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| Institution: Edinburgh Napier University |
| Unit of Assessment: Unit of Assessment 13 – Architecture, Built Environment and Planning |
| 1. Unit context and structure, research and impact strategy 1.1 Unit Context and Structure <p>Research in Architecture, Built Environment and Planning (UoA 13) in the School of Engineering and Built Environment (SEBE), Edinburgh Napier University (ENU), centers on the Construction of the Built Environment and Transport Planning. Set within the United Nation's 2015 Sustainable Development Goals, and global challenges these set for society, the Unit draws on funding from Research Councils in the UK and European Commission (UKRI and Horizon 2020) to champion scientific research and technological innovation in construction and transport. The Unit's research and innovation is conducted by the following organizations:</p> <ul style="list-style-type: none"> • The Institute for Sustainable Construction (ISC) • The Transport Research Institute (TRI) <p>ISC houses five Centers. The Building Performance Centre works on building acoustics and the development of low carbon materials (Prof Smith). The Scottish Energy Centre conducts research into building energy performance, micro-renewables and occupant behaviour (Prof. Currie). The Offsite Construction Centre undertakes research into advanced manufacturing systems for the automation of building provision (Prof Hairstans). The Centre for Smart Cities carries out research into digital platforms as ecosystems for the construction of buildings capable of sustaining the environment as part of a climate neutral adaptation strategy (Prof Deakin). The REBEL Centre specializes in embodied carbon, the circular economy, building efficiency, optimization and sustainable development in the Global South (Assoc Profs Pomponi and D'Amico).</p> <p>TRI is the most well-known transport research group in Scotland and in the top 10 for the UK. Comparative Transport Policy specializes in the development of new policy concepts, such as sustainable transport, mobility, neighbourhoods and parking (Prof Rye). Public Transport conducts research on transport franchising models for rail and bus services as mass transit systems (Dr Cowie). User-behaviour Modeling covers research on user route choice, responses to crowding in stations and real time traveler information (Assoc. Prof Fonzone and Dr Fountas). Electric and Autonomous Vehicles conducts research into the first autonomous bus route in Scotland (Assoc. Prof. Fonzone). Traffic Management and Road Safety conducts research into pedestrian behaviour at signaled crossings and junctions (Prof Salah). Health and Well-being carries out research into the impact of commuting on health and well-being across modes of transport (Prof Davies).</p> <p>ISC and TRI have 6 professors, 4 associate professors, and 6 lecturers with significant responsibility for research, and 4 research fellows and assistants. Within the Unit there is a Head of Research, a Research and Innovation Officer, and Director of ISC and TRI. Directors and Officers take strategic decisions on research fellow and assistant appointments, PhD studentships, support for seed-corn research projects by early career academics and public engagement. They also monitor output and impact case study development. Support for knowledge exchange (KE) activities and commercial enterprise (CE), is provided centrally by the Research, Innovation and Enterprise Office (RIE).</p> 1.2 Strategy Following REF 2014, the Unit aimed to: |

- *engage a greater number of staff*
- *increase PhD completions*
- *improve the quality of outputs*
- *generate internationally excellent and world class outputs*
- *further extend the strategic partnerships*
- *build the staff profile*
- *strengthen research capacity in key areas*
- *expand existing international collaborations*

The FTE Category A Staff for 2014 and 2021 is 7.9 and 12.6 respectively (70% increase), and staff involved in funded research, either as Principal or Co-Investigators, has increased from 4 to 10 (150% increase). PhD completions have also increased from 8 to 19 (140%). Outputs are now published in scientific journals with high impact factors. For example; Cleaner Production (IF 7.2), Buildings and Environment (IF 4.9), Energy and Buildings (IF 4.8), Analytical Methods in Accident Research (IF 9.2) and Transport and Research: Part 2 (IF 4.8).

Strategic partnerships have been secured with the EC, UK and Scottish Government, Centre for Scottish Innovation in Construction (C-SIC), Transport Scotland, the South East Scotland (SES) City-Region Deal on Infrastructure and Housing Construction and SES Transport. In the period these partnerships have been further extended to include:

- *Smart Cities and the Sustainable Islands Growth Strategy*
- *Climate Neutrality as a Clean Growth Strategy*
- *Smart Specialization as a Sustainable and Inclusive Growth Strategy*
- *Circular Economy in the Construction and Transport Sectors*
- *Offsite Sector's Construction of Affordable Housing*
- *Relationship between Travel Speed Restrictions and Road Safety*
- *Association between Transport, Air Quality and Health*
- *Impact of Commuting on Subjective Assessment of Well-being*

This research has lifted staff profiles within the research community, as members of research councils, reviewers of grant submissions, contributions as principal investigators, and through the dissemination of findings in scientific journals. The Unit has also expanded international collaborations, be they with Europe, the USA, Middle East, Africa, Asia or China. These developments have made it possible for the Unit to collaborate with universities, industries and governments across the world to strengthen research and innovation in smart and sustainable development.

In line with the University's Strategic Plan for Research and Innovation, the School has identified 4 thematic clusters for members of UoA13 to concentrate future effort on. They include **Health, Environment, AI and Technologies and Culture and Communities** (see REF5a).

With regards to the **Environment**, and **AI and Technologies** themes, the **Building Performance Centre**, **Centre for Offsite Construction** and **Centre for Smart Cities** shall continue research into advanced manufacturing systems, along with innovations in building information modeling (BIM). Innovations in BIM include energy systems, water and drainage and waste management. The **Scottish Energy Centre** shall support research into BIM by modelling the development of alternative fuel cells and battery storage systems. The **REBEL Centre** shall underpin the **Environment**, and **AI and Technologies** themes by focusing on the infrastructures needed to underpin such innovations and the circular economy required to support this.

Under the **Environment**, and **AI and Technologies** themes, TRI shall continue to focus research on **Comparative Transport Policy**, **Public Transport**, **User Behaviour Modelling**, **Electric and Autonomous Vehicles**, and **Traffic Management and Road Safety**. Emphasis shall be placed on the **AI and Technologies** of user behaviour modelling, especially in relation

to **Electric and Autonomous Vehicles** (buses and taxis). TRI shall also develop the **Health, and Culture and Communities themes** this research relates to by extending the **Comparative Transport Policy** studies it has completed on commuting and well-being.

1.3 Research

1.3.1 Institute for Sustainable Construction (ISC)

Building Performance Centre engages in the development and assessment of new robust details for Part E sound insulation, now encompassing over 600 apartment design combinations. Development of new approaches for assessing low frequencies in buildings has led to a new ISO draft standard (**Smith**). Major contracts in France funded by SNCF rail network have secured over £1.2 million to develop the acoustic standards of building facades.

The **Scottish Energy Centre** focuses on the modelling of building performance as part of the SME Energy Challenge, and an evaluation of retrofit strategies for non-domestic public buildings (**Currie**). This studies energy optimization and the development of novel and innovative renewable energy systems (HySpirits & 4GDH, & Inverted Hydro Generation).

The **Centre for Offsite Construction and Innovative Structures (COCIS)** undertakes research for industry, government and public sector bodies on industrialized building systems. Project funders include EPSRC, UK Commission for Employment & Skills (UKCES), CITB, Scottish Funding Council, Scottish Enterprise and other industry organizations. With a strong focus on advanced manufacturing systems, the Centre delivers construction technologies for tomorrow's communities. Its expertise ensures optimization of building performance, market viability of offsite products and creation of value for forward thinking construction organizations. Projects include new offsite systems, complex structures, productivity and capacity research and structural timber applications. **COCIS** also meets future skills needs via the development of training material and the delivery of continual professional development. **COCIS** has also developed software in collaboration with Trimble Tekla. This facilitates the specification of timber technologies able to comply with new European codes of practice.

Research by **Deakin** in the **Centre for Smart Cities** has been supported by two EU funded projects (CLUE and Online S3) and the ERDF Smart City Accelerator grant. These awards focus on the design of climate-neutral smart city-districts (CLUE) by the construction sector, and application of the entrepreneurial discovery model (Online S3) as an urban and regional innovation (ERDF Smart City Accelerator) able to sustain these developments. Ex-anti assessments have also been conducted of the climate smart city-districts this model of urban and regional innovation sustains in Milan and London. Research undertaken with **COCIS** for C-SIC, and on behalf of Scottish Government's clean growth strategy, has also been conducted to accelerate the impact of advanced manufacturing systems on the construction of affordable housing (**Deakin**).

The **Resource Efficient Built Environment Lab (REBEL)** is a globally recognized research centre on embodied and whole-life carbon of buildings, life cycle assessment (LCA) and the circular economy in the built environment. **REBEL** has secured three grants from the Royal Academy of Engineering (RAEng) and one grant from the EPSRC (**Pomponi**) since 2017. Funded research from the RAEng has advanced knowledge on local and low-carbon construction materials in sub-Saharan Africa, as well as novel shelter designs for deployment in the aftermath of natural disasters and man-made conflicts. EPSRC research has also been carried out to conduct embodied and whole-life carbon comparative assessments. These innovations support informed material selection that minimizes environmental impacts early in the design stage and which drive construction towards climate neutrality. In addition to these projects, **REBEL** has also engaged in several collaborations with industry (e.g. The Concrete Centre, Zero Waste Scotland) and on interdisciplinary proposals with **COCIS** (EU InFutURe-Wood project).

1.3.2 Transport Research Institute (TRI)

In the field of **comparative transport policy** and policy transfer, **TRI** has enjoyed considerable success with six EU funded projects running during the period. These aim to transfer new policy concepts from one part of the EU to another and **TRI's** role is as evaluator and/or trainer (**Fonzone** and **Cowie**). Topics include sustainable transport measures in four demonstration cities (CIVITAS DYNAMO), parking management (Park4SUMP), sustainable neighbourhood design (SUNRISE) and Sustainable Urban Mobility Plans (PROSPERITY). Recent work on **public transport economics** by **Rye** includes a study of local public transport franchising in Norway, Denmark and Sweden for the Urban Transport Group, whilst **Cowie** has produced high quality outputs analyzing productivity and consumer surplus in the UK's privatized rail and bus industry. **Fonzone** has also carried out a study of public transport fare strategies in cities around the world, published by the European Mass Transit Association (EMTA).

Work on the **modelling of individual transport users' behaviour** covers; user route choice responses to crowding in stations and to real time traveler information (**Fonzone**), and pedestrian behaviour at signaled crossings and junctions (**Saleh and Cowie**). In the field of **electric and autonomous vehicles**, **Fonzone** is working with Scottish Transport to study the attributes of the world's first autonomous bus route on the Forth Bridge, Edinburgh. Work on active travel, street design and road safety activity is also underway with the City of Edinburgh. This is breaking new ground in design standards in Scottish Transport and influencing the debate on the bike sharing schemes advanced by Edinburgh and Glasgow (**Rye and Fonzone**).

1.4 Impact Strategy

The Unit has a strong track record in delivering significant impacts across the construction and transport sectors. The Impact strategy is led by **Hairstans, Currie, Deakin and Fonzone**, who all have extensive experience of working with industry, government and the public and can evidence impact across a wide range of stakeholders. Methodologies used to support the nurturing, development and expansion of impactful outcomes include:

- Specialist 1:1 impact support meetings for academic staff, ECRs and PGR students held with the professorial leads for impact. These are held every 6 months and ad-hoc.
- School (and Unit) impact workshops, including "*developing the impact journey*" and "*pathways to impact*", drawing on previous and current case studies of how academic staff, ECRs and students have developed impact.
- Pump prime (seed-corn) funding by the School to support impact development. This involves ECR and PGR visits to industry, government or third sector organizations to reach out and explore the "from research to enterprise" theme promoted by EU and UKRI funding bodies.
- Linking with and establishing Industry Advisory Boards, involving strategic partners across industry, government and the public sector, to advise and engage with new scientific developments. Examples include; strategic partnerships with the industry led Construction Scotland Innovation Centre (C-SIC), the regional transport partnership SESTrans, and the Scottish Offsite Hub (with 9 industry partners), established following scientific developments within **COCIS**.
- Participating in impact escalator and accelerator workshops. Examples of this relate to both EU and British Council arranged impact events, for example an accelerator event (from enterprise to commercialization) organized by the British Council in Warsaw to promote the uptake of UK Smart City Innovations.
- Engaging with the public. Examples of this include public lectures, seminars, workshops, exhibitions, challenges and demonstrations (see Section 4.4).
- Leading the Housing Construction and Infrastructure fund for the South East Scotland City-Regional Deal Gateway. This growth fund (2019-27) covers the following:
 - *Inclusive Reach & Early Skills*
 - *Accelerating into Work & Upskilling*
 - *Employability – New Trades and Short Courses*
 - *Advanced Skills & Gender Diversity*

- *Talent Development*

This fund is being used to accelerate research associated with the digitization of housing and construction, infrastructure relating to the next generation of low-level heating district systems, and innovation in the provision of intelligent transport systems.

1.5 Interdisciplinary Research

The Unit participates in the University's interdisciplinary groups. This is put into practice through University and School-wide research seminars on interdisciplinary themes such as the informatics of health, and well-being of sustainable communities, where staff and PhD students can learn about the impact of related work conducted by colleagues (**Deakin, Davies and Pomponi**). This involves collaboration with the Schools of Computing, Arts and Creative Industries and Health and Social Care. Interdisciplinary projects involve research fellows and PhD students working on the social informatics of census data capture (Computing and Creative Industries), the relationship between travel to work zones, health and well-being (Health and Social Care) and machine-based learning as a basis to reduce energy consumption, capture carbon and sustain communities (Computing, Creative industries, Health and Social Care). A social informatics PhD studentship is funded by AHRC. Funding for travel to work zones and health and well-being draws on ESRC, SusTrans and Paths4all grants. The equivalent for machine-based learning is drawn from EPSRC and ENU awards.

These themes are the drivers behind a new Interdisciplinary Urban Research Platform known as UiREKA. The Unit hosted the inaugural Conference of this group in November 2018. This consortium includes the Universities of Applied Sciences in Amsterdam, Gent, Helsinki, Oslo and Frankfurt and holds an International Conference to progress this research agenda and absorb research-led teaching into the taught curricula.

1.6 Open Research

The University's aim is for all ENU research outputs to be openly accessible and fully compliant with the Concordat on Open Research Data. Since 1st April 2016, most of the articles published in the Unit have followed the Green route to Open Access.

To ensure compliance with this policy, the School Head of Research and Research Officer regularly communicate with, and provide support to, staff via email and WebEx training events. REF outputs also comprise a standing item at the School Research and Innovation Committee. The same compliance protocol is applied to meet the Gold standard Open Access Policies set by the EC and UKRI funding bodies. The Gold standard outputs produced since 1st April 2016 are disseminated by Publishing Houses under the appropriate Creative Commons License.

1.7 Integrity

The Unit is committed to providing an environment that recognises and supports research excellence. Research is conducted to the highest levels of integrity, supported using appropriate research frameworks. This ensures findings are robust and defensible. Researchers are also expected to adhere to the highest level of research ethics, in line with requirements set out by national and international regulatory bodies.

All staff and students are familiar with University's integrity and governance procedures as outlined in the ENU Code of Practice on Research Integrity. The Code of Practice defines the research principles and practices all staff and students in the Unit must comply with and covers all staff and post-graduate student research. It also covers research involves human participants, personal data and human tissue, and applies to any research partners who may be conducting research with staff on ENU premises.

2. People

2.1 Strategy

The Unit comprises 14 submitted staff. 50% are lecturers, 14% are associate professors, and 36% are professors. 86% are on permanent contracts and 14% on fixed-term contracts.

Since 2014 the staffing strategy has been to increase the quality of research and grow existing areas of excellence where there is critical mass. All new staff are expected to have a PhD and are recruited following a thorough selection process which includes a School research presentation and a demanding interview. The Unit carefully considers whether the research interests of potential staff are aligned with the School's. The 5-year School plan recognises the need for succession planning, particularly in leading research groups, and this is accounted for when determining the level of recruitment.

2.2 Staff Development

Staff wishing to develop a career in research are recruited onto the Research Pathway of the University Promotions Framework. In this framework staff with significant responsibility for research are guaranteed at least 0.2 FTE of protected research time. Where external research work brings esteem to the School, staff are also given protected time to undertake such work. Staff development objectives are jointly set with line-managers and research group leaders, and are agreed annually via the University's MyContribution scheme.

The School is also committed to increasing the percentage of staff holding a PhD. This is currently 76% across SEBE. Where appropriate, staff are encouraged to undertake PhD study on a part-time basis. In many cases the appropriate method is PhD by-publication.

2.3 Staff Recruitment Policy

During this REF period the Unit has made several strategic appointments (**Davies, Fountas, Smith, Pomponi, D'Amico and Jaradat**). In addition, three staff members have been promoted to associate professor (**Fonzone, Pomponi, D'Amico and Jaradat**). The emphasis in all cases is to recruit and promote staff who are research active, and this recruitment strategy is responsible for the noticeable improvement in the quality of outputs over the period.

All new researchers are supported by the mentoring of experienced staff, often a research professor, and collaborations with existing researchers is encouraged.

2.4 Early Career Researchers (ECRs)

Each of the 6 ECRs appointed since 2014 have mentors who have helped them develop a research and publication strategy. This mentoring doubles-up as a first level of peer review on proposals and papers, as well as helping ECRs identify new funding opportunities. ECRs are particularly encouraged to bid into University "seed corn" funds for pilot research projects. They are also encouraged to submit an RUK Early Career Research grant application, and there is a peer review scheme for grant proposals ECRs (along with all other staff submitting grant proposals) are required to follow.

The Unit has directly invested approximately £400,000 in the period on the recruitment of ECRs. 75% of the ECRs appointed are included in this submission.

2.5 Staff Policy – Leave and Sabbatical

It is recognised that concentrated periods of research offer an opportunity for staff to create, maintain and develop research capacity. The University has developed a sabbatical leave policy

which defined a sabbatical as a period of ENU-funded research greater than 0.25 FTE in a year. This definition includes research leading to the preparation of applications for substantial external research grants.

2.6 Exchanges

Exchanges between staff and other researchers are extensive. These include:

- *Exchanges between Universities.* Including; Harvard University, Cambridge University, Imperial College London, Milan Polytechnic, Aristotle University, Lund University, Oslo Metropolitan University, Bari Polytechnic, Rio Di Janeiro University and Ningbo University (**Hairstans, Currie, Deakin, Rye, Fonzone and Cowie**).
- *Exchanges between University and Industry.* Including; Besblock, Icopol, Stewart Milne Timber, Timber Systems Glenalmond Timber, Euro-gypsum, Energy store, Vattenfall, Link Housing, Scottish Craft Distiller Association, Carbon Dynamic, Robertson Group, McTaggart and Mickle (**Smith, Currie and Hairstans**), Concrete Centre, Zero Waste Scotland, ARUP (**Pomponi and D'Amico**). Bristol Robotics, Fusion Processing and Stagecoach (**Rye and Fonzone**).
- *Exchanges between University, Industry and Government.* These occur with C-SIC and Scottish Government on the productivity of the construction sector in the provision of affordable housing (**Smith, Hairstans and Deakin**). Exchanges with Scottish Government have also developed by way of both the Scottish Construction Skills Report and the City-Region Deal for Edinburgh and the South East of Scotland (**Smith and Hairstans**). Exchanges between University, industry and Government also include SESTrans (**Rye and Fonzone**).
- *Exchanges with the public.* These include public lectures at expos and science festivals, workshops, blogs, demonstrations and exhibitions. Examples include; public lectures on Smart Cities at the 2015 World Expo in Milan, public lectures on AI at the Edinburgh Science Festival 2018 (**Deakin**), workshops and blogs on the Net Zero Protocol in Leeds and Edinburgh 2017 (**Pomponi, D'Amico and Hairstans**), demonstrations of offsite construction at the 2019 UK Sustainable Development Challenge, and an exhibition of offsite construction using timber-products at the V&A London 2017 (**Hairstans**).

2.7 Staff Rewards

To ensure fairness in the allocation of research support and recognition, the School has utilised the University's Workload Allocation Model (WAM). This has expanded from a simple spreadsheet format to measure research outputs, esteem indicators and proposal writing and as such now offers an online record of academic activity. Staff deemed "significantly responsible for research" (SRR) are allocated at least 0.2 FTE (one day per week). Under the ENU REF Code of Practice, any allocation that exceeds this allowance must be centrally funded on a competitive basis. In such instances, staff performance is taken into consideration when allocating funds.

2.8 Research Students

There are 23 Postgraduate Research Students (PGR) currently registered in UoA13, enabling a vibrant postgraduate community. It is planned that by 2025 PGR numbers will grow considerably, helped by close links with industry, partnerships with national and international institutions and the School's commitment to offering a minimum of 3 fully-funded PhD places each year from the research fund. Work is under way to grow the number of joint PhD scholarships with overseas partners. The funded PhD studentships will be competitive to ensure the strongest possible students.

Student-representatives take part in the School Research and Innovation Committee, ensuring a smooth working relationship between staff and students. PGR students are also encouraged to take on developmental roles, such as seminar coordinator, and are encouraged to play a full part in organised events. An annual School PGR conference is organised to showcase student work across all levels. This conference is organised by the students.

PhD students who have visited **CSC** and **TRI** from other Universities include:

- Nick Hammer, University of Utah, visiting Masters student undertaking internship, 2017
- Maria Luisa Regalo from the Università Degli Studi Roma Tre (Italy) 2017.
- Cassandra Lafond, University of Laval, visiting PhD Student, 2018
- Fiona O'Donnell, University of Massachusetts Amherst, visiting PhD Student, 2019
- Alexandre Morin-Bernard, University of Laval, visiting Master student undertaking internship, 2019

2.9 Supervisory Arrangements

All supervisory teams are appropriately trained via the University's compulsory training course, which runs several times per year. In terms of supervisory structure, the School assigns each PGR student a Director of Studies, and a minimum of one other supervisor. Students are also assigned an Independent Panel Chair (IPC). This role is independent of the research conducted and offers an oversight of the PhD process.

2.10 Research Student Recruitment

In addition to internally funded PhD opportunities, research active staff advertise on FindAPhD to attract self-funding students. The School also encourages KTP Associates to register for a PhD.

2.11 Major PGR Funding Sources

PGR recruitment has enjoyed internal support (6 Anniversary Scholarships covering fees and stipend were awarded between 2015-2019). The School has also set up research student collaborations with five universities in China. Under this agreement PGR students are supervised jointly by University staff and their counterparts from partner institutions. Similarly, fee income is jointly split while the award remains an ENU degree. One of the benefits of such a collaborative arrangement is the potential for more extensive academic cooperation between the respective institutions. To date, the School have joint supervision agreements with Shanghai University of Engineering Science (SUES), Dongguan University of Technology (DGUT), Guangxi University of Science and Technology (GXUST), Shanghai Normal University (SHNU) and Zhongkai University of Agriculture and Engineering.

2.12 Monitoring, Support and Completions

Meetings are held every six months for monitoring purposes. The Independent Panel Chair oversees all meetings to monitor student progress (e.g. determination of thesis topic and first year progress review). Each meeting provides an opportunity for the student to reflect on progress made, and identify any training needs or potential barriers. The supervisory team is also present at these meetings and offer the student suitable support.

UoA 13 has secured 19 PhD completions since 2014. Between 2014 and 2017, there has been an average of 2 graduations per annum. During 2018 and 2020 this has increased by 100% and is currently running at 4 graduations per annum.

2.13 PGRS Skills Development

There is an annual PGR Student Conference, normally held over two days at an external location, at which research supervisors are active participants. Every fortnight there is a School research seminar at which PGR students give presentations on their work to peers, staff and external visitors. This is well attended and provides opportunities for direct feedback. Other support mechanisms include writing groups, research “off-campus” retreat weekends and a regular journal club where students and staff discuss and give feedback on the preparation of papers for publication. This latter is part of a wider initiative to mentor and support PGRs to co-author papers with their supervisors, which has led to some students publishing up to three refereed journal papers as well as submitting their thesis on time.

2.14 Equality and Diversity

The School obtained the Athena Swan Bronze award in 2016. The School Inclusion Monitoring Group (see REF5a) is responsible for monitoring E&D data, ensuring processes are followed and reasonable adjustments are put in place.

The demographic profile of the Unit is diverse, with 14 members of staff returned against a Category A pool of 25 (56% of the total eligible Category A Staff). 14% of these are female and 86% male. Within this profile 40% of the eligible female Category A staff are returned and 60% of males.

86% of all staff are permanent contracts, with only 14% on fixed-term contracts. For permanent staff, 50% of the eligible Grade 6 staff are returned, and 100% of the G7 and G10. 50% of the eligible staff aged between 25-35 and 35-45 are submitted, along with 100% of those aged between 45-55 and 56% aged between 55-65. Within the age profile, 75% of the Early Career Researchers (ECR) are submitted.

These figures indicate that UoA 13 has increased the total number of Category A Staff submitted and the proportion of all eligible staff submitted, as well as increasing the number of submitted staff aged between 25-55 and those with ECR status.

3. Income, infrastructure and facilities**3.1 Income**

The Unit has generated £4,064,869 in external income since the last REF. This has been sourced from: 3% BEIS Research Councils, The Royal Society, British Academy and the Royal Society of Edinburgh, 8% UK based charities, 41% UK government, industry and other UK sources, 2% tax credits, 42% EU sources, and 4% Non-EU sources.

3.2 Organizational Infrastructure

In line with the University Strategy for Research and Innovation, the School has identified 4 thematic clusters (**Environment, AI and Technologies, Health and Culture and Communities**) for ISC and TRI to orientate future developments around. These build upon the strengths of existing institutes as centers of excellence for scientific research and technological innovation. Research concerns the smart, sustainable and inclusive development of the construction and transport sectors, which directly benefit the health and well-being of communities. Continuing with the strongly applied, impactful and collaborative approach to research and innovation, the Unit shall also draw on these developments to strengthen the strategic partnerships it has forged with industry, government and the public.

3.3 Infrastructure and Facilities

Between 2014-19 the University invested over £5 million in specialist labs and equipment. Most

of this expenditure has funded the new purpose-built test laboratory facilities at 7 Hills industrial estate in the West of Edinburgh. The 7 Hills laboratory provides test facilities for building performance and offsite construction prototypes.

The University is also funding the refurbishment of the design studio and computer labs used by the Unit. The £300,000 of capital expenditure secured shall provide the facilities to launch the Trimble Design Studio and Lab as a digital hub for construction and transport research.

3.4 Specialist Research Infrastructure and Facilities

Specialist labs and equipment have been fundamental in the development of the Units wider impact. The laboratory provides all the facilities for **ISC** and facilitates research by the **Building Performance Centre**, **Scottish Energy Centre** and the **Centre for Offsite Construction and Innovative Structures**. The **Centre for Smart Cities** and **REBEL Centre** will also use the design studio and computer lab. These facilities are located where much of the research will be performed, where strategic partnerships will reside and where collaborations with industry and the third sector will be undertaken.

The specialist labs and equipment have also been instrumental in developing the impact captured in both the case studies on **Insulation for UK and International Housing** and **Offsite Timber Engineering** brought forward for this submission.

3.5 Collaborative Use of Research Infrastructure

The strategic partnership recently entered with C-SIC provides the opportunity for joint access to the laboratories at this organisation's headquarters and at the 7 Hills facility.

3.6 Major Benefits-in-Kind

This research and innovation is also supported by benefits in kind from Trimble Tekla. This includes specialist software, hardware and a series of specialist training exercises. The software includes Sketchup, Sefaira, Realworks, Tedds, Structural designer and Structures. The hardware covers virtual reality equipment, infrared cameras, and 3-D scanners.

4. Collaboration and contribution to the research base, economy and society

4.1 Collaboration and Contribution to the Research Base

4.1.1 Institute for Sustainable Construction (ISC)

At the **international level**, **Smith** is UK lead and co-founder of EU COST Action TU0901 (involving 32 countries) in "*future harmonization in sound insulation standards*". He was keynote speaker on the "*future of global housing*" at the World Housing Congress in Portugal, and had a follow-on article published by the World Economic Forum. He was guest speaker at the IRCC 2015 (the G16 nations for building regulations), and was an invited member of scientific committees for building physics and sustainable design conferences in Turin, Krakow, Faro and Mumbai. **Smith** also served as international reviewer to the Chilean and Portuguese governments building research proposals, and was invited acoustic expert for the Welsh Government's review of sound insulation standards (Part E).

Hairstans is a member of the Harvard Graduate School of Design and is founder of the International BeX (Built Environment Exchange) programme for Masters students. This initiative promotes collaborative research projects with industry in USA, Sweden and Canada.

Deakin's is recognized a panel member of the European Science Foundation, and reviewer for the US, EC, Swiss, German, Belgium, Finnish, Swedish, Israeli and South African Research Councils. **Deakin** was also a member of the Scientific Committee for the World Expo in Milan and keynote speaker at Conferences on Smart Cities organized by the Universities of Milan,

Turin, Naples, Berlin, Bordeaux, Thessaloniki, EURAC in Bolzano and the Emirates Centre for Strategic Studies and Research in Abu Dhabi. He was also a keynote speaker at the 2018 EU Week of Cities and Regions in Brussels and runs a Smart Cities network on LinkedIn with 7,000 members.

Pomponi is a reviewer on the 2020 Energy Technology Perspective, led by the International Energy Agency, and an invited expert for International Energy Agency Policy Forum on Materials Trends in Building Construction. In 2018 he was invited to the Expert Meeting of the International Energy Agency on BIM and LCA. In 2019, **D'Amico** was reviewer of the TRAIN@Ed Fellowship, part of the Horizon 2020 Marie Skłodowska-Curie Actions COFUND Scheme. He was also invited to be a reviewer of the Netherlands Organization for Scientific Research (NWO).

At the **national level**, **Smith's** is Co-Chair of the Advanced Construction Group convened by C-SIC, Chair of the Scottish Government New Housing & Future Construction Skills Committee and Depute Chair of the Robust Details Technical Standards Committee. He also served as reviewer for EPSRC proposals, Member of the Carnegie Trust Select Panel, Construction Scotland Innovation Centre Review Panel and Textiles Future Forum Panel. **Smith** has given keynote addresses at NHBC Building for Tomorrow, ASBP Plastics in Construction and Scot-Build Expo. He serves on the CIAT Architectural Technology Research Committee and the Scottish Engineering Research Partnership Infrastructure Group. **Smith** has been invited twice to give evidence at the Scottish Parliament committees, addressing climate change plans and the construction sector.

Currie is also a panel member responsible for reviewing research proposals submitted to the EPSRC and AHRC, and sits on the Scottish Government Low Carbon Infrastructure Transition Programme Panel. He is a Fellow, Past Chairman and Member of Council of the Energy Institute, Chairman of the Energy Institute Accreditation Panel, Member of the Engineering Council UK - Engineering Accreditation Board, Board Member of the Energy Technology Partnership, Co-Chairman of Scotland's 2020 Climate Group and founder of Retrofit Scotland.

Hairstans is a Member of the Advisory Panel for Construction Scotland Innovation Centre and Forest and Timber Technologies. He is also Co-Chair of the international Modular and Offsite Construction Summit, reviewer for EPSRC, Digital Built Britain and the Swedish Knowledge Foundation and lead academic for Offsite Solutions Scotland.

Pomponi has been interviewed by the BBC World Service in 2020 on Urban Heat Islands. He is also an Expert Review Panel Member for the Ministry of Housing, Communities & Local Government (Approved Document B). In 2019 he was an adviser and reviewer for the International Energy Agency report on "*Material Efficiency in Clean Energy Transitions*". He also contributed to the 2017 Statement from the RICS on '*Whole Life Carbon Measurement: Implementation in the Built Environment*'.

4.1.2 Transport Research Institute (TRI)

At the **international level**, **Rye's** is a member of the Scientific Committee of the respected TU Munich MobilTUM conference. He is also a member of the Swedish National Public Transport Research Centre (K2) International Advisory Group. He is a Visiting Professor at Technical University Krakow and project reviewer for the EC. **Saleh** is Chair of the Scientific Committee for the Biennial International TDM conference, member of the Scientific Committee International Symposium for Transport Network Reliability and has been invited on numerous occasions to give guest lectures in various countries across the Middle and Far East.

Cowie won the Best Paper Award at the prestigious international Thredbo Conference on Transport Regulation in 2015. **Fonzone** is member of the editorial board for the Journal of the ITS, won best paper award at mobil.TUM 2016, has examined PhD students in France, Sweden, Italy, and has given invited talks at Universities in Europe and Japan.

At the **national level**, **Rye** was Chair of the Universities Transport Studies Group (UTSG), an

umbrella body for all universities in the UK and Ireland working on transport. He played a key role in planning the organization's 50 Anniversary celebrations, in revamping its annual meeting format and in developing a common message for research funders about transport planning as a discipline. **Rye** sits on the National Board of Trustees for the Pedestrians' Charity Living Streets, has been a board member for the Sustainable Transport Lobby Group (Transform Scotland) and is a member of the organizing committees of the Scottish STAR and English Transport Practitioners Conferences. He has been invited on several occasions to provide oral evidence to Scottish Parliamentary Committees, sits on the Cross-party Parliamentary Group on Cycling, Walking and Buses, and was appointed to the Research and Evidence Group of the Scottish National Transport Strategy. In 2018 he was asked by the UK Department for Transport to review a Foresight Report on Transport Governance.

Fonzone is member of the College of Peer Reviewers on the Engineering and Physical Sciences Research Council (EPSRC). He represents the Transport Research Institute in the UK section of the International Association of Public Transport and was visiting lecturer at King's College London.

4.3 Wider Contributions to Economy and Society

These are framed in terms of the contribution the Units research makes to the Global Challenges set by the UN for Sustainable Development, the EUs Smart Cities and Communities agenda and national interpretation of these agendas by UKRI. These cover clean growth strategies for smart, sustainable and inclusive development of a circular economy for the construction and transport of affordable housing, with travel speed restriction, road safety and air quality able to support health and well-being.

4.4 Engagement with Diverse Communities and Publics

In addition to the usual vehicles, the results of this research are disseminated to diverse communities. These vehicles include the following:

- Interviews with BBC television and radio, social media posts, and UK and International press coverage including the Guardian and La Stampa.
- Presentation of public lectures hosted by the Scientific Committee for the 2015 World Expo in Milan. These lectures relate to the development of Smart Cities as eco-systems able to produce and distribute food in an efficient and equitable manner. The Scientific Committee also developed these lectures into a seminar series on Smart City Food Systems. These were also supported by the Food and Agriculture Organisation (FAO) and drawn upon as a basis for the keynote speeches made by the UN and C40 at the World Food Day in October 2016 (**Deakin**).
- A public lecture on the virtues of Smart Cities at the 2019 Edinburgh Science Festival (**Deakin**).
- Delivery of lectures to secondary schools across Europe in 2017-18 (the UK, Spain, Poland, Greece and Turkey) on the virtues of Smart Cities as STEM-based subjects, and laboratories for learning about the next generation of technical innovations (**Deakin**).
- Participation in a workshop organized by the UK Green Building Council and CIEMAP (University of Leeds) in 2017 Advancing Net Zero: Next Steps in Holistic Carbon Reductions. This included blogging on the "net zero protocol" on social media, writing an article for The Conversation on the virtues of this assessment, and sharing these insights with a series of public lectures held with 2 disadvantaged communities in Edinburgh (**Pomponi and D'Amico**).
- Organising a blog in 2017 for Architecture & Design Scotland (ADS) on Offsite Construction and public exhibition on the manufacturing of housing provision (**Hairstans**).
- Exhibition of offsite construction at the 2019 Wood-Based Construction Conference held in Boston, Massachusetts (**Hairstans**).

- Exhibition of Multiply Timber Products at the 2018 V&A London (**Hairstans**).
- Demonstration of how offsite construction can meet the 2019 Sustainable Development Challenge by way of a 9,000-unit development known as Otterpool Park by Folkestone and Hyde, through the UK Government's Garden Town Programme (**Hairstans**).
- Demonstration of the Bio-OSM at the COP26 Conference in Glasgow 2021 (**Hairstans**).
- The Ice Box Challenge, set as part of Bio-OSM Demonstration. This challenge involved building a pod to current building regulations and another to Passivhaus standards. As part of this challenge, a block of ice will go into each of the pods to demonstrate how well insulated the Passive Haus version is relative to the standards laid down by current building standards. This demonstration is a collaborative venture with the Passive Haus Institute (**Hairstans**).

4.5 Contribution to Future Development

ISC shall also continue research into the advanced manufacturing systems of Industry 4.0, developed by smart cities as innovations in BIM. Those models shall cover energy systems, water and drainage, and waste management, and can be designed to close the skills gap needed for construction and transport to secure a sustainable and inclusive growth. **TRI** shall continue to research comparative transport policy, public transport, user behavior modelling, electric and autonomous vehicles, traffic management and road safety. Emphasis shall be placed on the user behaviours of electric buses and taxis as autonomous vehicles, and the opportunities 5G offers to deploy machine-based learning as a platform to accelerate the adoption of these transit options.

The Unit currently has a portfolio of 11 projects dedicated to these developments and an income of £1.1million to fund this research and innovation over the next 3 years (2021-24). These include research and innovation projects funded by Innovate UK, RAEng and C-SIC. This portfolio offers the prospect of acquiring an interdisciplinary knowledge of how digitally enhanced machine-based learning can support the growth of the construction and transport sectors. This platform and will serve as a laboratory for construction to experiment with the data analytics of Industry 4.0, and for transport to model the informatics of 5G-based applications as part of that clean growth strategy which these sectors both sustain the development of and uphold as the metabolic of climate change adaptation.

4.6 Contribution to the Research Base (indicators of wider influence)

4.6.1 Editorial boards

Deakin is on the Editorial Boards of 5 Journals; Urban Technology, Sustainability, International Journal of Intelligent Buildings, Sustainable Cities and Society (2014-17) and Urban Science. He is also the Co-editor of the Smart Cities Book Series from Elsevier. **Hairstans** is on the Editorial Board for the International Journal of Industrialized Construction. **Saleh** sits on the Editorial Board of The Journal of Transport and the International Journal of Transportation. **Fonzone** is on the ITS Journal. **Rye** is on the Editorial Board of Transport Policy, Transportation Demand Management and the Scientific Journal of Silesian University of Technology Series Transport.

4.6.2 Fellowships

Deakin is a Fellow of the European Science Foundation. **Currie** is a Fellow, Past Chairman and Member of Council of the Energy Institute, Chairman of the Energy Institute Accreditation Panel, Member of the Engineering Council UK - Engineering Accreditation Board, Board Member of the Energy Technology Partnership, Co-Chairman of Scotland's 2020 Climate Group and founder of Retrofit Scotland.

4.6.3 Prizes

Smith and **Hairstans** have been awarded the 2014 Queens Anniversary Prize for Innovation in Timber Construction and Wood Science. **Deakin** won the outstanding paper award at the 2014 Conference on Smart Cities, hosted by the Emirates Centre for Strategic Studies and Research

in Abu Dhabi. **Cowie** won the Best Paper Award at the prestigious international Thredbo Conference on Transport Regulation in 2015, and Most Innovative Presentation Prize for a paper presented at JCT Traffic Signals Symposium, University of Warwick, 2017. This research into the safety of traffic signaling at junctions also received six awards. These are the:

- 2016 Smart Road Safety Award - Chartered Institution of Highways & Transportation
- 2016 Most Innovative Transport Project - National Transport Awards
- 2016 Road Marking Project of the Year - Highways Magazine Excellence Awards
- 2016 Excellence in Technology and Innovation Award - Scottish Transport Awards
- 2017 UK Scheme of the Year Award - ITS
- 2017 UK Forward Thinking Award - ITS

Pomponi and **D'Amico** also won the 2019 UK RISE award for Design, Innovation and Creativity.

4.6.4 Research Councils

Smith serves as a reviewer for EPSRC proposals, Member of the Carnegie Trust Select Panel, Construction Scotland Innovation Centre Review Panel and Textiles Future Forum Panel. **Smith** served as international reviewer to the Chilean and Portuguese Government's building research proposals, and was invited acoustic expert for the Welsh Government's Review of Part E sound insulation standards. **Rye** is a reviewer for EPSRC, Digital Built Britain and the Swedish Knowledge Foundation. **Deakin** is a member of the European Science Foundation (ESF) US, EC, Swiss, German, Belgium, Finnish, Swedish, Israeli and South African Research Council Grant Committees. **Fonzone** is member of the College of Peer Reviewers for the EPSRC.

4.6.5 Invited keynotes, lectures and/or performances, or conference chair roles

Deakin was Chair of the Smart Cities Conference held at the Queen Elizabeth Conference Centre at Westminster and Scotland's Climate Change Conference in Holyrood, Edinburgh. **Deakin** has also presented keynote papers at Conferences on Smart Cities hosted by Turin Polytechnic, Milan Bicocca University, Naples University, Berlin Technical University, Bordeaux University and Dublin University. **Smith** was keynote speaker at the World Housing Congress (Portugal) and at the IRCC 2015 (the G16 nations for building regulations), and invited member of scientific committees for building physics and sustainable design conferences in Turin, Krakow, Faro and Mumbai.

Rye was Chair of the Universities Transport Studies Group (UTSG), an umbrella body for all Universities in the UK and Ireland working in transport. He also sits on the National Board of Trustees for the Pedestrians' Charity Living Streets, has been a board member for the Sustainable Transport Lobby Group (Transform Scotland) and is a member of the organizing committees of the Scottish STAR and English Transport Practitioners Conferences. **Saleh** is Chair of the Scientific Committee of the biennial international TDM conference, member of the Scientific Committee International Symposium for Transport Network Reliability.

4.6.6 Participation in the refereeing of academic journals

Members of ISC and TRI review papers for the following journals:

Accident Analysis and Prevention, Elsevier
 Analytic Methods in Accident Research, Elsevier
 Annals of Operations Research, Springer
 Applied Energy, Springer
 Architectural Engineering and Design Management, Taylor and Frances
 Artificial Intelligence Review, Springer
 Building Engineering, Elsevier
 Building Pathology and Adaptation, Elsevier
 Building Research and Information, Taylor and Frances
 Building Simulation, Springer
 Case Studies in Transport Policy, Elsevier

Cities, Elsevier
 Climate Policy, Taylor and Frances
 Construction and Building Materials, Springer
 Construction Innovation, Emerald
 Construction Management and Economics, Taylor and Frances
 Ecological Economics, Springer
 Energies, MDPI
 Energy and Buildings, Elsevier
 Engineering Structures, Elsevier
 Environmental Research Letters, IOP Science
 Environmental Science & Technology, Springer
 Environmental Sustainability, Springer
 Facilities, Emerald
 Habitat International, Elsevier
 Housing and the Built Environment, Springer
 Industrial Ecology, Wiley
 Intelligent Buildings International, Taylor and Frances
 Intelligent Manufacturing, Springer
 International Journal of Life Cycle Assessment, Springer
 International Journal of Space Structures, Sage
 International Journal of Sustainable Built Environment, Springer
 International Wood Products Journal, Taylor and Frances
 Journal of Applied Statistics, Taylor & Francis
 Journal of Big Data Analytics in Transportation, Springer
 Journal of Corporate Real Estate, Emerald
 Journal of Environmental Management, Elsevier
 Journal of Industrial Ecology, Sage
 Journal of Infrastructure Systems, ASCE
 Journal of Intelligent Transportation Systems, Taylor & Francis
 Journal of Technological Forecasting and Social Change, Elsevier
 Journal of Transport Economics and Policy, University of Bath
 Journal of Transportation Engineering: Part A, ASCE
 Journal of Transportation Planning and Technology, Taylor and Francis
 Logistics Research, Taylor and Frances
 Mechanical Engineering, JSME
 Nature Sustainability, Springer
 PLOS ONE, Plos
 Public Works Management & Policy, SAGE
 Renewable and Sustainable Energy Reviews, Elsevier
 Research in Transportation Business and Management, Elsevier
 Research in Transportation Business and Management, Elsevier
 Research in Transportation Economics, Elsevier
 Safety Science, Elsevier
 Sensors, MDPI
 Structure and Infrastructure Engineering
 Structures, Elsevier
 Sustainability, MDPI
 Sustainable Cities and Society, Elsevier
 Traffic Injury Prevention, Taylor & Francis
 Transport Policy, Elsevier
 Transportation Letters, Taylor & Francis
 Transportation Research Part E: Logistics and Transportation Review
 Transportation Research Part F, Elsevier
 Transportation Research Record, Sage
 Transportation Research, Part A, Policy and Practice, Elsevier
 Transportation, Springer
 Transportmetrica A, Taylor & Francis

Travel Behaviour and Society, Elsevier
Urban Technology, Taylor and Francis