MARIE SKLODOWSKA-CURIE FUTURE ROADS FELLOWSHIPS (FUTUREROADS)

Call for Applicants

Deadline: 16th June 2023

Photo: Civil Engineering Building, University of Cambridge

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UNIVERSITY OF CAMBRIDGE

CALL FOR APPLICATIONS

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FUTUREROADS - Marie Skłodowska-Curie Future Roads Fellowships

The University of Cambridge is pleased to announce that up to 11 Fellowships are available for the third cohort of the FUTUREROADS-MSCA COFUND programme. The Future Roads Fellowships Programme (FUTUREROADS) is hosted by the University of Cambridge. The scheme is funded by the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie actions (Grant Agreement no 101034337) and cofunded by partners Costain Group Plc and National Highways and industry partners; AECOM Ltd, Amey OW Ltd, Atkins Ltd, Balfour Beatty Civil Engineering Limited, BAM Nuttall Limited, Bentley Systems (UK) Ltd, Keltbray Holdings Limited, L Lynch Plant Hire and Haulage Ltd, Ordnance Survey Ltd, Ramboll U.K. Ltd, Ringway Infrastructure Services Ltd, SAP (UK) Ltd, Telent Technology Services Ltd, TRL Limited, Cambridge Grapheme Ltd (Versarien), Galiford Try, Trimble Europe B.V., Kier Highways Ltd and Jacobs UK Ltd.

The programme offers 27 fellowships over three recruitment rounds focused primarily in digital twins, smart materials, data science, automation and robotics, and sustainability solutions for the road infrastructure industry. The duration of a fellowship for Cohort 3 is expected to be 34 months. The programme allows applicants to have the freedom to develop their own ideas with access to excellent facilities. FUTUREROADS will enhance fellows' understanding of the methodologies and approaches of other scientific disciplines at the highest level.

The aim is also to establish a multidisciplinary training platform to strengthen researchers' capabilities such that they are capable to work anywhere in Europe and, therefore, attract researchers from around the globe to Europe and contribute to the European goals of increasing the numbers of researchers with innovation skills in Europe.

The programme supports incoming fellowships for postdoctoral researchers on a competitive basis. It aims at high-potential individuals primarily interested in following a career in the transportation infrastructure sector or academia. Awardees will be offered an employment contract with a postdoctoral-level salary and will be entitled to an individual mobility and research budget.

Why apply

The University of Cambridge (UOC) is a collegiate research university in Cambridge, United Kingdom. It was founded in 1209 and is the world's fourth-oldest surviving university. Cambridge is formed from a variety of institutions which include 31 semi-autonomous constituent colleges and over 150 academic departments, faculties and other institutions organised into six schools. UOC provides FUTUREROADS Fellows with a thriving research environment, strong connections to industry and a strong international network. UOC is consistently ranked in the top 10 universities in the world.

The FUTUREROADS programme is for researchers who are looking for an opportunity to pursue research as part of an innovative programme that has international and industry connections. The Fellows will be involved in a unique cohort-oriented programme that is part of a wider initiative at the UOC researching the future of road infrastructure.

Marie Skłodowska-Curie Future Roads Fellows will have access to support via local and international academic supervisors and industry partners. They will have access to career and skills development opportunities as part of the activities directly associated with the FUTURERAODS programme and more widely at the University of Cambridge.

The Fellowship offer

FUTUREROADS offers 34-month fellowships in Cohort 3 linked to the programme's thematic areas; digital twins, data science, smart materials, automation and robotics, and sustainability, all in the context of the road network. Fellows are offered career development support and training events to develop their non-scientific skills. They are expected to take part in teaching activities at Cambridge and are encouraged to apply for additional competitive funding. The programme is open for all applicants who meet the MSCA mobility rules for fellows.

All Fellows will have their primary base at the Department of Engineering, University of Cambridge. However, they may have supervisors in other disciplines. Fellows also have the opportunity to pursue secondments.

Who can apply

The fellowship is designed to support post-doctoral researchers with up to 2 years of postdoctoral research experience (after completion of the PhD) at the time of applying. Applicants with 3-4 years of postdoctoral research experience will be considered in exceptional cases.

Applicants must comply with the following MSCA mobility rule:

Mobility rule: The researcher must not have resided or carried out his/her main activity (work, studies, etc.) in the host organisation's country for more than twelve months in the three years immediately prior to the call deadline. Make sure you check all specific requirements in the guide for applicants.

How to apply

Applications must be submitted online via the University of Cambridge's job application system at https://www.jobs.cam.ac.uk/.

Applicants can search for the Marie Skłodowska-Curie Future Roads Fellowship advertisement (job reference: NM35935) and apply online. The Future Roads website https://drf.eng.cam.ac.uk has a Guide for Applicants – this guide provides essential information about how to correctly supply the required supporting documents for the fellowship posts. Please note that applications that do not meet the criteria regarding mandatory documents will not be considered.

When to apply

The deadline for cohort 3 applications: 23:59pm GMT 16th June 2023

Application timeline for cohort 3:

UNIVERSITY OF CAMBRIDGE

CALL FOR APPLICATIONS

Deadline 16th June 2023

- Opening of call: 16th March 2023
- Deadline for applications: 23:59pm GMT 16th June 2023
- Evaluation period: app 8 weeks
- Applicants will receive answers: August 2023
- Fellowship period begins: December 2023

For more information about the process, guidelines or application system, please get in touch with the Future Roads Programme Managers at DRF-initiative@eng.cam.ac.uk or visit website .

Core challenges to be explored by applicants:

<table>
<tr><th colspan="2">1. DIGITAL TWINS
Potential applicants may contact the digital twins theme lead, Professor Ioannis Brilakis (ib340@cam.ac.uk), for any queries regarding these challenges.</th></tr>
<tr><td>DT1 How can we plan a Road Digital Twin?

We know what the planning stage looks like for a road Physical Twin (PT). We don't know what the planning stage looks like for a road Digital Twin (DT). How do we derive scope, assess feasibility, and estimate costs for the digital asset? We need to derive (a) a flexible DT scope definition process; (b) methods to quantify DT costs and overall feasibility across all relevant Key Performance Indicators (KPIs). The purpose is to enable planning process standardisation and compliance with the National DT programme, while ensuring that all planning parameters are considered.

• What can we learn from relevant literature and staff of the sponsor on planning Physical Twins (PT) to draw parallels?
• What can we learn from stakeholder guidelines from national bodies that roadmap the DT planning process to understand how to scope and identifying knowledge gaps?
• How can we validate findings with the broader industry?
• How can we identify and assess planning steps that quantify costs and feasibility and produce a Highway DT Planning Manual as a possible standard?
• What sponsor use cases can be leveraged to demonstrate the outcomes?</td><td>Professor Ioannis Brilakis

Industry partners: Ordnance survey</td></tr>
<tr><td>DT2 How can we design a Road Digital Twin?

What exactly is a road Digital Twin (DT)? What is it made of, and how is it structured? Where does it sit, and who does it interact with and how? We know these answers for road Physical Twins (PT), but still struggling to define them for DTs. To answer these questions, we need to derive (a) highways stakeholders' user and information requirements for DTs; (b) a road Foundation Data Model (FDM); (c) a road Reference Data Library (RDL), and (d) a road Integration Cloud Architecture (IA), consistent with the Information Management Framework (IMF) proposed by the Centre for Digital Built Britain. The purpose is to enable (i) productisation; (ii) interoperability with the National DT programme; (iii) data security; (iv) futureproofing; and (v) static and dynamic data curation.</td><td>Professor Ioannis Brilakis

Industry Partners: Ordnance survey, Ringway, National Highways</td></tr>
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• What can we learn from relevant literature, stakeholder guidelines, and staff of the sponsor to derive road stakeholders' user and information requirements to produce a comprehensive road Information Delivery Manual (IDM)? • How can we address the DT design challenge, an under-constrained problem with millions of viable solutions? • How can we leverage IDM constraints and rules to scope down on the possible design solutions? • How can sponsor staff be engaged to influence the solution that best fits their priorities to derive the FDM, RDL and IA?	
DT3 How can we construct and maintain a Road Digital Twin? The cost and effort currently necessary to make a rich road Digital Twin (DT) for a specific road Physical Twin (PT) counteracts the value of the DT and is therefore not performed for most roads. At the PT design phase, we lack the generative design tools necessary to complete low level, laborious design tasks. At the PT construction and operation phase, we lack the digital twinning tools that will generate DTs of existing road assets and allow us to affordably maintain them. We need ways to (a) match objects and object properties to the PT, then generate/update the DT; (b) fuse information that sits in sponsor and client databases. • What are the best Simultaneous Pose and Correspondence Methods (ICP, RPM, TPS-RPM, KC, etc.) for registering sponsor provided PT data on a pre-existing DT (when available)? • How can we verify/update presence and spatial properties against existing DT geometry? • Where existing DT geometry is not available, how can we detect new road assets (lanes, lane markings, median barriers, etc.), their condition (damage properties) and their spatial relationships to other DT assets? • How can we fit reference data library objects to detected assets and add them to the DT? • How can we fuse design, construction, maintenance, and operation information siting in separate databases?	Professor Ioannis Brilakis Industry Partners: Ordnance survey, Ringway, Telent
DT4 How can we interact with Road Digital Twins? The complexity behind the hardware and software of a smartphone is significantly more than the complexity of a road Digital Twin (DT). However, smartphone complexity is extremely well encapsulated, making it possible for nearly any human to use without prior training and get value fast. DTs have a long way to go to reach that standard of encapsulation, yet it is necessary to drive adoption across the sector and thus derive value out of DTs. We need to (a) derive protocols for (i) highways IoT-DT-enterprise cloud communication, and (b) DT to information visualisation environments communication. The purpose is to enable (i) secure information exchanges; (ii) true usability; (iii) low latency; and (iv) futureproofing. • How can we extract and convert user interaction requirements into interface principles for both machine-information and human-information communications?	Professor Ioannis Brilakis Industry Partner: Ordnance survey, Costain Limited

• How can we leverage sponsor information insight teams to assess suitable solutions? • How can we verify information exchange integrity during "round trips" (to IoT/DT and back) and assess user experience performance to produce DT interaction design principles as a possible standard?	
DT5 How will a world with Road Digital Twins be different in the future? Road Digital Twins (DT) are both a tool for better servicing existing road Physical Twins (PT) as well as a tool for changing the nature of a PT, as a product and process. This also considers future changes in their use, autonomous vehicles, the decarbonisation agenda, the drive for simplification, automation, and productivity, and other factors that will simultaneously have an effect. • How will PTs change, as a product? • How will PTs change, as a process (planning, design, construction, maintenance, and operation)? • How will the PT users change, and how will PTs be used differently? • What is the likely timeline of the changes, and how should sponsors adapt to it?	Professor Ioannis Brilakis Industry Partner: Ordnance survey
DT6 How can Road Digital Twins generate value from connecting areas? The relationship between roads, buildings, and neighbourhoods is becoming increasingly important to decision makers, with particular attention paid to road Digital Twins (DT). A side effect of DT development is the impact on building permit processes. Besides the enrichment of 3D city models in an urban and cities' interconnecting context, DT include significant information for decision making during the building permit process. This process can be viewed as a part to accelerate, improve, facilitate, and influence from the perspective of both planning and building permit authorities and applicants. • What are the use cases for DT-based building permitting? • How a business model of DT-based building permitting looks like from a management perspective (processes, people, technology)? • What information and what granularity of information are needed for these use cases? • Where and how information is stored and communicated? • Can DT-based building permit processes increase the certainty in construction and lower the risks in calculation (of time and costs)? • How does the DT-based business model for building permits fit into building permit systems at an international level? • Can a toolkit or a guideline be derived for regulating data collection / pushing adjusted sustainable regulations – how regulation should look like – influence human behaviour?	Professor Ioannis Brilakis Industry Partner: Ordnance survey, Keltbray
DT7 How can we build an Underground Digital Twin and what should it do?	Professor Ioannis Brilakis Industry Partner: Ordnance

Significant advances have been made on Digital Twin (DT) enablers for a wide range of above-ground physical infrastructure. However, DTs for the underground space are much less advanced and are currently non-existent in industrial practices. This is because there is a lack of clarity around how we design, build and maintain underground DTs and how they add value for our road infrastructure; this is further complicated by inherent geotechnical uncertainties. We need a state-of-the-art framework for the development of underground DTs to mitigate adverse geotechnical effects on our road infrastructure e.g. subsidence, sink holes, slope failure. • How can we learn from and import recent advances in above-ground digital twins from the literature and sponsor experience? • What should an underground DT for road infrastructure do for users and how do we extract value? • How can we build 3D uncertainty-quantified geotechnical models and handle large amounts of often conflicting heterogeneous data? • What information do we need from the physical twin to be able to update our underground DT?	survey, Telent, Keltbray
2. AUTOMATION & ROBOTICS Potential applicants should contact the automation and robotics theme lead, Professor Fumiya Iida (fi224@cam.ac.uk), for any queries regarding these challenges.	
AR1 Automated large-area 3-D printing This project topic aims to develop control and sensing framework for fully autonomous 3-D printing of building materials over large areas. The process should involve scanning existing topology, calibration and localization of print morphology with respect to the scanned surface, motion/print planning with existing robotic devices.	Professor Fumiya Iida Industry Partners: Versarien, Balfour Beatty
AR2 Swarm robotics for traffic management and inspection This project topic aims to develop a feasibility study on the usage of swarm robots for automated traffic management and inspection. Simulation studies will be conducted on deployment and control of swarm robots for traffic cone placement, traffic divergence, inspection, temporary lane closure, load management, etc. In-lab experiments will be conducted to validate some of the processes.	Professor Fumiya Iida Industry partners: Ringway, TRL, Telent, Balfour Beatty
AR3 Road surface monitoring with non-conventional sensors Existing road monitoring devices use specialized sensing technologies for detecting damage or bulk properties. However, they are expensive to develop, has low update rate and is limited in their sensing capabilities. This project aims to use non-conventional readily available sensors for road condition monitoring. For instance, using IMUs and traction information in autonomous cars for detecting onset of aquaplaning.	Professor Fumiya Iida Industry partners: Versarien, Balfour Beatty, Costain Limited, Amey
AR4 Automatization of existing heavy machinery A large number of existing heavy machinery rely on human operators manually operating them with limited sensory feedback. This project aims to improve the accuracy and robustness of existing heavy machineries by adding sensor-motor loops or by improving state feedback to the human operator. For example,	Professor Fumiya Iida Industry partners: Ringway,

improving the accuracy of mobile cranes by adding proprioceptive elements (encoders, cameras, etc) for state estimation and a feedback controller on top of this coupled with a high-level controller for the user.	Trimble, Balfour Beatty, L Lynch Plant Ltd
AR5 Feasibility study on robotics for future road infrastructures Building and maintenance of road infrastructure still heavily relies on manual processes. This project is a feasibility study on the usage of robotic technologies for automating these processes. Research includes meta-analysis of existing technologies and their progress, surveys with industrial partners, development of guidelines/ research projects / collaboration networks, etc.	Professor Fumiya Iida Industry Partners: BAM, Ringway, TRL, Versarien, National Highways, Balfour Beatty, Keltbray
3. SUSTAINABILITY Potential applicants should contact the sustainability theme lead, Dr Kristen MacAskill (kam71@cam.ac.uk), for any queries regarding these sustainability challenges.	
ST1 How can public behavioural change measures be best facilitated and measured for impact to improve road service provision on existing assets? At the top of the carbon reduction hierarchy is 'build nothing', closely followed by 'build less'. The typical historical approach to developing a strategic road network is through expansion via construction (i.e. more road lanes). An alternative to approach to is to use the existing asset more productively. For example, increasing the operational capacity of the existing asset to support more vehicle trips. Research can contribute to building confidence in alternative operating models or new technologies for improving consistency of service provision beyond traditional civil engineering interventions. For example, interventions could target user behavioural change. This may also require behavioural change within the industry. We are keen to see proposals that will explore productivity of the existing network asset through an increased understanding of how behavioural change models can best be implemented to help maximise the effective use of infrastructure. For example, how might nudge theory be applied to effective management of road infrastructure?	Dr. Kristen MacAskill Industry Partners: Ramboll, National Highways, AECOM
ST2 To what extent can an equity, diversification, and inclusion (EDI) agenda change the way we approach road infrastructure planning and design? There is increasing recognition of the limitations of infrastructure planning and design practice when it comes to EDIA. Accessibility has become a standard consideration in urban planning and now, for example, gender-oriented considerations and changing emphasis in transport hierarchies (e.g. prioritisation of active transport) are coming to the fore in urban planning. However, implementation of EDI-driven design is still a relatively new concept in infrastructure planning and design, and we welcome proposals that set out an ambitious vision for research into supporting the development of diversity principles and design practice for urban road infrastructure.	Dr. Kristen MacAskill Industry Partners: Ramboll

ST3 How can the sector best manage risk sharing among stakeholders to achieve future “beyond net zero” targets effectively and quickly? The highways sector remains relatively traditional in its infrastructure delivery mechanisms covering planning, design, procurement, construction, operation and maintenance. It is not generally considered a leader in technological and organisational innovation. Considering major changes in society that are influencing demands on and expectations of the road network (e.g. population growth, alternative technologies, equity, resource efficiency, climate change), the Future Roads partnership would like to see a shift in the sector’s capacity to adapt to new demands. The basis of this challenge is to look beyond existing “net zero” carbon reduction targets. In exploring this sector ecosystem challenge a particular emphasis should be placed on how risk is most effectively shared across stakeholders. Through the Future Roads partnership network, a fellow responding to this challenge will have a unique opportunity to access stakeholders from across the UK Highways sector to conduct applied research. This access should be considered in applicant proposal methodologies.	Dr. Kristen MacAskill Industry Partners: TRL, Versarien, L Lynch Plant Ltd, Keltbray
ST4 How does carbon management relate to level of spending in the road sector? The Future Roads partners are interested in supporting a fellow to explore carbon management from a supply chain/stakeholder ecosystem perspective, with a particular emphasis on exploring the relationship between carbon-related decision making and the amount of spending that takes place across an asset lifecycle. This will help to build on the principles set out in the PAS2080 Carbon Management in Infrastructure framework. It will help to provide quantitative evidence and clarity around the relationships between decisions to reduce carbon and links to associated spending across asset lifecycle phases from initial investment through to maintenance and end of life. Essentially, we are interested in understanding what the flow of “capital” looks like compared to the flow of carbon.	Dr. Kristen MacAskill Industry Partner: Amey
ST5 How ready is the current infrastructure for the changing environment? Climate change science reporting clearly outlines how our climate is changing - the latest State of the UK Climate 2018 report highlights several key indicators are consistent with the expected effects of a warming climate. This includes record temperatures and an increase in extremely wet days. While National Highways is clearly promoting its agenda for digitalisation and net zero operations (in line with government priorities), less emphasis has been given to planning for climate adaptation, and more broadly a future hazard scape that is different to what is faced today. A recent UK Parliament Joint Committee Report (published 27 October 2022) "Readiness for storms ahead?" highlights a lack of government responsibility for critical national infrastructure resilience. There is some leading research in the UK on national infrastructure hazard risk assessment, but more work to be done in taking these frameworks and modelling more towards tactical and operational decision-making for managing and developing the UK's national road asset. Scenario modelling might be explored to understand the risk profiles associated with different possible futures. Research proposals could consider the need for increased	Dr. Kristen MacAskill Industry Partner: National Highways, L Lynch Plant Ltd

maintenance, costs, and cascading failures associated with exposure to more extreme events.	
ST6 What strategies could be used to achieve biodiversity (or more broadly ecosystem services) net-gain in managing a national highway network? Supporting biodiversity is an emerging consideration for the design and management of road-related assets but there is no clear method to be able to quantify biodiversity measures in a meaningful way. As a result, biodiversity measures are often not a core consideration, but an “add-on” consideration for project implementation. The basis of this challenge is to establish more comprehensively what “green estate management” could feasibly look like as a key underpinning basis for managing land linked to the highway network. A proposal under this theme might opt to explore ecosystem services more generally, considering the possibilities for regenerative land use that gives more space to nature, so returning carbon to the soil and oxygen to the atmosphere, and how this might be integrated with the wider management of a national highway network. This might involve some form of comparative study. For example, how are the development options different in situations such as the Middle East and China where massive new urbanisation is underway?	Dr. Kristen MacAskill Industry Partner: Colas, BAM, National Highways
ST7 How can existing available technologies be utilised to improve both sustainability and safety on construction sites for road-related projects? The current rate of technology development is outstripping the ability of industry to be able to strategically assess and deploy these technologies on construction sites to manage sites effectively, safely and sustainability. This project is expected to develop some form of product mapping that enables effective comparison of technologies and what they might offer the industry. It is expected that the project would need to include the consideration of how behaviours and/or site management protocols might need to change in order to effectively adopt technologies. The project will help to support the development of site specifications that will facilitate the adoption of technologies to deliver on desired outcomes of improved safety and sustainability.	Dr. Kristen MacAskill Industry Partner: L Lynch Plant Ltd, Costain Limited, Keltbray
4. DATA SCIENCE Potential applicants should contact the data science theme lead, Dr Lavindra De Silva (lpd25@cam.ac.uk), for any queries regarding these challenges.	
DS1 Synthetic data generation for improving automated classification of highway assets and defects Manual monitoring of highway networks is time-consuming and subjective. Thus, there is an increased interest in automating monitoring, using data collected by connected passenger or dedicated vehicles. Most passenger vehicles are already equipped with sensors such as accelerometers and cameras, while dedicated vehicles have higher-resolution sensors, such as laser scanners. Collected data are then processed by machine learning and computer vision-based algorithms to detect and classify highway assets and defects. A major challenge in training these algorithms is having the appropriate datasets. For instance, certain types of assets or defects are rare and thus there are not enough data for training. This project is focusing on generating synthetic	Dr Lavindra De Silva Industry Partners: Colas, TRL, AECOM

data via state-of-the-art data augmentation techniques and generative algorithms. The outcomes will accelerate research and training simulations, contributing to more reliable automated highway inspection.	
DS2 Digital Twin-driven spatiotemporal modelling and analysis of supplier and material durability for decision-making When building or maintaining roads, a wide array of suppliers and materials are readily available. The issue that then arises is which supplier or material should be chosen? A vast quantity of historical data such as the supplier, materials, construction costs, carbon footprint, age, condition, and maintenance history of highway assets and pavement can be obtained from various sources. Given these historical data, is it possible to make a more informed decision? The key challenge is to assemble and fuse the datasets containing all these relevant data within the highways' Digital Twin, and to develop statistical, spatial and temporal models to evaluate the quality, durability and sustainability of given materials and/or suppliers through data analysis and inference.	Dr Lavindra De Silva Industry Partner: Amey
DS3 Using productivity techniques and Digital Twins in design and construction planning to achieve greater certainty of delivery and cost Planning and certainty of design and construction activities are critical in highway construction projects, but notoriously difficult to obtain due to the many interfaces, stakeholders and variables. This challenge is to research the key areas of project planning and develop tools and processes to increase efficiency and provide informed decision-making. The project will include reviewing the National Highways (NH) major projects programme and analysing trends and unpredictability factors that create risk and delay in the construction process through effective risk modelling techniques. The aim is to develop a platform that integrates collaborative planning and productivity techniques with rapid planning decision tools. Additionally, incorporating a construction project's design into Digital Twins (DTs) can inform and progressively develop construction programmes, costs and carbon emissions over its lifecycle. The developed platform should enable users to identify points of failure and model solutions that can track and minimise waste, rework and defects from the construction phase. Included in the platform should also be a visual dashboard to ensure progress on all projects can be monitored effectively and in real time.	Dr Lavindra De Silva Industry Partners: Kier, Trimble, TRL, National Highways, Keltbray
DS4 Connected Corridors of the Future and big data The Strategic Road Network (SRN) of the future will rely on connectivity of vehicle to vehicle as well as vehicle to asset and vehicle to Digital Twin. This connectivity will underpin operation and maintenance activities of the SRN as well as users of the SRN. This will require communication protocols to be standardised as much as possible without hindering innovation nor creating cybersecurity weak spots. Open data initiatives aim to optimise digitisation and accelerate innovation. They have shown great potential in other sectors such as the already established open banking, open energy, as well as the OFWAT-funded STREAM project in the water sector. Additionally, the sheer volume of data exchanged must be processed efficiently and make optimal use of the computing resources available. The aim of this challenge is to investigate current initiatives and build a framework that optimises data flows and increases bandwidth for efficiently and securely aggregating the vast amounts of data	Dr Lavindra De Silva Industry Partners: Trimble, TRL, Ringway, Telent, Costain Limited

collected by connected vehicles and sensors on the SRN. This architecture must also ensure seamless communication and open/permissioned exchange of data between vehicles, assets and the Digital Twin.	
DS5 Behavioural Analysis and efficiency modelling The University of Cambridge is in collaboration with the Universities of Westminster and Heriot Watt through the Centre for Sustainable Road Freight (CSRF) to investigate behavioural patterns for Heavy Goods Vehicles (HGVs) during the decarbonisation phase. HGVs account for 15% of traffic on the SRN. This is an opportunity to leverage some of that work for the remainder of 85% traffic on the SRN, which mainly comprises private users. How is an incident or congestion on the Strategic Road Network (SRN) caused by the behaviour of a driver, and conversely, how does the state of the SRN (e.g., defects, roadworks) impact road users? This project will apply modelling and inference to characterise regional traffic and shed light on the dynamic relationship and impacts the user has on the SRN and the SRN has back on the user. The goals are to assess the social impact and carbon benefits on the road user of modal shifts and new policies, traffic limits, etc. This challenge will increase secure journey reliability and transform NH from infrastructure provider into data optimiser and the DfT/Government into the policy holder.	Dr Lavindra De Silva Industry Partners: Ordnance Survey, National Highways
DS6 Data-driven safety improvements during highway activities Highway activities, such as maintenance and replacement, are crucial for having healthy highway networks, ensuring passenger safety. These activities rely on temporary traffic management. For instance, “Live Traffic” delivers real-time traffic updates, dynamically rerouting vehicles to avoid hold-ups. However, temporary traffic management has proven dangerous for drivers since there are instances such as vehicle incursions into road works. The frequency of the use of Live Traffic is constantly growing, and so are the safety risks, as the focus of Transportation Authorities is more on updating existing infrastructure than developing new infrastructure. The frequency increases even more due to the need for upgrading infrastructure to support electric and autonomous vehicles. However, major progress in the last two decades in collecting and processing data, using artificial intelligence, smart materials, automation and robotics, has the potential to significantly improve safety during Highway Activities. A natural question then arises: how can we use collected and available data together with artificial intelligence to improve the accuracy of Live Traffic, and safety in general throughout Highway Activities?	Dr Lavindra De Silva Industry Partners: L Lynch Plant Ltd, Keltbray
DS7 Trust in Data and Artificial Intelligence algorithms applied to highway networks Collected data can help us monitor and predict traffic, asset condition and weather. Additionally artificial intelligence-based algorithms offer a great opportunity to improve highway monitoring and maintenance, reduce traffic delays, and enhance users’ comfort and safety. However, to what extent do asset operators and users trust data, i.e., its veracity, and the results coming from artificial intelligence algorithms? For instance, road users do not always follow instructions related to the suggested path for reaching their destination in the shortest time. Additionally, highway managers do not completely trust automated techniques for asset condition monitoring and consequently combine automated monitoring with manual monitoring or validation. This has led to a	Dr Lavindra De Silva Industry Partners: Ordnance survey, Telent

crucial gap in science and industry: How can we define, measure, and improve trust in data and artificial intelligence?	
5. SMART MATERIALS Potential applicants should contact the smart materials theme lead, Professor Abir Al-Tabbaa (aa22@cam.ac.uk), for any queries regarding these challenges.	
SM1 Whole-life Zero Carbon Roads: Capital and operational decarbonisation of road materials The UK Net Zero Highways document has set a target of net zero carbon for construction and maintenance by 2040. However, current road construction and maintenance operations are far from being carbon neutral, and road materials significantly contribute to carbon emissions throughout their service life. From a decarbonisation perspective, there is now a significant push to upgrade existing road assets in preference to building new ones. Can suitable low-carbon and durable road materials be designed, validated and rolled out to contribute to carbon reductions in construction and maintenance? What elements of the different road materials and components can we make the quickest and largest impact, and how? These elements could include the exploration of low-carbon materials and alternatives to cement (blended cements and alternative cements), asphalt (bio-based), aggregates (for bound and unbound layers) and steel reinforcement (e.g. basalt fibres). How can we accelerate the validation of new low-carbon materials and products for construction and maintenance to fast-track their implementation into specifications and standards? Can lessons be learnt from existing or past projects? What is the best way to balance cost, carbon, performance and longevity? What are the opportunities for carbon sinks, carbon-negative materials and carbon sequestration within road materials and the wider road infrastructure network and assets? Where are the low-hanging fruit for decarbonising road materials, and can they address both capital and operational carbon? Can we continue to reduce the carbon footprint of roads throughout their service life? How do we quantify those benefits in whole-life carbon calculations and life cycle analyses? Can we develop sufficiently accurate carbon calculators for the construction and maintenance of roads? How can current carbon calculators be expanded and enabled to accurately and reliably assess the whole-life carbon of roads?	Professor Abir Al-Tabbaa Industry Partners: Ringway, Versarien, AECOM, Costain Limited, Galliford Try, Amey, Keltbray
SM2 Future-proof roads: Data-driven materials for durable and climate resilient pavements Roads deteriorate throughout their service life and this deterioration is not only financially costly but is costly in terms of carbon. Therefore, by using more durable pavement materials, the road sector could save money and achieve its net zero carbon goal. This challenge requires the generation of the much-needed evidence-based relevant data and the creation of suitable statistical models to enable the assessment, optimisation and integration of durability performance and carbon impact. How can statistical models assist in optimising carbon across the lifecycle of a highway asset to understand the carbon impact through more durable materials? We know that data plays a fundamental role in enhancing our understanding of materials and structural behaviour, providing knowledge, insights and predictions that were not possible before. How can currently available data, e.g., weather and traffic data, or data generated on-demand, e.g., from road conditions sensors, be used to deliver the data-driven smart pavements of the future that are durable and low-carbon? This challenge covers understanding the available road	Professor Abir Al-Tabbaa Industry Partners: TRL, AECOM, Amey

data, material performance and ensuring resilience against future climatic- and loading-related actions. How can we design digital roads with materials and sensors that enhance the life span, longevity and durability of this critical infrastructure? How should design specifications be updated for resilience based on the available data and future predictive models? What will be the most relevant failure criteria for designing resilient roads in a changing climate? What are the relevant failure mechanisms and detections methods for pavements that will impact material durability with changing fleet pattern, and increased demand? What are the modes of failure and the failure mechanisms in different types of physical and digital assets, and with this understanding, what mitigation measures and proactive maintenance approaches can be implemented? In addition, recent extreme cold weather events in the UK demonstrate the urgency for alternatives to salt gritting to keep our roads safe and trafficable. Conductive pavement technologies are already used in colder climates to deice airport runways and strategic road bridges. Could similar or alternative technologies be implemented to keep roads free of ice and snow?	
SM3 Zero waste roads: Capitalising on existing materials and eliminating the mining of natural resources The construction and maintenance of highways consume huge volumes of natural resources and generate vast quantities of waste. Can future roads use minimal to zero natural resources, and when we maintain and repair existing roads, can the road be intelligently used as a quarry for these operations? For example, asphalt is 100% recyclable, but only ~50% is usually reused. What are the blockers and challenges and how can we address them? What are the most efficient processing approaches for those road materials to enable their reuse? Road construction involves the excavation and movement of earthworks. Can we reduce the volumes needed to construct embankments using stabilised and reinforced earthworks? Can we up-cycle existing pavement materials, creating roads of higher quality and value? Potential areas for applicants to consider include: the development of additives, including nanomaterials or rejuvenators, to improve the performance and functionality of recycled materials. How can we innovate to reuse existing materials and their components and elements on site? What reprocesses are available for particularly challenging highway wastes to enable a higher percentage of waste reuse on-site? Can we do all of this on-site, reducing transport costs? Can we do this with the currently available technologies? What technologies will be required in the future? What changes to specifications and quality assurance procedures and what incentives are needed to drive such innovation and reuse? As road schemes are site and location-specific, this challenge can be addressed at the project level and draw lessons from previous road projects. How can we address the barriers to adopting such materials and products? Can we develop accelerated ageing tests to test these materials and foster adoption? How can those new materials be better integrated into the standards? Designing for decommissioning is another relevant element. This challenge could also be expanded to take a systemic view of materials to deliver environmentally responsible zero waste roads.	Professor Abir Al-Tabbaa Industry Partner: Colas Ltd, Balfour Beatty, Amey, Keltbray
SM4 Maximising road life: Smart materials and sensors to extend the life of existing assets	

The UK's strategic road network is valued at more than 128 billion pounds, and it is expected that this amount will increase with the majority of the assets still being in service in 2050. The assets that make up the network are ageing, and it is now acknowledged that the maintenance and repair of the existing assets (as opposed to demolishing and rebuilding) is the most sustainable approach to maintaining its services. A potential area for applicants to consider includes developing smart materials that can significantly enhance the life of existing assets. Can we deploy sensors to assess the current state of the pavements? Can sensor data help us make smarter decisions? Can smart materials and sensors be combined such that the pavement can report its state of health to help with the proactive maintenance of the assets and lengthen their operating life? Can smart materials assist in achieving efficient design, whereby we design with less materials and reduce overdesign in the maintenance of assets? Can we use this body of data to model the performance and deterioration of these materials and, ultimately, their whole life performance to inform intervention needs? Can we capitalise on the sizable body of existing data (owned by National Highways and others) to improve our knowledge of the current state of the assets? Can we employ car sensors, e.g. on Royal mail vehicles, to help in this regard? Can we use sensors and data extracted from sensors to eliminate disruptions and enhance traffic flow? Can we design or deploy low-cost multifunctional sensors, e.g., for combined asset management, traffic flow analysis and temperature measurements? Could pavement sensor technology be future-proofed to work in the future road network, e.g., so that they are compatible with the electrification of the network and future climatic scenarios? Can we integrate data from multiple sources and produce information and knowledge to inform strategic decisions regarding cost, carbon and environmental benefits?	Professor Abir Al-Tabbaa Industry Partners: Versarien, Telent, Costain Limited, Galliford Try, Amey
SM5 Automated Roads: Potential for 3D printing in future road construction and maintenance The National Highways Digital Strategy includes a roadmap to digitise the strategic road network by 2025. This commitment is paving the way for a range of innovative and impactful autonomous, robotic, remote and smart delivery approaches. 3D printing has emerged as a technology with huge potential to transform how we construct and maintain our infrastructure assets in a smart, cost-effective, resource-efficient and sustainable fashion. 3D printing enables fast and easy manufacture of on-demand complex and variable designs with minimal waste material without requiring formwork. The recent successful 3D printing of road elements has demonstrated the huge potential for future highway projects. Advanced 3D printing techniques would enable the delivery of multiple pavement materials (e.g., bituminous, cementitious and polymeric), with different compositions, including low-carbon alternatives, with very different properties and with a range of additives, including fibres, as well as composite materials with complex functional architectures. Precast and in-situ elements for road construction and maintenance applications can be 3D printed. Proposals could explore the potential for 3D printing various pavement applications, such as bespoke construction and repairs and robotic-assisted on-the-spot maintenance and assess and test the areas that would be most feasible and deliver significant impacts. These proposals could be extended using optimisation techniques and lead to full-scale trials. Sensor-instrumentation of 3D printed elements and components and assessment of response under a range of structural and environmental stresses would accelerate our understanding of the performance of 3D printed materials. In addition, can life	Professor Abir Al-Tabbaa Industry Partners: BAM, Versarien, Balfour Beatty, Costain Limited, Keltbray

cycle assessment and cost analyses serve to demonstrate the added value of 3D-printed construction?	
SM6 Smart earthworks: Soil for all seasons and harnessing excavation soil as construction materials Earthworks usually form a significant part of road projects involving excavation, cut and fill, and soil blending and reworking activities to create stable soil-based road spaces. These activities usually require working with both excavated soils (both granular and cohesive) and natural weak or unstable ground conditions; both usually requiring some form of soil stabilisation processes. In addition, most major infrastructure projects usually involve the excavation of significant volumes of excavation materials, primarily soils. For example, the construction of HS2 and the lower Thames crossing, are expected to result in the generation of several million tonnes of such excavated material. Excavated materials are a considerable industry concern as their export from sites and their disposal are very costly and have significant environmental impacts. In addition, in wet winter conditions, digging is usually stopped for around 6 months which places significant strains on project progress. Particular material of concern are the 'fines' components and fines also represent a major problem in quarrying activities. Hence, excavation and quarrying wastes constitute a major problem, yet they are valuable resources. What innovative processing and reworking can be deployed to convert such excavated soils into value-added products tailored to highway projects? Can cost-effective, low-carbon, and ideally waste-based stabilising additives and associated processing be developed and deployed? Can they be a source of pozzolanic materials to replace the diminishing supplies of slag and ash? Can the options for cementitious and alternative binders be expanded for soil stabilisation applications. What is the role of bio-based additives and nanomaterials here? Can waste from earthworks be used to generate a range of construction materials and products to enable different applications within road projects, such as supplementary cementitious materials, binders, aggregates, earthen construction materials, constructed elements, e.g., curbs, barriers, and others? Can rapid testing, design and quality assurance procedures be developed to enable rapid commercial deployment of such products? Can we explore regional feedstock to minimise transport and costs as well as degradation of the material due to stockpiling? How can we encourage material exchange between sites? Can we plan sufficiently well in advance to use projects in the pipeline to optimise the exchange process? Can we use existing project data, currently within the supply chain, to help in this regard and to inform optimisation processes and future decisions? How can we enable circular economy approaches within the network and beyond? What are the costs, carbon and environmental impacts/benefits of such activities and processes and is there a convincing and meaningful business case to make?	Professor Abir Al-Tabbaa Industry Partners: Versarien, AECOM, Galliford Try, Keltbray
SM7 Energy-harvesting roads: How much energy can we harvest in our roads? Transportation is one of the most energy-consuming sectors, but could this energy be harvested from the road infrastructure? Significant opportunities lie with the road infrastructure for energy harvesting, including solar, mechanical (vibration and friction from vehicles) and geothermal energy. High temperatures this summer made asphalt reach its melting point and led to significant road problems. Harvesting such energy through extraction and at the same time reducing this surface heat would deliver double benefits. The development and	

application of smart technologies and materials that capitalise on those resources, could easily turn the road infrastructure into a net energy producer. This energy would then provide the power for future electric vehicles, road furniture, and building assets within the network and for de-icing certain pavements and cycle paths where gritting or ploughing is difficult or undesirable. What is the potential for material innovations both in energy capture and storage? What is the potential of, e.g. piezoelectric, phase change or pyroelectric materials, thermochemical storage systems, highly reflective adhesive films, such as ethylene-vinyl acetate (EVA) films, conductive fillers, smart transparent coatings, layered composites and energy storage within concrete batteries. Hydronic systems such as asphalt solar collectors (ASC), thermoelectric generators, induction heating, solar panel roads, photovoltaic (PV) sound barriers have been deployed in pavements for energy harvesting trials in other countries. What can we learn from their experience and technologies? Can we combine two or more systems to maximise their potential for energy-harvesting all around the year? What kind of sensors are needed to measure/monitor the energy harvesting in pavements? Can we use these energy harvesting materials as sensors themselves? Can piezoelectric materials can be used to convert mechanical energy to electrical energy to power sensors to monitor traffic and pavement deterioration? What are the cost and carbon values, environmental impact, and electric loads of such proposals and systems? How long can such systems function without intervention? What kind of maintenance is needed for these systems? What are the storage systems needed to store the power harvested?	Professor Abir Al-Tabbaa Industry Partners: BAM, Colas, Ringway, Amey, Keltbray
SM8. Nano-inspired Roads: Role of nanomaterials in the delivery of low-carbon smart future roads Nanomaterials and nanotechnology will play a vital role in delivering future smart, sustainable and resilient roads and pavement materials. For example, graphene-asphalt and graphene-concrete composites were recently deployed in full-scale field trials as viable pavement materials to significantly enhance the life of road surfaces. Potential areas for applicants to consider: exploring the potential for graphene in the delivery of low-carbon pavement materials, including concrete, asphalt, fibres and other reinforcement, coatings, and road markings; the development of pavement composites using graphene and waste materials to maximise the use of wastes and recycled materials; the development and deployment of 3D printing with graphene, including concrete with graphene reinforcement for tailored applications; graphene for intrinsic condition sensing in roads; durability enhancement of pavements with graphene, e.g. resistant to chlorides or enhancing the wear performance. How can we accurately quantify the environmental credentials, carbon reductions, cost savings and longevity enhancement of those materials and products? What is the role of data-driven approaches in optimising material mixes for different designs and client requirements? How can we integrate such nano additives and new materials into the standards? There is also scope to explore impacts on a project or scheme level and explore refinements to existing life cycle software and commercial carbon calculators.	Professor Abir Al-Tabbaa Industry Partners: Ringway, Versarien, Balfour Beatty, Costain Limited
SM10 New Materials Roads: Designing with the end in mind, using the right material in the right place. How can we ensure we are still using the right pavement materials, in the right place, in the right way, for the right duration and to their full capacity? The future	

of road design must be able to predict, identify and map needs for alternative materials or novel materials and trends outside the sector. How are pavement materials supporting the network of the future? For example, could conductive pavements be used for power generation and charging or support for example digitally enabled workers/road users and operations? Can we design smart lane markings to enhance safety? What are the selection criteria for materials that balance cost, longevity/performance, and low carbon? What are the unintended consequences of new materials and hence what are the challenges associated with enablers for uptake of these materials? How will these new materials be incorporated in design and delivery considering aspects of specifications? Implementing of new materials will require building confidence in new materials' performance but also thinking outside the current toolbox. What is the role of non-conventional methods, accelerated testing and customer experience input in standards? Can commercial or policy incentives be leveraged to implement new materials? How do we translate innovation in materials into design? What is the role of innovative design here? How can we ensure performance and eliminate constraints? How can we contribute to a performance-based pavement design? How can we design for effective and proactive maintenance, or how can we design for minimal or no maintenance? Can we design pavements that fail in a prescribed manner or location? How should different trade-offs be considered? For example, Belgium's new pavement design standard is moving towards using thicker roller-compacted concrete pavement to address climate resilience. Should we design thinner sections and use less materials or thicker concrete pavements with less reinforcement to reduce the carbon footprint? What can we learn from experiences in other countries? Can we design for decommissioning? For example, design with fewer pavement material phases to ensure easy and complete recycling? Do precast pavements, as those applied in airfields, have a role to play here? Can we design future roads to reduce the need for new construction? Can we construct our roads like Lego from standardised elements and components, saving on design and construction costs and making it easier for reuse and decommissioning? Can new materials solve technical challenges in terms of drainage and water discharges? What are performance-based testing methods which can be used to assess new material?	Professor Abir Al-Tabbaa Industry Partners: Versarien, Balfour Beatty, Galliford Try
SM11 Oil-free asphalt for future roads: Sustainable materials for flexible road pavements Asphalt is mainly composed of bitumen mixed with aggregates of crushed stone. Bitumen is a by-product of crude oil distillation and contributes hugely to emissions and environmental impacts. In a future not reliant on fossil fuels, can we develop asphalts from alternatives to crude oil bitumen that deliver the same or better performance? For example, can asphalts be developed from waste biomass, including cooking oils and sewage? Or can they be developed using biopolymers like lignin or alginate? Can these oil-free asphalts have increased resistance to damage and deterioration? Can the chemistry of these oil-free asphalts be tailored to improve their properties and performance? Can the performance of these oil-free asphalts be improved by adding fibres, and can they self-heal? If commercialised, what will the cost be of these oil-free asphalts? Will they be cheaper than current asphalts? What will their whole life performance be? Can we develop suitable accelerated tests to provide confidence on their longevity and performance? How will the material and resource flow for their production look? How sustainable will they be? How will their performance in a life cycle analysis look like, and what would their end of	Professor Abir Al-Tabbaa Industry Partners: Ringway, Versarien, National Highways, AECOM

life look like? Can we balance the environmental impact, cost, performance and longevity? Can we accelerate their adoption into the standards?	