Welcome to the Department of Civil, Environmental and Geomatic Engineering’s 2017 Research Report, which brings together the activities and interests of our diverse interdisciplinary department as we celebrate 190 years of engineering a better world.

Our department is internationally known for its talented teams and individuals who work on challenges ranging from mitigating risk through engineering our cities and communities for natural disaster resilience to advancing spatial big data science. Working as a trans-disciplinary team we are able to uniquely understand and optimise the way our increasingly complex societies and infrastructures function. As a department we are well-known for our focus on the interaction between people and the engineered environment. For example in PAMELA, our human interaction laboratory, we uniquely create full-scale spaces where individuals and crowds can interact with trains, buses, roads and buildings in order to better design sustainable infrastructure suited to the citizen.

During the past five years we have invested in new staff to build stronger teams in materials, geotechnics, structures, fluids, environmental engineering, geomatics and transport. We have renewed our focus and energy on experimental engineering with world-leading new laboratory facilities at Here East in East London to investigate long-term structural fatigue loads and cyclic weathering action in parallel with an internationally unique factory-scale robotics capability, targeted at expanding human capabilities in digital manufacture and fabrication.

We hope you enjoy reading about our research activities, aspirations and impact. We are very much open for business and are looking for wider engagement with counterparts in industry, health, government, and infrastructure planning. If what you see inspires you, please get in touch.

Stuart Robson FRICS
Head of Department

Contact us

Department of Civil, Environmental & Geomatic Engineering,
University College London,
Gower Street, London WC1E 6BT

Web: www.cege.ucl.ac.uk
Tel: 020 7679 4079
Email: cege-research@ucl.ac.uk
Twitter: @CEGE_UCL

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Civil, Environmental and Geomatic Engineering at UCL – a history of experimentation and expertise

In 2017, UCL’s Department of Civil, Environmental and Geomatic Engineering marked its 190th anniversary, celebrating the skills, expertise and research achievements of the Department over almost two centuries.

A broad heritage

Engineering was one of the first subjects to be taught at UCL. John Millington, England’s first Professor of Engineering, was appointed in 1827, the year after the then ‘London University’ (now UCL) was founded. Millington’s title - ‘Professor of Engineering and the Application of Mechanical Philosophy to the Arts’ – reflects the ethos of UCL’s founders, who wanted to create an institution which was open to all, and whose work was relevant to the needs of a rapidly changing society.

Our engineering teaching and research has continued to look beyond traditional engineering disciplines. Over the years our staff, researchers and students have collaborated with experts in other fields to explore how engineering skills and knowledge can be used to create a better world. Much of the Department’s research links engineering expertise to other disciplines, such as health, environment, and urban and developmental planning. The Department also contributes significantly to the understanding and management of many global environmental issues caused by earthquakes, flooding and other natural phenomena.

Key dates in the Department’s history include:

1827 – John Millington was appointed Professor of Engineering and the Application of Mechanical Philosophy to the Arts. Millington was Professor of Mechanics at the Royal Institution and gave the inaugural Royal Institution Christmas Lecture in 1825.

1841 – the first Chair of Civil Engineering in the country was established at UCL. Professor C.B. Vignoles, a leading railway engineer, was appointed to the role. He pioneered the use of a flat-bottomed railtrack, often referred to as the ‘Vignoles rail’. This method is now standard across the world.

1866 – Fleeming Jenkin was appointed Professor of Engineering. Through his work on undersea cables, including some of the first work on transatlantic cables, he came to be known as the ‘father’ of electrical engineering. He also developed the ‘telpherage’ cable car system, which could transport goods and passengers in large panniers on an electrically-powered wire or conductor. The system was often installed in postal depots and factories to move goods around.

Images © UCL
1871 – Professor of Engineering Alexander Blackie and William Kennedy established laboratory courses and coined the term ‘engineering laboratory’. Lab experiments became an essential part of the students’ work.

1894 – the Chadwick Building opened on UCL’s main Quad. The building was named after Sir Edwin Chadwick, social reformer and former assistant to UCL benefactor Jeremy Bentham. The Department is still based in the Chadwick Building - it also administers the Chadwick Trust, a small charity which supports research and projects in public health, sanitation and engineering.

1898 – Chadwick’s son, water treatment and sanitation engineer Sir Osbert Chadwick, was appointed UCL’s first ‘Chadwick Professor of Municipal Engineering’. His work often took him overseas including to India and Russia. He designed the ‘Chadwick Lakes’ in Malta, a series of lakes and dams which provide fresh water for farmland. Professor Nick Tyler is the current Chadwick Professor of Civil Engineering.

1945 – the Department was renamed ‘Department of Civil & Municipal Engineering’.

1947 – formal graduate degrees in surveying were introduced.

1961 – a separate ‘Department of Photogrammetry and Surveying’ was formed.

1962 – leading UK soil expert Robin Arthur was appointed Lecturer. He became Professor of Geotechnical Engineering in 1985. Arthur developed the directional shear cell (DSC) apparatus, which became known worldwide and was copied in several countries.

1965 – Department of Photogrammetry and Surveying academics mapped sites in Jordan’s historic city of Petra using photogrammetric technology.

1967 – Reuben Smeed was appointed UCL’s first Professor of Traffic Studies. His earlier research and statistical analysis of road traffic issues led him to propose ‘Smeed’s Law’, correlating traffic fatalities to traffic density. In 1964 The Smeed Report was published, showing Smeed’s research into the benefits and feasibility of congestion pricing for urban road networks. Much of Smeed’s work has contributed to better road design and traffic calming measures still in force today.
1991 – the Department of Civil & Municipal Engineering was renamed ‘Department of Civil & Environmental Engineering’, reflecting the increasing importance of environmental issues in society.

1997 – the Department of Photogrammetry and Surveying became the ‘Department of Geomatic Engineering’, incorporating research work in navigation satellite systems, earth laser scanning and GIS (Geographic Information Systems).

2006 – the Pedestrian Accessibility Movement Environment Laboratory, known as PAMELA, opened. Life-size replicas of pedestrian infrastructure, including train carriages and underground platforms can be built and tested at the PAMELA lab. PAMELA has been used for research collaborations with Transport for London and the Thameslink 2000 railway project.

2006 – the Department of Civil & Environmental Engineering launched pioneering new degrees in Civil Engineering and Environmental Engineering.

2007 – a broad ‘Department of Civil, Environmental and Geomatic Engineering’ was formed by merging two Departments, Civil & Environmental Engineering and Geomatic Engineering.

2011 – the Department received £17.2m of funding from the UK Engineering and Physical Sciences Research Council (EPSRC), more than any comparable university department.

2017 – significant funding was awarded to the Department from the UKCRIC programme (UK Collaboratorium of Research in Infrastructure and Cities). The Department convenes UKCRIC, which comprises major research collaborations amongst 13 UK universities.

The UKCRIC funding included a £9m EPSRC award towards PEARL (People-Environment-Activity Research Laboratory), an enhanced version of the PAMELA facility. PEARL will be located in East London and is expected to be operational in late 2018. At that stage, PAMELA activities will transfer to the new facility.

2018 and beyond – the Department will deliver several new programmes at ‘Here East’, UCL’s newly-developed East London site located at the former Olympic Park. The programmes will combine disciplines such as engineering, architecture and design. The site incorporates the Cyclic Environmental and Mechanical Multi-Scale Lab, a new cutting edge laboratory where architects, engineers, computer scientists, mathematicians and anthropologists of the future can learn, research and collaborate.
The word ‘curator’ has traditionally been associated with art exhibitions and museums. More recently, however, the use of the word ‘curator’ has grown in popularity, particularly on the internet, where there are countless options and ideas to be selected, understood, linked, reinterpreted, and juxtaposed.

That being the case, this booklet should be read as a curation of the research activity carried out in UCL’s Department of Civil, Environmental and Geomatic Engineering (CEGE).

It has been difficult to show the interlinkages, influences and collaborative works that are intrinsically part of each of the research areas we have presented in this publication. Nonetheless, the idea of classifying our research under three broad headlines – Built Environment, Measurement and Big Data, and Infrastructure – is intended to demonstrate the breadth and advances developed in civil engineering research by the Department in 2017. It is indeed a curation, but it is also a display window of civil engineering 4.0.

Francesca Romana Medda
Director of Research
Department of Civil, Environmental and Geomatic Engineering

Image below: Engineering – spanning the past, reaching into the future
Cracks in concrete – what controls are required?

Chanakya Arya, Takhmina Myrzakulova

The significance of cracks in concrete to reinforcement corrosion remains an unresolved technical problem with seemingly no universally accepted solution. This was discussed in the Concrete Society Technical Report 44 (2015). It is important that this question is answered because cracks in concrete structures are unavoidable and reinforcement corrosion is a worldwide, trillion pound problem. It is generally acknowledged that cracks can hasten the penetration of carbon dioxide from the atmosphere and/or chloride ions from sea water (in the case of coastal structures or salt used as a de-icing agent during winter maintenance on land based structures). Eventually this results in embedded reinforcing bars losing passivity and becoming susceptible to corrosion.

Although cracks undoubtedly reduce the initiation time for corrosion, the effect on the subsequent rate of corrosion is controversial. The commonly-held view is that a large number of narrow cracks is the most desirable option, yet the results of more recent research contradict this assessment. Both views are based on the analysis of test results obtained from specimens where the cracks occur transverse to steel reinforcing bars. But given that steel reinforcement in virtually all members is present in two orthogonal directions, in practice cracks which are transverse to one set of bars will inevitably be parallel to the other. If any of these cracks lie over steel bars, termed coincident cracks (see illustration), they could give rise to significant corrosion. However, very little work has been carried out on the risk of coincident cracks to corrosion.

We believe that our research on this risk aspect will help resolve the debate on the significance of cracks to corrosion and provide the necessary guidance for designers to design sustainable reinforced concrete structures which will remain durable during their service life.

Advancing our understanding of how climate and natural hazards impact on the built environment


Our research focuses on the interaction between the built environment, climatic conditions and natural hazards. We develop modelling tools based on evidence from field work and laboratory work. We have invested in a new multimillion laboratory - the Cyclic Environmental and Mechanical Multi-Scale Test Lab - situated at Here East, UCL’s new East London site.

At Here East, we have created a unique integration of strong floor and reaction frame facilities with large-scale environmental chambers, where real-size models
replicating elements of the built environment can be tested for extreme environmental and structural scenarios, simulating earthquakes, windstorms and flooding. This allows us to calibrate and validate our advanced modelling of historic masonry structures response (STORMLAMP), the mechanical response of ancient tapestry to indoor environmental conditions, and the response of historic composite timber and masonry structures to flood and wind-driven rain (PARNASSUS). We also work on the development of dissipative devices to improve the seismic resilience of historic buildings.

Our fieldwork activities aim to improve the base knowledge of the built environment on which the vulnerability and resilience of specific structures and infrastructure to single or multi-hazards is simulated. We are investigating the potential of digital tools such as drones and omnidirectional cameras to improve fundamental understanding of how buildings are built and how they are damaged by earthquakes or other hazards. We are using this information in two ways: to record observed damage in a spatial temporal frame and enhance our interpretation of the structural response, and to produce better and more realistic structural models of real buildings and other infrastructures. This knowledge underpins the application of our vulnerability and resilience procedures to historic buildings, schools, hospitals, residential construction and road infrastructure, looking at structural damage, functionality loss, recovery and the whole life cycle. Our field work has taken us to many parts of the globe, from Guatemala to Nepal, from the Philippines to Italy.

Image below: Studying the mechanical response of ancient tapestry to indoor environmental conditions.

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**Pursuing excellence in low carbon cement and concrete technology**

Yun Bai

The overall vision of the Advanced and Innovative Materials (AIM) Group is to establish a London-based International Centre of Excellence for Low Carbon Cement and Concrete Technology. The research activity is mainly focused on low-carbon cementitious materials.

These include: alkali-activated cementitious materials (AAM) – for example alkali-activated slag and fly ash – calcium sulfoaluminate cement (CSA), calcium aluminate cement (CAC), magnesium oxide-based cements (MgO) and Portland cement-based composites. In addition, some unique and tailored research capacity and facilities have been developed which have strengthened our leadership in certain areas of low-carbon cement and concrete. Typical examples include microwave-based curing, Raman spectroscopy-based monitoring, and carbonation-based accelerated curing.

In September 2017 the AIM Group hosted the 37th Annual Cement and Concrete Science Conference at UCL. The Conference was organised jointly by AIM and Institute of Materials, Minerals and Mining’s Cementitious Materials Group.

[www.ucl.ac.uk/aim](http://www.ucl.ac.uk/aim)
Characterisation of soil particle roughness

Béatrice Baudet, Ting Yao (University of Hong Kong), Hongwei Yang (formerly University of Hong Kong)

The surface of a soil grain is not smooth, especially under examination with finer resolutions. Evidence that surface roughness influences the inter-particle contact behaviour as well as the continuum behaviour of soils prompts us to develop advanced means of roughness characterisation for soil grains. Due to the complex nature of the soil forming process, the surface of a soil grain usually exhibits random features, unlike engineered surfaces. Existing advanced metrology technologies are difficult to apply to real soil grains, in particular because of the irregular shape of soil grains, which can influence the measurements. For example, roughness measurements are generally made by interferometry. Using a built-in programme to separate shape and roughness may not be appropriate for irregular shapes and does not usually give a scale for roughness.

In this research we are proposing a new method, partly borrowed from tribology and uniquely applied to soil grains, which uses unaltered measurements of the soil grain surface morphology obtained by interferometry. We show that by first calculating the surface area by triangulation at various discretisation lengths, it is possible to determine a cut-off length between roughness and local shape. Assuming an auto-correlation function for heights formed by random processes, the data can also be expressed in terms of power spectral density (PSD), so that the spatial surface height data are transformed into a spatial frequency domain. The statistical roughness can be calculated from the PSD, while the self-affine nature of the surface allows determining fractal dimensions which, when combined with other parameters, provide additional information about the surface structure and roughness to the value of roughness alone. The parameters characterising the roughness can be used to reconstruct the surface of soil grains by using the Weierstrass-Mandelbrot function, for example for constructing realistic numerical particles for discrete element models of soils.

A new method is proposed to quantify the roughness of soil grain surface. The parameters determined from the analysis will allow the reconstruction of numerical surfaces for use, for example, in discrete element modelling of soils.

Image above: Statistical resemblance between (a) computed and (b) measured surface data on sand grains measuring 0.6 to 5mm.
Interaction of extreme flooding with built environment

Eugeny Buldakov

This experimental project is a collaboration between UCL CEGE and the Department of Architecture & Civil Engineering, University of Bath. The aim of the project is to generate flash floods in a controlled laboratory environment to provide physical understanding of the impact of intensive flush fronts on buildings.

The project provides high quality flash flood data to the research community for the development and calibration of future numerical models. The data will allow us to validate numerical models to be used for minimisation of extreme flood impacts on the built environment. Understanding of velocities and impact forces on buildings associated with flash floods will help to provide recommendations for safe design of buildings in areas of high risk of extreme floods.

Image below: Simulating flash floods at UCL’s Fluids Laboratory.
The particle scale mechanics of sands

Matthew Coop, Vincenzo Nardelli (University of Hong Kong), Wang Wanying (Guangdong University of Technology)

In contrast to many other civil engineering materials, such as concrete or steel, the behaviour of soils is dominated by its particulate nature. Nevertheless, a continuum approach is usually applied to soil as for other materials, so design is by means, for example, of a finite element programme. The equations used to represent the soil behaviour that might be used in such an approach are often then highly complex as they try to capture a behaviour that is actually particulate.

In the future, we might therefore abandon our continuum approach when we design soil structures such as foundations or tunnels and instead try to model every particle of the soil individually using a discrete element approach rather than finite element. Current attempts to do this often use simplistic spherical soil particles, but soon we will be able to use realistic shapes. What is missing is the mechanics of the individual particles and this project addressed that aspect of the problem.

Innovative new apparatus were developed to test individual particles, examining the behaviour when two sand particles touch and also how, when they are loaded together far enough, they break. The results have shown that the mineralogy, size, shape and roughness of the particles controls their contact behaviour and their strength and that neither the way sand particles break nor the load-deflection behaviour up to breakage correspond very well with currently accepted theories.
Dynamics, fatigue and damping in offshore wind turbine structures

Philippe Duffour

Philippe’s research on offshore wind turbines focuses on their dynamics and fatigue. He is currently working on detailed modelling of the damping in these systems as damping directly affects the amplitude of turbine responses to wind and waves.

He also collaborates with Dr Gennaro Senatore (formerly of CEGE, now at École polytechnique fédérale de Lausanne) on adaptive structures to save energy. The large-scale adaptive truss prototype built at UCL to demonstrate the practical potential of the design methodology developed during Gennaro’s EngD was nominated in the 2016 Institution of Structural Engineers’ Structural Awards ‘Small Projects’ category. The prototype was also nominated and won the 2016 National Instrument Engineering Impact Award in the ‘Precision and Control’ category at a ceremony held in London in November 2016.

Philippe continues to collaborate with UCL Bartlett on developing combined cost and carbon structural optimisation tools for buildings. The project integrates optimisation and multi-criteria decision-making tools within a building information modelling platform (BIM).

He is also supervising a PhD student thesis on the potential of using graphene oxide as a Portland cement additive.

Resilient steel structures

Fabio Freddi

Fabio’s research interests are in the response of structures to extreme loads, including earthquake engineering and structural robustness.

His research focuses on integrating structural modelling, computational techniques, probabilistic concepts and experimental results into a coherent framework for the performance evaluation and design of structures responding to urgent needs of modern societies for resilience and sustainability.

Fabio’s research covers seismic design and retrofit, seismic risk assessment, smart structural details, resilience, and robustness of structural systems. These areas involve analytical and probabilistic studies, numerical simulations and large-scale structural tests.

The emphasis of his research is mainly on steel and steel-concrete composite structures.

In the past year Fabio has focused on three main research themes:

• smart structural details for steel frames: a rocking damage-free self-centring steel column base, using post-tensioned high strength steel bars and friction devices has been developed. While a design methodology has been proposed, numerical and experimental results demonstrated the effectiveness of this innovative solution

• progressive collapse of self-centring moment resisting steel frames: while these structures demonstrated their seismic performances, considerations about other hazards are required. Numerical studies based on advanced 3D finite element models offer insights about the robustness of this structural typology

• dual systems based on moment resisting steel frames and buckling restrained braced frames: this research focuses on the definition of design recommendations for the dual system.

Image left: Large-scale experimental test using smart-innovative column base connections for resilient steel structures.
Catastrophe Risk Engineering Laboratory (CRE-Lab)

Carmine Galasso, Chen Huang, Biao Song, Alexandra Tsioulou, Omar Velazquez (UCL Earth Sciences), David Wilkie

Probabilistic catastrophe (CAT) risk models are becoming increasingly popular tools for estimating potential loss due to natural hazards. Such models incorporate detailed databases and scientific understanding of the highly complex physical phenomena of natural hazards, and engineering expertise about how infrastructure, buildings and their contents respond to those hazards.

Our research in this area focuses on the development and use of advanced probabilistic and statistical methods for modelling and managing risk caused by extreme loads on the built environment, with an emphasis on earthquakes and wind hazards. We are collaborating with national and international research institutions and stakeholders to promote CAT risk engineering (CRE).

Recent advances in this area by our group include:

- the generation, validation and use of physics-based and stochastic simulated ground motions for seismic risk modelling (in collaboration with the Southern California Earthquake Centre (SCEC), the University of California, Irvine, and the University of Notre Dame)
- the development of a real-time, Bayesian, CAT modelling framework for designing engineering applications of earthquake early warning in Italy and Mexico
- the development of a framework for multi-hazard risk assessment and risk-based design of offshore wind energy technology in Europe (in collaboration with AIR Worldwide)
- the development of innovative statistical algorithms for modelling ground motion spatial correlations and uncertainties for seismic loss estimation (a collaboration with UCL’s Department of Statistical Science and CEA, the China Earthquake Administration)

Improving soil quality

Susana Lopez-Querol

Susana’s research focuses on soil dynamics, advanced numerical modelling in soil mechanics and ground improvement techniques.

Ground improvement: In recent experimental research on Aeolian sand from Jeddah, Saudi Arabia, Susana showed that when sand is mixed with different additives its bearing capacity is improved. The research showed that dune sand was improved by the addition of cement. A new testing procedure to evaluate the mixture’s bearing capacity has been proposed. A paper on this research was published in Construction and Building Materials (October 2017); follow-up papers are in progress.

Susana also explored the influence of fly ash (pulverised fuel ash) on the improvement of poorly-graded sandy material, when activated with cement. The study focused on establishing the optimum quantity of fly ash content for stabilisation of this type of soil, and on the effects of such soil improvement techniques on the
bearing capacity, measured through CBR tests. For this project she worked with and supervised PhD student Siavash Mahvash (University of West London). They published journal papers in Science Direct’s *Heliyon* (March 2017) and in *Proceedings of the ICE – Ground Improvement* (October 2017).

Susana co-supervised PhD student Pedro Navas (University of Castilla La Mancha, Spain), working on mesh-free coupled numerical models in soil mechanics. Navas developed a computational code to simulate high strain problems in dry and saturated soil under different loadings. Susana and her colleagues will now apply the same code to other problems, such as the installation of piles. Two papers have been published on this research in *Computers and Geotechnics* – another three papers will shortly be published.

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**Bamboo Structures for the 21st Century**

Rodolfo Lorenzo

For decades bamboo has been identified as one of the most promising alternatives to help reduce the rising demand for industrialised building materials in the Global South. However, numerous technical and cultural challenges have so far prevented its widespread use in construction. As it operates today, the construction sector will not be able to meet this demand based only on the energy-intensive building materials developed during the last century for a very different world. Steel, concrete and aluminium, the three main construction materials, are already responsible for almost 50% of all global industrial CO₂ emissions and demand is expected to double by 2050.

This research re-examines the structural use of natural bamboo culms (thick stems) against the context of the digital age, postulating a new design and fabrication framework to support the construction of high-quality, sustainable and resilient bamboo structures suitable for the 21st century. This framework is based on a new high-tech, low-energy design approach, centred on managing – as opposed to forcibly eliminating – the inherent variability of bamboo, based on the use of modern 3D scanning and digital fabrication technologies. A technological framework that supports expressive, high-quality designs incorporating a rational use of bamboo is required, in order to increase acceptance of bamboo as a sustainable and attractive construction material.
EPICentre – an interdisciplinary centre for natural hazards resilience

Tiziana Rossetto

EPICentre was founded in 2007. It is a dynamic multidisciplinary research centre that investigates risk to society and infrastructure from earthquakes and other natural hazards. It provides a forum for multidisciplinary research into risk from natural hazards and disaster risk reduction. The driving force behind EPICentre’s research is the ambition to drastically reduce loss of life, livelihoods and economic loss in natural disasters. Today, EPICentre links 16 academic staff, 30 PhD students and 13 research associates from six departments across UCL, and holds a portfolio of research projects valued at over £10m. A few of our research highlights are:

- development of models, statistical and probabilistic frameworks, data and tools, for assessing the risk to infrastructure subjected to earthquakes, tsunami, floods, wind and fire. Our models are widely used for catastrophe modelling and insurance in the structural engineering industry and heritage preservation sectors.
- we have developed fundamental understanding of tsunami impact on buildings using unique experiments, coupled with theoretical work and numerical fluids and structural analysis. This work has a strong potential to impact future building codes for tsunami and current seismic codes in areas at risk from tsunami.
- we have pioneered research in people’s risk representation that has led to the design and implementation of an intervention to improve earthquake and fire preparedness behaviours in communities in Seattle (USA) and Izmir (Turkey). Our longitudinal monitoring of community preparedness has proved that one year after its completion, the intervention was successful. This work paves the way towards effective large-scale mitigation programmes.

We have developed practice-oriented methodologies and computer tools for ground motion simulation, selection and modification for nonlinear structural analysis (REXEL/REXELite/REXEL-DISP) and for physical vulnerability assessment of masonry dwellings (FaMIVE) and low- to mid-rise RC buildings (FRACAS). These methodologies and tools are acknowledged in several seismic risk assessment guidelines in Europe.

www.ucl.ac.uk/epicentre

Image below: Strengthening beam column connections with fibre-reinforced polymer.
Long-term performance of lightweight advanced composite road bridges

Wendel Sebastian

Advanced composites are corrosion-resistant, high specific stiffness, high specific strength materials that have revolutionised the aerospace industry by enabling lighter, more fuel-efficient passenger aircraft such as the A380. These materials also show strong potential to revolutionise our surface transport infrastructure by enabling prefabrication of lightweight, durable road bridges which can be quickly craned into position on site, thus minimising traffic flow disruption during construction.

Our research at CEGE is focused on assessing the long-term performance of these composite road bridges under combined environmental and mechanical actions (millions of lorry load cycles which become more onerous over time). In a three-pronged approach the research draws together continuous monitoring of bridges on the road network using state-of-the-art sensors, with computer modelling of the bridges and fatigue testing of full-scale bridges in the lab.

This work is supported by the EPSRC and also by industrial partners including Highways England and Network Rail. It is pursued in collaboration with academic partners both in the UK and abroad, such as EPFL (École polytechnique fédérale de Lausanne) in Switzerland. Advanced composite bridge technology is still young and so this research will underpin a new generation of such bridges, while also producing reliable, user-friendly guidance for the design of these novel bridges by practising engineers.
Scour around the foundations of marine structures

Richard Simons, Mohammed Al-Hammadi, Eugeny Buldakov, Kate Porter, Nick Tavouktoglou

Offshore wind farm arrays are being constructed in countries all around the world to meet the unprecedented expansion in demand for renewable energy. In the UK, arrays of wind turbines are being built in deeper waters, at sites where the structures are based on complex soils, and where they are required to operate under extreme environmental conditions. The design of foundations for the wind farms developed for these locations is presenting a series of new challenges.

Working closely with industry, researchers in the CEGE Coastal Group are carrying out a series of investigations to understand and predict how seabed sediment is scoured from around the foundations of wind turbine support structures. This is of critical importance in the design process, because excessive scour can lead to structural failure, whilst conservative design can add massively to costs.

Recent projects have examined the effects of waves and currents on different forms of marine foundation in a variety of seabed sediments under a range of environmental conditions. This work has led to:

- publication of a new formula which allows designers to predict the scour around marine structures with complex geometries such as gravity-based structures which are suitable for deployment in deeper waters
- identification of conditions under which scour in mixed or layered sediments can exceed the values predicted by conventional design methods
- measurement of changes in scour depth through a full spring-neap tidal cycle and in the presence of combined waves and currents
- identification of the effects of structural vibration on the depth of scour in cohesive and non-cohesive sediments and on the performance of scour protection.

The CEGE Coastal Group’s research into seabed scour around marine structures is helping designers to understand the effects of waves and currents on foundations with complex shapes. This will help to improve design procedures, particularly in the UK, where wind farms are being built in deeper waters, at sites which are often subject to extreme environmental conditions.
Each year, humans extract about 60 billion tonnes (60,000m) of resources from the planet. The majority of this is non-renewable and about two-thirds is emitted to air, water or land, leading to climate change and pollution. The circular economy offers a more sustainable vision of resource cycling at high value, with continual interlinked cycling of man-made materials, and cascading cycling of biological materials to ultimately nourish the earth. Its goals are greater economic stability, with more equitable sharing of resources, and maintenance of consumption and environmental impacts within planetary boundaries.

UCL CircEL aims to harness the full breadth and depth of UCL expertise, to tackle circular economy-related problems of any size or stage of development. In the past year, CEGE’s Centre for Resource Efficiency & the Environment (CREE) has led workshops with academia and industry to consider how circular economy research can support the growth of small and medium-sized enterprises, and how circular economy principles can be embedded in multidisciplinary teaching at all levels.

Our Circular Economy-related projects include research on the potential environmental impacts of using industrial wastes to make cement, re-use of timber harvested from the demolition of buildings, creating biofuels from agricultural waste, and growing algae using emissions from ships.

Images right: Light microscopy photographs – morphological differences between ordinary cement clinker and cement clinker made with 35% air pollution control residue from an energy-from-waste plant.
Dynamics of large-deformation structures under moving loads

Gert van der Heijden

The problem of a continuously distributed system carrying a moving concentrated load or mass has broad applications in engineering, including space tethers, satellite antennae, launch systems, robotic arms, pipelines, cranes, flexible manipulators, high-speed train railroads and highway bridges with moving vehicles.

The classic example of a moving-mass problem is the idealisation of a vehicle-bridge system in which the moving vehicle is treated as a moving load and the bridge is modelled as a small-deformation beam. However, with the current drive to use thinner and lighter materials in order to save material and reduce costs, large deformations of slender structures become increasingly important.

In recent work we have developed a formulation for the problem of a slender structure undergoing large deformations under the action of a moving mass or load, motivated by inspection robots crawling along bridge cables or high-voltage power lines. The structure is modelled as a geometrically-exact Cosserat Rod that allows for arbitrary planar flexural, extensional and shear deformations. The formulation handles the discontinuities of the problem well - for example, the shear force has a step discontinuity where the point load is applied.

Application of the method to a cable and an arch problem reveals interesting new non-linear phenomena. For the cable problem we find that large deformations have a resonance detuning effect on cable dynamics. For the arch problem the moving load has a stabilising effect: buckling or collapse of a statically unstable arch is delayed by a moving load and suppressed altogether at sufficiently high speed.

Images right: Deformation of a slender arch under a moving load.
Multiscale modelling of concrete durability: From microstructure to macro-scale properties

Mingzhong Zhang

Concrete is the most widely used man-made material in the world. During its service life, reinforced concrete may interact with its environment and suffer from various types of degradation, such as chloride-induced corrosion of reinforcing steel, carbonation and so on. As a result, a large percentage of the total infrastructure budget is spent on the repair and maintenance of concrete structures. All these degradations are related to transport phenomena in concrete, for example the ingress of chloride ions, $O_2$ and $CO_2$ into concrete. This means that transport properties of concrete including diffusivity and permeability are usually considered as indicators to assess the durability and predict the service life of reinforced concrete structures. Transport properties of concrete depend on the evolution of concrete’s underlying microstructures over a wide range of length scales.

In this work, for the first time, the transport properties of saturated and unsaturated concrete are investigated from a multiscale point of view. A range of advanced experimental techniques including X-ray micro-CT, a scanning electron microscope, and computer-based models are used to characterise the internal microstructure of concrete. An integrated multiscale lattice Boltzmann-finite element modelling scheme from micro- to meso-scale is developed (based on the 3D microstructure that was developed). The modelling scheme is applied to simulate single- and multi-phase flow in concrete, which is then used to determine transport properties as a function of both the moisture content and pore structure features.

This research makes it possible to accurately predict the service life of reinforced concrete and thus support decision-making by government and industry on the enhancement of durability concrete structures. The multiscale approach we have developed opens up the potential for a wider variety of applications outside cement-based materials, such as petroleum engineering and geosciences, waste containment and disposal, fuel cell and so on.
MEASUREMENT AND BIG DATA
Jeddah Historic Building Information Model
Jan Boehm, Ahmad Baik

This project explores the application of Building Information Modelling (BIM) for the documentation and management of heritage buildings. A task we frequently face today is how we can preserve, manage and record historic buildings to save them from the risk of collapse and erosion by natural and human factors or disastrous events. While most of the recent BIM work and related protocols focus on new construction projects, the approach can be extended and adopted for existing structures and heritage buildings. A major issue in this approach is the modelling of complicated architectural elements of historical buildings. The details of windows, stonework and ornaments give each historic building its individual character. But these details are difficult and cumbersome to model as there are no standard libraries to pick them from.

Our work focuses on the historic district of Jeddah, a major city in Saudi Arabia with a long history and many buildings that date back to the 16th century. Unfortunately, many buildings are abandoned today or have been lost over the last thirty years and because of that, a part of the city’s history has been lost. Recently Historic Jeddah has received renewed attention as it has been added to the UNESCO World Heritage List. Jeddah’s historic buildings are characterised by the Hijazi architectural style, which it shares with other Arabic cities. Our proposed Jeddah Historic BIM uses 3D laser scanning and photogrammetry to create detailed geometric models. Ahmad Baik’s major thesis output was the development of a custom library of architectural elements, the Hijazi Architectural Objects Library (HAOL), to facilitate and reduce the cost of the 3D modelling process.

More details are given in ‘Hijazi Architectural Object Library (HAOL)’, published in International Society for Photogrammetry and Remote Sensing (February 2017).

Better patrol routing strategies for better policing
Tao Cheng, Huanfa Chen, John Shawe-Taylor

Providing distributed services on road networks is an essential concern for many applications, such as mail delivery, logistics, and police patrolling. For example, delivery companies need to work out how to pick up packages from multiple depots and deliver them to customers who may be dispersed over a large geographical area. A well-designed route can improve the efficiency of this process and substantially reduce the cost of the distributed service. Therefore, routing problems have long been an essential area of operations research, and are receiving increasing attention in both research and applications.

Routing problems become more complicated when multiple vehicles from different depots are involved, where the balance of workloads and route lengths should be considered. In the case of policing, police patrol officers belong to different stations, and should cooperate to cover a set of important crime hotspots in the region. The patrol routes should be balanced in order to target crime and promote public confidence through visibility, whilst preventing work overload.
At UCL, we are researching how to design balanced routes for police patrol, in order to improve the efficiency of policing. This involves formulating the problem on the road network, and then solving the problem with intelligent computational algorithms. You can read about the latest progress of this research in our paper ‘Balanced Route Design for Min-Max Multiple-Depot Rural Postman Problem (MMMDRPP): a Police Patrolling Case’– International Journal of Geographical Information Science (October 2017).

This research solves the route design problem where multiple vehicles from different depots cooperate to cover a set of locations on the road network. An efficient algorithm has been developed to determine balanced routes for vehicles, based on their depots. The method is applied to police patrol routing.


Paul Groves, Mounir Adjrad, Claire Ellul

Global navigation satellite systems positioning (GNSS) in dense urban areas is poor because buildings block, reflect and diffract the signals. Position errors on a smartphone in urban areas are typically several tens of metres, compared to just a few metres in open areas. 3D mapping of the surrounding buildings can be used to aid GNSS positioning in several different ways, significantly improving accuracy.

At UCL, we combine several different techniques. Terrain height aiding constrains the 3D position solution to a 2D surface. Shadow matching, pioneered at UCL, determines position by comparing GNSS signal strength measurements with satellite visibility predictions over a grid of possible positions. Finally, 3D mapping-aided GNSS ranging enhances conventional GNSS positioning by using satellite visibility predictions to select different statistical distributions for directly-received and reflected signals.

Image above: The intersection of police stations (green dot), police patrol routes and crime hotspots (red).

Image above: 3D diagram of the City of London.
We have tested our new 3D-mapping-aided GNSS algorithms using data recorded at the City of London, Canary Wharf, the UCL campus and streets nearby, and in Peterborough. We have achieved significant accuracy improvements in both across-street and along-street directions, reducing the 2D root mean square error (RMSD) of an outdoor position from 23m to 3.7m using a consumer-grade receiver. An error reduction from 28m to 4.2m was achieved using an Android tablet equipped with smartphone GNSS technology. During the trial we also ran our algorithms in real time on a Raspberry Pi 3, providing a new position fix every second.

We are currently finalising our performance evaluation and implementing our algorithms on a smartphone. In 2018, we will extend our algorithms from a series of one-time fixes to continuous positioning, which should lead to a further improvement in accuracy. We are also talking to industry about implementing these algorithms in their products.

By using 3D building mapping and advanced algorithms, UCL has improved the outdoor accuracy of global navigation satellite systems (GNSS) in dense urban areas by a factor of five.

Who you are is how you travel: Detecting mode of travel from people’s movement patterns

James Haworth, Thanos Bantis

Nowadays, smartphones are near ubiquitous in many countries. They enable people to carry what would not so long ago have been a powerful desktop PC around in their pocket, opening up unprecedented opportunities for communication, navigation, entertainment and business on the move. This rise in smartphones has led to the generation of vast amounts of data on the movements and activities of individuals. Used responsibly, such data can reveal fascinating insights into the collective behaviour of people. Google’s live traffic information is one such example.

The problem with such data is they tend to be ‘noisy’ and ‘unlabelled’ – we know broadly where people have travelled, but not how they travelled, where they were going precisely, or what the purpose of their trip was. At UCL, we are researching how to use smartphone data to infer both the type of transport people use as they move about the city, and the types of activities they carry out when they stop at a location. In particular, we are interested in how patterns in the data differ in people with different mobility impairments. This involves integrating data from smartphones with individuals’ characteristics and geographic data from other sources, and feeding them into a Bayesian probabilistic model. The latest progress in this research appears in our paper, ‘Who you are is how you travel: A framework for transportation mode detection using individual and environmental characteristics’, published in Transportation Research Part C: Emerging Technologies (July 2017).

This research makes use of the data generated as people use their smartphones to learn about how people move around cities, with emphasis placed on those with mobility impairments. A technique has been developed to automatically detect what transport mode people are using based on their movement traces.

Image left: Movement patterns of a wheelchair user (red) and a crutches user (yellow), overlaid on the Index of Multiple Deprivation.
Sharing transport expertise globally

Benjamin Heydecker

Ben was Visiting Erskine Fellow at University of Canterbury, Christchurch NZ for a two-month sabbatical, where he taught an MSc course unit on quantitative methods and their application in transport studies. He joined the transport group there and engaged in research on interpretation of automatically collected data to extract traffic management information. This research and his contact with that group will continue, with further exchange visits planned.

He also taught a graduate course on mathematical and statistical modelling at Shanghai Maritime University. Whilst at Shanghai, he and UCL graduate research student Hajar Hajmohammadi also attended a meeting on their project (part of the International Institute for Transport and the Environment), and contributed to a workshop on the project. This joint project with Cornell University and the University of Michigan is developing methods to estimate relationships between vehicle movement on road networks and emissions from those vehicles. This will be used to investigate the effects of traffic management and control on emissions and ultimately to establish control methods that will reduce emissions.

Ben and his colleague Helena Titheridge are co-organising the Universities Transport Study Group (UTSG)’s 50th annual conference, to be held at UCL in January 2018. This three-day conference brings together academics working in transport studies from around the British Isles – and in this 50th anniversary year from around the world – to discuss their latest research. The conference will include over 80 paper presentations.

SnakeGrid

Jonathan Iliffe

SnakeGrid is a concept developed at UCL that develops low-distortion coordinate systems for large engineering infrastructure projects – in particular railways, highways and pipelines. For this type of project, the curvature of the earth is significant and conventional mapping and coordinate systems have to introduce distortions in order to be able to represent the work on a horizontal plane. This then leads to problems when relating 2D designs to the actual construction on the ground. The SnakeGrid algorithm gets around this by providing a single seamless coordinate system with a scale factor within a few parts per million of unity all along the route and for several kilometres on either side – even for projects that extend for hundreds of kilometres.
Effectively, this means that all computations on the project can be treated using a ‘flat earth’ assumption, eliminating the need for corrections and adjustments, and reducing the possibility of costly misunderstandings.

SnakeGrid is used on all major rail routes in the UK, and on some overseas projects. The algorithms it develops are incorporated into software and equipment by most of the major survey manufacturing companies.

Over the last year, several new SnakeGrid coordinate systems have been adopted, including one for a major pipeline project in Cumbria. A new software suite called SnakeGrid Projector has also been developed for Network Rail as a plug-in to Feature Manipulation Engine software (FME), enabling Network Rail to transform data of many different types and in many different formats, between the different coordinate systems that they use.


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**Could busy, heterogeneous streets be better for the environment?**

**An interdisciplinary approach to modelling and monitoring pollution in urban streets**

Liora Malki-Epshtein

Our research combines field measurements in urban streets, Computational Fluid Dynamic (CFD) and laboratory modelling. This creates a robust approach to researching problems in complex urban environments, where neither simplified experiments nor full CFD simulations can resolve the features of the airflow on their own.

Urban designers know that regular symmetrical street canyons, favoured as aesthetically pleasing in many European city centres, lead to accumulation of heat and pollutants. A vortex of recirculating air is created, which does not allow ventilation from the cleaner atmosphere above. Our research finds that even a little heterogeneity in a street layout, with some variety in rooftop heights along the length of the canyon, and small gaps along the length of the street, can improve the ventilation of the street and effectively prevent the recirculating vortex from occurring – resulting in streets that are better for the environment.

In urban environments, traffic-related pollution accumulates in streets and concentrations on the ground may exceed recommended levels for long periods of time. Understanding the detailed properties of the airflow patterns in every major city centre street is crucial if we are to reduce human exposure to pollution and dust, prevent particle settlement on historical building facades, and improve the transfer of heat out of the street into the atmosphere above the urban boundary layer. A better understanding of these phenomena and the connection between airflow and the positioning of traffic lanes, green walls or trees, can help urban planners create better environments that are healthy, pleasant, and sustainable.

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Surveyors and engineers usually have to use correction terms to account for the difference between 2D plans and the real earth. This leads to the possibility of mistakes, and is difficult to implement for very long projects. SnakeGrid gets around this by ‘unpeeling’ the earth along the length of the project, a bit like unpeeling an apple or an orange - but using mathematical algorithms, rather than a knife!
Collaborative Approach to Trade: Enhancing connectivity in sea- and land-locked countries

Francesca Medda

The QASER team (Quantitative & Applied Spatial Economic Research Laboratory) was commissioned by the World Bank to produce the original study this book is based on – to strengthen modelling capability in regard to investment decisions for improving trade in sea- and land-locked countries. In this work we aimed to capture the complexities of multiple trade variables which continuously and simultaneously interact, change and adapt to specific contexts and trade chains.

We consider two perspectives. First, for the South Pacific Islands, given that we are able to examine how trade is influenced through a process of cumulative network interactions, we apply an outward-looking perspective using a network theory approach. In this case we analyse how to improve the connectivity of sea- and land-locked regions to outside markets – long- and short-distance international trade, regional trade, and accessibility.

For our second study, Uganda, we adopt an inward-looking perspective using agent-based modelling (ABM), where we examine agent behaviours in trade and logistics networks. Here, we test how the behaviours of trading agents are influenced by incentives and policies, with the aim of decreasing costs and delays.

Both methodologies effectively demonstrate how increasing and diminishing returns of the trade process can spur growth. Furthermore, we identify our new, 6C collaborative approach to trade, where growth and trade advantages can be gained through connectivity and interdependency within and between countries. We give specific solutions and elaborate the 6C factors: Cooperation, Competition, Consolidation, Coordination, Communication/Connection, and Co-creation/Co-sharing, the essential steps to improved trade. Altogether, the 6C factors can leverage financial resources and investments and help tackle trade ‘insularity’. In this work we have sought to examine how a collaborative trade approach can connect both market and social objectives, increase cohesion and inclusion, and ultimately, welfare. www.ucl.ac.uk/gaser

Light Controlled Factory

Stuart Robson, Jan Boehm, Steven Kyle, Ben Sargeant, Mark Shortis (RMIT University, Australia), Victoria Stephenson, Yanbiao Sun

This EPSRC-sponsored joint project with Bath and Loughborough Universities builds on a track record of large volume metrology, sensing expertise and robotic tracking from UCL to prototype accurately-tracked robotic inspection systems required for next generation digital manufacturing spaces. UCL’s task is the real-time measurement and positioning of parts and machines within an assembly factory using large numbers of low-cost cameras. Our goal is to simultaneously track multiple objects at accuracies between 0.5mm to 10µm within large factory spaces with low-cost photogrammetric techniques. The real-time six degrees of freedom information we produce (X, Y, Z, roll, pitch, yaw) at data rates from a few tens to a thousand locations per second has to be delivered under challenging factory conditions where variations in physical stability and thermal changes in the factory atmosphere have to be accommodated.
Now in its final stages, the project focus is on producing a series of full-scale demonstrators at each institution. The UCL demonstrator is designed to highlight the capability of low-cost photogrammetry to track a unique metrology sensing large volume snake robot with a reach of over 6m.

This work is closely linked to the €44.8m Airbus / Innovate UK-funded Advanced Wing Integration Centre being constructed at Filton near Bristol. Working with Airbus and the Advanced Manufacturing Research Centre, UCL’s role is to provide the metrology expertise needed to ensure the facility is able to meet exacting structural test capabilities required by Airbus both now and into the future.

Future manufacturing requires a step change in our capability to accurately measure the manufactured shape, location and orientation of components that are assembled together to form large assemblies of parts such as aircraft wings. This project builds on our expertise in large volume high accuracy measurement (metrology) using low-cost imaging sensors to create a step change in accuracy at significantly lower cost than current sensors such as laser trackers and laser radar units.

**Image below:** Snake Arm research – supported by the Robotics and Autonomous Systems Capital Fund. Funders: EPSRC and Innovate UK in collaboration with Shadow Robot Company and OC Robotics. UCL leads – Dr Vijay Pawar and Professor Stuart Robson.

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**Space Geodesy and Navigation Laboratory**

Marek Ziebart

**Our group works on figuring out where things are and how they move.** This can range from determining the motion of a tectonic plate, to helping a blind pedestrian navigate across a city, or to predicting the trajectory of a space vehicle thousands of kilometres above the surface of the earth moving at several kilometres per second.

Our methods include developing new hardware, exploiting GNSS signals (Global Navigation Satellite System) in novel ways and mathematical modelling of forces on space vehicles induced by the space environment. We design and conduct experiments. We simulate complex systems operating in space. We have several distinctive, niche capabilities that have led to successful long-term research relationships with NASA, the European Space Agency, the Ordnance Survey and the UK Hydrographic Office.

Key projects include intelligent positioning for cities using 3D city models, designing a navigation system for Mars for the European Space Agency, novel navigation systems for ambulances using multiple environment sensors, and orbit determination models (used as operational standards) for the principal missions used by NASA to measure sea level change from space. We like to think we embrace UCL’s values by doing impactful work that benefits many, many people.
INFRASTRUCTURE

3
Improving port and dependent supply chain resilience

Kamal Achutan, Taku Fujiyama

Seaports are critical to the UK. 95% of the country’s supplies come by sea including more than one-third of its food supply. However, both ports and supplies are vulnerable to disruptions. Hence, ports and their stakeholders need to be resilient and business continuous for the sustainability of supply chains, the economy and port business. Perceived increases in climate change-related risks, particularly storm surges, and emerging risks such as cyber security and space weather, have increased the need to help foster greater resilience amongst the UK’s ports.

The resilience of UK ports relies on the multiple stakeholders that make up the system and their complex interdependencies. Our research focused on developing decision support tools based on simulation models (MARS – Methodology for Assessing Resilience of Seaports), real-time data capture of freight movements and participatory methods that helped the port community to better understand their dependencies, risks and system impacts for disruption, thereby improving their resilience. In addition, we conducted research into extending the methods for assessing critical energy supply chain resilience such as coal and biomass specifically for coastal flooding scenarios due to storm surge events.

Funded by Natural Environment Research Council (NERC) along with the Department for Transport, the research delivered surge forecasting models and detailed flood maps to assess and plan resilience measures for scenarios of storm surge events and the resulting flooding.

Developing Life Cycle Assessment tools (LCA) to support community engagement and user led innovation in infrastructure projects

Aiduan Borrion, Sarah Bell (UCL Institute for Environmental Design and Engineering)

Decentralised infrastructure systems are likely to be important in building urban resilience and sustainability. Decentralised systems provide new opportunities for community and local economic development that have not been seen with conventional centralised infrastructure provision. Stronger engagement between local communities and infrastructure engineers and designers can enable positive co-evolution of engineered systems and society in response to environmental and climate change. However, new tools are needed to enable stronger engagement between infrastructure engineers and designers, local communities and users.

As part of the EPSRC-funded project “Engineering Comes Home”, an open source LCA Calculator has been developed to create a two-way exchange between community members and infrastructure designers. This will embed end user perspectives in the design and implementation of the infrastructure they use, taking into account lifecycle impacts of technology and material options. The LCA Calculator enables quick estimation of the impacts of new systems and technology to deliver water, energy and food (WEF), and manage waste.
at the household and neighbourhood scale, in a way that makes the information easy to understand and relevant to the community, while allowing infrastructure designers to better understand needs and use cases in the community.

In the next phase of our research, part of the EPSRC-funded project ‘Bottom Up Infrastructure’, we will develop LCA tools enabling quantification of the impacts and benefits of community engagement in infrastructure projects covering water, energy, food, waste and transport sectors.

Life Cycle Assessment (LCA) is a methodology for quantifying the environmental impacts of a product, system or service, over its entire life cycle. It was originally developed to compare the environmental performance of different products. It has evolved into a major decision support tool for engineers, designers, business and policy-makers.

Developing Impact Research on Container-based Sanitation Risk Assessment

Luiza Campos, Eve Mackinnon

Container-based toilets (CBS) offer alternative sanitation solutions to traditional pit latrines and ventilated improved latrines, especially in informal high density urban settlements. CBS systems are waterless systems that collect and aggregate faecal and urine waste from multiple individuals for various waste processing modalities. Numerous studies have established that a lack of and poorly-managed sanitation has negative impacts on human health, due to increased exposure to pathogenic micro-organisms in human excreta. There is limited evidence of health risks associated with CBS systems, given the infancy of these solutions. Paradoxically, this type of sanitation is used in canal boats in London.

Since its launch in February 2016, this research has started impacting the worldwide sanitation community working on sanitation safety plans (SSP) and CBS business. Fieldwork is being conducted with a range of CBS contexts in Kenya and the UK (both completed). Fieldwork will extend to Haiti and India in early 2018.

In April 2017, Luiza Campos and PhD researcher Eve Mackinnon organised and hosted a Sanitation Community of Practice (SanCoP) workshop at UCL which explored the context, challenges and safety of exposure of CBS. Guest speakers included representatives from the World Health Organisation (WHO), CBS Alliance, Loowatt and Sanitation First.
In July 2017, Luiza Campos presented on ‘Container-Based Sanitation: a solution for high water-table areas?’ at the third Afriwatsan workshop organised by the University of Nairobi in Kisumu, Kenya. PhD student Eve Mackinnon was awarded a UCL Beacon Bursary to run a public engagement event exploring the use and operation of CBS on canal boats in central London. This took place in July 2017.

The researchers collaborate with top researchers at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) in Lausanne, Switzerland, to develop quantitative models of exposure risks in CBS using a Micro-level Activity Time series methodology (MLATs) developed by EAWAG researchers. In September 2017 Eve Mackinnon developed content-specific material and supported the delivery of SSP training for WHO.

The new inquiry by the Business, Energy and Industrial Strategy Committee, ‘The future world of work and rights of workers’, was launched in December 2016. It identified questions about employment rights but none about health and safety. Currently, we know little about the risks associated with this largely unregulated area of work. Our research funded by RoadSafe and Highways England will explore the data on risk among those driving for work and talk to key stakeholders, including service providers, about how this occupational risk is managed.

How our changing pattern of work influences risks on the road

Nicola Christie, Heather Ward

People who drive for work are more likely to kill and injure others than themselves. It is estimated that a third of fatalities involve someone driving for work. This is not surprising when many of the vehicles they drive are large and heavy (buses, heavy goods vehicles, vans). Think of the many times that we see media reports of cyclists being killed in collision with lorries. Driving for work is also associated with many pressures including ‘in time deliveries’ and working at times when most people like to sleep.

The growth of digital platforms accessible via smartphones are transforming the nature of work and giving rise to new independent ways of working – think Uber, Deliveroo, Lyft. The ‘gig’ or sharing economy describes this new trend in work. In addition there is an increasing appetite among consumers for goods and services to be delivered at home, leading to an increase in vans and goods vehicles on our roads.

Development of novel antimicrobial filters using engineering solutions

Lena Ciric, Claire Bankier

Within the Healthy Infrastructure Research Group (HIRG) at UCL, we use engineering solutions to reduce the spread of infections within the indoor environment. One of the key aspects of our work involves testing anti-microbial strategies and developing preventative measures to reduce disease rather than relying on cure.

Numerous methods are currently used in the healthcare setting to help control and prevent infections – these often include air and water filtration devices. However, most of these filters only capture small particulate matter and cannot effectively destroy disease-causing microbes. Recent scientific research has shown that metallic...
nanoparticles, in particular silver, have strong anti-microbial properties that can effectively destroy bacteria and viruses whilst remaining non-toxic to human cells.

Through an EPSRC-funded collaboration between HIRG, UCL Mechanical Engineering and the University of Hertfordshire, we have developed an anti-microbial filter made from polymer fibres which have been embedded with engineered metallic nanoparticles that can effectively destroy pathogens. The filters have been developed using novel methods to spin the polymer fibres whilst incorporating different combinations of metallic nanoparticles within them. These filters are then tested within HIRG against different bacteria and viruses through scaled-down water and air ventilation systems. These filters are designed to fit in with the hospital environment and improve the current air and water filtration systems. Our work within HIRG involves testing the effectiveness of these novel filters and improving them based on their ability to destroy pathogens whilst remaining safe for use within healthcare.

We have developed novel air and water filters that improve upon current filtration systems used within the healthcare profession. The filters are created using polymers embedded with metallic nanoparticles which are known to destroy disease-causing pathogens. Incorporating these particles into filters offers a promising solution to help develop antimicrobial devices and improve health within the indoor environment.

Image below: A flow cytometer is used to calculate the proportion of bacterial cells which are killed when passed through a novel anti-microbial filter.

Research in National Economic Infrastructure

Brian Collins

High quality infrastructure is essential for supporting productivity growth. Delivering the right infrastructure at a local, city, regional and national level across the UK, is critical to the government’s long-term national industrial strategy.

This research into national economic infrastructure was carried out in a UCL International Centre for Infrastructures project (ICIF). It was jointly funded by EPSRC and ESRC and was completed in 2017. It provided evidence for the need for systemic consideration of all aspects of infrastructure investments, the importance of resilience, the rich interdependency between sectors and functions, project management, finance and funding, engineering and digital. Research outcomes include the potential for data and information management to enable new business models, to provide vehicles for sustainable value capture when combined with sustained organisation learning and at the same time to change the nature of the risks. The research also provided the basis for UK government guidance now in place to improve guidance for large public sector infrastructure projects (known as ‘The Green Book’) with regard to interdependency – an impact that had been anticipated in the original proposal.
The research has also provided a substantial fraction of the evidence that justified the significant investment now being made by the UK government in university resources and laboratories to accelerate and enlarge UK research programmes in national economic infrastructure. This programme, the Collaboratorium for Research in Infrastructure and Cities (UKCRIC), is convened by CEGE. It will ensure the collaboration of 13 UK universities at a scale of research not seen for decades.

The value extracted by services using current methods of investment in and operation of national economic infrastructure, clean energy, effective transport, water conservation, waste management and exploitation of the digital revolution is insufficient and unsustainable. The ownership costs of infrastructure platforms is unaffordable. The vision of UKCRIC, enabled by prior research and evidence, is to create, operate and coordinate a national and international transdisciplinary research programme to address these issues, in a partnership between industry, government and academia.

Modelling and simulation for optimal and resilient resource infrastructure under uncertainty

Tohid Erfani

Growing urbanisation and the emergence of climate change uncertainties call for better management of environmental resources.

Hydroelectric and thermal energy generation and transmission require water. Similarly, energy generation is used for extracting, treating and transporting water.

Next generation planning for sustainable resource management should consider energy and water resources simultaneously. It should also be able to suggest the right amount of new supply infrastructure at the right time to meet future water-energy demands cost-effectively. Planning solutions to such an interconnected system is a challenge in that it needs multidisciplinary research. This requires descriptive analytics, including system dynamic simulation and optimisation techniques, to help make informed decisions in this context.

Image below: Processes for maximising energy efficiency.
The research used big data analysis, decision sciences under uncertainty, multi-objective evolutionary search, and agent-based modelling to identify the best possible approaches to improving water-energy system efficiency, increasing their infrastructure resilience and reducing the financial risk involved. Methods developed have been applied to real-world problems such as capacity expansion to balance London’s Thames Water supply and demand, pipe leakage detection and scheduling in South America, analysing the interaction of water, energy and food in the Nile basin, trading off damage resiliency, disruption and economic cost of UK flooding, and managing climate change extreme events and CO₂ emissions in the Middle East.

Identification of water ingress in brick walls to aid preventive maintenance

Pedro Ferreira, Gunasingam Ravindran

This research is part of an EngD project on the use of new technologies to aid asset management. The research explored the role of thermal cameras in preventing water ingress in brick-lined tunnels.

Water ingress in metro tunnels causes many problems, such as signal failures and corrosion of support structures. These cause delays in the service, leading to loss of revenue. A system that could detect when water enters a tunnel would help to create scheduled maintenance plans rather than reactive maintenance.

To test thermal camera performance, a pipe system was installed, allowing water to enter the back of a model brick wall. Both thermal and normal photographs were taken. Thermal images were far clearer than normal photographic images, which only detected colour change when the area was very close to saturation.

After analysing the moisture content of the bricks, images were reanalysed using a software algorithm to plot saturation levels. These results were applied to thermal surveying of tunnel TL57, on London Underground’s District Line. They showed areas with saturation levels above 80%, indicating significant moisture in the bricks’ pores. This suggests the tool could be used in other structures where water ingress damages performance and increases decay patterns, allowing scheduling and budgeting for preventive maintenance and reducing reactive maintenance costs.

The research explored the use of thermal cameras to measure saturation levels in London Underground’s brick tunnel linings. This technology has the potential to identify areas needing maintenance to prevent water ingress, particularly around electronic equipment that controls trains. This would reduce both disruption and revenue loss for London Underground.

Image above: Thermal image of saturation levels in London Underground tunnel TL57.
Integrating passenger and train flow in complex mainline stations

Taku Fujiyama

Taku Fujiyama was presented with the Institution of Civil Engineers’ ‘Best Paper’ Award for his research ‘Investigating ramp gradients for humps on railway platforms’. The paper set out the scientific basis for platform humps which are being installed across London Underground’s network. It was published in the ICE journal Municipal Engineer. He was also invited to give a guest lecture at the Institution of Mechanical Engineers. The results of this research programme have also been used in design specification of new trains for the metros in New York and Melbourne.

Taku’s research ‘Developing and Evaluating Dynamic Optimisation for Train Control Systems’ is also close to implementation, in collaboration with EPSRC and RSSB (Rail Safety and Standards Board). The next step is to test the research algorithms using real trains. The project was featured in an RSSB Brochure to senior managers in the industry. It was also featured in a dedicated article in Rail Technology Magazine (September 2017).

Taku was also invited to give a keynote speech at an Anglo-French workshop on Station Flow Management. This event was hosted at SNCF and attended by major transport operators from France and the UK. SNCF and UCL have agreed to continue collaborative research on combining passenger movement management at stations with railway traffic operations.

Street Mobility and Network Accessibility project

Peter Jones, Paulo Anciaes, Ashley Dhanani (Bartlett School of Architecture), Muki Haklay (UCL Geography), Jenny Mindell, Shaun Scholes, Jemima Stockton (all UCL Department of Epidemiology and Public Health), Laura Vaughan (Bartlett School of Architecture)

The Street Mobility and Network Accessibility research project (January 2014-March 2017) was funded by three research councils – EPSRC, ESRC and AHRC. The project was led by a multidisciplinary UCL team from Civil, Environmental and Geomatic Engineering (CEGE), the Epidemiology and Public Health Department, and the Bartlett School of Architecture.

The project developed tools for assessing and overcoming community severance. Community severance (also known as the ‘barrier effect’) happens when transport infrastructure or the speed or volume of traffic acts as a physical or psychological barrier to the movement of people. Busy roads may lead to people avoiding journeys, whilst mitigation measures like footbridges and underpasses may increase distances or be considered inaccessible, unsafe or unpleasant. Residents living on busy streets may have smaller social networks; people with fewer social contacts tend to have worse physical and mental health. All these potential impacts are worse in older groups, for whom mobility and social ties are fundamental to good health and wellbeing.
The project also developed a policy toolkit comprising linked tools such as a survey that can identify suppressed travel and the wider consequences on health and wellbeing. Methods to estimate the level and type of community severance in an area and to estimate the economic value of solutions to the problem were also developed. The tools were developed in four case study areas in the UK – areas surrounding busy main roads in London, Birmingham and Southend - using a multidisciplinary approach and engaging with local communities and other stakeholders. The toolkit can be downloaded from http://www.ucl.ac.uk/street-mobility/toolkit by practitioners, community groups, or by the general public.

The research provided an empirical, evidence-based approach to analysing community severance. It will contribute to an increased understanding of how busy roads impact local communities.

Improving accessibility for disabled and older people

Roger Mackett

Much of Roger Mackett’s recent work has involved translational research in the field of policy to improve accessibility for disabled and older people. Roger is a member of DPTAC (Disabled Person’s Transport Advisory Committee) which advises the Department for Transport on accessibility issues relating to disabled people. He chairs the DPTAC sub-committee on research and evidence where he is helping to build up a knowledge hub of sound evidence to underpin policy-making in this area. He has produced a report for DPTAC reviewing evidence on the barriers to access for people with mental impairments including dementia, autism and mental health conditions. Research methods included discussions with stakeholders, examining written reports and analysing survey data. Roger is also a member of the Standing Committee on Accessible Transportation and Mobility of the US Transportation Research Board (TRB), which enables him to discuss these issues at an international level.

As part of his work on improving access for people with mental impairments, Roger was invited to give keynote addresses at the Prime Minister’s Champion Group’s Dementia-Friendly Transport Conference (July 2017). At the Conference’s ‘Healthy Mobility Symposium’, he spoke on the barriers to travel for people with dementia. He also spoke about travel by people with mental health issues at the Chartered Institute of Logistics and Transport Seminar ‘Issues for People with Hidden Disabilities’ (January 2017). Roger also chairs the Transport Working Group of the Age Action Alliance and has been involved in ensuring that the needs of older people are included in the Department for Transport’s Accessibility Action Plan.

Roger Mackett’s research involves improving the quality of life of disabled and older people, particularly people with mental impairments such as dementia and autism, by identifying the barriers that make it difficult for them to travel and exploring ways of overcoming them.
Integrated health, education and environmental intervention to optimise infant feeding practices through schools and Anganwadi networks (rural mother and child centres) in India

Priti Parikh, Monica Lakhanpaul (UCL Institute of Child Health), Marie Lall (UCL Institute of Education)

The idea of developing interdisciplinary links between health, education, engineering and environment (HEEE) came directly from discussions with academic institutions, NGOs and foundations in India. The World Bank had identified under-prioritisation of nutrition and health education as a barrier to progress, while its 2016-2030 global strategy emphasises the need to integrate multisector enablers that address education, gender, sanitation, water, agriculture and nutrition.

This research aimed to address development issues holistically and co-design solutions with local partners using a collaborative participatory approach. HEEE networks provide us with a platform to link expertise across three diverse UCL faculties - child health, education and engineering. They also enable us to hear local voices and develop solutions together to address global challenges with global partners. HEEE aligns with Government of India initiatives such as the Clean India Mission, Unnat Bharat Abhiyan (transforming rural areas) and Sarva Shiksha Abhiyan (elementary education).

India faces a triple burden of childhood malnutrition: 48% (61 million) of children under five are stunted, childhood obesity is on the rise, and most have a micronutrient deficiency. Key government nutrition and behaviour change interventions are being implemented through frontline workers, but barriers include outreach, variable levels of access to clean water and sanitation services, social inequity and the feasibility and effectiveness of localised integration.

Future funding applications will explore how the HEEE package can be scaled up to additional India states. UCL’s interdisciplinary team is collaborating with experts from Save the Children India, The Indian Institute of Technology, New Delhi (IIT-Delhi) and Jawaharlal Nehru University, New Delhi (JNU). In addition, four NGO partner institutions will provide contextual and programmatic advice along with members from the British Indian diaspora.

This innovative and novel project will bring together experts from the domains of health, environment and education to work with local communities and co-develop interdisciplinary solutions for enhancing the well-being of children in rural Rajasthan, India.
Evaluating public transport policies

Helena Titheridge

Many national and regional transport authorities are promoting public transport as a way to reduce the environmental impacts of transport. This research programme uses a holistic approach to foster greater understanding of why some public transport policies are more successful than others, and to identify the mechanisms through which changes in travel behaviour occur as a result. Using mixed methods, we are assessing the complex policy formulation and implementation processes, institutional roles and responsibilities, changes in travel satisfaction, attitudes and intentions amongst public transport users and non-users, and outcomes in terms of ridership and value for money.

As part of the programme, Dr Chien-Pang Liu assessed the Taiwanese National Road Public Transport Policy (NRPTP), launched in 2010. This policy, now in its second phase, aimed to increase bus usage by 5% per year. In the first four years of the Policy, bus usage increases were below target. The increase in use became smaller each successive year. By 2015 bus usage actually decreased compared with 2014. There was considerable variation in performance between municipalities. These variations resulted from factors including differences in political will, availability of skilled transport planners, and inflexibilities in how budgets could be spent. The research also found that the dense grid-like pattern of many Taiwanese cities, combined with poor regulation of motorcycle parking, encouraged motorcycle use to the detriment of buses.

People-environment-activity interactions

Nick Tyler, Sara Adhitya, David Ashmore, Derrick Boampong, Nuria Hernández, Xenia Karekla, Corina Kwami (UCL Science Technology Engineering and Public Policy), Liliana Ortega, Adriana Ortegon, Nikos Papadosifos, Ayako Suzuki, Tatsuto Suzuki, Natan Waintrub

Our research is a comprehensive transdisciplinary programme, which covers neuroscience through to civil engineering, and anthropology through to policy implementation. We look at how people see, hear, touch, perceive and use their immediate environment and how changes made to the environment might work to generate a better quality of life for everyone, regardless of their current capabilities.

We collaborate with people from many disciplines – artists, neurologist, psychologists, musicians, architects, chemists, philosophers, ophthalmologists, audiologists, clinical scientists and practitioners. We also work with researchers all over the world – EU, Japan, China, Latin America – as well as in the UK. We have been involved in the design of operations for railway systems, and the design of trains, streets and urban spaces, as well as changing the way sciences such as ophthalmology, audiology and psychology work in the real world.
Much of this work is undertaken in the controlled environment of PAMELA (Pedestrian Accessibility Movement Environment Laboratory) which allows us to construct life-sized environments and test them with potential passengers. PAMELA is currently being expanded into a new facility called PEARL (Person Activity Environment Research Laboratory), expected to open in late 2018.

Typically we study how multiple senses apply to the way we interact with the environment. We are interested in how a future city – say in 200 years’ time – will be enabled to support a society in which people can thrive equitably, socially and with a greater quality of life than at present.

Person-Environment-Activity interaction research involves testing people in real-world situations so that we can study how they might respond to different aspects of the environment. To do this we created a laboratory where we can build different environments, and study people’s physiological, sensorial, neurological, physical and emotional responses to different aspects of the design.

Image below: Experiment in the PAMELA facility to examine interactions between people and a new design for a tube train, including platform edge doors.
PHD AWARD SUCCESSES 2016–17

Congratulations to all our students who were awarded a Doctorate this year.

PhD (Engineering)
Monsuru Adepeju – 28/05/2017
Ahmad Baik – 28/06/2017
Seong Choi – 28/04/2017
Luca Cocconcelli – 28/07/2017
Nuo Duan – 28/12/2016
Abdullah Ekinci – 28/09/2016
Carina Fonseca Ferreira – 28/06/2017
Pierre Gehl – 28/04/2017
Alejandro Hammeken Arana – 28/04/2017
Xuelin He – 28/06/2017
Anthony Hurford – 28/10/2016
Rukayya Ibrahim – 28/07/2017
Konstantina Koutita – 28/04/2017
Tristan Lloyd – 28/10/2016
Jenny McArthur – 28/08/2017
Marta Modelewksa – 28/05/2017
Christian Nold – 28/08/2017
Viviana Novelli – 28/04/2017
Aris Pavlides – 28/05/2017
Daniel Pohoryles – 28/04/2017
Natalie Quinn – 28/04/2017
Amin Rafiei – 28/03/2017
Ramtin Rezaei – 28/08/2017
Mohammad Reza Rezaeian – 28/10/2016
Shi Shi – 28/02/2017
Kimon Voutsis – 28/08/2017
Hui Wen – 28/04/2017
Runing Ye – 28/06/2017

Doctor of Engineering
Paul James – 28/08/2017
Indranil Kongar – 28/05/2017
Dimitrios Margaritis – 28/04/2017
Kieran Mulholland – 28/05/2017
Athena Panayiotou – 28/08/2017
Gennaro Senatore – 28/11/2016
Ine Steenmans – 28/04/2017
OUR RESEARCH SUPPORTERS

We could not undertake the level and depth of research highlighted in this report without the very generous funding and collaboration we receive from our supporters. They include organisations from the UK and from overseas. They are drawn from many different sectors - industry, government, education, charity and technology. A big thank you to everyone who has supported our work during 2016–2017:

Airbus
AIR Worldwide
ARUP
Arts and Humanities Research Council (AHRC)
Association of British Ports
Atkins
Auckland Council
Bat Conservation Trust
Bentley
Bosch
BPD Water and Sanitation
British Academy
British Council
British Museum
British Red Cross
Building Research Establishment (BRE)
Bureau de Recherches Geologiques et Minières, France (BRMG)
Buro Happold
Camden Council
CARE International (TR)
Centro de Investigación para la Gestión del Riesgo de Desastres, Chile (CIGIDEN)
CH2M
Chinese Research Scholarship and Commonwealth Scholarship
Cintec International
Consejo Nacional de Cinecia y Technologia, Mexico
Department for Business, Energy and Industrial Strategy (BEIS)
Department for Communities and Local Government (DCLG)
Department for International Development (DFID)
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Engineering and Physical Sciences Research Council (EPSRC)
Economic and Social Research Council (ESRC)
European Union
European Research Council (ERC)
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Guy Carpenter
HM Treasury
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Habitat for Humanity
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Historic Royal Palaces
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Institution of Engineering & Technology
Innovate UK
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Italian Embassy, London
Japan Society for the Promotion of Science
Leverhulme Trust
Lloyd's Register Foundation
London Fire Brigade
London Underground
Maurice Francis Memorial
Metropolitan Police Service
NASA
Natural Environment Research Council (NERC)
Network Rail
Octoply
Petroleum Technology Development Fund, Nigeria
Philips
Polygon
Poplar HARCA
Practical Action
Public Health England (PHE)
Royal Academy of Engineering
Royal Embassy of Saudi Arabia Cultural Bureau in the UK & Ireland
Royal Society
Royal Society for Blind Children
Science Museum
Skanska
Smithsonian
SUSTRANS
Tower Hamlets Homes
Transport for London
United Nations
UNESCO (United Nations Educational, Scientific and Cultural Organisation)
HR Wallingford
Water Aid
Willis Re
World Bank
XL Catlin
SELECTED CEGE TWITTER HIGHLIGHTS, SUMMER 2017

CEGE UCL @CEGE_UCL: Sep 26
This very high tech & very expensive piece of kit is going to increase our research capability with geospatial mapping.

CEGE UCL @CEGE_UCL: Sep 11
Professor Dina D Ayala is recording today with Lion TV on the forbidden city and fireproof and resistant buildings. ΟUCL

CEGE UCL @CEGE_UCL: Sep 15
A huge congratulations to all who exhibited at the MSc poster fair. We had some amazing work on show. Pics here - Facebook.com/cegeeng

Loan Diep @loan_diep: Nov 10
Very much enjoyed working with the dynamics of this group. Fantastic example of diverse team working collaboratively. Well done @KResEdUCL and the @centre_iat_bch for great sessions #EngineeringforrrrDevelopment

Luiza Cintra Campos @luizacamp35: Sep 28
More on Technicians' training under @TheRoyalSociety @OFSTED_UK @EAthwart @CEGE_UCL 25-29 September 2017

CEGE UCL @CEGE_UCL: Oct 2
Advanced & Innovative Materials Group have hosted 37th Annual Cement & Concrete Science Conference. Read more - bit.ly/2UGJdQl
The new campus at Here East in all its cardboard glory.

Oct 17

Two CEGE students recently spent time with Bridges to Prosperity @B2P in Rwanda, see their video from the trip here:

UCL B2P Trip-Along in Rwanda
youtube.com

July 26

Lampeter 2017 was a blast! A huge thanks to all who came and made it so fun. Here are some highlights from the second week roads scenario.

Decoding Disaster, Series 4, A Timewatch Guide - BBC Four
Daniele Georges looks at how disaster documentaries keep pace with scientific theories.
bbc.co.uk

May 24

The end of a very hot day! Work, Bring on dinner!
Cover image: Miss Palak Shukla, Civil, Environmental & Geomatic Engineering

The movement of discrete circular particles as they loaded by a shallow foundation. The arrows show the direction the particles are moving in – the longer the arrow, the greater the movement.
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Contact Us
University College London, Chadwick Building, Gower Street, London WC1E 6BT
www.cenge.ucl.ac.uk | cenge-research@ucl.ac.uk | @CEGE_UCL