobility As a Service), also integrating legacy – physical networks with new and evolving technologies, such as driverless cars.

Collaborations

Engineering | Human Factors | Computer Science | Automated Scheduling Optimisation and Planning group | Social Science | Horizon Digital Economy Research | Institute for Aerospace Technology | Nottingham Geospatial Institute

Theme leads

Dr Brendan Ryan
Human Factors, Faculty of Engineering

Dr Robert Houghton
Human Factors, Faculty of Engineering

Example project

PASSME

A large European project that looked to reduce journey time, increase efficiencies and maximise perceived quality of an integrated travel experience from door-to-door. The project has reduced door-to-door travel times by an hour, improved the luggage handling process and provided passengers with real-time personalised information. Importantly, it has also reduced stress levels and enhanced overall passenger travel experience at airports.

Capabilities

Passenger experience, behaviour and comfort

Our work in understanding passenger experience, decision-making and needs has been important in understanding transport systems and this has been used in embedding new technologies within these complex socio-technical systems. Our capabilities cover a wide spectrum, from the modelling of systems through to the analysis of social media interactions. We have worked on many different modes of transport including rail and aviation. In rail, we have capabilities in passenger information and minimising disruption. We have carried out research into passenger movement, accessibility and seating design, to enhance overall passenger experience and comfort. We have expertise in public safety on the railways, including prevention of rail suicide and trespass. In aviation, our research has enhanced overall passenger experience at airports and reduced stress through use of personalised devices.

Participative and citizen centric design and engagement. Multi-stakeholder dialogue on new technology

With the constant introduction of new technology and infrastructure it is vital that the users and stakeholders are involved in their design and implementation. Our capabilities in this area ensure that future projects truly reflect the needs of the end users. Our knowledge is grounded in a user-centred approach in which we build upon a deep technical expertise in interaction and distributed systems to rapidly prototype new interactive technologies and employ multiple evaluation techniques. These techniques can range from ethnographic studies to simulator experiments, but all are designed to understand how these are experienced by people in the real world. This research is highly interdisciplinary and the capabilities are complemented by perspectives from across Computer Science, Sociology, Psychology and Art and Design.

Expertise in stakeholder engagement also includes integrated participatory planning, governance and policy – research has been carried out in real life examples including the HS2 expansion.

Mobility As A Service, and the modal shift of passengers

Within our well established Human Factors Research Group we have capabilities to understand and develop the incentivising of a seamless journey through modal changes. This can be partly achieved through improving the design and management of transport interchanges, which will help them become easier to navigate and more pleasant to use on a regular basis for wide range of users.

Fundamental to the effective introduction and continuing provision of end-to-end mobility as a service, is the clear understanding and support for a traveller's whole journey requirements, from departure point to destination. We have expertise in this field which will enable the introduction of these services into the global intelligent mobility market.

New methods and metrics for evaluating traveller behaviour and user acceptance

Our research and work with industry covers many different modes of travel including road, rail, air, marine, pedestrians and bike. Behaviour of transport users can mean different things to different people, such as the choices that people make in their mode of travel or the types of activities that are performed by passengers in trains or autonomous vehicles. Whilst many people will choose how they travel, for others the choices will be constrained by a variety of circumstances and it is important to understand how they respond to conditions during their journey.

The University has developed wide-ranging methods and metrics to understand how people interact with transport systems, which includes sensor technologies for movements and flows of passengers and vehicles, protocols and technologies for in-depth observations in field studies and survey and interview methods for understanding users' choices, preferences and experiences in transport journeys.

We also study the issue of 'trust', which is growing in importance in the transport sector with the rise of autonomous vehicles. Our expertise covers trust and user acceptance in and around autonomous vehicles and the University's capability in this area extends to the public's trust in timetabling providers and staff.

Traveller profiling, behavioural segmentation and predictive modelling techniques

The Human Factors Research Group at the University of Nottingham applies design techniques to support user-centred technology development. Through structured interviews and survey techniques it is possible to build a rich picture of traveller needs and thus create numerous traveller profiles. These profile templates can then be used to cater for specific needs or wants across a journey or mode. Our expertise in this area can be translated to other modes of transport which would be vital in the increasingly personalised journeys of the future.

We also have capabilities in the development of behavioural segmentation and predictive modelling techniques via novel computational and clustering methods applied to a rich range of data sources. A data driven approach focusing on real-world problems is reflected in our research, from which we can drive novel forms of demographic intelligence.

Ethics and crowdsourced data and passenger data collection

The University of Nottingham has expertise within the Horizon Research Institute that includes the ethics and exploitation of data. It has recently started to address the growing public concern over the exploitation of personal data and is now starting to deliver the transformation from the dominant focus on analysing centralised 'Big Data' to explore the private and ethical interpretation of 'human data'.

Our capabilities have allowed us to develop a human-centred approach to data focusing on human-centred data collection, richer approaches to interpretation, more transparent analysis and new perspectives on digital identity.

Further expertise exists around the growing issue of demographic biases in crowdsourced data, their impact on open source geospatial data projects and what the implications might be for the sustainable development of cities.

Behavioural economics and the optimisation of regulation and policies

Behavioural economics is a rapidly expanding field, investigating the human and social factors influencing the decisions made by consumers, borrowers and investors. The University of Nottingham's expertise incudes the study of microeconomic theory, macroeconomic theory, econometric theory and economic data analysis.

The Centre for Decision Research and Experimental Economics is a world-leading research group based at the University and it conducts research into how people make decisions though a combination of theoretical and experimental methods.

Exploring and improving public policy for policymakers, practitioners and the public is essential in addressing complex economic, environmental, political, social and technological challenges. Our expertise provides UK and international policymakers, practitioners and the public with the knowledge and understanding of how their decisions will influence events in a rapidly changing world. By looking at issues such as power, accountability and effective administration, together with factors such as politicians, pressure groups, frontline staff and external shocks, we will improve understanding of policy agendas, the policymaking process and delivery. We also examine why some policies change over time, and the role of public participation, user empowerment, and co-production in policy formulation and delivery.

We have been involved in research in rail human factors for over 30 years at the University of Nottingham, with a leading research group in this area and a key role in the organisation of a series of international conferences.

Capabilities for transport, mobility and cities

Infrastructure

Sustainable infrastructure needs to be safe, multifunctional and resilient, supporting power as well as transport services, while minimising environmental impact.

Transport infrastructure must be designed, constructed and maintained within tight budgets whilst delivering continuous service. Modern infrastructure needs to be resilient to increasing traffic and extreme weather. It must also be integrated with power grids both to exploit renewable energy and deliver charging infrastructure, and as a consequence will be integrated to buildings and the wider built environment and energy infrastructure. It must also reduce the environmental impact of construction and operation while exploiting opportunities to enhance local environments.

This requires improved construction materials and optimised maintenance programmes, based on smart sensor-enabled condition monitoring and interoperable, high frequency communications networks. Safety and operational risks need to be modelled and understood at network, as well as project level to reduce user and worker casualties and build in resilience and recovery after hazards, such as flooding or heat waves. Future needs, such as charging electric vehicles, managing water, and reducing noise need to be designed-in, and sustainability assessment systems integrated into decision making.

Collaborations

Architecture | Civil Engineering | Electrical and Electronic Engineering | Fluid and Thermal Engineering Research Group | Computer Science | Mathematics | Physics

Theme leads

Professor Mark Gillott
Buildings, Energy and Environment, Faculty of Engineering

Dr Tony Parry
Nottingham Transportation Engineering Centre, Faculty of Engineering

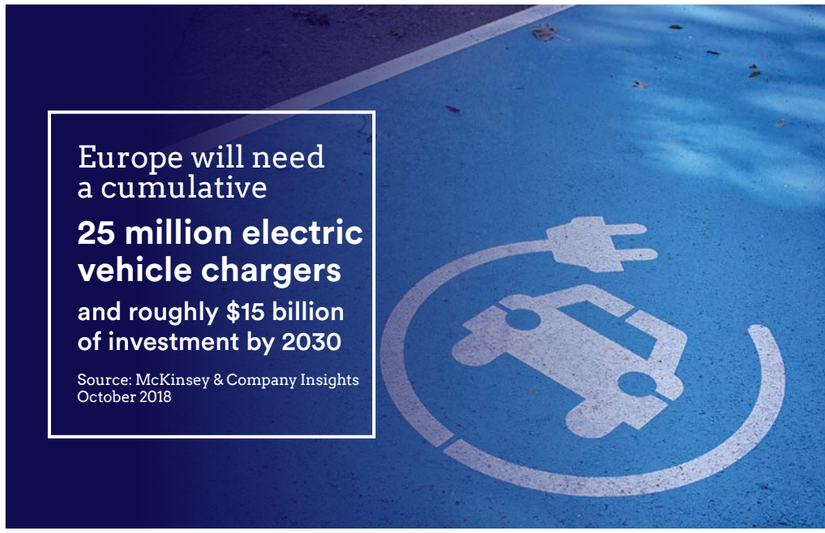
Example project

EV-elocity

EV-elocity is a research and development project looking at increasing the uptake of electric vehicles through helping consumers to monetise their investment using vehicle-to-grid (V2G) innovation. The project is exploring new technologies, encouraging behaviour change and developing business models that will enable the sharing of the value V2G can bring to the grid, local and regional businesses and the consumer. Our ecosystem of partners is looking to develop a new set of offerings using innovative V2G solutions such as dedicated and intelligent parking, loyalty programmes through new data patterns and inside airport individually targeted information.

The project aims to achieve economic, societal and environmental benefits such as promoting the uptake of electric vehicles by enhancing the case for “going electric” through the provision of a new revenue source for the owners; help reduce cost of energy for consumers; increase infrastructure resilience and security of energy supply; and support more sustainable life styles through encouraging behaviour change and raising awareness of energy.

Capabilities



Business models for EV charging and EV technology

Our expertise in this area includes identifying business models that will enable the sharing of the value that Vehicle to Grid technologies can bring and which can be scaled-up to link new technology to a range of service models. Our capabilities are currently being utilised in a large scale project which looks at EVs acting as aggregated battery storage. This project will also look at models which will help current and future EV consumer’s monetise their investment while accelerating the take up of EVs in UK through this trading monetisation.

Our expertise extends to power testing, measurements and EMC testing of the EV technologies, also the validation of innovative technology. We can also develop and evaluate management algorithms for the EV technologies.

Our world-leading Power Electronics Group has capabilities in developing state-of-the-art electrical machines for future transportation which push existing technology boundaries, and will help to develop this key enabling technology for all hybrid-electric and electric vehicles for application in the automotive sector.

We are also leaders in supplying Thermal Management solutions for energy systems such as electric car batteries.

Adaptive and responsive intelligent infrastructure

We have internationally-leading expertise in sensing and tracking technologies which link through to future intelligent infrastructure systems. Our capabilities allow us to take a multi-stakeholder perspective, identifying and meeting the information and data requirements of providers, passengers and business innovators in both normal and disrupted operations. This innovative approach can radically improve the network performance through its responsive and adaptive methods.

Our capabilities around sensor technologies and data analytic techniques can be used to monitor the state of the transport system – from bridges to wireless network performance which will help move future environments towards an integrated data approach – this will enable us to have a real time and proactive view of an infrastructure.

Infrastructure asset condition monitoring and support for asset decision making

We have utilised our expertise in Global Navigation Satellite Systems and Earth Observation technology to work with and monitor large infrastructure assets. The capabilities in condition monitoring and decision-making support allow infrastructure owners to make informed decisions on the safety, maintenance and operation of their assets.

New research into remote condition monitoring and decision-making support for assessing the internal condition of safety critical geotechnical assets has grown our capability in this area. The innovative assessment of the condition of geotechnical assets that we produce will help provide essential cost-effective maintenance and prevention of hazardous failure events which can cost millions of pounds in the UK.

This new system will be realised by implementing a fully automated software workflow for data analysis and information delivery, which will combine emerging geophysical ground imaging technology with wireless telemetry and Big Data handling. This will provide a smart framework for the more sustainable management of assets including road and rail.

Smart and multifunctional structures and health monitoring solutions

The University is performing multi-disciplinary research with the aim of developing novel materials, technologies and decision frameworks for the next generation of smart transport infrastructure. The next step is to bring together a platform where key stakeholders of the sector can work with our experts towards the goal of smartening the structures and systems. This will be done through using a variety of new technologies including high tech sensors, advanced monitoring equipment and automated structures.

This new applied research complements our existing capability in the area of health monitoring solutions. Our expertise provides users with real-time measurements of their assets during both normal and abnormal loading conditions. The technology also provides a complete picture of the structure in its changing landscape and can identify threats caused by environmental conditions including land motion, engineering works, mining and industrial activity.

City information modelling and building information modelling

Our capabilities in this area include BIM Level 2 processes, standards and application and is growing to include the integration of the design and analysis process. This has been achieved through creating a unified platform with both Building Information Modelling and numerical simulations.

Methods that have been developed to assist this platform include Finite Element formulations (on both element and constitutive level), artificial neural networks, optimisation algorithms, algorithms for sensitivity analysis and methods to handle massive computations and the analysis of the resulting data.

We also have expertise in the introduction of data and information management, data integration and fusion, spatial analysis and visualisation through CAD, BIM and GIS.

Control of the flow of energy in indoor wireless communication

The future of electronic communication devices will require communication at chip level and wireless chip-to-chip interaction. However, there is currently an information bottleneck that needs to be solved which cannot be overcome with current engineering simulation tools and models.

Our expertise at Nottingham is helping to design new and efficient modelling strategies for describing and exploiting noisy electromagnetic fields in these complex microchip environments, which will help overcome this bottleneck. Recent advances in Nottingham – in both mathematical physics and electrical engineering in handling complex, chaotic wave fields – will address these challenges.

Our capabilities in these complex areas will open up new pathways for microchip design and for carrier frequency ranges and our expertise will also improve the energy efficiency and the miniaturization of the technology in the future.

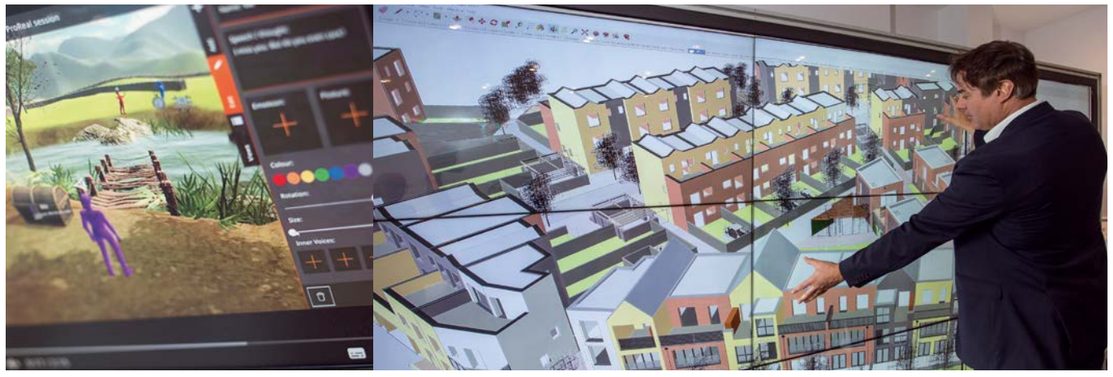
Living laboratories

The University of Nottingham houses the Creative Energy Homes – a £1.9m project, which is a key resource, particularly with respect to micro-smart grids, energy storage, demand-side management and occupants' acceptance of innovative technologies. The eight-house development provides a living test-site for leading firms including: E.ON, David Wilson Homes, BASF, Roger Bullivant, The Mark Group, Tarmac and Saint Gobain, to work with the University to investigate the integration of energy efficient technologies into houses.

The work undertaken within the Creative Energy Homes project is predominantly related to mitigating the impacts of, and adapting to, climate change, reducing energy use in the built environment, and enhancing comfort, productivity and well-being of building users.

The University of Nottingham also leads a ground-breaking new community energy project, where energy is being stored onsite at the Trent Basin Development in the largest community energy battery in Europe.

The aim of this project is to demonstrate that community energy is a financially and technologically viable approach to low energy housing. In this project we are utilising our cutting-edge Smart Home and Internet of Things capabilities to better understand and predict energy use and behaviour. This will allow us to arm residents with the information they need to make informed choices and to help optimise operation of the community energy scheme for the benefit of all.



The University of Nottingham houses the Creative Energy Homes – a **£1.9m project,** which is a key resource, particularly with respect to micro-smart grids, energy storage, demand-side management and occupants' acceptance of innovative technologies.

The University of Nottingham also leads a ground-breaking new community energy project, where energy is being stored onsite at the Trent Basin Development in the largest community energy battery in Europe.

Vehicles

The successful design, manufacture and operation of ground vehicles requires a holistic human-centered engineering approach. Modern road vehicles typically contain several complex sub-systems that must combine to provide the end-user with the desired overall performance, functionality, comfort and safety.

The end product must comply with ever evolving CO_2 targets, pollutant emissions legislation and evolving customer expectations. The accelerated shift towards electrified propulsion brings unique opportunities to re-optimise vehicle packaging and performance, but must be balanced against acceptable cost of ownership and limited charging infrastructure. Connected and autonomous vehicles will open up new modes of mobility and the potential for novel user experiences via the Human-Machine Interface, but creates many challenges in the design and evaluation process.

Collaborations

Computer Science – Artificial Intelligence | Machine Learning | Human Computer Interaction | Psychology – Neuropsychology | Driver Behaviour/Training

Theme leads

Professor Gary Burnett
Human Factors,
Faculty of Engineering

Professor Alasdair Cairns
Fluids and Thermal Engineering,
Faculty of Engineering

Example projects

Human–Machine Interface

HMI design for future vehicles aims to understand how drivers/passengers could/should interact with future vehicles.

The University of Nottingham has an on-going programme with major vehicle manufacturers and their suppliers – approx. £1.5 million over the last 8 years – in which studies conducted at Nottingham have had a direct influence on several vehicle designs and Human Factors design processes.

AceDrive

Aims to deliver the optimum electric drive for future hybrid and full electric passenger cars. This major programme with external partners will take the existing cross-faculty collaboration within the University, and utilise the novel electronics cooling technology to production.

Capabilities

Advanced propulsion systems, electrification and thermal management

With core expertise covering the fields of experimental fluid mechanics, computational fluid dynamics, two-phase flow, heat transfer enhancement and thermodynamics, the University is well placed to work on a large variety of technological applications. These applications include innovative internal combustion engines, HVAC and refrigeration, thermal management and heat exchangers. The research in these fields has led to improvements in the efficiency of fluid controls and both conventional and new energy cars.

This expertise underpins a wide variety of industrial sectors including automotive, power generation and renewable energy, and our capabilities have been demonstrated through internationally recognised partnerships across these areas.

Noise, vibration and harshness modelling

Predicting the propagation of wave energy for high frequency waves is a challenging task of fundamental importance in many engineering applications. These can range from acoustics and vibrations in complex structures such as cars and airplanes, to modelling electromagnetic radiation in the radio, to infrared spectrum with applications in communications. Overcoming this issue is vital and the expertise at Nottingham is well placed to overcome the challenges faced.

Our capabilities include using advanced mathematical tools including wave asymptotics to wave chaos theory to solve engineering wave problems in an interdisciplinary collaboration between Mathematical Sciences, Electromagnetic Research, Composites and Physics. We use pioneering approaches including Dynamic Energy Analysis which builds on the existing Static Energy Analysis, combining asymptotic methods and Wigner function approaches with random matrix theory and Phase Space Approaches.

Lightweighting, materials, aerodynamics and drag reduction

We have internationally recognised capabilities in lightweight materials through our long-standing research into the processing and performance of polymer matrix composites. We have well established interests in both thermoset and thermoplastic matrices and a growing interest in novel metal materials.

Our expertise covers: processing techniques, composite manufacture, recycling, fibre reinforced composite manufacture processes, predictive modelling, composite design, damage and failure analysis and aerodynamic flow control.

Research is applied within several sectors including automotive, aerospace and wind energy. Capabilities in the transport sector include advances in composite technologies which include the development of lightweight structures for improved vehicle performance and impact characteristics.

Driver simulator studies and prototyping

The Human Factor's interactive driving simulator is one of the most sophisticated University facilities in the UK, and is complemented by the three state-of-the-art driving facilities contained in the Nottingham Integrated Transport and Environmental Simulation (NITES) facility. The simulator has a range of medium and high-fidelity simulators and associated equipment. We have the capability to use instrumented vehicles to complement the simulators as a means of conducting research in a more realistic and ecologically valid environment.

The simulator is also easily adaptable and can be fitted with equipment to allow for the prototyping of innovative automotive technology.

The NITES facility combines multiple methodologies for undertaking behavioural research and systems design. It combines two separate simulation systems, with an on-road testing vehicle and a variety of videobased testing platforms. All three facilities are fitted with state-of-the-art eye-tracking technology allowing driver's eye movements to be recorded over a wide field of view. In addition, there is a suite of visual and psychophysiological testing equipment for driver screening and experimental testing.

Our capability in the field of prototyping extends from virtual prototyping, through multiscale information modelling to visualisation including mixed reality and visual analytics.

Vehicle–human machine interfaces, navigation and natural language, distraction

The University of Nottingham has a world-wide reputation in addressing the design and evaluation of Human-Machine Interface (HMI) for future vehicles. We have particular expertise in the use of driving simulators as a means of investigating the design and evaluation of vehicle base HMIs in a safe, controlled and cost-effective environment.

Research is also being carried out into the understanding of cognitive implications of handover to and from drivers in autonomous vehicles. This is becoming vital due to the rapid growth in this market. We are carrying out research in better system design, which will improve the usability of the new HMI technologies within cars of the future.

Autonomous vehicles

The University's capability in this area combines expertise from a variety of fields including reliability, positioning, verification and testing, data integration, HMI design and policy and regulation for future vehicles.

We hold several TMC related, Innovate UK funded CAV projects including i-Motors. This benefited from our knowledge of key trust and usability issues that affect driver's acceptance of novel information and series that will arise from autonomous vehicles. We also contributed to the project through our world-leading capabilities in positioning technology, which included implementation of V2V and V2I technology and the development of relevant standards and specifications.

We are also carrying out research into autonomous systems and their reliability, which is easily translated across vehicle modes. Our expertise includes creating fast system reliability assessment techniques including Binary Decision Diagrams which can be used as part of the decision-making process. This technique can show then the likelihood of the autonomous vehicle successfully performing its intended task becoming unacceptably low and what action needs to be taken to mitigate the situation.

Augmented Reality and Virtual Reality technologies

Our expertise in both virtual and augmented reality is reflected in the collaborative projects we have been involved with in this space over the last ten years.

We have been involved in an ambitious European project which utilised our expertise in virtual reality and mixed reality to enhance passenger comfort. Our capabilities drew on technology innovation and the psychology of perception to extend the feeling of space which enabled passengers to see themselves looking comfortable with more space in an existing cabin. This innovative work will influence the design of transport in the future including aircraft and automotive.

We have also worked with car manufacturers who have used our capabilities to create virtual and immersive environments which could become commonplace in the future and will accommodate increased customisation in wide-scale manufacture.

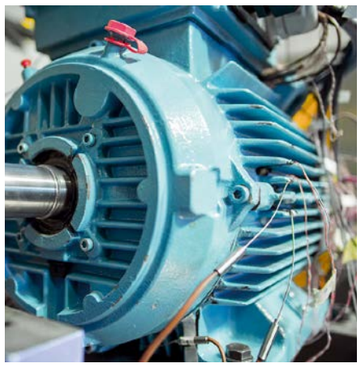
We hold several TMC related, Innovate UK funded CAV projects including i-Motors. This benefited from our knowledge of key trust and usability issues that affect driver's acceptance of novel information and series that will arise from autonomous vehicles.

Required navigation and performance safety

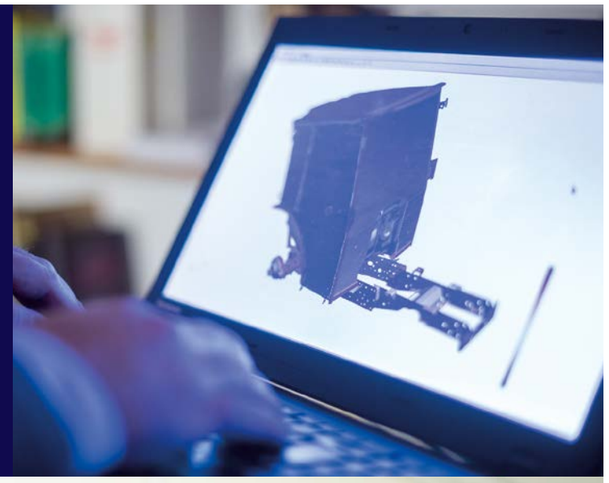
Our capability ranges from utilising our expertise in precise navigation and positioning technologies to sensors for detection of users and infrastructure, through to wireless communications to share this vital data.

The University of Nottingham has world-leading capability in the innovation of low cost, precise positioning technology, and we can integrate this with sensors to provide high quality dynamic mapping through advanced processing and fusion algorithms. The constant updating of a central map will allow other road users to take advantage of the most up-to-date information.

Our expertise in wireless communications has led to the increased sharing of data between vehicles. This increased information can assist the NRTK positioning solution and will develop cooperative positioning techniques for future vehicles. Our research has demonstrated the potential benefit of V2V communication and has been shown to provide accuracy of 20-30 cms with latency of less than 30 seconds. This technology could lead to improved platooning of vehicles which has wide benefits for users, passengers and the environment.



We have been involved in an ambitious European project which utilised our expertise in virtual reality and mixed reality to enhance passenger comfort. Our capabilities drew on technology innovation and the psychology of perception to extend the feeling of space which enabled passengers to see themselves looking comfortable with more space in an existing cabin.



Energy and sustainability

The move to a sustainable energy future will encompass all aspects of the transport system and city networks. Research strengths which can contribute to growth in this area include: technologies to underpin the digital transport infrastructure, modelling and managing building energy usage, lifecycle analysis with its associated environmental impact, the development of models for land use and transport, optimisation of urban transit routing and additive manufacturing. An overarching requirement is to ensure that this transition occurs with a responsible approach to research and innovation, and an understanding of the social responsibilities of the large corporations involved in this area.

Our research into new sources of energy, its harvesting and its storage coupled with ground-breaking power conversion technologies will help to ensure that the infrastructure for future electrified transport systems will be as resilient and sustainable as possible. It is vital also to look at the wider support for the transport system and our innovative research into this area includes Smart-Grid technologies and business models which will take on advanced data analytics to ensure the most efficient network possible.

A future transport infrastructure must be underpinned by an energy system which can exploit non-polluting sources, whilst maintaining resilience. Sustainability must also be extended to systems development and include life-cycle analysis and the use of a circular economy. Furthermore, we must develop energy sustainable future plans for cities.

Collaborations

Geography | Social Sciences – Laboratory for Urban Complexity and Sustainability

Theme leads

Dr Yong Mao
Physics,
Faculty of Science

Professor Mark Sumner
Power Electronics,
Faculty of Engineering

Example projects

Project SCENe

This award-winning project aims to accelerate the implementation of renewable energy systems in housing developments. The project will focus on the adoption of Community Energy Systems – a different way of generating and supplying locally generated heat and electricity to homes and commercial buildings. The benefits are reduced cost and more efficient use of distributed renewables to reduce the overall carbon emissions.

Project SCENe is based at a new housing development in Nottingham's Trent Basin. Involving solar photo-voltaic panels, Europe's largest community energy battery, local thermal energy production, distribution and storage and research expertise, the aim is to generate renewable energy, support local communities, address key research and policy gaps and deliver low carbon grid services to the National grid. Using novel consumer engagement tools and a focus on business model development the consortium will also develop and test business models that could be used by future developers.

Capabilities

Circular economy, lifecycle analysis and environmental assessment

Our innovative research in this area includes developing and identifying cost-effective resource utilization strategies to contribute to environmental sustainability objectives. Our expertise is in the application of systems analysis approaches (technical, economic, and environmental perspectives) to renewable and conventional energy systems and materials. This research involves both the development of novel analytical approaches as well as their use in informing system improvements in terms of non-renewable resource use, greenhouse gas emissions, and other parameters.

The most recent research has focused largely on biomass-derived fuels and materials, undertaking a multi-disciplinary approach including engineering, forestry, policy, and economics components.

We are undertaking similar whole-systems approaches in our research into non-bioenergy fields, including: carbon fibre composites recycling, critical materials, micro grids and energy storage systems, and heavy-duty vehicle fuels.

Energy efficient and smart materials

Material science has broadened from its historical roots in metallurgy and solid-state physics to underpin many aspects of physical and engineering science, spanning calculations and measurements of the nature of bonding in materials, through the mechanical behaviour of complex engineered products in extreme environments.

Supported by comprehensive material characterisation, scientists at the University of Nottingham combine fundamental, curiosity and application-driven research which drives the development of new materials, through interdisciplinary research conducted with colleagues in physics, chemistry, and electronic engineering. Research explores the links between processing of materials, development of their microstructure, and their useful functional properties across range of energy related applications.

Our expertise in smart and efficient materials has led to innovative work in thermochromic smart windows which can change colour and optical properties in response to temperature variations. We are also carrying out research into self-cleaning technologies for PV systems and green roofs which have the potential to alter construction materials and techniques in the future.

Energy harvesting, source and storage technologies

As society moves towards cleaner, renewable fuel supplies it faces new challenges which include how to move, store and then release energy efficiently. We are exploiting the University's capabilities in this area to develop new types of batteries and fuel cells that can be used in our vehicles, phones, cameras and computers.

The last few years have seen new generations of electric, hybrid and biofuel vehicles on the road, but they only account for a tiny proportion of current stock. One of the keys to creating a sustainable alternative to petrol or diesel could lie in hydrogen, a gas that only emits harmless water vapour, with no carbon outputs at point of use. Our expertise in hydrogen storage is focused on the development of solid-state hydrogen storage materials – light metal hydrides, intermetallic hydrides and complex hydrides. Research encompasses the development of new materials through to the engineering design of prototype hydrogen stores. Applications for these prototypes include renewable energy backup storage, microgrid and hydrogen fuelling stations.

A key problem to any type of energy producer from small scale micro generation right up to large scale power plants is to provide energy when needed. As more and more renewables form an integral part of our energy network then the problem of storing energy is vital. Our advanced research in Energy Storage includes Multiphase change thermal energy storage material, supercapacitor and supercapattery which could all help solve this growing problem.

Electrification and integration

All transportation systems will be challenged by the move to electrification. The supporting electricity distribution system must be both resilient and sustainable, and minimise impacts on the environment. We undertake fundamental research into energy technologies – new sources, harvesting, and storage – together with power conversion technologies which are more efficient and have higher

power density. We also work on system support structures such as vehicle-to-grid, off-grid operation and grid management and protection strategies which use increasingly powerful ICT infrastructures. These Smart-Grid technologies will exploit our research into Artificial Intelligence and Data Mining to provide increased resilience and condition monitoring at component and system level with the associated improved maintenance schedules.

Electric vehicles, the energy system and the city

Research in this area looks broadly at increasing the uptake of low-emission electric vehicles and the impact of this on the energy system and on city planning and citizen mobility.

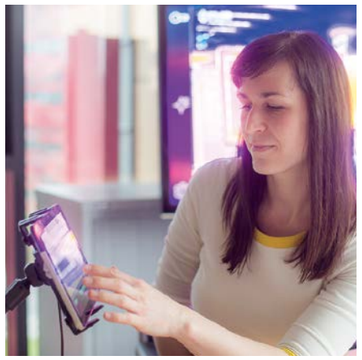
The research spans from developing new technologies including vehicle-to-grid innovation, encouraging behaviour change including increasing vehicle sharing, looking at the energy mix, increasing the efficient use of renewable energy and storage, and developing business models that demonstrate the value electric vehicles can bring to the grid, city and consumers.

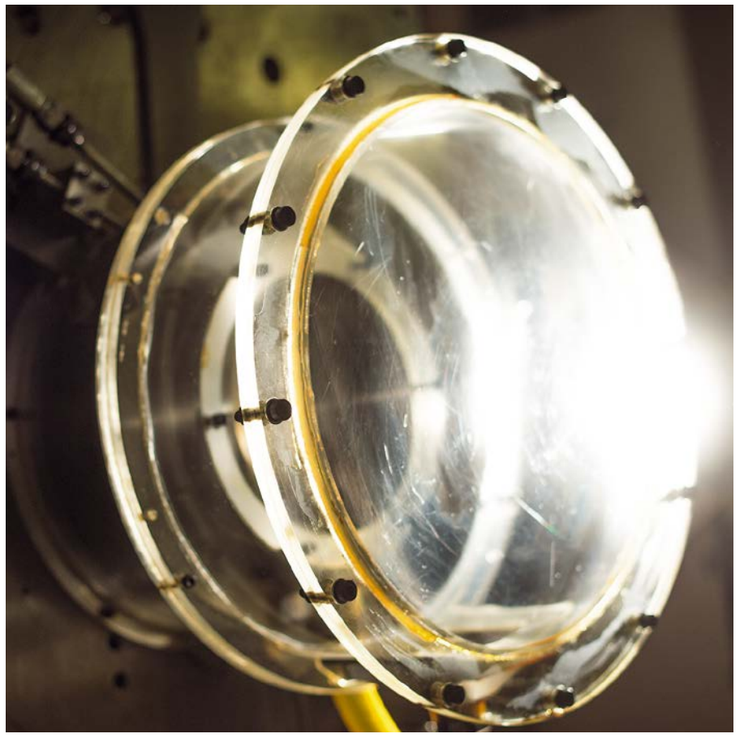
Building energy simulation

Our capabilities into energy simulation in buildings spans several subjects and building types and addresses both the challenges of new builds and retrofit. In particular, researchers at the University of Nottingham look into several aspects that contribute towards energy efficient buildings including building performance evaluation.

Research into energy efficiency in buildings focuses on sustainable design and new techniques for providing affordable, and environmentally sustainable housing.

Expertise at the University stretches to the move from Building Information Management (BIM) to Building Energy Modelling (BEM). This will assist the optimisation of building design and energy consumption. We are developing the modelling, analysis and optimisation of energy efficient buildings and identifying the potential and deficits of this innovative technique.





Smart-Grid technologies will exploit our research into Artificial Intelligence and Data Mining to provide increased resilience and condition monitoring at component and system level with the associated improved maintenance schedules.

Smart systems and operations

The concept of smart systems and operations is essential for enabling highly efficient transportation and seamless mobility of people and goods in cities and beyond. The design of such smart systems and operations requires high-quality digital communication infrastructure, sophisticated sensor systems, computer-based modelling, data science, optimisation and artificial intelligence tools. The digital communications infrastructure will be wholly reliant on the performance of both the wired and wireless communication systems and/or their respective sub-systems. Predicted performance may differ greatly to real-world performance when systems contend for bandwidth. The impact of adding greater numbers of sensor systems, whose performance is reliant upon achieving and sustaining high data rates, into an already congested airspace could severely limit overall system performance even further. The competition over available bandwidth will only grow due to the requirements of an increasing number of smart systems that support autonomy and anything to anything communications.

Therefore, additional capacity over and above the initial perceived requirements needs to be factored in at the early stages of design and certainly prior to deployment. Computer modelling, analysis, machine learning and optimisation techniques need to be capable of dealing with highly complex and dynamic systems and operations. They also need to be combined with experimental test-beds to provide a full understanding of how systems can co-exist whilst providing the necessary and expected levels of performance.

Collaborations

Electrical and Electronic Engineering | Nottingham Geospatial Institute | Computer Science | Mathematics | Architecture and Built Environment | Digital Economy Research Institute | Business School | Laboratory for Urban Complexity and Sustainability | Sociology and Social Policy | Physics

Theme leads

Dr Steve Greedy
George Green Institute for Electromagnetics, Faculty of Engineering

Dr Dario Landa-Silva
Computer Science, Faculty of Science

Example projects

Noisy Electromagnetic Fields – A Technological Platform for Chip-to-Chip Communication

This collaboration with a number of European partners including the Technical University of Munich, Centre National de La Recherche Scientifique and NXP Semiconductors France, worked to solve the emerging issues around wireless chip-to-chip technology. This project created a revolutionary electromagnetic field simulation toolbox which enabled users of chip-to-chip technology to predict and overcome problems in a safe environment.

COSLE –Collaborative Optimisation in a Shared-Logistics Environment

This innovative project in collaboration with Microlise brought together an array of data sets into a single environment. These large and busy data sets included location data, environmental data, GPS and vehicle telematics. The aim of the project was to reduce empty freight runs so saving money for logistics firms and also to reduce their carbon footprint. This was achieved through using optimisation algorithms created by the University of Nottingham along with image processing and mobile technology.

Capabilities

5G communication and connected vehicles

The University of Nottingham's Wave Modelling Research Group (WAMO) has expertise in physics-based channel modelling for 5G and beyond and is developing simulation software to better handle wireless coverage issues in 5G mobile networks and smart city applications. The methods developed over the last decade include a fast mesh-based ray tracer as well as statistical models of field fluctuations based on random matrix theory. The radiation patterns of terminal devices are used as a source of wireless energy, and human and vehicle mobility models can be integrated into the wireless channel model. Software defined radio appliances operating in a reverberation chamber facility is also available to validate and guide the models.

Simulation of the interaction and integration between smart roads, rail and vehicles and their users

The University has expertise in the simulation and modelling of the interactions between the many components making up today's complex transportation systems. For example, multi-agent systems (MAS) can be used for the simulation of complex systems like smart roads involving different agents acting with their own goals (such as, drivers, smart vehicles, traffic flow controlling components). Simulation allows a degree of control over experimental conditions that is impossible in a fielded system, allowing more effective and efficient integration. Our expertise allows the simulation of larger scale situated MAS with large numbers of interacting agents in scenarios like platform–train interface at a railway station.

Computer vision, sensors and sensing

Our capabilities in computer vision include developing novel and efficient techniques for the extraction of quantitative descriptions of viewed objects from a variety of images and sequences, and to translate those techniques into high quality software tools that can be used to address real world problems.

This is achieved through basic and applied research in image manipulation, analysis and computer vision. Importantly, this work is carried out with a high level of engagement with other disciplines. The strong links with life and medical sciences and the Human Computer Interaction community ensure that the work carried out is robust and resilient.

The integration of position, attitude and remote measurement sensors is an important research area at Nottingham. Its importance stems from sensors underpinning a wide variety of applications, such as pedestrian navigation, vehicle tracking, machine control and unmanned aerial vehicles (UAV). There is a need to incorporate a positioning capability into low-cost mass market devices – the challenge is to understand how people in different situations respond or relate to positional cues.

Our expertise in sensors and positioning technology allows us to understand how to communicate complex spatial information effectively through small mobile devices.

To enable these capacities, research and development of in-house software platform through adoption of the latest data fusion algorithms is essential. We have developed comprehensive software tools that range from GNSS signal simulation to integrated processing of the data streams from different sensor systems.

Decision making, optimisation and meta and hyper-heuristics

Intelligent decision support systems are playing an increasingly important role in providing solutions to various computational problems in society, industry, and government. However, the design, development and maintenance of computational models and solving methods underpinning those intelligent decision support systems are extremely challenging, time-consuming and costly, often requiring human expert intervention.

Smart systems and operations for intelligent mobility demand intelligent decision support systems that incorporate the ability to prescribe the best course of action at different decision points in time within a complex transportation system. Our strong capabilities in modelling and optimisation techniques include mathematical programming, evolutionary computation, meta-heuristics and hyper-heuristics among others.

We have capabilities in developing rigorous mathematical models and theories for a more profound understanding of real-world operational problems like those arising in transport systems. Our expertise in evolutionary algorithms, meta and hyper heuristics enables us to develop adaptive, effective, generic, reusable and low-cost optimisation tools for intelligent decision support. Our capabilities uncertainty modelling also allows us to develop smart systems and operations that are more robust to unexpected changes and hence offer a more resilient solution to intelligent mobility.

Open data and data science

Our expertise in this area has led to a number of projects including several large-scale transport collaborations across the globe. All of these projects have combined open datasets, mostly geographical, and fine-grained behavioural data from private sector partners with a range of data science and machine learning techniques – from convolutional networks, to multiple systems evaluation, to stochastic process modelling.

Machine learning considers the problem of extracting useful functional or probabilistic dependencies from a sample of data. Such dependencies can then be used to predict properties of partially observed data. Data mining is often used in a broader sense and includes several different computational problems, for instance, finding regularities or patterns in data.

Our capabilities include a focus on making machine learning and data mining algorithms faster and easier to use.

Computational intelligence, machine learning, fuzzy logic, AI, algorithms and systems integration

Our expertise in novel complex data analysis, knowledge representation, machine learning, decision support algorithms and the modelling of human decision making has created real-world impact in energy management and digital economy. Our work encompasses researchers from a variety of backgrounds including computer science, the biomedical sciences, operational research, mathematics, statistics and complexity science.

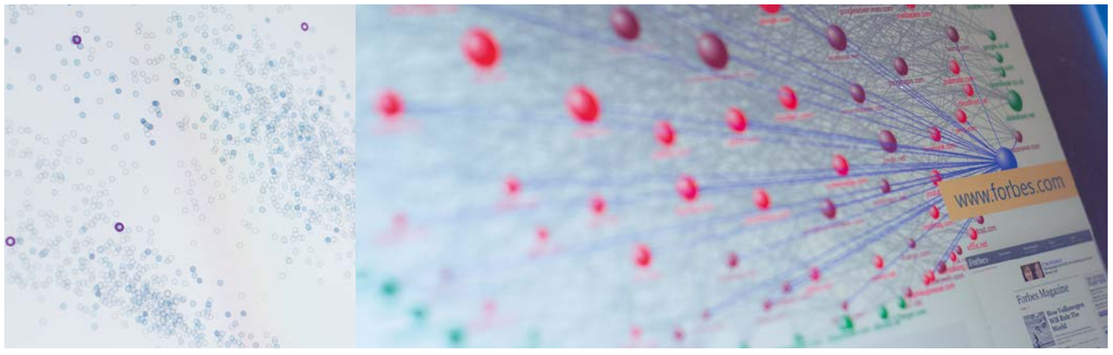
Objectives in this area include the modelling and representation of challenging problems, with particular emphasis on the digital economy application domain and take full advantage of our capabilities including AI-based data mining, computational modelling and fuzzy methodologies

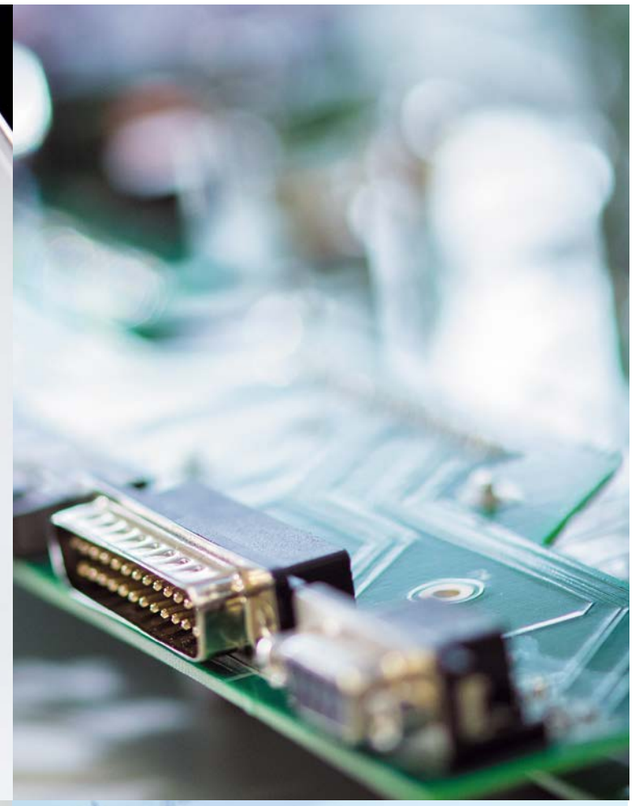
We also ensure our research fosters a cross-disciplinary approach to data science by developing machine learning and data mining algorithms and adopting principles of user-centred design to maximise the synergy between human intelligence and cyber-physical systems.

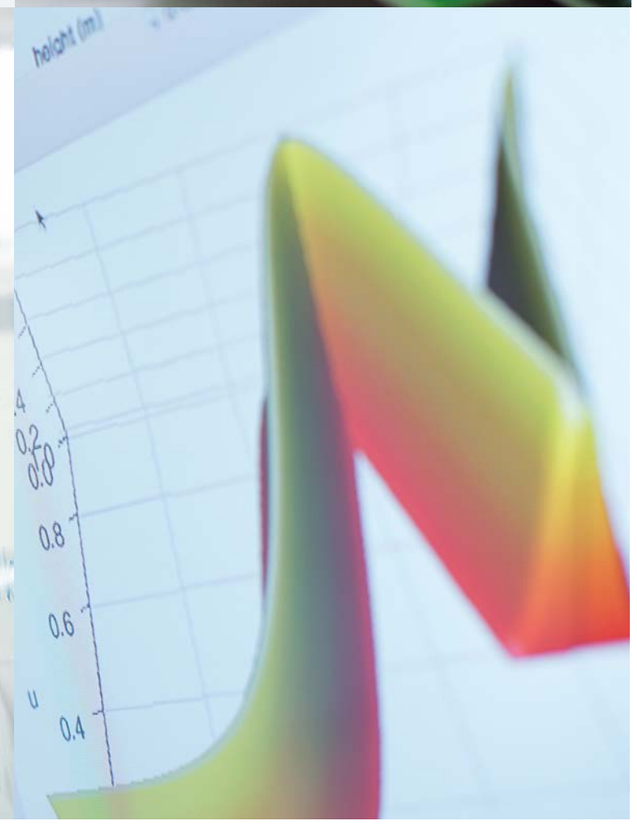
Evaluating safety interventions

The University is currently developing, demonstrating and testing innovative safety systems for vehicles with the aim of protecting road users. The innovative research will develop next generation collision avoidance systems which automatically brake or steer based on predictive algorithms concerning the potential path of road users.

Our expertise in novel complex data analysis, knowledge representation, machine learning, and decision support algorithms and the modelling of human decision making has created real-world impact in energy management and digital economy.







Resilience

The efficient performance of our critical infrastructure and its complex systems is vital to modern society, particularly in the transport, energy production and distribution, utilities and communications sectors. We are dedicated to conducting research into developing modelling techniques to predict ways of improving the design, maintenance, and operation of engineering systems in order to reduce the frequency and consequences of failure.

Research also focuses on improving the resilience of engineering systems to a broad range of disruptive events – from hazardous system failures, to natural and man-made disasters – ensuring adequate defences against their consequences, management of the disruptive event, and the rapid restoration of system functionality.

We also broaden the scope of the disruptive events from system failures to include natural disasters and terrorist activity. In addition, the defences against their consequences are extended to include the management of the disruptive event and the rapid restoration of the system functionality.

Collaborations

Human Factors Research Group | Nottingham Geospatial Institute | Centre for Structural Engineering and Informatics

Theme leads

Professor John Andrews
Resilience Engineering,
Faculty of Engineering

Dr Rasa Remenyte-Prescott
Resilience Engineering,
Faculty of Engineering

Example projects

Strategic University Partnership with Network Rail / involvement in the In2Rail H2020 Project

Development of new asset management modelling framework showing the models and data slow required to predict infrastructure performance, whole life costs, safety and service reliability on a whole system, whole life basis.

This is now the adopted approach across the whole of the Shift2Rail EU programme.

Capabilities

Whole life infrastructure asset management and planning

The University of Nottingham has a long-standing capability in this area which is demonstrated by the partnerships with industry that exist within the asset management group. We are conducting research into developing modelling techniques to predict ways of improving the design, maintenance and operation of engineering systems in order to reduce the frequency and consequence of failure.

We also have expertise in the technologies and decision frameworks aimed at facilitating the implementation of the circular economy and sustainability principles in transport infrastructure engineering.

Transport resilience to natural hazards and man-made threats

The University is focused on carrying out research which improves the resilience of engineering systems to a broad range of disruptive events from hazardous system failures to natural man-made disasters, ensuring adequate defences against their consequences, management of the disruptive event and the rapid restoration of system functionality.

Our capabilities include defining materials, frameworks and technologies to design, construct and maintain transport infrastructure which is able to adapt to progressive change and extreme events. This includes designing the materials, prototypes and laboratory tests to ensure the long-lasting performance of transport infrastructure.

Safety risk modelling, uncertainty, quantification and humans

The University has a strong track record in assessing safety critical systems, defined by their design, maintenance strategy and operation, to predict the likelihood or frequency of failure along with the consequences. From this, the optimal safety performance can be achieved accounting for the practical resource limitations. Asset Management specialists within the University use modelling to establish the most cost-effective maintenance strategy to ensure an acceptable condition of a system or infrastructure.

Resilience and recovery modelling

System resilience is defined as the ability to resist, absorb, accommodate and recover from effects of a hazard in a timely and efficient manner, including the preservations and restoration of its essential basic structures and functions. The concept of resilience provides a more appropriate alternative to risk analysis to view the performance requirements of modern safety critical systems and networks. In the past there has been a focus on ensuring that high risk system failures caused through component failure, human error or change in operating environment are highly unlikely to occur. System technology and their operating environments have now changed. Most now feature computer control making them vulnerable to cyberattack. Natural disasters, climate change, extreme weather conditions and terrorism are also included in range of threats that systems, infrastructure and networks must withstand. The concept extends the avoid strategy of risk assessment to include: withstand, recovery and adapt aspects with respect to the threat. Currently we focus on transport (railway and road) resilience metrics, their evaluation and modelling for improved system safety and efficiency.

Resilient stakeholders (emergency services and transport operators)

The University has one of the largest research groups in the field of resilience engineering in the UK and has active projects with stakeholders in the following sectors: transport, aerospace, nuclear, fuel cell, wind energy, oil and gas, manufacturing, military and medical engineering. Our expertise allows us to identify if the system is safe enough and how to provide the biggest improvement in safety for a given budget. We can also advise on the maintenance of an ageing system to provide an acceptable level of safety and then identify the optimal time to renew. We can determine faults on a system and then help make the system or network tolerant to these faults.

Increasing complexity, dealing with uncertainty and changing circumstances

The University is performing multi-disciplinary fundamental and applied research with the aim of developing novel materials, technologies and decision frameworks for the next generation of smart transport infrastructure.

System interdependency – energy, water and telecoms

Resilience of transport, utility and communications networks that are essential for modern cities and economies and the interdependencies between such critical infrastructures are included in this theme. The aim is to look at how to design and operate interdependent networks so that failures remain local and do not cascade through the network and across interdependent networks. The Resilience Engineering Research Group is currently leading an ESReDA (European Safety, Reliability and Data Association) Project Group on the 'Resilience Engineering and Modelling of Networked Infrastructure' to propose methods in this topic.

International

The International theme will draw together the research excellence across all of the other themes and transfer the technical advances into international contexts using the expert knowledge held across the University of Nottingham. The theme will target real-world impact through international development funds and United Nations SDGs. The University of Nottingham has strong links with both Malaysia and China through our campuses and our international reach stretches across the globe.

Collaborations

N/LAB – Centre for International Analytics | Nottingham Geospatial Institute | Laboratory for Urban Complexity and Sustainability | Computer Science | Horizon Digital Economy Research | Nottingham University Business School | Geography

Theme leads

Dr Xiaolin Meng
Associate Professor, Nottingham Geospatial Institute

Dr James Goulding
Deputy Director, N/LAB

Example projects

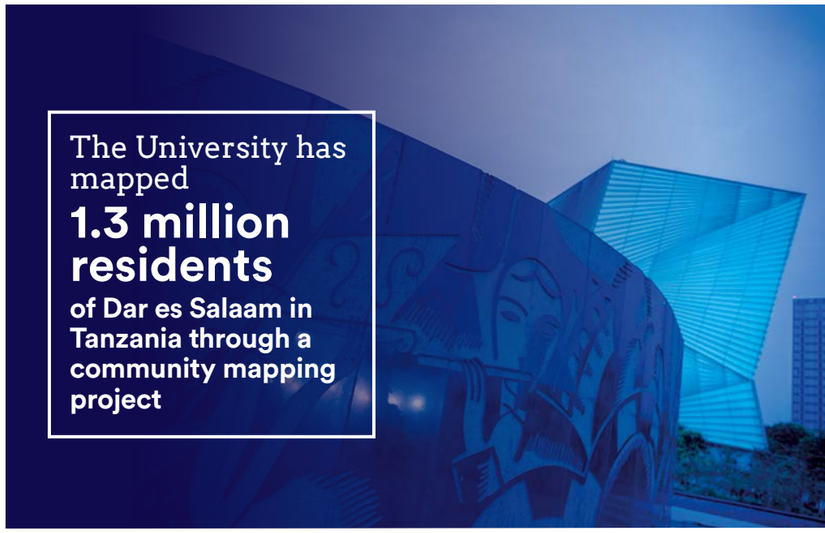
Transport, congestion and pollution modelling in Tanzania via CDR

Using Call Data Records from our mobile phone network partners in Tanzania, the University of Nottingham has created OD matrices and interfaces that reveal transport patterns throughout the year across Tanzania – data that was previously impossible to obtain, and additionally allows us to predict congestion and estimate pollution. The models are currently being used by World Bank in their East Africa Transport Masterplan.

Machine learning for automated road condition analysis in Zanzibar

Traditional road surveys are both prohibitively expensive and logistically challenging in DAC listed countries. Applying cutting-edge 'deep learning' techniques to drone imagery is allowing us to carry out automated road condition surveying at minimal cost. In collaboration with UK Department for International Development (DfID), analysis is to be used by the Zanzibar Department of Roads to identify badly needed road development.

Capabilities



The University has mapped
1.3 million residents
of Dar es Salaam in Tanzania through a community mapping project

Sino-UK Intelligent Mobility Forum

A UK Science and Innovation Network project entitled 'Building the Sino-UK Intelligent Mobility Partnership (IMP)', brings together IM practitioners, novel technologies, and intelligence and business models to enhance the implementation of intelligent mobility. Together, key experts from the UK and China form the Sino-UK Academy of Intelligent Mobility (SUAIM), establishing a number of priority areas which the academy aims to address.

Drone mapping

More and more transport planning projects are integrating analysis of earth observation imagery. Drones make up a significant part of our surveying capability, from video capture drones such as DGI Phantoms, to surveying grade imaging technology available on UAVs such as our Sensefly eBees. These are particularly useful in international projects, and our researchers are highly experienced in the use of such drone technologies, resulting in quick data collection times, and production of datasets with unparalleled resolution and positional accuracy. Remote sensing technologies such as these have been employed in projects across the globe and have been supported by our novel research that integrates high resolution data capture.

Mobility Modelling from Novel Data Streams

Understanding mobility at a population level provides key insights to transport planners, as well as being informative to businesses and policy makers alike. However, traditional survey-based approaches still common in the UK, are often unfeasibly expensive and resource intensive in many emerging economies. To address this, N/LAB has become adept in the analysis of novel transactional datasets, such as call data records (CDR), to produce automated, high-fidelity models of population movement and mobility in international contexts. These models are providing a cost-viable and customizable substitute to traditional survey-based approaches, while additionally being able to produce insight into congestion, commuting behaviours, and routing at national scales. A recent example of such work is in Dar es Salaam, Tanzania, where N/LAB has produced automated Origin-Destination (OD) Matrices from CDR data that are now being used as part of the World Bank's transport masterplan in East Africa.

N/LAB has become adept in the analysis of novel transactional datasets, such as call data records (CDR), to produce automated, high-fidelity models of population movement and mobility in international contexts.

Deep learning and computer vision

Leveraging the latest advances in deep learning and computer vision, the N/LAB research group has developed strong expertise in extraction of information and insights from geospatial information. Underpinned by a wide range of Earth Observation imagery (such as satellite, UAV and including both RGB and hyperspectral channels), convolutional network techniques are being used to address a wide range of transportation challenges. Examples of recent projects undertaken by the lab range from geospatial feature detection (roads, railways, buildings), infrastructure quality monitoring (for example road conditions) through to more traditional object detection (car, trucks, boats). Capacity in AI techniques such as this are allowing for improved urban planning and maintenance reports, at scales and frequencies that would otherwise be impossible.

Policy

The policy theme will bridge the space between the academic excellence that exists across the University in the field of Governance and Public Policy and external partners. Specifically, the theme will utilise the expertise of leading academics to promote meaningful stakeholder engagement and partner collaborations, to identify policy challenges and promote integrated transport and infrastructure solutions.

Collaborations

Business School | Sociology and Social Policy | Centre for Health Innovation | Leadership and Learning

Theme lead

Dr Amanda Crompton
Assistant Professor
in Public Policy and
Management

Example projects

Runaway Train: A case study of HS2's policy development

This five-year project examined the policy direction of High Speed Rail in the UK (HS2) and the response to this megaproject across a wide range of stakeholder groups (Chamber of Commerce, Business Partners, Community Groups and Protestors). The project focused on the public consultation that was undertaken by HS2 Ltd and the public's reactions to this consultation opportunity. The findings highlight the importance of engaging the public in infrastructure planning and development from project inception and throughout the development and implementation stages (Crompton, A. (2015) Runaway Train: Public Participation and the Case of HS2. Policy and Politics. 43(1): 27-44).

Innovation support for business

The University of Nottingham provides a wide variety of services to help make your business grow and become more profitable. The University has built a strong reputation for the quality and impact of its collaborative work, with a range of services that include research and development, offering new technology for licensing and other forms of commercialisation, providing consultancy expertise to solve business issues, and delivering training to meet staff development needs.

Support for business and industry at the University of Nottingham is organised through our Research and Innovation department. The department provides a range of services for both major corporations and the SME business sector, with support and advice services delivered through a number of dedicated teams:

Corporate Partnerships Team – develops and manages long-term strategic relationships with key corporate businesses in order to enhance the relevance and impact of the University's research and training activities, derive increased industrial income and further the University's external reputation.

Key contact: Ben Nichols
Email: ben.nichols@nottingham.ac.uk

Ingenuity – Ingenuity is the University of Nottingham's local business network. With some 2,000 members, the main aim of the network is to transfer knowledge and expertise from the University into the local SME business community. An extensive range of events and workshops are designed to encourage innovative collaborations between business and academia and for both parties to benefit from the connections they make.

Key contact: Gemma Morgan-Jones
Email: gemma.morgan-Jones@nottingham.ac.uk

IP Commercialisation Office – helps to commercialise technologies which have been developed through research by licensing the use of our technologies to a third party, utilising joint ventures to develop technology further and through investing in spin-out companies which frequently retain close links to the university. With our strong links to industry and investors, the IP Commercialisation Office provides invaluable market knowledge and experience, which is used by a highly professional team of Intellectual Property specialists to foster University research and develop it into marketable businesses.

Key contact: Gillian Shuttleworth
Email: gillian.shuttleworth@nottingham.ac.uk

Asia Business Centre – is the integrated Knowledge Exchange team located at our UK and China Campuses, incorporating the Continuing Professional Development Services team and India Office to deliver the University's knowledge exchange with Asia. Knowledge Exchange Asia is transforming the way the University develops its business partnerships in Asia. It is delivering sustained value for students, staff, and the University – and large scale commercial returns for partners. Specialist business knowledge and cultural competence is deployed to leverage strategic investment in student employability and entrepreneurship, international teaching and research partnerships and global alumni engagement.

Key contact: Min Rose
Email: min.rose@nottingham.ac.uk

Enabling Innovation – is a collaborative tri-university programme, its primary objective is to stimulate interest and investment in research and innovation within SME's across the counties of Derbyshire and Nottinghamshire. The programme is part-funded by the European Union which enables the University to deliver many of Enabling Innovation's activities at no cost to participating businesses.

Key contact: Jo Murphy
Email: jo.murphey@nottingham.ac.uk

Nottingham University Consultants – the University established Nottingham University Consultants to specifically provide management, commercial and financial support and expertise to staff wishing to carry out consultancy. The University adopts a positive attitude to academics acting as consultants as an effective way of disseminating knowledge. Examples of consultancy includes providing technical or creative expertise and solutions to industrial problems, serving on professional and government committees, provision of expert reports and acting as an expert witness.

Key contact: Malcolm Jackson
Email: nuc@nottingham.ac.uk

Training and Continuing Professional Development

Programmes developed for business and industry professionals

The University of Nottingham is able to provide a range of training solutions for business professionals. Combining the world-class research of Nottingham's academics and their teaching capacity, the University is also able to provide bespoke or open professional development courses tailored to the needs of industry.

The University has a dedicated CPD team within its Research and Innovation services whose purpose is to assist industry professionals with development of training and professional development courses and you can find out more about the team by visiting their website, nottingham.ac.uk/cpd or contact the team on cpd@nottingham.ac.uk.

The University of Nottingham has extensive experience in training professionals in part-time and distance-learning courses that are flexible and accessible and may be taken as stand-alone Continuing Professional Development or, in many cases, as part of accredited postgraduate award.

Programmes developed to suit the way you learn

- Bespoke training
- Executive Education
- Online and distance courses
- Part-time postgraduate programmes
- Short courses
- Summer schools
- Training workshops

Contact us: **cpd@nottingham.ac.uk**

Key contacts:
Michelle Hill: michelle.hill@nottingham.ac.uk
Lizzy Martin: lizzy.martin@nottingham.ac.uk
Debby Lin-Read: debby.lin-read@nottingham.ac.uk

Degree apprenticeships

Key contact: Ruth Eccles
Email: ruth.eccles@nottingham.ac.uk

Degree apprenticeships are a powerful way to develop your workforce and to drive innovation and growth. The University of Nottingham has ambitious plans for a comprehensive programme of demand-led level 6+ programmes to be delivered across all of our faculties.

Our apprenticeships will be crafted in partnership with industry to develop skills and knowledge which is directly relevant to your business. With our global reputation and world-class research and teaching, we are uniquely positioned to provide training which will have the most impact on your organisation. Apprentice students will undertake academically rigorous, part-time study that is built around your business.

Our programmes will help your employees to bring ideas and up-to-date knowledge and skills back into the workplace. Delivered under a blended learning model, apprentice students will benefit from a minimum of 20% of their working time being spent in off-the-job learning, whether on campus in lectures, seminars and practical workshops; through work based learning projects that directly benefit their learning and your business; or accessed online through remote learning.

We will work with local, regional and national businesses to understand your strategic priorities and challenges. Our programmes will be built to offer real value which can be tailored to a sector, or even developed bespoke to your own business. We are consistently ranked in the Top 100 universities in the world. Combining our excellent, TEF Gold award-winning teaching with our outstanding research capabilities and world leading campuses and facilities, presents a compelling case both for talent attraction and for retaining and developing existing staff within your business.

We are working with employers to develop degree apprenticeships in the following areas:

- Management
- Healthcare
- Scientific careers
- Engineering
- Digital and Computer Science

Transport Systems Catapult

The Transport Systems Catapult is the UK's technology and innovation centre for Intelligent Mobility (IM), harnessing emerging technologies to improve the movement of people and goods around the world.

The Transport Systems Catapult is the UK's technology and innovation centre for Intelligent Mobility (IM), harnessing emerging technologies to improve the movement of people and goods around the world.

We are here to support business growth, increase the UK's share of the global Intelligent Mobility market, and attract investment – creating jobs and generating long-term economic growth.

We will help sell UK capability on the global stage, while also promoting the UK as a superb test bed for the transportation industry. With a clear emphasis on collaboration, we are bringing together diverse organisations across different modes of transport, breaking down barriers and providing a unique platform for meeting the world's most pressing transport challenges. Our current areas of focus include:

- **Connected and Autonomous Transport** – focusing on the integration of automation and connectivity into the Intelligent Mobility system
- **New Mobility Services** – enabling the mainstream adoption of data-driven, dynamic and personalised on-demand transport
- **Open Data Platforms for Transport** – serving the rapidly emerging market for data-dependent products and services that will allow the two other sectors to operate at optimum efficiency and unlock additional revenue streams

As a thought leader in the Intelligent Mobility space, the Transport Systems Catapult has a pivotal role to play in connecting industry and academia. With the UK spending £4.6bn a year on science – and universities being the dominant research base player – it is important that academic research departments give Intelligent Mobility the focus it needs. Equally, as IM continues to develop, there will be a need for graduates trained in the new skill sets required for the flurry of jobs created by the sector. Thanks to our contacts at industry and policy-making level, the Transport Systems Catapult is ideally placed to communicate those future needs to the academic community and ensure that higher education establishments nationwide tailor both their curriculums and their research agendas accordingly.

The Transport Systems Catapult is one of an elite network of not-for-profit technology and innovation centre's established and overseen by the UK's innovation agency, Innovate UK.

Academic engagement

Designed to maximise the potential impact of academic research on industry and enable the sector to grow faster, our Academic Engagement Strategy has been created for industry, universities, national and local government, sister Catapults and further Research and Technology Organisations. Our strategy intends to build relationships within the IM ecosystem, both immediately and long-term – to bring thinkers, innovators, leaders and business owners together to benefit each other, the community and the UK.

Deep academic alliances

DAAs are key partnerships between universities, industry and the TSC that align research, commercialisation and strategies. They play an important role in maximising the potential of SME networks and creating a strong group of universities who can lobby for funding for IM to develop capabilities with industry for the benefit of UK PLC.

As part of the DAA programme, the TSC has been collaborating with the University of Nottingham to formalise TMC@Nottingham: Transport, Mobility and Cities. Over 60 academics working across 12 university departments have been engaged through internal workshops and are committed to support the vision of this cluster of activity which will act as a 'shop window' through which our external stakeholders can easily engage.

Collaborate with us

Find out more about how we can work with your business or organisation:

TMC@nottingham.ac.uk
+44 (0)115 748 4492
nottingham.ac.uk/research/groups/tmc