AHRC DESIGN FELLOWS CHALLENGES OF THE FUTURE

2.4%

MOBILITY
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INTRODUCTION

In December 2019, the Arts and Humanities Research Council (AHRC) issued a call for a three-month Design Fellowship at a Design Research Centre of Excellence in Mobility Research to review the British university-led design research landscape working on The Future of Mobility. The aim was to better understand the role of design research in this challenging area, the economic and social impact of design research and provide recommendations about how to support design researchers in academia, highlighting their contributions to the country as a whole. This resulting report provides insights through the lens of design professionals about design research in the context of the Future of Mobility – key research topics, where design is and is not used, emerging areas of design research in mobility, collaborations between design and other disciplines, the commercial value of design research, identified skill-sets for mobility design researchers, and supporting infrastructure.

1.1 What is design research in the context of the future of mobility?

Design research has developed out of the design disciplines (such as architecture design, furniture design, graphic design, product design and others) originally from the nature of designers' work to 'give form to things' (Alexander, 1971) to becoming an influencer in business and management by changing the mindsets of business innovators with 'designerly ways of knowing' (Cross, 1982) and 'acting' (Adams et al., 2010). There are two strands of viewing design or design thinking. One is focusing on designerly practices – giving form to physical things, materialising concepts and aesthetic experience which emphases inspiration, ideation and provocative ways of rethinking and reconstructing the world through activities that designers intimately involve themselves into the objects they work with and for. The other view has evolved from recent competitive commercialisation and business practices treating design as an innovative process to understand and interpret the needs of end users, stakeholders and customers, changing organisation's ways of thinking to focus on individual experiences. User-centred or people-centred are iconic terms that many business people and technical experts are now aware of and try to embed in their new ventures.

The UK Industrial Strategy (HM Government, 2017) defined the Future of Mobility as one of the grand challenges with the aim of positioning the UK to be a world leader in the way people, goods and services move. Mobility as a research area integrating land, sea, air and space transportation and related services has emerged in the last decade or so. It is an area facilitating researchers specialising in design, the humanities, science and technology exploration of new research topics together, conducting experimental practices that are innovations arising from traditional transportation fields. This includes urban mobility, which encompasses city infrastructure and digital systems; personal mobility including first-last-mile and portable mobility solutions; and transportation systems that will evolve from developments in autonomous vehicles, electric vehicles and other new technologies.

Design research in the context of the Future of Mobility is an emerging area which leverages creative intelligence to better address the challenges and opportunities of the mobility sector in the future such as business innovation, service innovation, technology invention and vehicle design. The uniqueness of this approach is that it focuses on social acceptance, individual awareness and adoption of new transportation/vehicle technologies. Design research methods (e.g. cultural probes, Gaver et al., 1999; experience prototyping, Buchenau & Suri, 2000; contextmapping, Visser et al., 2005) cover the whole process of designerly making – defining problems based on symbolic meaning and practical investigation; materialising concepts to quickly experiment with solutions and put plans into action and visualising the big picture of where and how the proposed solution could be implemented to magnify impacts. The outputs of design research in mobility include vehicle design specifications, service models, blueprints for service implementation, semi-functional and market-ready models and all these individual elements assembled into complete integrated products and services.

Because the nature of design has a grass-roots approach, where any expertise can be used to produce solutions and test them rapidly in the real world, bottom-up solutions are generated through interdisciplinary collaborations among those from the fields of design, psychology, sociology, science and technology specialities, and many others. In the context of the Future of Mobility, design research has the outstanding feature of providing a rapid operational structure for probing neglected problems, moving quickly to test ideas with end users and stakeholders, and introducing solutions in a visual and imaginative manner. The results of design research working in collaborative projects can be very practical, for example, defining and exploring a novel service model for electric vehicle parking and charging infrastructure, or designing a new transport tool for a market niche such as on-demand helicopter sharing. It can also be provocative for current imperfect systems when visualising the future, for example, probing for potential hidden biases for potential users of future autonomous vehicles, such as inadvertent barriers for the visually impaired.

1.2 Research methods

We screened the 102,881 UKRI funded projects in the UKRI Gateway to Research database in March 2020, identifying 1,294 mobility research projects. We investigated frequently researched areas and their relevance to design, the scale of project funding and the main research councils funding these mobility projects.

We then conducted surveys and interviews with academics from universities across the UK to collect information about research topics, expertise, projects, partnerships and where and how design research contributes or is overlooked in practice. 94 surveys were sent out and we received 33 detailed responses and conducted 17 follow-up online interviews. A workshop was hosted online with five mobility researchers representing research institutions across the UK to discuss centres of excellence in mobility research, regional weaknesses and strengths, personal expertise and experiences working in consortiums involving design researchers.

A further 45 surveys were sent to international mobility researchers working in universities and we received seven responses from countries including China, France, Germany, Japan, Singapore and the United States representing the world's mobility centres of excellence who provided opinions and overviews of their home country's mobility related design research in mobility.

145 surveys were sent to key automotive industry players in the UK and we received 17 replies from businesses ranging from major automobile companies to start-ups. 22 surveys sent to non-academic or commercial bodies, professional societies and institutions resulted in six replies from the Centre for Connected and Autonomous Vehicles, Connected Places Catapult, Knowledge Transfer Network, Innovate UK, and Intelligent Transport Systems (UK).

By combining these data collection activities as well as additional online searches, we identified examples of centres of excellence, individual researchers, and funded research projects to map and detail the landscape of design research in the context of Future of Mobility throughout the United Kingdom.

1.3 Analysis of UKRI mobility research projects

A keyword search (see table 1) of the 102,881 UKRI funded projects resulted in 7,002 candidate mobility projects (including 515 funded by the AHRC) which were then manually reviewed resulting in the 1,294 projects identified as being related to mobility topics. Of these, 132 either emphasised design or creativity methods such as user-centred design, co-design, storytelling, design interventions, journey mapping, scenarios design, inclusive design; or investigating user behaviour to improve experiences, technologies, testing, planning or policy.

Keywords used to search for mobility related projects in the UKRI database were chosen to be a balance between using terms that returned too many results to manually screen because they returned tens of thousands of irrelevant results and specialised terms that returned too few except for particularly relevant terms such as 'design research'. Wildcards were used where possible to catch words with variations in spelling and hyphenation as well as singular and plural forms and agent nouns.

We identified funded projects and programmes including research, centres of excellence, fellowships, studentships/ student projects and conferences. Funding bodies supporting mobility research included the Arts and Humanities Research Council (AHRC), Biotechnology and Biological Sciences Research Council (BBSRC), Engineering and Physical Sciences Research Council (EPSRC), Economics and Social Research Council (ESRC), Innovate UK, Medical Research Council (MRC), Natural Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC). The EPSRC and Innovate UK funded the most projects (1,153) relevant to the Future of Mobility.

The AHRC funded seven such projects, mainly focusing on history and urban environment studies, emphasising understanding the interplay of urban, social and cultural contexts. The 17 BBSRC funded projects mainly focus on carbon dioxide reduction and biofuels. The EPSRC funded 439 projects ranging from improving technologies for all types of mobility tools to testbeds, experimental technologies to user implementations. The ESRC funded 48 projects ranging from developing cost-effective business models to investigating the effects of an aging society and sustainable urban solutions. Innovate UK funded 714 projects focussing on novel solutions with commercial potential covering topics from cutting edge mobility innovations such as autonomous vehicles and electric vehicles to concepts that serve specialised markets such as golf buggies or stylish scooters. The MRC funded seven projects mainly with a focus on tools that serve the elderly and address travel related health issues. The NERC focused on air quality, net zero and urban resilience in the 31 projects that it funded. The STFC funded four projects, mainly focussing on transport systems and transport hubs and the platforms to realise such technologies.

Key research topics across all funders include electric vehicles (charging and infrastructure, parking, technology, demand forecasting), alternative fuels (biofuels, conversion of carbon dioxide to transport fuels, hydrogen and hydrogen fuel cells), energy (technology, management systems, storage and harvesting of), batteries (hybrid, technology, electric vehicle batteries and their manufacture), sensors (tracking, development, grids and networks), data (usage, gathering of, privacy, sharing, relating to autonomous vehicles and transport apps) and autonomy (systems, services, testing and features). Other topics that were less prevalent include collision avoidance, connectivity, driving systems, journey planning, materials (lightweight, bio-based and sustainable), parking, security, services, ticketing and traffic.

Table 1. Examples of keywords and number of hits recorded when searching the UKRI Gateway to Research (gtr.ukri.org) database for mobility projects	
Keyword	Number of related projects
Air Quality	45
Bicycle	35
Boat	37
Built Environment	47
Co-create	15
Congestion	115
Design Research	0
Driver	74
Electric Vehicle	70
Human Factors	16
Inclusive	17
Intelligent Mobility	6
In-Vehicle	77
Journey	197
Logistics	52
Luggage	10
Passenger	137
Scooter	8
Seamless	22
Service Design	0
Smart City	29
Transportation	233
Traveller	30
Urban Planning	6
User Centred	8
User Experience	14

Each funding body has its own emphasis, supporting certain skills and expertise, although they all encourage interdisciplinary research. EPSRC, as one might imagine, supports projects led by major departments of electronic and civil engineering, computer science, electrical engineering, geography and environment. We also found projects occasionally led by a management school, school of art, design and media, institute for communication systems, and city and transport studies. The largest single funded project went to support battery technology, setting up a centre to support universities neighbouring Harwell (£74,618,513). Innovate UK supports companies such as BMW, Ford, McLaren, Morgan, Rolls Royce and Tata Motors, and start-ups that collaborate with universities specialising in technology, some focusing on interface innovation and designing new products. The largest single funded projects support testbeds for Connected and Autonomous Vehicles (CAV) in Coventry and Birmingham (£17,566,099). The only project developed by a design school

was led by a design researcher and was funded by the MRC to improve safety for older public transport users with the resulting proposal emphasising feasibility studies to inform engineering solutions (£248,954).

It is noticeable that design skills are dramatically missing. When searching the more than 1,200 mobility projects, we found no design research or service design projects, eight user centred projects, 14 user experience projects, 15 co-create projects and 17 inclusive projects. We identified important design skills that were missing that are key when conducting research in the field including inclusive design, interface design, service design, vehicle design (in terms of interior design, exterior design, interaction and information design), and design process (practices extends before, during and after the artefact been designed). There are large areas where design skills are not particularly emphasised including aircraft, bicycle, boat, bus and built environment projects.

1.4 Analysis of the international mobility design research landscape

Five out of seven responses from international professionals were either researchers trained in design or working on mobility projects focusing on the input of design skills. They were from major research organisations and universities in China, France, Germany, Japan, and Singapore. Two of the researchers focus on human factors and mathematical methods for automated vehicles and refuelling infrastructure from major universities in Japan and the United States. They demonstrate a wide range of research topics: social design for future mobility through considering refuelling infrastructures and how they affect the accessibility of alternative fuel vehicles using mathematical methods; individual autonomous mobility and vehicles, urban transport and individual mobility of the elderly in society; emotional design of human-machine interfaces for autonomous public buses; new forms of multisensory communication between drivers and their Level 2-3 (Conditionally Automated) vehicles and new forms of communications in public transport situations; and human-centred design of autonomous mobility for public transport (road based only).

According to the survey responses funds invested in mobility research usually come from two sources, government and industry, with foundations and research agencies also key supporters. Government funding bodies such as the Japan Science and Technology Agency, Japan Society for the Promotion of Science, Ministry of Transportation in Japan, the National Research Foundation (NRF) and the Land Transport Authority, a statutory board of Singapore, mainly focus on technology challenges rather than design oriented projects and researchers also indicated that the design team is the smallest team in funded projects.

A design researcher in Japan said that successful applications to government funding bodies have a key technical challenge and use design as a part of the methodology to explore them. Private companies seem to see the value of design more than the government in these countries, with a Chinese design researcher mentioning that more than 90% of funding came from industry (both local and foreign companies) and that they face fierce competition as a Japanese design researcher indicated when seeking funding from their major automobile companies.

Generally, the design researchers work with other disciplines such as engineering and behavioural science but also aim to work with policymakers, paying attention to sustainable impact assessments, and associating with mobility (in most cases automobile) enterprises.

When asking 'How did mobility design research a) first occur and b) how did it develop to where it is today in your country and within your place of work?', most design researchers answered that the research in this area is mostly technology oriented. Quotes from a Singapore researcher: 'The research is mainly focussed on technical feasibility (e.g., AV (Autonomous Vehicle) behaviours, sensors) or behavioural sciences'. A Japanese researcher: 'There is a lot of technology research coming from universities and research institutes', and a Chinese researcher: 'As far as I know, this field has not yet formed a complete research field in China that can distinguish between vehicle design and traffic design. Most participants have industrial design or automotive design background. Some people can contribute good design solutions, but it is less able to provide proper solutions from the interdisciplinary perspectives of urban traffic planning, traffic regulation drafting, traveller needs, and vehicle design.'

2.1 The current UK design research landscape in relation to the future of mobility research

Like other countries at the forefront of mobility research into cutting edge subjects such as autonomous and electric vehicles, exploration of the sharing economy, public transportation and urban infrastructure, current UK research in relation to the Future of Mobility is still technology oriented and business centric. A good sign is that the UK government is aware of the value of design and tries to reinforce input from design research, design skills and design researchers. However, a typical trajectory when looking to ensure a design research contribution is still to fund projects that define a key technical challenge and using design as an add-on or part of the methodology for exploring research questions and helping create solutions.

Key topics covered by design researchers include the ageing society and the use of public transport, autonomous vehicles and train services. Key topics to which research consortia are trying apply design research or support research with some design methods tools include electric vehicles, passenger experience for public transport, parking and services, small vehicle design, intelligent systems such as scheduling, data privacy, routing, ticketing and transport management. There are topics always needing input from design as graphical assistance such as infotainment, interface systems and apps, but we rarely see anything funded with a design-led research team. Much research focuses on urban mobility but there is little that pays attention to rural areas. The UKRI funded projects database allows us to identify a shift from a focus on transport systems to paying attention to individual journey experiences, opening a wide research space where design research can contribute. The Design Council's consultancy work for Network Rail and Highways England and its collaborations with automotive and aerospace companies has influenced the value of design in industry and explored high-level policies and principles with national transportation providers, beginning the showcasing of design research and its potential contributions to the future of mobility in the UK.

The institutions that have been contributing to design research in mobility innovation include design schools, business schools, engineering departments, transport studies institutions and individual researchers from other faculties such as media, informatics and architecture studies. Typical centres of excellence for design include the Intelligent Mobility Design Centre at the Royal College of Art, representing design-led mobility research by leading Action Research for Design. Interventions range from inventing design methods and tools to creating novel concepts with enterprises, identifying future scenarios with the government and educating future leaders trained in design for the automotive business and research. Another such centre of excellence is the National Transport Design Centre (NTDC) operating within Coventry University's Centre for Future Transport and Cities with its user-centred, functional design and human systems integration groups focusing on exploring new areas of transport design research, finding new ways to use existing equipment and creating new technologies.

2.2 The importance of design research

Design research offers methods and toolkits for gathering tacit knowledge from users and the environment they interact with, creating narratives for identifying use cases and scenarios, and providing processes for applying knowledge from academic papers to specific solutions. Design research has shown its value for transportation services and systems that have been reconfigured in past decades by using its flexible process that enables researchers to move quickly and pragmatically with a unique customer focused view ensuring that the final delivered product meets their needs and desires. Design research also has limitations in that it typically does not include engineering so it is usually involved at an early stage of concept design and is the final stage for customer service design rather than used throughout the technical development process. One

industry interviewee mentioned that design methods are not always the right approach in terms of balancing time and costs and making the best commercial decision. This can be especially true when designing cars because of the huge expense of prototyping, testing and production, often under time pressure, with little space for error.

Design research is particularly beneficial in mobility research for:
- changing the focus from systems to individual journeys and from city centric to whole population solutions;
- communicating abstract knowledge among stakeholders (end users, manufacturers, service providers, local authorities and communities);
- making concrete demonstrations (future blueprints, service models, vehicle interior and exterior design, interface and information design for vehicle passengers, drivers and road users);
- working with business strategists to plan real market products from probing user demands to implementing concepts into vehicles and services with local communities and/or global customers;
- looking beyond the current needs and capabilities of transport methods and services identifying alternative mobility types and categories; and
- shifting from designing vehicles and technologies to designing services and driver/passenger vehicle interactions.

Design research methods such as journey mapping, storytelling, rapid prototyping, and service blueprinting can be easily applied and aim to save money for large scale projects thanks to its flexible and low-cost user study and prototype testing methods which aim to ensure that the products under development are as relevant as possible for the market. Designers' skills are sometimes transferred to electronic design or other engineering disciplines as demonstrated by some of the design researchers that we interviewed who are working on designing new technologies and finding ways to elevate technology innovations. These researchers are usually from product design, industrial design, or design engineering (a degree offering interdisciplinary study that draws on knowledge of design, advanced technologies, rapid prototyping and enterprise) whose skills can be applied to any field but are especially beneficial for advanced technical solutions due to their ability to design things that are both beautiful and functional.

2.2.1 The role of design researchers

Design research in the context of the future of mobility is conducted and commissioned by individual researchers. We divide the researchers into three categories:

Category 1: Researchers trained in design disciplines and working in the field of mobility. They are usually from vehicle design, industrial design, product design, textile design, interaction design and/or user experience design backgrounds.

Category 2: Researchers trained in non-design disciplines and working in design research for mobility projects. They are usually from anthropology, ergonomics, engineering and psychology backgrounds.

Category 3: Researchers trained in non-design disciplines and working in mobility research not related to design. Most of the researchers we identified and contacted are in this group. They are from mechanical engineering, civil engineering, mathematics, physics, energy, and many more science and technology related disciplines.

We mainly focus on the first two categories as they contribute to design research by establishing research topics and extending the boundaries of design knowledge and skills that can be applied to business and research. We also discuss the third category when reviewing where and how design research can contribute and why.

2.2.2 Design research in academia

Based on our survey and interview data, researchers working on mobility projects either led by design focusing on visible and tangible solutions or including design skills or aspects focusing on ergonomics and experience, are based in a range of British universities including Coventry University, Loughborough University, Northumbria University, the Royal College of Art and the University of Southampton.

They consider their research primarily falls into the categories of design-led (driven by design practices derived from design disciplines), people-centred (focus around needs and expectations of people) and innovation-led research (driven by novel solutions or new ways of conducting research) (Figure 1). Some researchers with design backgrounds working with engineers on cutting-edge mobility topics such as autonomous vehicles and vehicle passenger interfaces tend to consider their contributions fall into human factors, using user centred design approaches or socio-technical research to deliver technology based solutions. Most view their research as applied research, developing ways to achieve innovation and inventing something new (Figure 2).

How do you primarily see your research in relation to design research?
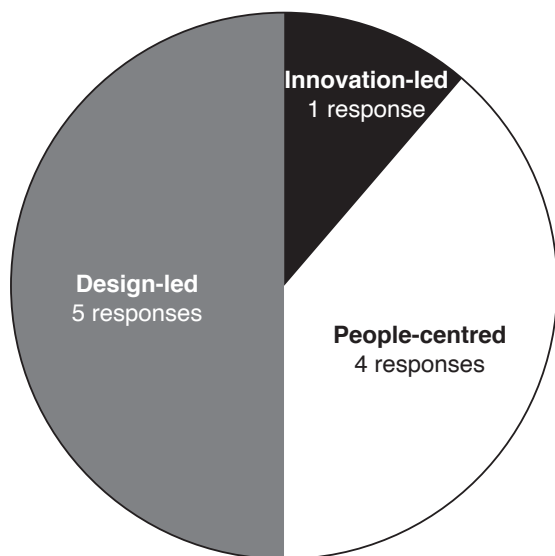(10 respondents)

What type(s) of research innovation do you do?
(10 respondents)

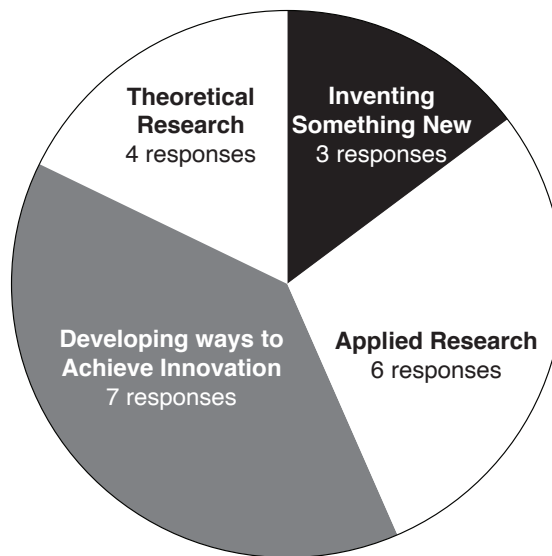Figure 1. Academic design researchers' responses about preliminary design research types

Figure 2. Academic design researchers' responses about types of research innovation

Other universities that have transport/mobility/automotive research groups include Brunel University (Brunel Automotive Hub), Cardiff University (Centre for Automotive Industry Research, Electric Vehicle Centre of Excellence), Cranfield University (Intelligent Mobility Engineering Centre), Edinburgh Napier University (Transport Research Institute), Imperial College London (Transport Systems and Logistics Laboratory), Lancaster University (CEMORE), University College London (MaaS Lab), University of Bath (Centre for Low Emission Vehicle Research), University of Leeds (Institute for Transport Studies), University of Oxford (Transport Studies Unit), University of Plymouth (Autonomous Marine Systems Research Group) and the University of the West England (Centre for Transport and Society). Mobility research is also conducted in advanced manufacturing research groups (University of Sheffield and University of Warwick) and in living lab or data/sensing research groups (University of Edinburgh, University of Glasgow and University of Ulster). It is common for researchers from computer science, energy, engineering, sustainability and environment groups to conduct mobility research. Research groups such as behavioural science, business, public policy, robotics, social science, tourism are also involved in mobility research projects.

This is not a complete list of mobility research players but it can be seen that traditionally mobility research is engineering oriented with collaborations between engineering, computer science, manufacturing and behavioural science. Design research is very new to the field and has been viewed as providing user centred design, design thinking and innovation methods.

Mobility research is largely a multidisciplinary area. It requires intensive collaboration across disciplines to study every aspect of vehicles, users, infrastructure, suppliers and manufacturing on topics including safety, technology readiness, comfort, legislation, material to utility, service and value. In order to report on design research, we mainly emphasise collaborations between design researchers (categories 1 and 2 as defined in 2.2.1) and other disciplines. What emerged from our interviews and workshop when talking about collaboration between design and other disciplines is that non-design background researchers confirmed the contributions of design research for visualising and communicating ideas quickly and effectively. Storytelling skills helped to illustrate specific journey and individual use case scenarios, and brought an ability to see

what could be improved and how to do so, working with science and humanities inputs to translate abstract knowledge into narratives that can easily be applied in a practical way.

Researchers from transport backgrounds working on specific systems such as trains say that as designers or design researchers typically come from outside the field, a lot of time needs to be spent building up their knowledge and experience to understand the needs of individuals and that it can be difficult for industry to implement the systems they design. One design researcher who worked in an engineering department stated that they formulated their skills to suit the socio-technical driven environment focusing on user experience, and that although their knowledge can be easily transferred, they still miss working on visualising ideas rather than being a part of a technological solution. In other words, one of the important skills – realising visual solutions - has been overlooked in traditional mobility research.

2.2.3 Design research and Industry partners

A number of partnerships and collaborations occur across many universities with large automotive companies and emerging small businesses. These collaborations vary from user interaction and experience design briefs to new transport platforms such as those that focus on last-mile journeys and the sharing economy. Of the seventeen individuals who replied to our survey from the 145 individuals from international, national and regional businesses within the UK who were contacted including individuals from major automotive companies (a 12% response rate), twelve respondents confirmed they had previously partnered with fifteen British universities for design research projects (Figure 3) with a further six stating they had not partnered

Have you ever partnered with a UK
university for a design research project?
(12 respondents)

Figure 3. Survey respondent university and mobility company design research project partnerships

with a British university. Seven noted that their company has a design research team and it is essential to their product or business with a further six stating that they do some design research at their company with respondents coming from both multinational companies and SMEs.

We performed four follow-up interviews with individuals from companies that had partnered with at least one UK university. They included three multinational car companies and a start-up, and we discovered that two defined design research broadly as innovation-led and dominated by engineering. One interviewee from a large automobile company stated that they have large design departments or teams with very design centric approaches focusing on aesthetic and graphical solutions. Another mentioned that in their design team there is a division mainly conducting research and providing strategic frameworks for how design knowledge can be a benefit company-wide. A head of design in a multinational automotive company stated that their

design department not only conducts design work but is also responsible for design research which is design process focused, strategic and is about identifying problems and executing solutions. They mentioned that they thought that creating the right brief is more important than execution and that design research helps with this process.

Although industry and academic collaborations take place regularly, very few respondents said they helped to commercialise a design research project. One mentioned a commercialised innovation-led research project between a university, a small and medium-sized enterprise (SME) and a multinational automotive company on vehicle interface and information systems. This suggests that there is potential for design-led research to

If you are familiar with design research, how do you think it can benefit your business? (16 respondents)

It can help us find disruptive solutions

94% **15** responses

It can help transfer research knowledge to implemented innovations

88% **14** responses

It can help make our end users more satisfied with our products

88% **14** responses

It can improve innovation in product design

88% **14** responses

It can improve innovation in technology development

88% **14** responses

It can improve innovation of business models

56% **9** responses

It can help to integrate different disciplines acting as a facilitator

56% **9** responses

Figure 4. How industry personnel believe design research benefits their business

Table 2. Economic value that design research brings – answers from industry personnel
It's invaluable; research and exploration is key to innovations that causes the industry to evolve
It can be the next innovation which creates revenues
Successful products and lower risks
Optimise a solution already in R&D
Innovation is investment in the future
Creating, developing, and delivering successful products
Understanding issues, trends, and opportunities to help focus design efforts for more targeted products
Design research assists in finding the best solution to customer needs and so for an industry generates economic value by overall efficiency and effectiveness
Objective insights to help the development of products with high customer appeal

help deliver concepts and execute production. Nine respondents stated that the design research can benefit business model innovation and fourteen said it can improve innovation in product design within their company. Fifteen respondents further added that it can help them find disruptive solutions. Fourteen respondents said that design research can help transfer research knowledge to implement innovations and make their end users more satisfied with their products (Figure 4).

During follow-up interviews with industry respondents we realised that in the past major automobile companies usually worked with universities through the teaching track, providing topics for design students to brainstorm and create fresh ideas. Few companies collaborated with university research groups on design research projects, however, this is changing as most of the companies interviewed realise that design research either has potential or is important to their business and that the emergence and expansion of design research would be extremely valuable for commercial implementation of technology ideas, service innovation and product propositions.

The economic value of design research has a generally positive response from the industry respondents (Table 2). Many who work in, or closely with those in the field, view design research as key to 'understanding

issues, trends, and opportunities to help focus design efforts for more targeted products' (a designer from a multinational). Some also see it as 'invaluable', a way for the industry to evolve through key innovations – 'research and exploration is key to innovations that cause the industry to evolve' (a designer at a sports car manufacturer). Some see it meaning successful products and lower risk. Several mentioned it is investing in the future or the next innovation and this creates revenue.

2.2.4 Design research and government partners

Most of the individuals from non-higher education institutes or commercial bodies, professional societies and institutions we contacted have a deep understanding about 'design research' as 'user research', 'user centred design approach', 'the method to identify the needs' and 'test ideas'. Some mentioned that they are not sure what design research is, or have never heard about 'design research' as it is often referred to by government or research council funders as 'behaviour change' or 'discovery activities' to encourage wide participation by research specialists, designers and social scientists. One of our respondents clearly distinguished 'academic research into design methods/processes' and 'research as part of a design process which might be carried out by a designer and/or a research specialist collaborating with a design team'. However, individuals also stated that there are no policies or strategies at their institution that consider or require the inclusion of design research, especially those who focus on connected and autonomous vehicles and connected transport.

The answers for 'should design researchers be included from the outset of cutting-edge projects such as manufacturing, electric vehicle charging and autonomous vehicles' are very positive. Some stated that design research could provide 'a structured approach to understand challenges' and to make sure 'the benefits of innovation in mobility will be available to all parts of the UK and all segments of society'. One elaborated that 'design research activity (whether carried out by a 'design researcher', 'designer' or 'someone else with appropriate skills') should be included within projects. Ideally, it should also be included before the start of these projects, to help make sure that the proposed topics (better batteries, EVs etc) are actually the right answer to the right question'.

The Connected Places Catapult, Innovate UK and the Knowledge Transfer Network (KTN) all stated that they have a design team or creative studio to make sure that they incorporate design innovation into their funded projects. Innovate UK has its Design in Innovation Strategy to boost the economic, social and environmental value of innovation activity. Almost all of the bodies recognise the social value of design research as 'meeting societal needs', making sure that products are designed for the entire population and are actually adopted by people and engaging stakeholders during the research and manufacturing process. The respondents also confirmed the economic value of design research as making the process more 'efficient', 'lost cost' and 'low risk' if it can be implemented from the very beginning of a project to avoid the likelihood of retrofitting solutions. One respondent emphasised 'consortiums including quality design research (and design!) are therefore more likely to achieve commercial success and business growth'.

2.2.5 Design research and charitable partners

Academic researchers seldom mentioned charities as essential partners. We found charities working both nationally and in developing countries to reduce air pollution, campaigning for better air quality and protecting the environment through developing and researching sustainable transport with the main areas being public transport (rail and buses), cycle networks (UK) and shared mobility schemes such as bike share, rideshare and car clubs.

A significant area that is supported by charities is inclusive mobility. This includes a wide range of innovations and accessible transport solutions to help people stay independent, provide quality of life, access services and engage with their communities. Inclusive mobility charitable research schemes are broadly divided into two key categories: ageing and mobility, and transport for disabled people. Transport solutions for disabled people include accessible vehicles as well as mobility devices such as scooters and wheelchairs. There are also community transport services charities that support accessible mobility inclusively.

Charities with mobility related research and ventures we found include Age UK, Campaign for Better Transport, Centre for Ageing Better, Children's Investment Fund Foundation (CIFF), Community Transport Association (CTA), CoMoUK, Design Council, ECT Charity, Interreg North Sea Region, Mobility Trust, Share North and Sustrans.

The Design Council has its special role as an independent charity and the government's advisor on design. It works with various transport providers from rail infrastructure to road design, as well as manufacturers in the aerospace and automotive industry giving independent advice to help incorporate design-led approaches. The council works using key design principles which include people, community and diversity, collaborative, inclusive, contextual, connected and innovative.

2.2.6 The value of design research

The value of design research has been confirmed by both industry partners and non-higher education institutions working closely with the government. Out of 18 answers we received from respondents working in industry, 11 people described design research as being about involving people/users interactively in the whole solution finding process; 11 people said it is about designing concepts, prototypes or applications; 10 about creating solutions for problems that bridge multiple fields which need a holistic view to answer them; a further eight mentioned that it is about visualising ideas and translating them into a planning document; and eight said it is a series of methods to help structure user/customer research (Figure 5). As mentioned in 2.2.5, individuals understand design research as 'user research', 'user centred design approach' and methods and processes to help produce relevant innovations.

The economic value of design research was described as avoiding risks by identifying the right challenges and where people's needs are in the early stage of the project, looking beyond the current needs of people and society and predicting future challenges to help target investment for the highest returns, illustrating and communicating ideas and knowledge to produce practical plans and solutions to make the process efficient, and quickly testing concepts with all levels of prototypes and enacted user interactions. Design research is also seen as important for innovation as the nature of design is depicting pictures of plans and solutions and it provides the ability to iterate systematically towards solutions before spending huge amounts of money realising them.

When asking individuals from companies 'what do you think is the economic value that design research brings to industry?', people's answers include 'innovation is investment in the future', 'successful products and lower risks', 'next innovation which creates revenues', 'optimise a solution already in R&D', 'objective insights to help the development of products with high customer appeal', 'Design research assists in finding the best solution to customer needs and so for an industry generates economic value by overall efficiency and effectiveness'. It is not hard to see that design research is closely connected with 'successful projects' and 'customer needs' which is design thinking's key impact in business. Summarising from the follow-up interviews, design research can offer more than this in the context of the Future of Mobility such as integrating design with wider teams working with engineers realising technology innovations, and influencing product and market strategy as well as company strategy resulting in effective collaborations between departments and organisations.

Surprisingly, we found most of our respondents from industry and non-higher education institutions think differently to the

What do you understand by the term 'design research'? (18 respondents)

It is about designing concepts, prototypes or applications
11 responses **61%**

It is about involving people/users interactively in the whole solution finding process
11 responses **61%**

It is about creating solutions for problems that bridge multiple fields which need a holistic view to answer them
10 responses **56%**

It is about visualising ideas and translating them into a planning document
8 responses **44%**

It is a series of methods to help structure user/customer research
8 responses **44%**

It is about creating technical solutions and proving them in the real world
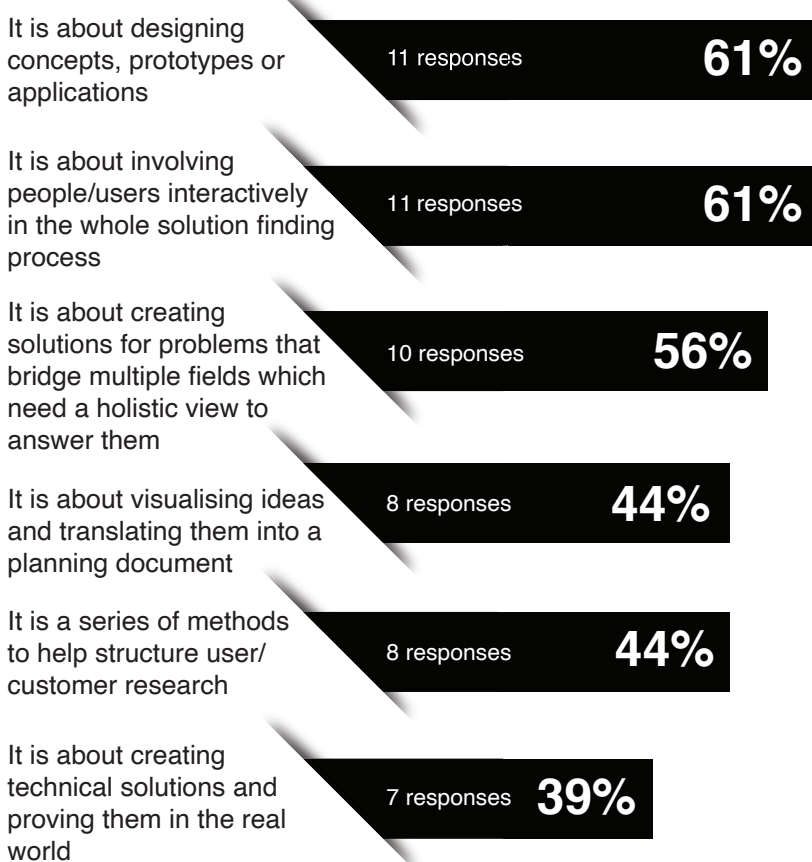7 responses **39%**

Figure 5. The understanding of what is meant by design research by industry

traditional view that design research's value is only applicable for styling and design of premium cars. Most recognised that its value should be recognised as being applicable much more widely and as a standard part of collaboration frameworks (Warwick Business School and Design Council, 2015).

The social value of design research in mobility innovation has been well recognised and developed mostly through social science driven projects. It is mainly recognised as helping industry and academia change focus from designing 'transport systems' to caring about 'individual journey experiences', to help the government widen their focus from urban, to urban and rural areas, from serving the majority of the population to serving the whole population (including disabled and marginalised people), and helping to invent bottom-up solutions by talking with, mobilising and co-creating with individual travellers and service users. The emphasis of the core design approaches such as the use of visualised journey mapping, scenario and storytelling, the invention of testing prototypes and processes to enact the potential interactions with end users and stakeholders, and the creation of briefs of products and services deserve more attention in future collaborations or project consortiums.

2.3 How design research is supported in the UK

Investment is mainly from industry, research councils (EPSRC and Innovate UK) and non-academic and commercial bodies (Catapults). Overall, the industry invests money exploring what design knowledge and skills can be a benefit for their business usually under the name of 'investing in the future'. Collaborative projects were typically funded as university consortiums involving design researchers working on user centred design packages (EPSRC). Corporate project costs were shared between research organisations and companies (all sizes) to invent new businesses and bring products to market, often including design skills as styling and customer satisfaction. One academic department received a substantial amount of funding from a High Value Manufacturing Catapult (£100m).

The money mainly supports collaborative research and development on cutting edge topics such as vehicle electrification and connected and autonomous vehicles by universities and industry. EPSRC put money into the Centre for Doctoral Training in Sustainable Materials and Manufacturing (EngD) at the University of Warwick which is very engineering and technology oriented. AHRC funded the Design Centres for Doctoral Training supporting research in Responsive and Inclusive Design: Sustainability: Vehicle Design at the Royal College of Art, with one PhD project having been supported to date.

The AHRC does not have funding schemes targeting specifically the mobility sector. Their mobility related funding schemes are generally targeting global challenges such as GCRF Global Engagement Networks and ESRC-AHRC-CASS International Centre Partnerships where climate change and urban sustainability is one of the topics. The Greenhouse Gas Removal Demonstrators Programme has a broad scope for assessing sustainable routes for large-scale greenhouse gas removal (GGR) from the atmosphere. UK-China Creative Industries Partnership Development Grants involves fields including travel and mobility. Innovate UK's CR&D competition, low carbon automotive capacity, future flight challenge, ATI programme, adaption cutting-edge technologies, and technology inspired innovation are generally for technology or manufacturing innovation. There are funding programmes targeting mobility from Innovate UK such as connected and autonomous vehicles, world leading off-highway vehicles, vessel efficiency, maritime autonomous systems, enhancing customer experience in rail travel, integrated transport: enhancing the end to end journey, the road to market, building an automotive supply chain for the future, disruptive technologies in low carbon vehicles, introducing driverless cars to UK roads, and innovation in vehicle-to-grid. Most Innovate UK funded projects are practical technology innovation for market use and the few we found related to design include 3D vehicle design process tools and exploring new designs of mobility solutions, for example, personal/small mobility tools.

Museums such as the Coventry Transport Museum, the Design Museum, the London Transport Museum, the Science Museum and the V&A have been working on putting design research in the automotive sector on display and exploring possible working hubs, exhibitions, training and networking events for design research in mobility innovation. The Design Council has been exploring the value of design in the aerospace and automotive sectors and published key findings in collaboration with universities such as University College London and the Warwick Business School as well as with automobile companies such as Aston Martin and Rolls-Royce. Strategically partnered with Network Rail and Highway England, the Design Council supported capability-building to enable a design-led approach to rail infrastructure and developing principles for Good Road Design.

There are gaps that need support such as PhD student training for new mobility challenges and interdisciplinary collaboration, networking programmes for design researchers to showcase their capabilities and to encourage design-led resources in consortiums, conferences and seminars involving museums and the automotive industry, and PhD studentships for design-led mobility research projects, and fundamental research for design research methods. Design researcher's involvement as design or business fellows at organisations such as the AHRC and the Connected Places Catapult should be explored in partnership with the organisations for intelligent transport systems, connected and autonomous vehicles, and transport departments.

2.4 How design research is supported internationally

From our international survey, we found 'autonomous vehicles', 'human centred design in urban mobility', 'individual mobility', and 'public transportation' are key topics. Design research in mobility is relatively new in all of the countries we investigated. Researchers are exploring collaborations between disciplines and industry sectors, as well as making representations for design research to be part of government funded projects. Government funded international collaborations are common except for researchers from countries that have a strong automotive industry and large local markets (e.g. China, Japan, USA) where private funding is more common.

Design research in mobility innovation is an emerging area in all countries we investigated with most design researchers implying that design research needs to be properly recognised so that its economic value can be fully realised. Except when seeking government funding and major automotive company sponsorship, researchers try to partner with public transport operators, local authorities, small transportation firms and insurance companies. Most respondents have domestic and international partnerships usually between Asian and European organisations, and attend mobility and design research conferences or attend meetings of professional societies (for ergonomics and human factors) to extend their networks.

Funding policies for these countries' academic mobility research encourage innovation, technological advances, the creation of new knowledge and the strengthening of both local and overseas collaborative work. Priorities include the digital economy, engineering, enterprise, environmental systems, human systems, manufacturing, services, sustainable urban systems and technical challenges.

2.5 Case studies – centre of excellence for design research in mobility

By analysing the survey responses from international academics and the interviews with industry, we identified three centres that represent either design-led research or combine design research and other disciplines to pursue mobility innovation.

Intelligent Mobility Design Centre (IMDC), Royal College of Art, UK

An established vehicle design and research world leader, IMDC's multidisciplinary research centre has a core design-led people-centred approach focusing on new ways of designing, influencing behaviours and developing methodologies and mobility typologies that address societal issues, operating at the intersection of design disciplines at a time of radical change in modes of mobility. The urgent need is to re-focus on journey, experience, design of services and systems, and the complexity of infrastructure and interactions that mobility in modern societies entails. IMDC's design research is tools for conducting research; theories guiding strategies for consultancy; practices for designing concepts, prototypes and applications. Three studios incorporate design skills and design research methods through practice – Automotive Transition (aesthetics, materials and trends), Humanising Technology (experience, service and socio-technical design) and People and Places (neighbourhoods, mobility hubs and planning).

https://www.rca.ac.uk/research-innovation/research-centres/intelligent-mobility-design-centre/

ITS and UTMobi + DLX, University of Tokyo, Japan

The Institute of Industrial Science's (IIS) Advanced Mobility Research Centre (ITS) advanced mobility research and development fuses research fields related to infrastructure (road and city), moving bodies (vehicles) and humankind. The Mobility Innovation Collaborative Research Organisation (UTmobi) is a state-of-the-art research organization working on mobility research focussing on autonomous operation, drawing from every university department. It promotes basic research in innovation design, big data analysis, and human machine interfaces, systemization of knowledge and implementation of local communities contributing to mobility innovation through interdisciplinary collaboration. The IIS Design-Led X (DLX) platform fuses design, engineering and design engineering education, believing "design should bring value to people". ITS and UTmobi mostly focus on technical challenges with DLX providing design and innovation input.

http://www.its.iis.u-tokyo.ac.jp/en/
http://www.its.iis.u-tokyo.ac.jp/utmobi/ja/
https://www.iis.u-tokyo.ac.jp/en/research/department_center/design-led-x-platform/

Insight and Strategy, McLaren Applied, UK

McLaren Applied works at the intersection of technology, data and human ingenuity delivering quantifiable performance advantages in industries as diverse as health and fitness, public transport, automotive and motorsport. Their design team is split across mechanical engineering, product/industrial design and insight and strategy, with the integration of design research core to the development process, mainly through conducting research and providing strategic insights framing how design can widely benefit all projects. As a design strategist says 'design research can be a complex process. It's often challenging work, emotional, frustrating, sometimes misunderstood and underappreciated. This means that it can be difficult to instantly embed into an organisation effectively. When done properly, it can change an organisation's goals, create otherwise unforeseen business opportunities, change people's lives, and become the most rewarding work you'll do.'

https://www.mclaren.com/applied/about/

SKILLS

3.1 Skills pipeline

3.1.1 Design researchers in mobility fields

The design researchers working in academic and industry mobility research came to their current roles from a variety of design training backgrounds including design studies, graphic design, goldsmithing, industrial design, smart textiles, user experience design and vehicle design (Table 3). Others also working in the field of mobility design research came from diverse academic backgrounds including computing, civil engineering, electronics, engineering, ergonomics, human factors, mathematics, mechanical engineering, physics, psychology, science, social anthropology, and systems engineering (Table 4).

Table 3. Design backgrounds of mobility design researchers
Design Studies
Goldsmithing
Graphic Design
Industrial Design
Smart Textiles
User Design
Vehicle Design

Table 4. Non-design backgrounds of mobility design researchers
Civil Engineering
Computing
Electronics
Engineering
Ergonomics
Human Factors
Mathematics
Mechanical Engineering
Physics
Psychology
Science
Social Anthropology
Systems
Technology

Few researchers trained in design consider themselves full time mobility researchers, either because before they entered the field they were not trained in transportation or related subjects, or because the few researchers trained in design, work on a variety of projects including mobility. Some see their research approach as innovation-led or people-centred as it can be applied to a wide range of research. They emphasise their work is not only about styling but also enterprise, therefore their skills can be transferred to other disciplines.

Researchers trained in behavioural science, ergonomics, social science, engineering, technology and business who work full time in mobility fields consider their research approach as innovation-led, people-centred and discovery-led. Almost all talked about the needs of users, design as a holistic view and cross-disciplinary approach with some mentioning applying design processes such as double diamond, design as communicating ideas for the future, and design research as a socio-technical lens for investigating technologies involving people.

3.1.2 Career development pathways

A typical career development pathway for a design researcher begins by studying design or craft in a variety of specialisms (as seen in Table 3) at undergraduate and postgraduate level. Many then further expand their skills and continue their professional development with doctoral studies. After completion, they may either work in design research at a university or within the automotive industry and related fields.

Mobility design researchers have a variety of educational backgrounds in subjects that may be design-led or non-design. This is because mobility research encompasses a wide range of specialist areas contributing to the overall development of strategy, design, engineering and technology. Paths vary for mobility design researchers developing their careers with options available through technology, creativity, teaching and management tracks.

A typical technology track career pathway can start with a creative background in fine craft skills at university while at the same time acquiring computer aided design and product engineering skills and then continuing

to design-led doctoral studies whilst developing digital technologies. This is often followed by academic leadership in creative innovation and technology development.

An individual who intends to follow a creative track in their career will inevitably study design at undergraduate and possibly postgraduate level. They follow their educational experience with work in the automotive industry or a university mobility centre where their creative skills will be used alongside design-led research.

A teaching career often progresses by first studying vehicle design and/or industrial design or user centred design. After acquiring some industry experience as well as freelance and consultancy work, their skills are applied to university lecturing in mobility design. Alongside this, they conduct academic design-led research projects and publications funded by the university, industry and UKRI.

An individual who has followed a management track has typically studied some form of design or human centred research degree before working in academia or industry and gained years of experience leading teams and working with government and major automotive companies on large scale projects. They then progress to strategic research management roles, again either in academia or industry.

Publication channels for design researchers are slightly different to researchers in other fields. Exhibitions, shows and design objects are viable outputs which have similar or even greater influence than papers. For mobility design researchers, publishing research outputs in all these publication channels would be ideal for career advancement, however our research found that journal and conference papers are still the most common type of research output for researchers from all backgrounds. The key publication channels that our research participants mentioned are conferences and journals managed by design societies such as the Design Research Society (DRS), Co-design - International Journal of CoCreation in Design, and the Arts, and the International Association of Societies of Design Research (IASDR); specialised mobility organisations such as the Association for European Transport (AET), Low Carbon Vehicle Event (LCV Cenex), Passenger Experience, Society of Automotive Engineers (SAE), and Transportation Research Board (TRB); or in the normal outlets of research fields that include mobility topics such as the Anthropology + Technology Conference (A+T) conference, Conference on Human Factors in Computing (HCI), and Applied Ergonomics. There is a notable lack of conferences dedicated to mobility design research.

3.2 Activities emerging from doctoral training centres and partnerships and individual research organisations

Research councils such as the AHRC and EPSRC support doctoral training centres for specialised mobility research topics.

AHRC funded Design Centres for Doctoral Training – the London Doctoral Design Centre supports research in Responsive and Inclusive Design: Sustainability: Vehicle Design at the Royal College of Art. The London Doctoral Design Centre/Consortium currently funds one PhD student on the Intelligent Mobility programme at the Royal College of Art on a project called The Public in Public Transportation. The Doctoral Training Centres, Northumbria-Sunderland Consortium, Design Star, and 3D3 REACT (Research and Enterprise in the Arts and Creative Technologies) do not list any mobility related PhD students in receipt of funding.

AHRC Doctoral Training Partnerships - the South West and Wales Doctoral Training Partnership, CHASE Consortium for the Humanities and the Arts South-east England, Northern Bridge Consortium, Techne (The craft of research in the arts and humanities), White Rose College of the Arts and Humanities, Midlands for Cities, The Open-Oxford-Cambridge Doctoral Partnership, Northwest Consortium Doctoral Training Partnership and the Scottish Graduate School for Arts & Humanities - do not appear to have any funded mobility related PhD students. LAHP (The London Arts & Humanities Partnership) has none to date, but a student will be starting in late 2020 at the Intelligent Mobility Design Centre (IMDC) at the Royal College of Art on a collaborative project between the IMDC and Tata Motors titled Inclusive Design for Shared Autonomous Vehicles.

EPSRC sponsored doctoral training centres we identified using the UKRI database include areas such as Future Infrastructure and Built Environment, Advanced Automotive Propulsion Systems, Future Autonomous Robotic Systems, Transport and the Environment and Cyber Security. All are technology oriented with some focusing on elements of technology development that are used or enable functionality or user experience for

transportation or vehicles.

Doctoral training varies among different universities, but generally, there is a lack of interdisciplinary training courses for students. Mobility research is a very interdisciplinary field and students that have previously graduated from a typical narrow specialised program do not necessarily have all the background knowledge they need for their research topics, meaning that providing short courses to fill in knowledge gaps is necessary. Some researchers also mentioned building multicultural networks and awareness in their students is very important as they are often from different parts of the world with different backgrounds. Interviewees also noted that some universities make design research courses compulsory as part of their first year teaching, covering methods such as semi-structured interview, focus groups, storytelling and other practical design research methods.

Executive education is delivered by some research organisations to industry partners. Universities from the Midlands produce mobility related executive programmes and masterclasses covering areas such as retail management and strategic leadership that are suitable for dealer principals and managers; strategies for artificial intelligence and digital services that are suitable for executives and help inspire the incorporation of cutting-edge technologies into their organisations. Most courses are delivered through business schools. Many new mobility topics are not covered by these courses such as service innovation and new mobility solutions, product innovation for new user demands, or how to identify and target new niche mobility markets. For technology innovation, many companies set up their own research centres in universities to directly transfer research knowledge, typically around specific scientific topics, to commercialisation. National funding organisations set up strategic partnerships with universities to gain an overview of mobility topics in relation to transport and cities including environmental design, intelligent mobility and transport platforms.

3.3 Early career design researcher support

Creating opportunities for early career design researchers in mobility fields by creating opportunities for access to networking, academic and industry partnerships, funding and buying time to do research (for those who are on teaching tracks) were frequently raised in interviews with academics.

One workshop participant working as an academic researcher within a university stated that their research projects are mainly funded by the EPSRC and other sources. Funding directed towards vehicle safety comes from Horizon 2020, an EU funding programme for research and innovation. Innovate UK was also mentioned as funding research projects with industry support. For another attendee, the EPSRC was their university's main government funding body but they also had industry funding from vehicle manufacturers and mobile technology companies.

The workshop participants mentioned that there are funding schemes targeting early career researchers such as Circular Economy Network+ in Transportation Systems (CENTS), Early Career Researchers (ERC) Fellowships, EPSRC Fellowship Scheme, Foundation for Integrated Transport Fellowships (FIT) and the Marie Curie Fellowships. However, several researchers said that the major barrier preventing them applying for funding and performing research are their teaching duties.

When describing activities expected of an early career researcher over the course of a typical year they were encouraged to be independent. During a year, an early career researcher would have very limited opportunities for networking, proposing and submitting funding bids and completing research projects because of their teaching and other academic duties. They needed more networking opportunities with industry and academia so that they could identify partners and funding sources and gain experience proposing project ideas and forming consortiums.

3.4 The skill sets needed by design researchers

Our research data suggests that design researchers' skill sets have always been seen as new forms and language for brands, user interactive engagement and study, visualising and prototyping, and future thinking. It is time to develop this further to tackle a wider range of questions in public transportation, city design, sustainable mobility behaviours and alternative transport tools. All these issues require wide collaboration to solve challenges that solo players have limited ability to address. The skill sets needed for design researchers

to work in the field are mixed with the main body of knowledge from design subjects, social science and behavioural science and additional knowledge and skills in engineering, computer science and business. The new skills that many design researchers need to acquire include business model design, city and infrastructure, computing, electronics design, marketing, policy, supply chains and many others as required by project specifics.

The skill sets that are mastered by design researchers and that could make significant contributions to mobility challenges include:

1. Skills to help change mindsets -
    *   Visualising and communicating future challenges and potential solutions and,
    *   changing the view from the system as a whole to individuals and journeys

2. Skills to help produce products -
    *   Rapid prototyping and testing with end users and environments and,
    *   using flexible methods and toolkits to deliver solutions quickly and applicably

3. Skills to help increase revenue –
    *   Matching final deliverables to users' needs and desire from an early stage and,
    *   translating research knowledge to applicable and concrete solutions

From the data analysis of funded mobility research projects (see Table 1), keywords that were evident in skill areas in relation to mobility design research include built environment design, city design, co-design, design, vehicle design and vehicle design technology. Other skills we identified for mobility research include city planning, computer technology, electric vehicle charging, engineering, fuel, human factors, inclusivity, information technology, manufacturing, mobile technology, renewable energy, systems development, technology, testing, transport modelling, transport planning, users and policy.

From our interviews, we found that participants' careers led them to mobility design research from a variety of academic and work experience backgrounds. These included design disciplines such as goldsmithing, graphic design, industrial design, mobility design, smart textiles and user centred design. Others experienced different training and employment routes, such as engineering including civil engineering and mechanical business, engineering, ergonomics, human factors, mathematics, power systems, psychology, physics, smart grids, social anthropology, science, systems security, technology and user experience.

From our workshop, we discovered that the participants agreed that a diverse and broad set of skills were important for mobility research. Their teams of researchers had a range of design skills including boat design, industrial design, intelligent vehicle design (autonomous and smart vehicles), service user design, user-centred design of technology and user-experience design. Other transport related skills identified within the participants' teams that were not design related included biomedical engineering, computing, data, engineering, low carbon vehicles, molecular biology, safety, social systems, systems development, transportation planning, as well as vehicle and passenger interaction.

In order to face future mobility challenges, design researchers need to develop a wider set of skills that go beyond traditional automotive design and be able to work across fields and collaborate with various functions and suppliers, particularly new ones (Warwick Business School and Design Council, 2015). These skills should be across most of the knowledge areas listed above including common design skills such as drawing (as a communication tool and creativity method), prototyping and developing visible solutions as well as implementing concepts into technological assembling and societal acceptance.

3.5 Case studies

We have synthesised personas representing typical career paths for design researcher categories 1 and 2 described in section 2.2.1. The three career path categories – senior design researcher, early career design researcher and PhD student were identified as typical major career stages by participants in our interviews and workshop.

Senior design researcher in mobility innovation

Our personas describe two types of career path in this category – a graduate from a design school trained in relevant subjects and working in mobility research, and a graduate trained in non-design subjects and working in a design school on mobility topics.

Persona 1 - Senior Design Researcher

A senior design researcher who completed an undergraduate degree in Vehicle Design and followed a career in academia, researching automotive design and the transport industry. This has included being involved in major research projects in the UK and exhibitions at several British museums showcasing historic car design and groundbreaking new innovations. They lead collaborative research projects with other universities, government funded transdisciplinary research as well as conducting transdisciplinary academic teaching. Their key challenge is promoting design research in mobility emphasising its creative methods and design execution skills.

Persona 2 - Senior Design Researcher with experience in academia and industry

A senior design researcher who completed an undergraduate degree in Social Psychology, a Masters in Psychonomics and a PhD in Human Factors leading to work in the area of automotive and transport human factors in both academia and industry. Their focus is on human-centred design of future vehicles particularly from the aspect of passenger experience. Typical research topics include investigating safety, comfort and trust for mobility users. They usually lead collaborative research projects with industry partners focusing on technical challenges. Their key challenges include establishing research encompassing design practices, engineering and science, and promoting it to appropriate audiences.

Early career design researcher in mobility innovation

Our personas represent two types of career path in this category – a graduate from a design school trained in relevant subjects and working in mobility research and teaching, and a graduate trained in non-design subjects and working in a design school on mobility topics.

Persona 3 - Design School based Lecturer and part time Researcher

An early career researcher completed their degrees in Transportation Design and Industrial Design and now works mainly teaching in a university's design school where they also conduct mobility research when time allows. They describe their skills as being focused on innovation process and strategy, innovation through cross-disciplinary collaborations, as well as operating and applying mobility concepts through a broad lens. Their major challenge is balancing research time with their teaching duties.

Persona 4 - Design School based Early Career Researcher

An early career researcher who completed their degrees in Ergonomics, Human Factors and Behavioural Science, working in a university's design school as a researcher focusing on user-centred design for experience for transport, human factors, technology innovation and research fields. They do not only focus on mobility research, but also apply their knowledge to other relevant research fields such as the ageing society, digital technologies, healthcare and wellbeing. Their major challenge is limited access to networking opportunities due to the time taken by teaching and other institutional duties.

PhD students in mobility innovation

These two case studies describe one PhD student with a non-design background working on a non-design subject in mobility innovation that is closely related to design research and its contributions, the other a PhD student with a design background studying mobility research in a design school.

Persona 5 - Social Anthropology PhD candidate

A PhD candidate in Social Anthropology looking at emerging technologies in society in relation to transport modes and future mobility. Their main area of expertise is ethnographic study techniques, but they work as an independent researcher conducting qualitative studies of social behaviour, interaction and perception. Their view and experience of design research is based on incorporating design research methods such as semi-structured interviews, focus groups, storytelling and other practical tools into their short bursts of interdisciplinary research quickly and efficiently. Their major challenge is a lack of networking opportunities to discuss research methods with peers and mentors.

Persona 6 - Intelligent Mobility PhD candidate

A PhD candidate in Intelligent Mobility design research who completed previous degrees in design and engineering. Their research topics include pedestrian behaviour, the street environment and design engineering methods to solve issues around vehicle-street-road users' interactions. Their approach to mobility design research is between design and engineering, therefore they need support from both creative methods such as design-led user research and problem definition, and video observation, as well as engineering skills such as understanding systemic approaches and computer modelling. Their key challenge is finding technical partners and relevant training and short courses.

RESEARCH

4.1 Cutting edge research topics for the future of mobility

After analysing our UKRI funded mobility project database and the academic and industry surveys we distributed, we identified the most frequently funded areas and mobility research projects where design research was not used but could or should have been, and by applying our knowledge of future mobility challenges identified future research topics where design research or design researchers could contribute and provide significant value.

Out of thirty-three responses from university-based academics, twenty-one focus on autonomous vehicles and infrastructure, sixteen focus on human machine interaction, fifteen are on smart cities and sixteen on user experience. The others repeatedly mention areas including human factors, artificial intelligence and computing, electric vehicles and infrastructure, and inclusive design (Figure 6).

Which of the following fields are most relevant to your mobility research? (33 respondents)

Autonomous vehicles and infrastructure

64% **21** responses

Human machine interactions

48% **16** responses

User experience

48% **16** responses

Smart cities

45% **15** responses

Human factors

39% **13** responses

Inclusive design

33% **11** responses

Engineering

33% **11** responses

Electric vehicles and infrastructure

33% **11** responses

Artificial intelligence and computing

33% **11** responses

Social research

30% **10** responses

Transport planning

27% **9** responses

Business

27% **9** responses

Policy

24% **8** responses

Low emissions

24% **8** responses

Energy

21% **7** responses

Robotics

15% **5** responses

Figure 6. Most common academic mobility research areas

Cutting-edge research topics frequently funded by UKRI include AI and interface systems, battery and alternative fuels, connected and autonomous vehicles (CAV), data usage and privacy, digital technologies, electric vehicles and charging, energy storage, journey planning and wayfinding, mobility as a service (MaaS), on-demand parking, safety and wellbeing, testing for CAV and smart mobility, transport management, and vehicle materials.

The academic survey shows academics are paying attention to research topics such as Advanced Driver Assistance Systems (ADAS), alternative mobility solutions, circular economy and vehicle services, human machine interactions, integrated transport hub, materials innovation and public transport, mobility experience, responsive transport, shared mobility, social integration of autonomous vehicles, sustainable mobility, transport planning, transport security and resilience, and zero emission vehicles.

The industry survey shows a focus on research topics including autonomy and shared mobility, electric, MaaS, mobility data, personal transportation, premium experience, small freight, technologies and advanced manufacturing, urban transport, zero accidents, zero waste, and 5G applications.

The most frequently mentioned research topics by all three groups are autonomous vehicles, digital technologies, electric vehicles, and mobility services. We do not see design research being used much in these areas despite its ability to provide service innovation, interface and interaction design, and information system innovation insights, as well as elevating existing technology for

future customer needs. We would also expect design research to contribute to new technology development and early adoption feedback, the study of public spaces and community (such as the planning of land use of walking, cycling and driving), and robotics and autonomous systems but did not identify any such projects.
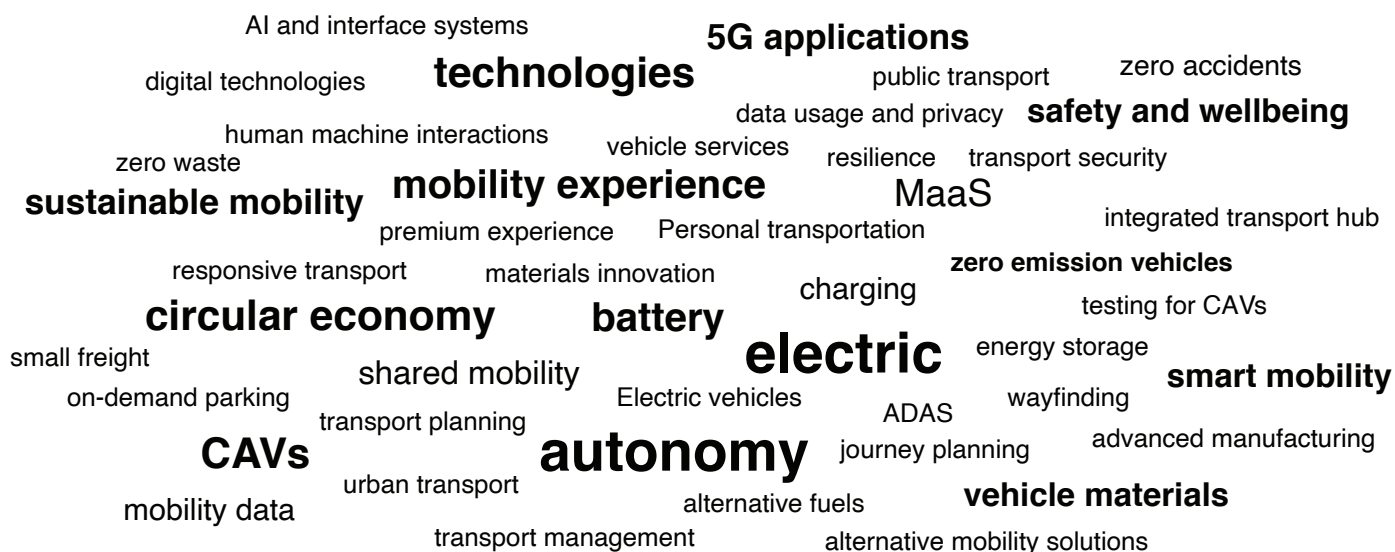

Figure 7. Cutting-edge research topics frequently funded by UKRI and studied by academics and industry

4.2 Relevant emerging areas of design

By analysing UKRI funded projects and interview data from academics, industry personnel and non-commercial bodies, we identified seven research areas that are future facing and where design research could add value to accelerate the development and exploration of research questions and solutions:

1. New technology application and early adoption such as user adoption of autonomous vehicles, the use of personal data, uptake of electric vehicles and early adoption cases for further technology and manufacturing improvements;
2. Digital technologies managing cities and transport such as where and how to use Internet of Things and data sharing among vehicles, cities and road users;
3. Robotics and autonomous systems such as drones, first-and-last mile travel assistance, delivery robotics, and door-to-door solutions;
4. Service models for EVs, CAVs and transport hubs such as EV charging infrastructure and service, adoption models for autonomous vehicles and innovations for transport hubs involving door-to-door solutions, electric vehicle and autonomous vehicle docking and many digital technology applications;
5. Urban mobility in developing countries and transferrable solutions for all economies;
6. Rural mobility and solutions considering the population living outside of cities in the UK; and
7. Ageing society, inclusivity and accessibility such as travel assistance for marginalised populations using public transportation and studies of early autonomous vehicle adoption by elderly and disabled users.

In these seven areas, design research mainly contributes to actively leading exploration of future demand gaps to suggest research directions and generate practical and visible solutions, the study of early adoption cases and feedback for technology development and service creation, providing inclusive design methods that can be applied to solution development for the ageing society and accessible mobility.

We also identified research areas where design research is likely to be able to provide little or no contribution or direct influence such as alternative fuel and battery development, energy storage and topics such as climate change. We could argue that design research can engage with a wide range of stakeholders, individuals and society and could fundamentally help change people's behaviour to adapt sustainable living styles and thus potentially influence climate change. However, such an approach focuses on a grand vision rather than the individual practical challenges that design research is perhaps better positioned to identify and address.

4.3 Collaborations - a cross-disciplinary research space

Mobility research is a relatively new area that has emerged as traditional transportation services and systems are reconfigured for the needs of today and the future. It requires cross disciplinary collaboration among design, humanities, science and technology practitioners and begins to flourish when these collaborations that cross research disciplines as broad as design engineering and information experience design to subjects as specialised as bio-inspired design and socio-technical design; as well as crossing sectors such as inclusive design and automotive engineering, creative industries and automotive design, urban planning and vehicle design, the circular economy and the automotive industry.

4.3.1 Collaborations among design professionals and researchers from other disciplines

Traditionally, the involvement of design professionals in collaborations with researchers from other disciplines in mobility research mainly focuses on visual packaging, using forward thinking to create solutions and creative methods to supplement well-established research or a semi-functional, functional or fully developed prototype. As design research develops, its strengths in combining creative methods (e.g. drawing, interactive enactment, rapid prototyping) with probing end user experiences looking for future demands and developing products/services with bottom-up approaches, mean it would be more valuable if it was involved from the beginning, defining research questions, identifying consortium and key methodologies, through to developing prototypes with researchers from other disciplines.

Our interview and workshop summaries show the involvement of design professionals in research projects usually changes collaborator's focus from a system to an individual's perspective, improving gender balance and population inclusivity, illustrating specific interactions to inform potential opportunities, identifying spaces for future innovation by the use of methods that engage the public. There are also concerns such as that attractively packaging developed technological solutions costs more and might not be necessary, that the knowledge generated by design research can be difficult to implement due setting up design work as a separate package. Our sense was that these problems can be solved by involving design research from the start of a project, helping to define inputs and explore solutions as well as helping to ensure that teams from all disciplines collaborate closely.

Design professionals generally communicate their research approach as innovation-led and user centred design when working with other disciplines because it is a common language to communicate the value of creativity. They transfer their knowledge to fit other subjects and research aims, usually through providing outstanding communication and insight integration skills during quickly changing situations from defining problems and performing user research to electronic design and prototyping. The design researchers we interviewed who are in early career stages mostly felt they need more experience and knowledge in engineering and opportunities to attend activities provided by professional societies in order to be able to be fully involved in mobility research and enjoy good collaborative relationships. Some design researchers also mentioned that their most challenging experiences when working with engineers and computer scientists were dealing with sector specific jargon and an inability to see the value in detailed people centred experiences.

One collaboration example we investigated between design researchers and researchers from other disciplines is between a UK leading design school and three other universities where the researchers were from computer science and transportation research groups. The role of design research was to study passenger data describing public transportation user experiences. Another type of collaboration is within interdisciplinary research groups. At one university we interviewed several researchers from science and design backgrounds all working in a transportation research group with a focus on real user mobility solutions. For each project they work on, they distribute design, engineering and science researchers from within the same group to work closely together. Both types of collaboration seem to work well as long as they have a mutual understanding of each other's field and ascribe equal value to realising knowledge through collaboration and outputs.

4.3.2 Cross-sector research topics

With high value collaborative and transferable skills originating from design research, it is relatively easy for design researchers to contribute skills to collaborative projects across sectors. For example, **inclusive design** has a developed methodological framework and its intervention in **mobility services and technology realisation** make solutions easy to use and users willing to adopt them. Such research collaborations are

especially valuable for topics such as public adoption of autonomous vehicles, electric vehicles and seamless public transport services as inclusive design methods are specialised in identifying design opportunities according to user's adoption.

An emerging area which has typically not seen much collaboration is between **automotive design** and the **creative industries**. This is a space with great potential for commercialisation, for example, providing immersive journey experiences involving fashion and textiles for interior and exterior design as well as wearables for drivers and passengers. Emotional experience on wheels is another popular topic requiring collaboration between creative industries and automotive design.

Collaboration between **urban planning** and **transport design** prominently contributes to transportation hub design and design for walkable cities. Planning for post covid-19 cycling, walking and driving routes as well as electric and autonomous vehicle infrastructure development needs to receive more attention.

Collaboration between those working on the **circular economy** and the **automotive industry** could redefine competitiveness in the automotive sector in terms of price, quality, and convenience and could double revenue and lower costs by reconfiguring design and manufacturing processes. Typical methods include using parts made from recycled materials, remanufacturing of car parts and looking at the design of new cars with special consideration for environmental impact throughout the whole lifecycle of a car. There are large opportunities for changes such as reconfiguring supply chains and working principles with original equipment manufacturers (OEMs). Design research offers knowledge from textiles and vehicle part design, service innovation through rethinking the purchase and sales processes, as well as production processes.

4.4 Case studies

By collecting data from interviews with academics and industry personnel and the internet, we identified research projects that demonstrate emerging areas of design and research projects led by design professionals investigating novel areas of mobility research.

4.4.1 Research projects demonstrating emerging areas of design

The following cases describe emerging areas of design in the context of the future of mobility and show what design research can contribute by exploring cutting edge topics as well as everyday transport solutions.

GATEway project

An InnovateUK and Centre for Connected and Autonomous Vehicles funded collaboration between research organisations Commonplace, Royal College of Art, TRL and University of Greenwich, and partners Fusion Processing, Gobotix, Oxbotica and Westfield Sportscars, with contributions from DG Cities and the Royal Borough of Greenwich. GATEway generated insights into how people interact with, use and share autonomous vehicles, and automated valet parking, home delivery and urban shuttle technical innovations. Design research helped develop visions of a future city with autonomous vehicles serving the population's travel needs, rethinking how vehicles and urban environments should develop. Researchers engaged the public in open creative workshops, exploring potential impacts and changes these vehicles might trigger, allowing identification of many opportunities for technology and service innovations.

https://gateway-project.org.uk/

Volvo Your Concept Car by an all-women team

Volvo said "it's been said that if you meet women's expectations, you often exceed the expectations of men. That's why we targeted our solutions to appeal to both genders", a statement that resonates with the push for equality throughout the automotive sector. User research guided many aspects of the design with features such as gullwing doors and keyless access allowing those carrying children or bags to easily open the car. It is not always easy to create a change and "there are always some people who find it difficult to think along new lines" explained Camilla Palmertz of the Concept Development department. The impact of women in design and design research hugely influenced the outcome of Your Concept Car and provides a model throughout the mobility industry.

https://www.media.volvocars.com/global/en-gb/models/ycc/0

4.4.2 Research projects with design research contributions demonstrating novel advances

The following cases show novel areas either led by design research or a combination of design and technology where design research dramatically influenced the project outcome and pointed to future directions for research innovation.

AirGo

Anna Wojdecka designed a smart cycling helmet with an integrated air filtration system during her joint Innovation Design Engineering MA/MSc at the Royal College of Art (RCA) and Imperial College London. Innovative design allows urban cyclists to breathe freely without a pollution mask thanks to a curtain of filtered air. Wojdecka used research on urban air pollution to guide the project's direction, focusing on avoiding detrimental health effects such as asthma, heart attacks and strokes. Ergonomic features of the helmets have been designed to be seamlessly integrated into cycling fashion. Informed design research has taken AirGo from concept to reality, bringing an industrial product to cycling consumers with support from the RCA's InnovateRCA enterprise, entrepreneurship, incubation and business support centre.

https://www.rca.ac.uk/research-innovation/innovationrca/innovationrca-start-ups/airgo/

Auditory concepts for electric vehicles to communicate risk to pedestrians

ustwo investigated how to design electric vehicle auditory concepts to warn road users of proximity as regulations are enacted requiring vehicle noise at low speeds. Using design research intelligence and user-centred approaches, researchers explored approaches for improving pedestrian safety, rethinking all aspects of the role of vehicular sound and car/pedestrian interactions from city, OEM and road user perspectives. Vehicle-emitted sounds are symbolic for brands, affect soundscapes and communicate information between road users and cars. Researchers used utopia scenarios after investigating technical frameworks to identify design opportunities around manoeuvring, pedestrians, weather and other scenarios. Design research helped understand pedestrians' expectations of their sense of safety and noise pollution. Design results included using virtual reality hazard testing prototypes to showcase concepts.

https://www.ustwo.com/blog/future-of-external-vehicular-sound
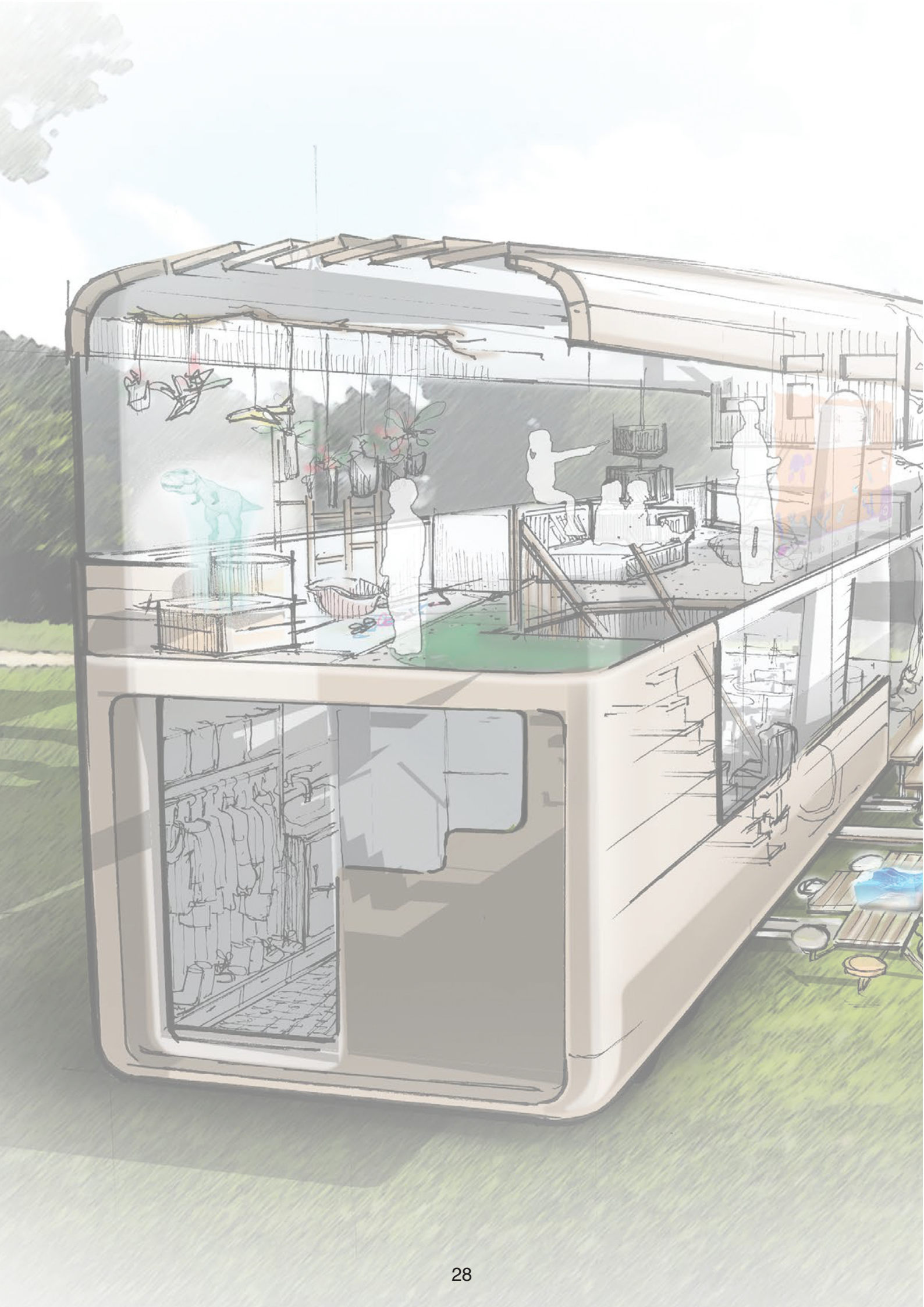
PARTNERSHIPS

5.1 Centres of excellence

We discussed two UK centres of excellence for design research in mobility innovation in section 2.5, one university based, one industry based. Both show how design-led research approaches can be incorporated when developing novel concepts with enterprises, identifying future directions with the government and integrating design research into a company's strategy. Here we list more centres of excellence that represent mobility research topics that are leading major innovations in the UK which are mainly funded through three channels. One group is funded by the government through research councils, one is funded by industry and based in universities, and one is initiated by universities drawing on expertise from different departments to take part in mobility research. This is not an exhaustive list, we provide examples covering different types of centres representing a variety of research areas and locations.

Centre for Transport and Society (CTS)

The Centre for Transport and Society at the University of the West of England (UWE) in Bristol focuses on research linking lifestyles and personal travel with social and technological change. Research topics include the ageing population, experience of the travel environment, mobility, social science research into travel behaviours, society and motor vehicles, sustainable mobility and technologies and travel. A key focus of mobility innovation at the centre is having social researchers study mobility topics.

https://www1.uwe.ac.uk/et/research/centrefortransportandsocie.aspx

Edinburgh Napier Transport Research Institute (TRI)

TRI developed out of Edinburgh Napier University's expertise in civil and transportation engineering. Its main areas are transport policy, public transport economics, road safety and the modelling of users' behaviour and electric vehicles as well as travel and street design. Key skills include engineering, economics, business, mathematical modelling, psychology and sociology. The value of the institute for mobility innovation through a design research lens is their adding of value by applying inclusive design and the understanding of users in an engineering context.

https://blogs.napier.ac.uk/tri/

Electric Vehicle Centre of Excellence (EVCE)

The EVCE at Cardiff University was created to draw expertise from the School of Engineering, Cardiff Business School's Centre for Automotive Industry Research (CAIR) and the School of Psychology to conduct interdisciplinary research in the electric vehicle (EV) value chain including investigating barriers to adoption and methods of encouraging uptake, potential regulatory issues, smart grids and energy demand management. Key innovations from its centre for mobility research include user and regulator centric methods for expanding EV uptake as well as technological.

https://www.cardiff.ac.uk/research/explore/research-units/electric-vehicle-centre-of-excellence

Smart Mobility Living Lab (SMLL)

Funded by the Centre for Connected and Autonomous Vehicles and Innovate UK, with sponsorship from the Royal Borough of Greenwich and Queen Elizabeth Olympic Park, the lab is led by TRL, focusing on using public roads to test and evaluate the use of connected and autonomous vehicle technology. A key benefit of the laboratory from a mobility innovation point of view is its approach that goes beyond connected and autonomous vehicle testing by also considering services and societal acceptance as well as testing vehicular technologies.

https://smartmobility.london/

5.2 Improving access to centres of excellence

In terms of improving access to centres of excellence, we should look at how to improve the channels of the centres with academia, industry, research students, potential employees and external employers and how to attract postgraduates to work with them.

For academic researchers and institutions, how to access any centre of excellence in mobility research seems fairly clear, there are multiple opportunities for participating in seminars and symposiums, sharing knowledge and identifying funding opportunities to establish projects together. To improve access to centres of excellence for design research in mobility, we suggest funding bodies encourage collaborations not only across disciplines but also across sectors especially those involving design skills and design research methods.

For industry partners to access centres of excellence for design research, more showcases are needed to present what design research can do instead of only recognising it as a means of styling and aesthetic design. More collaboration needs to be explored between industry partners and design researchers in terms of technology innovation, product development, testing and feedback from end users and planning research at the strategic level.

Research students should be encouraged and given opportunities to attend research seminars and networking events in the centres of excellence. We discovered that recently networking budgets either from research councils or their own institutions to allow students to find and attend such events are hard to find or non-existent. Funding is usually only available to attend research conferences when their work is published. There is a lack of short-term courses that would allow students to acquire specific mobility research related technical or design thinking skills that many need to successfully complete their research projects.

Attracting potential employees is always a problem for the centres of excellence. Many researchers mentioned difficulty recruiting researchers for projects due to academic funding favouring short and fixed-term contracts which do not support recruiting permanent researchers, a particular problem with mobility projects which often have long time scales. Research programmes supporting the funding of long-term design researchers for mobility studies should be developed.

Corporate employers are currently mainly recruiting new MA graduates as designers and occasionally for design research work. The major recruiting channels are graduate shows and internship programmes. KTP collaborations and collaborative PhD studentships need more attention to ensure that PhD graduates have more job opportunities and industry is aware of the talent available.

5.3 Regional strengths and weaknesses

The UK research environment for mobility design research as a stand-alone area is limited because mobility research is commonly intertwined with wider issues. These include manufacturing, technology, engineering, transport systems, cities, energy, environment, pollution and more as shown in Table 1. When we analysed the UKRI's mobility research projects we found none supporting design research. We found that funding bodies support mobility research in the wider context yet not specifically mobility design research. This shows a gap in the utilisation of design-led research skills receiving core funding which results in reduced opportunities for mobility design researchers.

University centres get funding for mobility design research from a mixture of both government and industry support for their initiatives. Government funding can be distributed from local councils, or be awarded by regional and central funding bodies. Commonly we found that universities were involved with local industry initiatives as well as larger national and international companies. They share their expertise from academic staff as well as their research students whilst technical staff manage the facilities and equipment in order to conduct the projects. The knowledge gained is disseminated through seminars, workshops, exhibitions, conference and journal publications. Public engagement is often central to the projects to gain not only opinions and involvement with ideas but to also gather feedback on the outcomes. The ability to adapt and diversify to attract funding is a strength and shows the resourcefulness of universities and evidence of their engagement with both regional and national problem-solving concerning mobility research.

We found that the main funding bodies providing support are the AHRC, EPSRC, Horizon 2020 and Innovate UK and they provide strong support for mobility research initiatives. Innovate UK established and core funds the mobility related Catapult Centres - Connected Places, Digital, Energy Systems and High Value Manufacturing - which operate by joining with business and independently funded projects. However, the overall picture demonstrates a weakness in supporting design-led mobility research.

We found from the workshop, interviews and database research that several universities are receiving funding from regional enterprises and funding bodies. Combining their skills and resources with other universities which have different specialist expertise and facilities as well as involving business enterprises in their region provides a pool of resources that support mobility design research at many levels.

If your company does design research, where geographically is your design research based? (16 respondents)
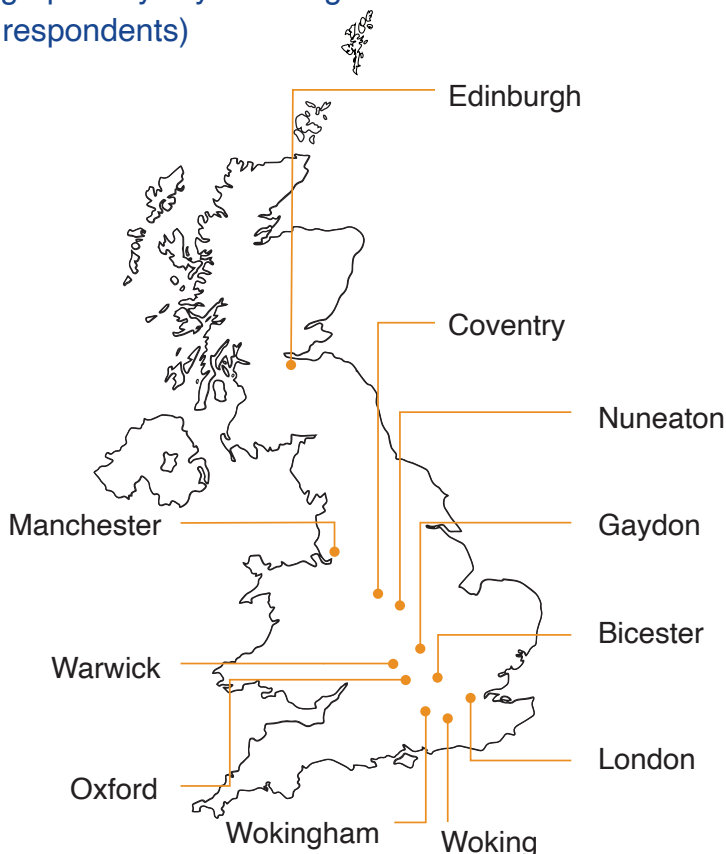
We discovered that nationally supported regional funding schemes are usually organised by local universities by securing a large scale grant targeting a research area for local solutions. At our workshop participants spoke of regional funding in the Port of Tyne provided by the Maritime Innovation Hubs industrial strategy fund, and how the Midlands is focused on developing a stronger identity around mobility and research as car manufacturers are located there. Local authority funding is in general scarce for mobility and innovation projects due to limited availability of resources. Regional strengths also depend on the locations of major manufacturers and new businesses because the acquiring of partnerships is important for research development. Figure 8 shows where the major automotive companies and new businesses identified by our surveys are located.

Figure 8. The geographical locations where industrial design research of survey respondents takes place

5.4 Ensuring research results reach the whole country

When summarising regional strengths and weaknesses, mobility research has been broadened from traditional technology and design aesthetic oriented automotive research to the consideration of social acceptance, service innovations and customer adaptation. The regional focus is gradually changing from Midlands-led to multiple clusters driven by local culture and transport systems. There are many outstanding local projects generating huge benefits to local populations and economies, access to these examples should be encouraged to make sure that locally successful projects are put in front of a wider national audience.

While most research schemes encourage research outputs to be beneficial for the whole country, we discovered from our workshop discussions that there is a lack of a cohesive set of local funding opportunities, particularly from local authorities. A few researchers mentioned that local authority funding is stripped back to a bare minimum making it difficult for them to get involved in any meaningful way in innovative ideas involving mobility. Some said that they cannot expect a local authority to dedicate resources to a project if it is speculative or focusing on the far future.

An ideal model is to support both local and national projects and ensure that all outputs are easily discoverable and disseminated across the nation. In section 5.5 we present two examples of centres showing both a regional centre and its contribution to the whole country, and a national centre and its local influence.

5.5 Case studies

By analysing academic interview and workshop data, we identified two representative centres conducting regional and national mobility studies.

MobOx – a regional mobility research institution contributing nationally

The MobOx (Mobility Oxford) Foundation has the support of the Oxfordshire Local Enterprise Partnership and other key local stakeholders from academia, business and government in Oxfordshire. Its aim is to research and respond to mobility challenges in the region by utilising communication technologies, data and networking, and established the Oxford Living Lab (OLL) with the goal of becoming a centre of excellence for the development of integrated transport solutions. It explores local business opportunities with Oxford County Council and entrepreneurs, supporting their growth in Oxfordshire and the South East. The collaboration between MobOx and Oxfordshire County Council is generating a web of information about local and national business support services and case studies describing elements of the innovation ecosystem.

https://mobilityoxford.com/about-mobox/

NTDC – a national institution influencing local industry

The National Transport Design Centre at Coventry University operates within the University's Centre for Future Transport and Cities, receiving funding from the Advanced Propulsion Centre, Horizon 2020, Innovate UK and other UKRI entities, and has a strategic partnership with Horiba Mira via the Centre for Connected and Autonomous Vehicles. Its industry oriented focused research areas include vehicle and infrastructure, vehicle-passenger interactions, vehicle design, human factors, engineering and advanced systems across transport modalities. Their value in mobility innovation revolves around evidence-based and technology driven design approaches. It collaborates with UK based automotive companies and supports education for transport designers through regular interactions across school networks and its relationship with the Coventry Transport Museum.

https://www.coventry.ac.uk/research/areas-of-research/institute-for-future-transport-and-cities/our-facilities/national-transport-design-centre/

RECOMMENDATIONS

6.1 The contributions of design research to mobility research

Design research proves its value to mobility research in commercial execution, visualisation and concept demonstration skills, structured research for user study and stakeholder engagement and by providing a holistic view and forward thinking for strategic planning. In the industry survey, the most popular description of 'design research' by mobility experts was 'it is about involving people/users interactively in the whole solution finding process' and 'it is about designing concepts, prototypes or applications' (Figure 5). Design research was also described as being 'about creating solutions for problems that bridge multiple fields which need a holistic view to answer them', especially in mobility fields where systems and services are in the process of being reconfigured.

The Design Council has been growing the evidence base for the value of design and mapping its use across different sectors of the economy for several decades. The Design Economy reports (Warwich Business School and Design Council, 2015 and Design Council, 2018) detailed the state of design and its value to the UK economy showing for the first time how design contributes across all economic sectors, not just within design industries. According to the reports, 68% of design's £85.2bn gross value added (GVA) in 2016 was created by people working in industries such as aerospace, automotive and banking.

The key contributions of design research to mobility research can be summarised as:

1. Visualising and communicating concepts for future mobility challenges
2. Guiding the commercial execution of projects to match people's needs
3. Providing guidance, methods, tools and processes for understanding users and stakeholders at every stage of research development
4. Providing a holistic view to facilitate collaborations across disciplines and sectors and translate research knowledge into realised solutions
5. Providing strategic thinking to support leadership

6.2 Recommendations for design research practitioners, industry, government, research councils and non-HEI organisations

6.2.1 Make design research integral to every aspect of critical mobility challenges

Design research has a natural ability to look beyond current use cases for future demands, which when combined with its visualisation skills and understanding about cutting-edge technologies, can be extremely valuable for envisaging opportunities and identifying barriers when developing new solutions. Design research is also practical, it seeks appropriate products and services for individual users, communities and cultures. Design research should be involved in all future facing mobility projects from the beginning, as a key partner helping to define suitable directions, as well as being integrated into every phase of research development from new technology innovation and production to service implementation.

Recommended actions:
1. Include a requirement for applicants for mobility funding to demonstrate how they will incorporate design research and design research skills in all phases of their research, ensuring it is not just used at the beginning and end and not limited to aesthetics and customer satisfaction tools
2. Roll out a national programme demonstrating the value of mobility design research in emerging engineering oriented, new transport model and social adoption topics (see 4.2 Relevant emerging areas of design)

3. Set up a national forum with an annual conference to encourage collaboration and cross fertilization of ideas between engineering, social science and design researchers
4. Provide a framework to allow the secondment of design researchers to engineering companies and academic departments and vice versa
5. Set up a national database of creativity tools, methods and tutorials for non-design mobility practitioners to learn the fundamentals of design research
6. Encourage and enable formal collaborations between design research and mobility professional societies to develop programs to help embed design research skills in their members' standard research processes

6.2.2 Encourage and ensure gender equality in mobility research

Less than a quarter of our academic survey responses (seven out of thirty-three) were from women, and just one out of fifteen responses to our industry survey was from a woman. Follow-on academia interviews were split 30% female, 70% male (five and twelve participants respectively), and 25% female and 75% male in the follow-up interviews with four participants from start-ups and multinational companies. Two female interviewees talked about gender equality and one implied that design researchers have a better sense of gender inclusivity. Mobility research has traditionally been a male-dominated field due to the nature of engineering and the arguably male focused car industry that forms much of the mobility industry. However, female perspectives have the potential to better address user experience and services in terms of discovering unarticulated and overlooked demands, as well as the obvious advantages of actively involving half the user base.

Recommended actions:
1. Set up school programmes to encourage women to study mobility, design and engineering as undergraduates
2. Provide outreach programmes to encourage female undergraduates to apply for research degrees in mobility and design research
3. Provide scholarships and fellowships for female postgraduate students and early career researchers in the field
4. Collaborate with industry to provide internships and degrees with time in industry for female candidates
5. Provide support for women returning from career breaks in academic mobility research
6. Establish a Women in Mobility program and forum modelled on the Women in STEM initiatives

6.2.3 Promote and support design research involvement in local projects

The workshop with university-based academics found that there are major barriers for design research participation in local authority funded projects as they tend to focus on practical solutions for existing and historical issues and allocate little or no budget for speculative or horizon scanning activities. Design research tackles current issues with forward thinking helping to ensure that designed solutions not only address current but also future situations and potential demands. This helps ensure that once a solution has been implemented it is not instantly outdated due to rapid technology development or changes in the local environment.

Recommended actions:
1. Specific funding opportunities should be made available to local authorities to enable them to utilise design research
2. The design research community should develop an outreach program with conferences and forums to actively seek out relevant decision makers in local councils and demonstrate the benefits of design research
3. Establish a national award scheme for the best use of design research by local authorities or regional sponsors
4. Create an online database to showcase successful local mobility innovations and creativity methods that can be applied to other locations nationally
5. Provide funding programmers for early career researchers in mobility design research to work with local authority, business and industry partners for existing and potential challenges

6.2.4 Showcase the benefits of design research to academia, industry and government

Design research in mobility is an emerging area and its contributions are overlooked whether in the value it brings to project execution or its potential for influencing strategic research, from interdisciplinary research communication to enabling transport experts and technologists to rapidly and successfully turn concepts into reality. Opportunities for showcasing results to all relevant communities from all levels of design research whether research methods and processes, practical solutions, studies of future demand, and cross-sector research and different transport modes should be supported.

Recommended actions:
1. Establish a national annual showcase of the 'Best of British Design Research – The Future of Mobility' embracing both academic and industrial excellence
2. Create exhibitions and activity programmes across the UK in collaboration with local museums to showcase the contribution of mobility design research to the modern world
3. Set up funding programmes to encourage collaborative mobility research especially encouraging cross-discipline and cross-sectors collaborations (see 4.3.2)
4. Improve access to mobility design centres of excellence by encouraging them to establish mini-showcases of successful projects with academia to accelerate collaborations with industry especially through Knowledge Transfer Partnerships (KTPs), joint funding of research students and reaching out to potential employees

6.2.5 Provide design research PhD short-term training and networking opportunities
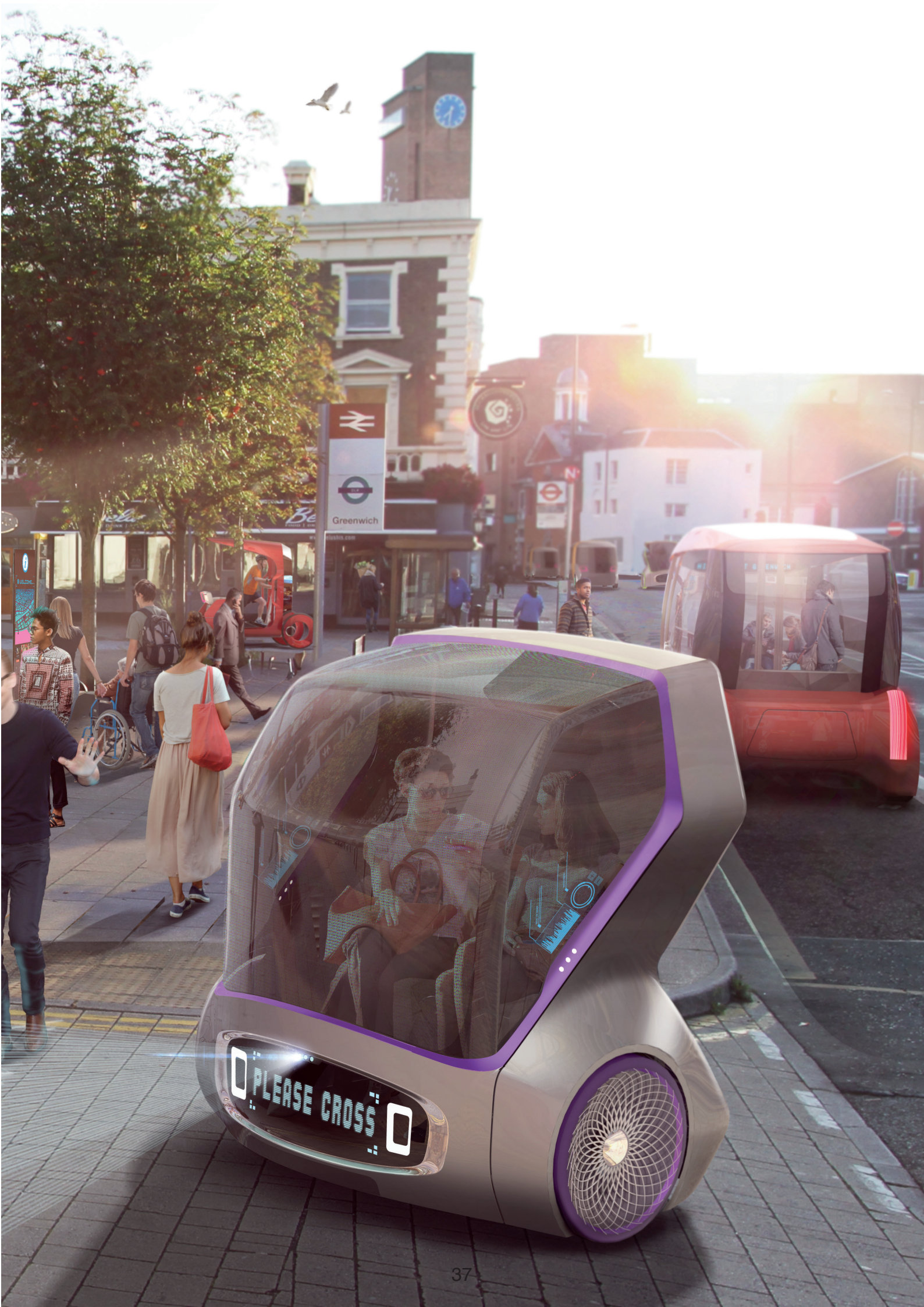
Interviews with mobility design research PhD students identified a lack of funding opportunities from academic institutions and research councils to support networking with other students and researchers from a variety of backgrounds such as design, humanities, science and technology. As mobility research is an interdisciplinary field, to develop their research projects and careers they need opportunities to acquire networks and skills outside of their potentially narrow primary discipline. Short courses, also with potential great utility for industry, could be provided in relevant online and face-to-face formats, for quick-to-learn and easy-to-master skills. Seminars, workshops and summer schools for relevant computing, design thinking and engineering skills would also be helpful.

Recommended actions:
1. Establish a national mobility design research postgraduate forum to provide networking and career development opportunities for students
2. Provide a central database of design research and internship opportunities which is marketed to both academia and industry to provide maximum viability of the opportunities
3. Co-fund industrial placements and short-term funding opportunities to pump-prime the systematic creation of these opportunities for students
4. Fund design research specific PhD studentships which aim to embed students across multiple mobility modes
5. Establish national design research short courses accessible to PhD students from any British institution. These could also be the basis of executive education courses for industry which could eventually cross subsidise and even fully fund the PhD courses

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