

Institution: University of Northumbria at Newcastle

Unit of Assessment: UoA13 Architecture, Built Environment and Planning

1. Unit context and structure, research and impact strategy

1.1. Overview

UoA13 at Northumbria University (NU) is composed of 52.0 staff (49.8 FTE) in the **Department of Architecture and the Built Environment**. This represents a nearly threefold increase in the number of staff returned to this unit in REF2021 compared to REF2014. This growth builds directly on the university strategy set in 2013 (REF5a, section 2.1) and has been achieved by fostering high-quality research that addresses key regional, national and global challenges in the built environment, while strengthening our core research groups through the development of staff and strategic recruitment.

Strengthened by a renewed identity and sustained by the acquisition of a new, iconic home that enabled the development of collaborative research ideas and opportunities for networking (section 3.2.1), our long-term vision for achieving research excellence in Architecture and the Built Environment has been to transform from an academic community of exceptional teaching and islands of research excellence into a unit with a pervasive research culture and driven by the ambition of leading the world in digital construction and people's well-being through design.

To achieve all this, we have employed a strategy centred on:

- 1) growing the extent (size and capacity), diversity and quality of the research staff base (Table 1);
- 2) developing existing strengths in three 'signature' interdisciplinary research themes: Creative/Adaptive Reuse, People and Places, and Connected Construction through BIM (section 1.2);
- 3) creating connected research facilities through structured capital investment (section 3);
- 4) developing new, tailored processes and financial systems (sections 2, 3 and 4) to foster, sustain and grow an ambitious, vibrant and engaged research community.

Evidence

- research innovation and partnership work, as exemplified by the Ministry of Building, Innovation and Education (MOBIE)'s Northumbria Homes for the Future Innovation Centre, a project with 15 university match-funded doctoral students set to work in partnership with a range of industrial partners over the period 2020–2022 (section 4.1);
- our research excellence in BIM, nationally recognised by the *Times Higher Education*, where our **BIM Academy Enterprise Ltd (BIMAE)**, a joint venture company between NU and Ryder Architecture, was winner of the 'most innovative contribution to business-university collaboration' in 2017;
- growth in the research quality of our design portfolios, as evidenced by the range and number of prestigious design awards received, for example the Constructing Excellence and Civic Trust Award and the RIBA North West Regional Award (*A. Couture*, for Manchester City Library), the Liget Budapest International Design Competition (*Ingleby*, for Museum of Ethnography), and the NE Property Award 2020 (*Jones*, for Humbledon Hill Houses);
- a more than twofold increase in the average number of outputs published per year: this number has gone from 39 in REF2014 to 83 in REF2021 (section 4.3.2);
- twice as many outputs with international co-authors since REF2014 (section 4.3.2);
- an increase in our postgraduate completions: from 10 during REF2014 to 29 during REF2021.

Table 1: Transformation of our unit since REF2014

	REF2014	REF2021	Increase
FTE submitted	18.2	49.8	+174%
Percentage of REF-eligible staff submitted	26%	83%	+219%
No. of women submitted	3	16	+433%
No. of ECRs submitted	3	11	+267%
Percentage of staff with PhDs in the Unit	29%	51%	+76%

To achieve sustainable growth in staffing we have focused on research quality enhancement (i) through the targeted recruitment of exceptional cross-disciplinary leaders and future leaders, and (ii) by raising the aspirations, capacity and capability of existing staff. Mentoring and new support structures and processes enabled our staff to develop new, high-quality, collaborative and impact-rich research agendas. To grow our research sustainably, we focused on unique collaborations with industry, such as the award-winning **BIMAE** and the **International Centre for Connected Construction (IC3)** – a new centre of excellence involving innovative north-east academic, industrial and government organisations that are co-creating positive transformation in the global construction industry (section 4.1).

We have reconfigured our estate through the acquisition of a new iconic home and the refurbishment of our laboratories, and introduced new interdisciplinary communities (section 1.2). Since 2014 we have appointed 28 new members of staff, 11 of whom are early career researchers (ECRs) and we are strongly committed to the development of our community of scholars at all stages in their career (section 2.1.2).

1.2. Unit structure and achievements

Our researchers actively work across three interdisciplinary themes, both within their research groups and in synergy with other groups, to foster cross-pollination of ideas (Figure 1). Our research environment has matured since REF2014, as the unit's groups have evolved into progressive, productive and engaging research communities, with identities of their own and with freedom to innovate. Membership is intentionally fluid: many members of staff belong to both a primary and a secondary group, as fits their research interests.

Inter- and multidisciplinary research has become an integral part of the unit's current successes, being supported by NU's strategy around multidisciplinary research themes (MDRTs; see REF5a, 2.2), which provides platforms for large strategic collaborative research-funding applications aligned to global, national and regional 'grand challenges' (section 1.4). Research groups support the development of grant applications, knowledge exchange, and the exploration of new ideas, outputs and impacts. Each group is outlined here in further detail, with examples of key funded projects.

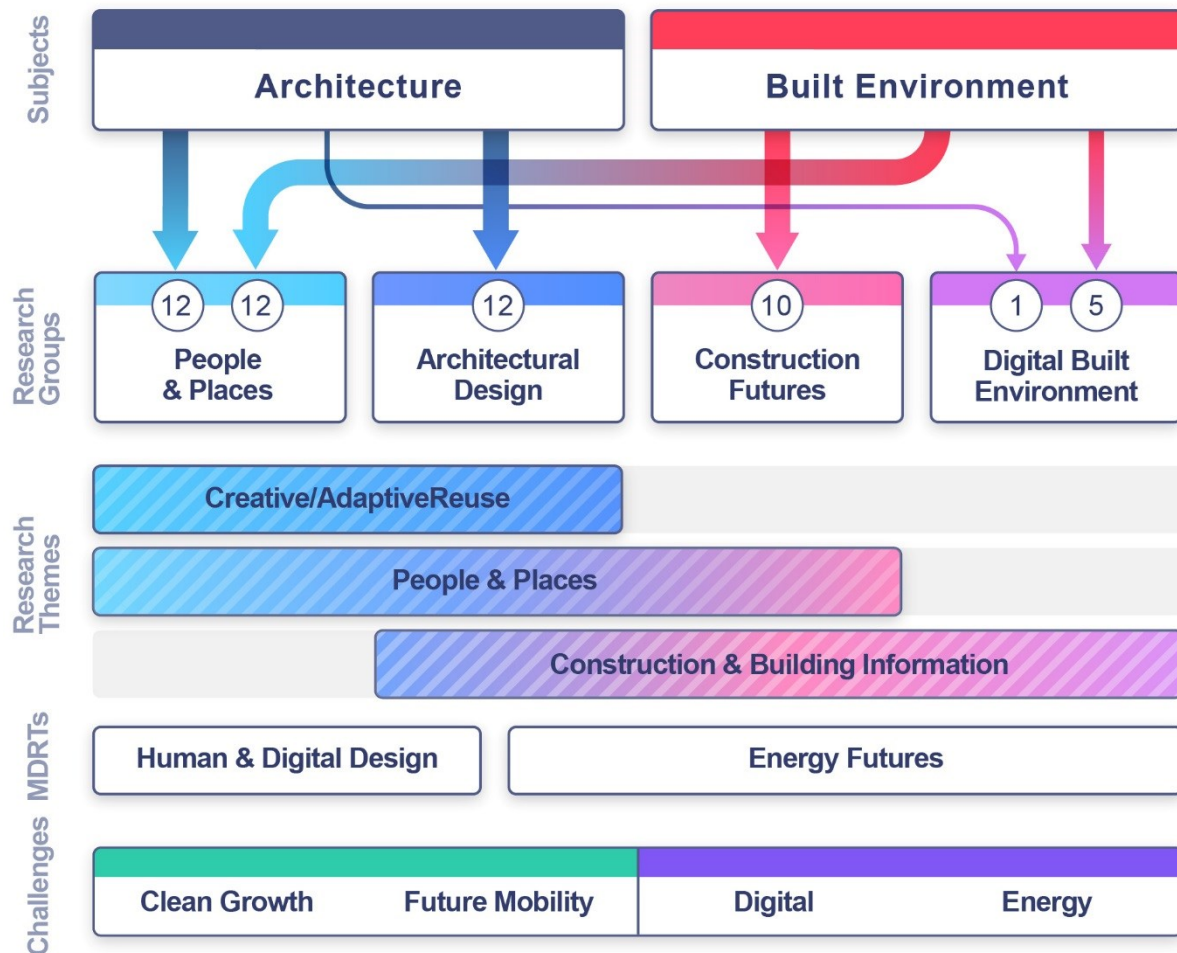


Figure 1: Unit organisation and alignment to university structures, including our MDRTs (see REF5a, Figure 1) and global challenges. Numbers indicate the number of staff members.

'Challenges' are aligned to the UKRI Industrial Strategy Grand Challenges (green) and to North East Local Enterprise Partnership (NE LEP) areas of strategic importance.

1.2.1. Architectural Design (12 staff)

This group focuses on designing the built environment across multiple scales, in order to address the needs of individuals and society. Staff members in this group are active professional practitioners, who engage with authentic real-world design problems. Research themes in the group span architecture (*Campbell, Ingleby, Jones, MacKinnon, Messer, Morton, Roberts, Young*) and interior architecture (*A.Couture, B.Couture, Dixon, Ring*). The impact of our research and projects with a diverse range of partners is detailed in section 4.

Architecture

Our outputs include notable international design projects. A research team led by *Jones* presented designs for a £350k brachytherapy and holistic well-being centre to members of the Barbados government as the centrepiece of the team's health tourism strategy. Its members have also

contributed to urban civic and educational buildings such as the £40M multi-award-winning Manchester Central Library (*A.Couture*) and the £30M Lancaster University Management School and New Campus Gateway (*Campbell*). Our researchers are also advising for and contributing to significant housing projects, such as 1,700+ homes for Riverside Sunderland (*Jones*); they also participate in designing a village centre and 1,500 homes for South Seaham Garden Village (*Jones*), which is one of the first projects of its type in the country.

Interior architecture and urban design

Our research activity in interior architecture has informed projects across a range of contexts – for example adaptive reuse projects at nationally important **National Trust** sites such as Gibside and Seaton Delaval Hall (*Ring*, *A.Couture* and *Jones*). [text removed for publication].

The projects undertaken by the research group have won more than 30 design commendations, including RIBA, RICS, Civic Trust Awards and Constructing Excellence, and our design projects have been the focus of several highly cited journal papers and Paper of the Year awards.

Examples of funding successes and partnerships

- *A.Couture*: Manchester City Library, a £40M multi-award-winning design, made in collaboration with Ryder Architecture and using BIM and post-occupancy analysis;
- *Jones*: European Social Catalyst Fund (£62.5k), used to design flexible housing for people to age in place, at South Seaham Garden Village;
- *Jones*: British Council (£25k), used to support an architecture and urban design strategy for a new cultural quarter in Kiev, for the Ukrainian contemporary arts organisation Izolyatsia.

1.2.2. People and Place (24 staff)

This multidisciplinary research group focuses on the social and economic aspects of the built environment. The group recognises the multifaceted and complex nature of this kind of environment as a place for people as well as for social and economic activity. Research within the group falls under three themes:

Real Estate Markets

Researchers involved in this theme – *Greenhalgh*, *Muldoon-Smith*, *Robson*, *Wedawatta*, *Williams*, and *Zhang* – investigate topics such as spatial governance and state strategies, building conversions, urban land economics, sustainable urban development, urban policy evaluation, and commercial and industrial property market modelling. The theme hosts the R3 Intelligence project (<http://r3intelligence.co.uk>), which is led by *Greenhalgh* and *Muldoon-Smith* and provides

innovative real estate analytics and modelling to external organizations such as **Citibase PLC** and the **British Council for Offices**.

Place Making & Urban Morphology

Research interests in place making engage all facets of urban life, places and people. Researchers include *Bertolino, Clarke, Giddings, Hatcher, Holgate, Kirk, McGuinness, McIntyre, and Reeves*, who have published extensively in a variety of related fields: urban regeneration, economic development, mainstreaming of nature in policy, and decision-making processes and outcomes. Work in urban morphology focuses on the morphological and spatial aspects of the built environment. It encompasses GIS and space syntax analysis, which incorporates areas that emerge from shared, integrative data. Some of the researchers are *Brown, Morton, Ozbil Torun, Seo, and Vialard*.

Well-Being & Health in a Sustainable Future

Research into well-being in the built environment (*Ahmed, Alvanides, Hipwood, Jin*) includes the sociocultural side of the 'user experience', which embraces ethnographic studies of the human sense of belonging, the perception of place and environment, and the impact of psychological factors that impinge on well-being. This theme also focuses on the diverse roles that the built environment plays in society's transition towards a sustainable future; thus it deals with the post-occupancy evaluation of existing building stock and with building energy performance modelling, and it employs a 'nexus of practices' approach to understanding sustainable building measures in a wider social context.

Examples of funding successes and partnerships

- *Costa Santos*: AHRC-funded project (£196k) titled 'Place and belonging: What can we learn from Claremont Court housing scheme?'
- *Seo*: British Council Newton Institutional Links (£133k) for designing an incremental structure-infill housing prototype system for low-income populations in Malaysia;
- *Ozbil Torun*: British Academy Humanities and Social Sciences (£38k) project titled 'Supporting children to be active: Identification of objective and perceived neighbourhood environmental features supportive of physical activity and mental well-being';
- *Dalton*: ESRC (value £28k) for a research on dementia-friendly care homes.

1.2.3. Construction Futures (10 staff)

This group brings together an interdisciplinary team across construction, civil engineering and geography to focus on developing sociotechnical innovative solutions meant to address wider issues in the construction industry under two main themes:

Construction Management & Economics

The researchers involved (*Ameyaw, Anyigor, Thurairajah*) focus on (1) the wider use of information and knowledge in construction projects and organisations, including BIM and artificial intelligence; (2) economics, cost management, whole life costing, and value management; and (3) construction process and improvement or re-engineering initiatives, procurement and construction contracts, and risks.

Construction Technology for Decarbonization and Disaster Risk Reduction

The researchers involved (*Dawson, Ginge, Kelly, Kirk, Onaopepo, Pesce, Zingre*) focus on (1) construction technology, with a view to reducing energy consumption in construction processes and buildings; and (2) the design of sustainable cementitious material. Energy-related research investigates the decarbonisation of buildings, dealing with low-carbon and renewable energy for heating, air conditioning, power and lighting in buildings. Research into Disaster Risk Reduction is about developing practices that should build disaster resilience into the construction process.

Examples of funding successes and partnerships

- *Pesce*: funding for several projects with Historic England (£30k overall), to support the reintroduction of the 'hot mixed lime' technology in the conservation of historic buildings and to assess the performances of mortars for the conservation of Hadrian's Wall and York Minster (York);
- *Ginge*: European Union's Education Audiovisual and Culture Executive Agency award (£73k) for an interdisciplinary project titled 'Collaborative action towards disaster resilience education', and designed to mainstream disaster resilience in the construction process through the development of an innovative professional doctorate programme;
- *Thurairajah* and *Wedawatta*: Building Resilience in Flood Disaster Management in Northern Peru, a Newton Fund researcher link initiative with Birmingham City University.

1.2.4. Digital Built Environment (6 staff)

Researchers within this group (*Alwan, Arayci, Charlton, Crilly, Kumar, Watson*) creatively apply cutting-edge digital engineering technologies such as 3D printing, digital scanning, remote sensing and BIM to improve productivity and performance in the construction industry. Research themes are:

Virtual Reality & Visualisation (VRV)

Research into virtual city modelling at NU has developed new digital solutions for two urban areas in the north-east of England: Virtual NewcastleGateshead (VNG) and Virtual Sunderland (VS; *Charlton*). These innovative tools have provided city planners with the ability to conduct comprehensive assessments of the visual impacts of a development against current and future cityscapes. The insights provided efficiencies that have saved time and money and created a more effective process for assessing key planning applications.

BIM

Our research into BIM has redefined digital transformation policies in national construction sectors and has been used in high-profile developments (e.g. Durham Cathedral; *Charlton*). Our work on BIM upskilling has contributed to the development of a framework for developing BIM competency that is now in use in large organisations like Historic Environment Scotland (*Kumar*). We have developed xBIM (*Lockley*; retired in 07/2017), a new building informatics digital toolkit that has seen widescale industry uptake (21,486 users as of November 2020).

Examples of funding successes and partnerships

- *Charlton*: funded by Newcastle City Council (£20k) for the research project 'Hadrian's wall: Augmented reality central section';
- *Alwan*: funded by Cambridge University's Centre for Digital Built Britain (£57k), for a research on the evaluation of BIM maturity and benefits tools;
- *Lockley*: funded by the Technology Strategy Board (£83k) for a research project titled 'Digital engineering for customised compliance in maintenance regimes';
- *Kumar*: funded by Innovate UK (£72k) for a research project titled 'Optimising equipment used in construction with BIM, IoT and data science'.

1.3. Impact strategy

Building lasting collaborations with our external partners in order to drive significant beneficial changes that endure and grow, has been a strong feature of our pathways to impact and has been supported by targeted investment in people and processes. Such investment has concentrated on three main areas:

- #1 the championing of research in policy and decision-making;
- #2 support for evidence-based practice that should deliver new, solution-focused approaches;
- #3 the embedding of our research in large international and national organisations in order to stimulate and facilitate innovative partnerships.

This REF period has seen a consolidation and development of our impact activities designed to build on our professional strengths, methodological innovations and links with industry. The resulting submission of impact case studies (ICS; see sections 4.1–4.3) reflects our targeted approach to achieving transformative, research-led change at global to local levels.

#1 Research within our **Digital Built Environment** group led by *Kumar* and *Charlton* has provided visualisation solutions designed to support decision makers in 20 major developments throughout north-east England (>£1.3B). Our research has a direct impact on how the associated stakeholders plan, market and assess new developments (REF ICS *Charlton*), while the impacts on research-led policy-making and planning are pervasive. *Greenhalgh* and *Muldoon-Smith's* research (**People and Place**) on spatial inequalities across the country informed legislative scrutiny of the Business Rates Retention Scheme, and contributed to shaping national recommendations on changes to the business rates system (REF ICS *Greenhalgh* and *Muldoon-Smith*).

#2 *Jones* and *Ring's* research (**Architectural Design**) uses evidence-based practice to drive cultural change in the approach to ruin preservation and reuse. The research has helped organisations such as the **National Trust** to ensure the longevity of local heritage sites. [text removed for publication]. *Dalton's* extensive evidence-based research on the way people navigate around buildings led to a research partnership with **Alzheimer's Research UK (ARUK)**. Further research resulted in the development of an innovative interactive game that generated extensive data and boosted public awareness of dementia, contributing to a 38% rise in charitable donations to **ARUK** (REF ICS *Dalton*).

#3 Close collaboration with companies such as **Ryder Architecture**, **Space Group**, **Sir Robert McAlpine** and **AECOM** – focussed on activities dedicated to addressing specific, business-critical problems – and active engagement with organisations and bodies such as the **Construction Innovation Hub**, the **Ministry of Housing, Communities and Local Government**, **Historic England**, the **BRE Trust** (e.g. REF ICS *Ring* and *Jones*), and the **Centre for Digital Built Britain** have provided the context and platform for our research to transcend conventional boundaries and achieve significant impacts beyond academia. Such impacts are often supported by the unit's quality-related (QR) budget (section 4).

Actions taken to develop impact: investment in people

- We created an academic lead for impact (*Ozbil Torun*), who works closely with our researchers and the central university impact support team.
- We enabled concentrated blocks of staff time in the form of impact-focused sabbaticals (e.g. *Jones, Ring, Charlton, Dalton*); we provided 281 hours of teaching cover over the past two academic years (e.g. beneficiaries *Greenhalgh, Muldoon-Smith, Charlton*); and we funded RAs to the value of 270 hours (e.g. beneficiaries *Dalton, Greenhalgh* and *Muldoon-Smith*).
- University impact support officer positions were specifically created to directly support ICS development.
- We advanced >£25k from the unit's QR funds to support the development of new international research networks (e.g. to *Ginge, Wedawatta, Giddings, Jin, Ozbil Torun, Seo, Vialard*) and of impacts on policy (e.g. *Greenhalgh, Muldoon-Smith*) and practice (e.g. *Dalton, McIntyre*).

Our approach to impact has been supported by university-wide investment in the central impact support team (REF5a, 2.3) and by the inclusion of impact activities in the annual personal development objective setting and in the promotion criteria. Our departmental director of Research & Knowledge Exchange (R&KE; *Kumar*), our unit-aligned research development manager from Research & Innovation Services (RIS), and a business development manager support our researchers in identifying and nurturing the opportunities for knowledge co-production and transfer, business engagement and commercialisation.

Beyond REF2021, our approach ensures sustained support for and focus on maintaining and developing new areas of impact (e.g. net-zero carbon buildings). These maturing and nascent research areas are beginning to set impact agendas of their own and address key national and international challenges.

1.4. Interdisciplinary research

Interdisciplinary research is enabled and enhanced through the university-wide MDRTs (REF5a, 2.2; Figure 1). A strong component of our interdisciplinary research is linked to the global challenges of climate change, clean growth, health and well-being. The MDRT **Human & Digital Design** brings together our research expertise in architecture and the built environment with those in artificial intelligence, information processing or modelling, and Human-Computer Interaction. The MDRT **Energy Futures** tackles various challenges, including clean growth and future of mobility, and, to do so, unites staff from **Construction Futures** and **People and Places** with

structural, civil and electrical engineers as well as with physicists and economic and political geographers.

Examples of the unit's interdisciplinary work

- *Giddings* led the AHRC Research Network Grant project 'Future of the city centre' (£42k), which examines pressures on city centres across different cities of the world and how these are changing, in order to explore the future of city centres. The project involved architects, urban planners and project managers.
- As a network member of Big Data in Obesity Research, *Alvanides* contributed to an EPSRC-funded UK expert network. The network integrated specialists from various disciplines such as health nutrition and data analytics, to explore new ideas on how to make best use of the wealth of data to inform positive change.

1.5. Research integrity, open research and open data

The unit builds on institutional policies (REF5a, 2.2) so as to support the enhancement of research outputs through an intentionally open and inclusive research culture, where all staff members engage with supportive mechanisms (section 2.1) and with accessible research group communities that facilitate the cross-fertilisation of collaborative ideas. Financial support is provided for gold open-access article processing charges, resourced through both university- and unit-level funding.

Free-to-access data repositories such as Figshare (institutional licence) and Northumbria Research Link (institutional license) are actively promoted and widely used within our research groups. We routinely provide access to published data and analytical codes, thereby enhancing the reproducibility, robustness and impact of our research outputs.

All research projects require approval from an ethical audit. The university has developed an online research ethics system that enables researchers to assess the level of risk and the wider implications of their proposals (higher risk projects undergo an independent review by the Ethics Committee). Researchers receive ethics training every three years. This is a mandatory requirement if they wish to obtain permission to conduct research and to supervise doctoral students.

1.6. Summary of transformation with reference to REF2014

After REF2014, our strategy has been to grow high-quality research that has generated an orchestrated step change in the unit's capability and capacity. The unit's successes with the strategic objectives set out in REF2014 (given here in *italics*) are as follows:

1. *To increase staff capacity:* Strategic appointments of new staff – alongside resources designed to develop existing staff and to enable its members to undertake in-house doctorates (9 staff) – have led to a 2.7-fold increase in category A staff submitted to REF2021 by comparison with REF2014, and to a 76% increase in the number of staff members with doctorates.
2. *To develop existing areas of research while recognising new areas with potential:* The substantial growth of our research-engaged staff base enabled a restructuring of research groups, strengthening our core themes (section 1.2).
3. *To increase our PGR population:* PhD titles awarded per year doubled (an average of 2 per year in the REF2014 period went up to an average of 4.1 in this REF period). The unit's current PGR base is made up of 32 students.
4. *To increase research income to a level commensurate with the progress made in research activity over the REF2014 period:* During this REF period, unit members were able to secure research grants and contracts worth £2.2M.
5. *To ensure excellent facilities and administrative and technical support:* We have more than doubled our investment in research-focused capital projects (section 3) through new facilities such as a new home for architecture, state-of-the-art studios, and laboratories that support research across all our four research groups. Technical and administrative support staff has been restructured to better facilitate research processes.

1.7. Future strategic aims and objectives (2021–2028)

The unit's research objectives build upon our current trajectory, with the intention to consolidate and capitalise on this growth over the next REF cycle. As such, we have set ambitious but achievable goals for the unit and for the delivery of the wider university strategic vision for 2030 (REF5a, 1.2). In particular, the research themes that will drive our activity will focus on (i) streamlining the construction process, from procurement to maintenance, with IT solutions (e.g. AI and big data); (ii) developing net-zero carbon buildings, from conceptualization to deconstruction (clean growth); (iii) improving well-being in indoor environments and urban spaces (e.g. by limiting the effects of acute infectious disease); (iv) improving human–building interaction (e.g. ageing society and smart buildings).

Our objectives for the next REF period are as follows:

- to enable and diversify impacts locally, nationally and internationally by further collaborating with industry and stakeholders in order to identify and solve challenges in the built environment, to the benefit of society (e.g. through **IC3** and **MOBIE**; section 4);
- to grow our research group **Digital Built Environment** (section 1.2.4) still further, so as to strengthen our leadership and reputation in BIM. We will explore technologies such as digital

twinning, IoT, and Bio Digital with the aim of increasing productivity and performance in the construction industry;

- to nurture our research group **People and Places** (section 1.2.2) into leadership in human–building interaction and people’s well-being;
- to support our large pool of ECRs to transition into research leaders and to ensure the sustainability and relevance of the growth in the staff base (a) by diversifying the research income streams through new, strategic international research partnerships focused on our new research hubs (e.g. **IC3**); and (b) by securing additional funding for new posts and new projects;
- to continue the active promotion of equality and diversity, which guarantees appropriately diverse contributions to the future directions of research within the unit (section 2).

To support these objectives, we aim to

- consolidate our research excellence by increasing the numbers of successful grant awards and high-quality outputs (as measured by REF criteria);
- diversify our portfolio of externally funded PhD programmes from research councils, CDTs and industry;
- increase our industrial impact by obtaining KTP awards and strengthening our connections with industry. We expect significant growth around our research in BIM and project management;
- develop a significant, creative and pervasive strategy for continually enhancing equality, diversity and inclusivity within the unit and for achieving an Athena SWAN Award (first submission November 2021).

2. People

2.1. Academic staff strategy and development

In order to achieve a sustainable and structured growth in research capacity, our staffing strategy has relied on (1) empowering our academic staff and PGR community through supportive and inclusive development; and (2) a rigorous and targeted recruitment of internationally excellent research leaders and dynamic and ambitious ECRs aligned with our core research themes.

In this REF cycle 83% of the unit’s REF-eligible staff have significant responsibility for research (that is, academic staff with an agreed independent research objective as defined in our code of practice; REF5a 3.4) – by comparison with 26% in REF2014 (Table 1).

All our principal lecturers have been supported to transition successfully to associate professorships, in line with the university’s strategy (REF5a, 3.1). A quarter of staff in the unit

(25% of staff are Professor or Associate Professor) offer strategic research leadership (Figure 2), for example development and steering of MDRTs and research groups, development of the university's research policy, and research mentoring for staff.



Figure 2: Composition of the unit by career stage.

The recruitment of ECRs through the university-wide Vice-Chancellor Fellowships (VCF) scheme (REF5a, 2.2) incrementally integrates staff members into our unit by assigning to them a full academic workload over three years. This allows them to maintain a strong upward research trajectory while transitioning into lectureships (e.g. *Brown, Watson*).

The development of the research environment has been further galvanised through structured research support in the form of financial enabling funds, managed within the unit alongside university investment, and internal output and proposal review panels where support is encouraged before submission (see also section 3). Examples include travel, collaboration-focused funds and specialist training such as mock panel events. The allocation of the unit's financial support is overseen by a mixed-gender, mixed-ethnicity, multi-career-stage panel that considers (i) the diversity and spread of funding across the unit, (ii) engagement with the wider support structures in place (research mentors, research development managers and research groups), and (iii) significance and potential outcomes.

The unit has used its QR budget as a research enabler and supported over 40 staff members. Examples include:

- making presentations at national and international conferences and delivering invited and keynote speeches (e.g. *Greenhalgh* at the International Urban Regeneration Symposium, Korea, 2017 and at the GETM3 Horizon 2020 conference at Warsaw University of Technology, 2018; *McIntyre* at the Access Association AGM Conference, UK, 2019; *Brown* at the International Conference of the German National Committee of ICOMOS, Munich, 2018);
- enabling staff to develop international research collaborations (e.g. *Ginge*, *Wedawatta*, with universities in Sri Lanka and Zimbabwe);
- providing funds to support the development of outreach and public exhibitions – e.g. the Scottish Royal Academy exhibition (*Ingleby*), the Tyne Theatre exhibition 'A Theatre for the 21st Century' (*MacKinnon*), and the Alnwick Gardens exhibition (*MacKinnon*);
- providing funds designed to open new research avenues (*Vialard*, *Hipwood*) and to support future impact activities (e.g. *Alwan*) and travel funds designed to stimulate grant development (e.g. *McIntyre*, *Hipwood*, *Vialard*, *Moreton*).

2.1.1. Recruitment, probation, mentoring and promotion

All new appointees follow a standardised selection and interview process (REF5a, 3.2). The use of video conferencing tools for interviews has facilitated a truly worldwide and diverse recruitment. A probation period is mandatory for all new starters, who agree with their heads of department on a probation plan that links appropriate research objectives and career progression with support mechanisms (funding, mentoring and guidance) to achieve them. Progress against the research plan is reviewed and thereafter supported monthly by the research mentor. Probation panels have independent representation from other faculties, so that parity is ensured, but individual circumstances (e.g. caring responsibilities, maternity leave, sickness absence) and evolving situations may dictate when research objectives are assessed.

Each member of staff has a research mentor focused on research output quality enhancement and on research plan development. Throughout the COVID-19-affected period, staff members have contacted mentees more frequently, enabling open and responsive research support networks. A key role of research mentors is to challenge mentees' level of ambition. Research mentors are also responsible for supporting researchers throughout their career growth. Both mentors and line managers are expected to help staff members to map themselves against the promotion criteria and to create a personalised route to promotion. During this REF period,

eight staff members were promoted from senior lectureships to associate professorships (e.g. *Mackinnon, Seo, Ring, and Morton*), while *Greenhalgh* obtained a professorship.

2.1.2. ECRs

In REF2014 we submitted three ECRs; in this REF cycle we submit eleven (the number includes VCF holders and lecturers). The unit has invested significantly in the development of the current cohort of ECR. ECRs are prioritised for internally funded PhD studentships (where staff new to supervision are paired with experienced staff to act as mentors), are provided with a flexible budget on arrival to establish research directions, and receive collegiate support through highly restricted administrative duties and lighter teaching loads allowing them the necessary intellectual development time, physical resources and guidance to build their research profile.

Our strategy is to support researchers to grow and develop their careers at all levels. To stimulate and facilitate exchanges between academia and industry, we supported the recruitment of staff with industrial experience (e.g. *B.Couture, Campbell, Crilly*). We limit the use of fixed-term contracts for category A staff in the Unit. Where we have category A staff on fixed-term contracts, we actively seek to invest in these staff, supporting them with their career development and in applying for permanent contracts. Three fixed-term staff (*Moreton, Young and Crilly*) successfully moved from fixed term positions to Lecturers following competitive recruitment processes.

The university runs an ECR Forum, and the ECRs' voice is influential through the university, R&KE committees and the implementation of feedback from the Careers in Research Online Survey. Representatives of the unit's self-organised ECR network led by *Hipwood* attend (i) departmental management groups, to ensure that inclusive perspectives and ideas are considered; and (ii) MDRTs steering groups, to contribute to defining wider research directions at the institutional level. The unit upholds the principles set out in the Concordat to Support the Career Development of Researchers (REF5a, 2.5).

2.1.3. PDA and sabbaticals

A biannual performance and development appraisal (PDA) system is used for formulating and reflecting on an individual 'research and innovation plan' that sets stretching but clear and achievable aims in order to continually raise grant applications and heighten output quality impact. This process is facilitated by engaging with the appropriate support structures.

Every year the unit runs a research sabbatical scheme. One-semester sabbaticals are allocated through a competitive application process, informed by a track record of high-quality publications and external funding, along with plans for external engagement and impact and for the strategic and inclusive development of the unit. All staff members are encouraged to apply every seventh semester, regardless of their FTE percentage. Incoming colleagues, so long as they have navigated probation, can access the scheme more quickly, and sabbatical opportunities are promoted for staff members on return from career breaks or other periods of leave. Examples of the diverse activities that have been supported through sabbaticals, across all career stages, are

the development of an ICS (*Jones*), the preparation of research grant applications (e.g. Flexible Homes; total value of the applications £990k; *Jones*), and the production of REF outputs through developmental sabbaticals (*Ring, Charlton*). Sabbaticals also enable staff to refocus on research after maternity leave (e.g. *[text removed for publication]*).

2.1.4. Technical support for research

In parallel with increasing the numbers and the quality of its academic staff, the unit has restructured its technical and administrative support team to facilitate grant applications and the delivery of research. The unit is supported by two technicians (*Purvis, Cosheril*) and one technical manager (*James*). The technical team oversees health and safety in studios and laboratories and provides staff members and PGRs with training on specialised equipment (e.g. 3D printers) and with support and guidance during procurement processes. A dedicated grant development officer is involved in every external submission (see section 3.1 for details of the unit's administrative research support).

2.2. PGRs

The number of postgraduate students in the unit has increased from 25 in 2013/14 to 32 in 2019/20. Completions in this REF cycle increased to 29 from the 10 in the REF2014; none represents a professional doctorate. Currently the unit has 14 home and 18 overseas students; 30 of them are funded through university studentships and 2 externally, through AHRC and ERDF.

In recognition of the value provided by PhDs, we have supported 9 members of staff to carry out doctoral research since 2014, and seven of them have already achieved independent research outputs (*Dawson, Dixon, Messer, Morton, Hatcher, McGuinness, and Reeves*).

Many collaborative PhD projects see our students partnering with major international organisations (e.g. **Thermacore Europe, Ministry of Education of Brazil, Qatar Embassy**). These collaborations occasion invaluable developmental experiences and strengthen our partnerships with external stakeholders.

To rise to the challenge of continuing to increase total postgraduate numbers that are externally or collaboratively funded, the unit has participated in initiatives such as the Northern Bridge Consortium (e.g. *Messer, Jones*) and the **MOBIE** (section 4.1), where a strong collaboration with non-academic institutions is required.

2.2.1. PGRs' progression, training and environment

Student progression is assessed through an initial project approval stage (3-6 months) followed by two progression reviews at months 11 and 23 (pro-rata for part-time students). Our regulations require formal and documented monthly contact between supervisor(s) and supervisee, with a synopsis of the discussion and agreed next steps logged on a central electronic system. All PGRs enrol on the university's Professional Development and Researcher Training Programme, which is

mapped onto the four learning Vitae learning domains. Training consists of a mixture of mandatory and optional sessions, including unit-specific sessions.

PGRs in the unit are based in dedicated PGR suites located adjacently to staff offices. Since 2018, they can access (i) dedicated areas within the new Research Commons space in the University Library; (ii) collaborative and networking space for digital and open scholarship, with bookable rooms for reading, meetings and consultation; and (iii) expert face-to-face support across the research cycle.

University-funded students have access to a budget (typically £3,000 over three years) that covers bespoke research expenses and travel. As well as validating appropriate supervisory teams, the unit's dedicated PGR lead academic (*McIntyre*) organises a welcome and an induction for incoming students and works with the postgraduate community to organise writing retreats, journal clubs, social events, and workshops on careers. The lead also facilitates participation in outreach events and ensures that teaching opportunities are broadly advertised, so that all postgraduate students who want to teach have a fair opportunity to do so.

Students are supported and encouraged to be proactive in organizing their own specialist training events. For example, it was a collective and coordinated request from the PGR community that led, in July 2020, to our institutional membership of the Construction Industry Research and Information Association. Students are encouraged to engage with domestic and international subject-relevant societies and institutions (e.g. RIBA and RICS), and supervisory teams advise them on how to access external research funding (e.g. Research Professional). Using this network of support, students have been able to externally showcase their work and win external funding so as to advance their studies and achieve important awards.

Our postgraduate students have:

- (a) won research design competitions (*Sedgewick* won the NAA William Glover Trust Award – Research Design Award, Northern Architectural Association, and the APS National Student Design Award in 2018, as well as the RSA Student Design Awards in 2020);
- (b) won awards
- for socially engaged research (*Abozied* won the Civil Society Scholar Award in 2016);
 - for the best case study (*Dyca* won the Case Study Award 2020 from the Lincoln Institute of Land Policy and the Association of Collegiate Schools of Planning);
 - for best student talks at conferences (*Babelon* won the best paper award at the AESOP Young Academics Conference, 2016, and *C.Pesce* won the best oral presentation at the 39th Cement and Concrete Conference, 2019);
- (c) secured invitations and fellowships with external partners (*Dyca* was selected as a Fellow for Short-Term Scientific Mission in Nijmegen, Netherlands in October–December 2019, and invited to attend the World Bank conference ‘Land and Poverty 2020’).

NU Science, Technology, Engineering and Mathematics (NUSTEM, REF5a, 4.4) is an initiative for reimagining STEM outreach and of addressing the gap in academic attainment for school-age students with protected characteristics, and especially the under-representation of women and young people from disadvantaged areas. Our postgraduate students proactively engage with NUSTEM and other non-academic communities in order to deliver outreach workshops in schools or at NU, on topics as wide-ranging as ‘STEM and architecture/built environment activities for children and families’, or ‘BIM inspiration day: activities for children and families in architecture/built environment’ (e.g. *Ranathungage*, *Yesiltepe*).

The COVID-19 pandemic has brought specific challenges to staff and PGRs. As well as being given increased flexibility to accommodate these challenges, for example by adapting research plans or through extended deadlines for PGR Annual Progression reporting, PGRs have been able to access a suite of mental health and well-being support services such as counselling.

2.3. Equality, diversity and inclusion (EDI)

The unit recognises that cultivating diversity, addressing inequality and creating vibrant and inclusive research environments are fundamental to our success and sustainability. EDI issues are a standing item on the agenda of Department Management Group meetings, and a department Athena SWAN self-assessment team led by *MacKinnon* is actively working towards submission for a Departmental Award during 2021.

A central commitment throughout the growth and development of the unit has been to integrate its academic members and the wider researcher base into an inclusive community, supportive of all staff, and especially of those with protected characteristics (e.g. with disabilities such as Asperger syndrome: representing 2% of REF-eligible staff). The unit supports university-wide engagement with the Race Equality Charter and its Black, Asian and Minority Ethnic Staff Network (REF5a, 3.6). Currently 20% of REF-eligible staff are BAME, and the continued increase in staff from outside the UK over this REF period (Figure 3) highlights our growing diversity and ability to recruit members who hold non-UK citizenship and further contribute to our multicultural environment.

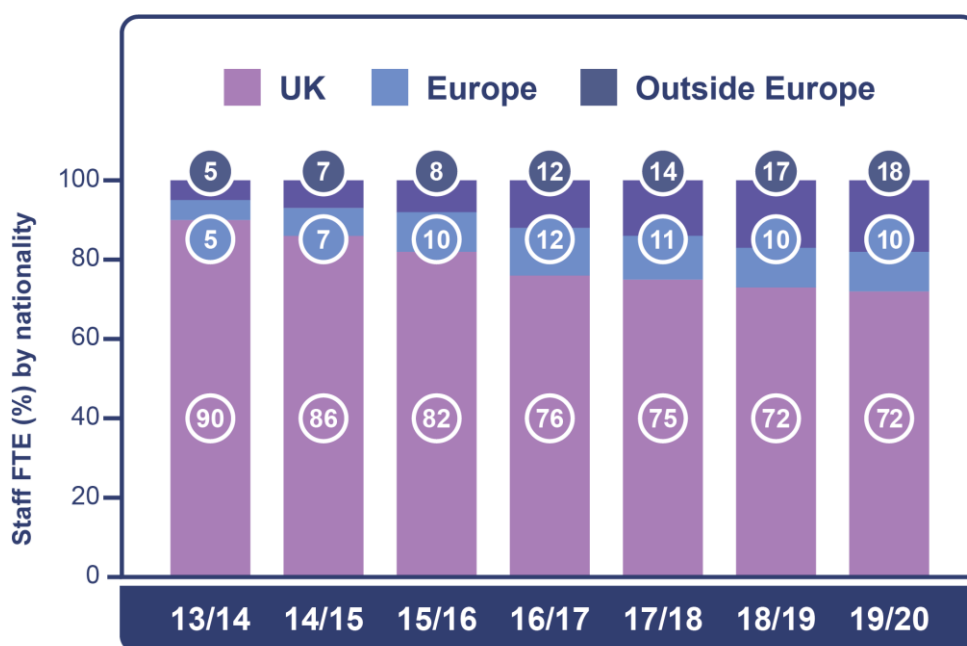


Figure 3: Percentage of staff FTE by nationality over this REF period.

The unit's strategy to improve its EDI is based on (i) a continued investment of effort and resources into rectifying the imbalance that affects young people from BAME and disadvantaged socioeconomic backgrounds who enter architecture and the built environment profession (e.g. we funded a research project led by *Ginge* in collaboration with the University of Moratuwa, Sri Lanka that involves ECRs from BAME backgrounds); (ii) a consciously flexible and inclusive strategy for recruitment and working practices that is overseen by departmental Athena SWAN committees and involves a variety of people in all the stages of the recruitment process; and (iii) compulsory and accessible professional training for all members of staff, so as to raise awareness among them and reduce the occurrence of unconscious bias.

The unit also ensures that all externally facing webpages and social media platforms use balanced imagery and terminology in order to attract to academic and postgraduate opportunities

a higher proportion of researchers who are women and/or from ethnic minorities. All adverts are checked for gender-coding words (<http://gender-decoder.katmatfield.com>).

Within the PGR training programme, sessions on post-PhD career progression are designed to encourage women and ethnic minority students to pursue careers in research and in industry. At present, no staff member or PGR identifies outside of the male–female binary. In addition, the unit has been proactive in promoting **Women in Construction**, to reduce gender inequalities and to showcase the contribution of female architects and surveyors. Our current submission of 15 female staff (equivalent to 32% of eligible FTE staff) compares positively with the 3 female staff submitted in REF2014 (equivalent to 15%), while in the postgraduate community the gender split in PhD completions is 59% female and 41% male.

Formal meetings are scheduled between 10 am and 4 pm, to facilitate the attendance of staff with family responsibilities. The unit aims to keep at least one day per week free of teaching for each member of staff. Bespoke packages of research leave were created to help staff members who return from extended periods of career break, including maternity leave (e.g. *[text removed for publication]* in 2016), by restoring momentum to their research. Tailored research plans for all staff members not included in REF2014 were created. They entail support for one or more of the following elements: workload management, financial research support, mentorship, the creation of internal collaborations. Part-timer staff are entitled to all the career opportunities open to full-time staff (in this REF cycle, eight category-A staff members work or have worked part-time). Policies and support are in place to allow for the possibility of return to full-time work whenever desired.

The unit recognises that good physical and mental well-being is fundamental to maintaining staff vitality and the delivery of sustainable research. A Wellbeing Hub offers a range of supporting materials, including gender-specific matters and carer support, access to a Health Advantage app that provides proactive well-being tools, and additional guidance for navigating the challenges of the COVID-19 pandemic (e.g. guides to remote working). The Wellbeing Hub also coordinates positive action, for example providing free ‘fruit on Fridays’. Mental health is supported by training programmes available to the entire staff, and a parenting network creates a caring space in which members from across the university can meet, discuss and share ideas and experience without judgement.

The final output selection of our REF submission was made on the basis of quality, research groups, and male–female–BAME representation. The aim was to ensure, as far as possible, that the selected outputs were representative of the submitted staff. A diverse mix of staff members participated in the output review and calibration exercises; the UoA lead (*Pesce*) acted as a moderator, to ensure the absence of conflicts of interest.

3. Income, infrastructure and facilities

3.1. Research income and organisational strategies

During the current REF period we have successfully secured over 50 research grants and contracts worth £2.2M, and RGCI of just over £1M. Our researchers received funding from AHRC, ESRC, EPSRC, InnovateUK, Public Health England, the British Council, the British Academy, RIBA Enterprises, RICS, other charitable trusts and public bodies such as Historic England, and the British Council for Offices. Design-led research outputs have often been realised through independent commissions or direct funds such as the Lottery Heritage Fund, and through the **National Trust**.

Highlights for the unit's research income include:

- AHRC (£198k; *Costa Santos*), 'Place & belonging: Exploring placemaking and community'.
- InnovateUK (£233k; *Lockley*), 'Tier2Tier'. Developed a collaborative interface between construction contractors and their supply chain.
- British Council (£133k; *Seo*), 'Development of the incremental structure and infill housing for low-income population in Malaysia'. Developed a new approach to the design of low-cost housing, especially for those who relocate from rural villages or urban squatters.
- InnovateUK (£131k; *Lockley*), a KTP project in collaboration with **Lucion Environmental Ltd**, expanded the company business in BIM.

Processes of grant application development, as well as of grant management, are coordinated by University Research and Innovation Services (RIS). Funding calls, tailored newsletters summarising current opportunities, and UKRI and UKRO funding related news are disseminated via email, call briefing events and workshops, social media and dedicated intranet pages where additional resources are made available – such as examples of previous successful grants on a range of funding topics.

Staff are supported through (1) 'Impact in Funding Bids', which assist PI's in developing frameworks for pervasive impact throughout a proposal; and (2) 'Fellowship Ready' and 'Future Research Leaders' cohort programmes designed to support ECRs and mid-career researchers who intend to develop substantial personal fellowship applications or collaborative research grants.

In 2014, the unit also revised its internal finance models to invest QR funding directly in activities aligned with research quality enhancement and to sustain new areas of success and growth. All staff members can apply for unit QR support, which usually ranges between £500 and £3k per individual per annum and encourages all activities that can positively contribute in the long-term to income generation (examples in section 2.1.4). The outcomes from this outward-

looking resource are tracked by the unit lead and by the director of R&KE for the purpose of continually raising the unit's profile. Sabbatical leave also plays a key role in providing the time for staff to write grant proposals (section 2.1.3).

The ongoing evaluation of research effectiveness within the unit is coordinated through departmental business review meetings and a university-wide committee. Data on a range of research metrics are supplied monthly and quarterly to the director of R&KE and to unit leads; these data allow for investment plans to be modified, so as to meet arising challenges and take advantage of research opportunities.

3.2. Infrastructure and facilities

3.2.1. Architecture studios, workshops, laboratories and community spaces

In early 2019, the unit moved into Sutherland Building (a nineteenth-century grade II listed building, in the centre of Newcastle) after the completion of a bespoke extension hosting architecture studio, offices and community spaces (value £4.8M). Designed by architects from Page\Park, the new home enables the development of collaborative research ideas and opportunities for networking in open plan spaces. The project won the RIBA North East Award 2019, was highly commended by the Scottish Design Awards in Architecture 2019 and was shortlisted for the Glasgow Institute of Architects Awards 2019.

Since 2014, the unit has also benefitted from considerable investments in workshops and laboratories. To support design-led research, we have extended our machining and prototyping facilities through the addition of a Mazak 5-axis CNC milling machine and a range of 3D printers, forming machines and laser cutters; these amount to more than 30 individual tools available to all staff and students – a total investment of £970k, including the associated workshops. These investments have provided our researchers with access to cutting-edge equipment, fostered a high capacity for knowledge transfer and impact opportunities, and ensured that sought-after specialist skills are nurtured and developed in the whole unit, from undergraduates through to PGRs and staff members (e.g. *Jones* made substantial use of the 5 axis CNC and of the 3D printers for his projects, the Humbledon Hill and the Bradpad; see the REF-submitted design-led portfolios).

To assist the **Digital Built Environment** research group, we have improved the existing Virtual Reality and Visualisation (VRV) Suite, which supports BIM and 3D surface analysis research and interactive usage. The VRV Suite played a key role in the development of a Virtual NewcastleGateshead city model, now used in planning processes. Our 3D laser scanners and drones were used to create the model (*Charlton*). A new 3D concrete printer underpins collaborative research with researchers in other departments (e.g. *Kelly* with staff in Engineering).

Our research into innovative sustainable materials for the modern construction industry has been supported by the establishment of a new Material Characterisation Laboratory, which houses a new high-resolution scanning electron microscope and a new powder X-ray diffractometer (total investment £1.35M). A dedicated experimental officer (*Maïello*) was appointed to support staff members and PGRs who use these instrumentations in their research. Research on the development of new sustainable construction materials (*Pesce*) makes extensive use of these facilities. Such projects, developed within the **Construction Futures** research group, also benefitted from the investments made for redesigning and expanding the Concrete Laboratory.

Cross UoA facility access within Northumbria includes, for example, the use of Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) and X-Ray fluorescence by *Pesce*, for his research on the effects of additives on the characteristics of lime.

3.3. External facility access and collaborations

Access to data sources not available internally is facilitated through a range of external collaborations and partnerships. Our staff work with companies and organizations such as **Urban Big Data Company** (Glasgow University; *Adebayo*), **Whythawk** (*Greenhalgh*), the **North East Chamber of Commerce** (representing 3,000 businesses), and the **British Council for Offices** (*Muldoon Smith*). The data shared (and in some cases also the time allocated) by these organizations inform our research and contribute to overcoming the technical barriers around data exchange in the built environment. Further examples of benefits in kind are materials for testing obtained from companies such as **Tarmac**, **Singleton Birch** and **Lhoist UK**.

3.4. Future intentions for our estates

To drive research excellence and to support our researchers, we will make further investments in our estates. We highlight here key priority items for the unit's five-year strategic plan to 2025:

- additional facilities for nanomaterials and materials chemistry and new wet laboratories for research on construction materials;
- a new, state-of-the-art test facility for developing innovative, energy-efficient building technologies, as well as materials and technological solutions for hygrothermal performance and air quality in indoor environments;
- a new building for the International Centre for Connected Construction (**IC3**).

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

Our research has had economic, social and cultural impacts locally, nationally and internationally. We have created systems that aim to educate and reduce inequalities, influenced policies and

designs, and established networks that engage with diverse communities and publics (section 4.4). Our academic reach is global (section 4.3).

Across the unit, during the current REF period we have achieved:

- economic impact – achieved through over 30 externally funded collaborations with industry (e.g. **Historic England**, **Ryder Architecture**, **GT3 Architects**, **Newcastle123 Ltd**), by delivering 10 high-profile industrial speaker events, and by providing leading roles in 8 professional body networks;
- impact on policy and process – achieved by influencing national-level decision-making (e.g. *Greenhalgh* and *Muldoon-Smith's* contribution to public bodies such as the HM Treasury Select Committee and the Department of Business Energy and Industrial Strategy);
- academic significance – achieved through a wide range of national and international indicators of esteem: we won 12 design awards; obtained important placements in 6 national and international design competitions; organised 5 national exhibitions; obtained 8 academic honours and awards; secured 18 memberships of industrial, governmental or international advisory boards; delivered 15 invited presentations and keynotes; organised significant conferences, 7 external to Northumbria, 9 internal; secured 10 memberships of scientific committees of conferences external to Northumbria; secured 18 editorial positions; obtained leading roles in 4 professional and academic body networks; and established international collaborations with academics in 14 countries.

4.1. Major industrial collaborations and partnerships

Our impacts evidence the success of our strategy (section 1.3) in facilitating innovative partnership work that involves large international and national organisations.

Supported by the unit's research-enabling funds, research into BIM supported the continuous international growth of the **BIMAE**. *Lockley* was one of **BIMAE's** key founders, and **BIMAE** has helped to shape international uptake in BIM by conducting activities in the UK, Australia and Hong Kong as well as training schemes in mainland China. Successful projects led by **BIMAE** include work on Durham Cathedral, where *Charlton* was responsible for laser scan data capture and modelling designed to support BIM processes. In 2015/16, **BIMAE** generated £534k in direct consultancy income, £110k in training revenue and >£400k from research projects.

Lockley was instrumental in the creation and development of an open-source BIM tool (xBIM Toolkit) for the automated transfer of accurate and complete information throughout the design, construction, operation and maintenance phases of the building lifecycle. In 2014 *Lockley* received funding from Innovate UK for two major projects on the use of BIM in construction

projects. One of these, 'Tier2Tier', served as a collaborative interface between construction contractors and their supply chain.

Research carried out by *Charlton* and *Thompson* into city-modelling management and visualisations has led to strategic collaborations with local authorities and industry to provide state-of-the-art solutions to urban problems through data-led visualisations. Throughout this REF cycle, such solutions have become increasingly adopted into the planning practices of Newcastle and Gateshead councils, allowing for a more efficient assessment throughout the planning process and helping to save time and costs. Overall, this research has supported the assessment of 20 major developments throughout the north-east (>£1.3B), directly impacting how the associated stakeholders (e.g. local authorities and architects) plan, market and assess new developments (REF ICS *Charlton*).

IC3, based at and led by NU, is a recently established centre of excellence for digital construction. Industry and academic partners include Dynamo North East, Newcastle University, Newcastle City Council, Gateshead Council, NorthstarVentures, Ryder Architecture, Space Group, NBS, Womble Bond Dickinson, Waterstones, Arup, Cundall, and **BIMAE**. The Centre fosters world-leading research and innovation, in collaboration with industry and the public sector, and champions the use of digital technologies to drive productivity, improve safety and procure for value across the entire building and infrastructure lifecycle. **IC3** has already secured £100k of funding from the NE LEP and £50k for the seedcorn stage of UKRI Strength in Places – Wave 2, and this has enabled the submission of a £44M partnership with UKRI and the North East Local Enterprise Partnership including £7.5M of private investment.

The recently established **MOBIE–Northumbria Homes for the Future Innovation Centre** (*Jones*) helps businesses involved in the design and delivery of homes to access the latest in research and innovation at NU so as to transform the sector. The centre investigates new methods of construction, design, offsite manufacture, digital competencies and materials – all with the aim of making housebuilding a more efficient and precise process, while ensuring that the needs of residents and communities are met. From 2020 to 2022, Northumbria will offer 15 jointly funded PhD studentships whose recipients will work with industry partners through the centre. The first intake of PhD students (delayed by six months as a result of the pandemic) will start in April 2021.

4.2. Transforming practices and perspectives, influencing policies and networks

Since 2012, staff members in the **Architectural Design** research group have undertaken research devoted to enhancing and protecting significant heritage assets in the north of England such as the Gibside estate and Durham Cathedral. Using design-based and historical research, the team (led by *Jones* and *Ring*) has developed design solutions that have been used by a range of organisations to acquire external funding to support the redevelopment of heritage assets that total >£50M. In turn, this has led to a significant boost in visitor numbers and has generated new revenue. The innovative collaborative work done by members of **Architectural Design** and the

National Trust on the Gibside estate has become widely known as ‘the Gibside model’ and functions as a paradigm of best practice in guiding the development of other heritage sites across the UK (REF ICS *Ring and Jones*).

Research by *Greenhalgh* and *Muldoon-Smith* on changes to business rates was used as evidence during the House of Commons’ Communities and Local Government Select Committee’s enquiry into the business rates retention scheme (2016) and the Treasury Select Committee’s enquiry into the impact of business rates on business (2019), directly informing legislative scrutiny into the commercial tax reform. In addition to being adopted among policymakers, the research carried out in the unit shaped business response to the reform (i) nationally, through the **British Council for Offices**, which represents over 3,000 companies, and (ii) regionally, through the **North East Business and Innovation Centre**, which represents 130 businesses, and the **North East Chamber of Commerce** (REF ICS *Greenhalgh* and *Muldoon-Smith*).

4.3. Academic significance

4.3.1. International collaborations

The allocation of unit QR funds has supported staff to develop strategic relationships with the most relevant partners nationally and globally, to access networks, to pursue research avenues and to extend the reach of impacts. Here are some examples of the wide reach of our international collaborations: Asia: Universiti Teknologi Malaysia and Korea Institute of Ecological Architecture & Environment (*Seo*), Sultan Idris Education University (Malaysia; *Alvanides*); Europe: University of Genoa (Italy) and Sorbonne Université (France; *Pesce*); Universidade de Lisboa (Portugal; *McIntyre*), Delft School of Architecture (Netherlands), Belgrade University Faculty of Architecture (Serbia), Skopje (Macedonia; *Giddings*), Bergische University Wuppertal (Germany; *Ozbil Torun*); America: American University School of Architecture and University of Michigan-Flint (MI, USA; *Ozbil Torun*); Tecnológico de Monterrey (Mexico; *Alvanides*), Universidad Nacional de Ingeniería (UNI) (Lima, Peru; *Messer*). Australia: Sydney University (*Ozbil Torun*).

Evidence

Our international partnerships have doubled the proportion of journal articles with international co-authors written during this REF period by comparison with REF2014 (source: Scopus, Oct. 2020, outputs with Northumbria’s address).

Dalton’s collaboration with ETH’s Future Cities Laboratory in Singapore produced an interdisciplinary line of research on the creation and development of a mobile phone game app, Sea Hero Quest (SHQ), as part of the activities of a cross-institutional team comprising experts from UCL, Cambridge, **ARUK**, and two global communication companies, **Deutsche Telekom**

and **Saatchi & Saatchi**. SHQ is designed to gather crowd-sourced data on normal navigational ability in order to further dementia research. Since its official launch in 2016, SHQ has been played by approximately 4.3M users, generating extensive data and hence contributing substantially to the development of our knowledge of dementia, as well as boosting public awareness of the disease (REF ICS *Dalton*). The unit has supported this research with QR funds for hiring a RA for the collection of secondary data and with time allocations for the leading researcher.

4.3.2. Discipline contributions

Members of our unit published over 580 outputs in this REF cycle – the equivalent of a 148% increase from the 234 outputs published in the previous REF cycle (source: SciVal). Our outputs include prize-winning architectural designs of international disciplinary significance and articles in high-impact journals (evidence in section 1.1).

Evidence

Over 21% of our journal and conference papers are among the 10% most highly cited titles in the field (field-weighted by subject area, publication date and output type; source: Scopus, Oct 2020).

The unit supported its staff in organising events and conferences, both financially and operationally (e.g. with time allocations for organisers). Here are a few examples.

- (i) The 36th CIB W78 2019 Conference, focused on ICT in design, construction and management in architecture, engineering, construction and operations, was organised and chaired by *Kumar* and held at NU. The conference attracted some 150 delegates from around 30 different countries.
- (ii) The 'IV Young Researchers' Forum' of 2017 was organised and chaired by *Pesce*. Over 30 PhD students and ECRs from academy and industry, from UK and European organisations, presented their research on new construction materials. The event was supported by the Institute of Material, Mineral, and Mining (IOM³), the Institute of Concrete Technology, and the Society of Chemical Industry.
- (iii) *Messer* organised the 2015 RIBA Design through Production, which was promoted by the RIBA and RIBA Academic Member schools of architecture and sponsored by the IOM³.
- (iv) In 2015–2016, *Jones* organised a conference and workshop in three venues – Newcastle, Bangalore, and Montreal – on the cultures of creativity. The conference was entitled 'Cultures of Creativity and Innovation in Design' and funded by the AHRC's International Research Network Grant.

Further disciplinary and scholarly contributions have been made by staff members who act as editors of scientific publications (*Environment & Planning B: Urban Analytics and City Science*; *Alvanides*) and as associate editors of journals such as *Frontiers in Psychology* (*Seo*), *Architecture and Urban Design* (*Giddings*), the *Journal of Transport & Health* (*Alvanides*), *IE: Studio* (*Ring*),

Engineering, Construction and Architectural Management and the *Electronic Journal of Information Technology in Construction* (Kumar).

Our staff members have peer-reviewed articles for more than 30 journals, for example *Nature Communications*, *Habitat International*, *Energy Policy*, *Building and Environment*, *Construction and Building Materials*, the *Journal of Cultural Heritage*.

Our researchers also support funding bodies' vital work of reviewing and selecting projects for funding (e.g. *Giddings* for AHRC and *Alvanides* for EPSRC), and have been involved as external examiners in PhD examinations across a range of national and international institutions (e.g. the universities of Oxford, Huddersfield, Heriot-Watt, Salford, Leeds-Beckett, and Aberdeen in the UK; Chalmers University in Sweden and the University of Copenhagen in Denmark abroad).

4.4. Community and public engagement

Staff from the unit (e.g. *Holgate*, *Stonehouse*, *Kirk* and *MacKinnon*) and PGRs contribute to engagement activities through NUSTEM and the North-Eastern Educational Research Association. Research topics related to STEM activities span architecture and well-being, assessment for learning, and the improvement of children's perceptions and uptake of STEM subjects (section 2.2.1 for information on NUSTEM).

Holgate received the RIBA Research Award in 2017 for a collaborative project with Professor MacClean (Robert Gordon University) on mental health in UK architectural education. Members of the unit have also been involved in organizing exhibitions. The 'Northern Landscapes Exhibition: Capability Brown', at Alnwick Castle and Gardens, was organized by *MacKinnon* in 2017 and attended by over 50,000 visitors. In 2019 *Bertolino* organized the international exhibition 'The City of Commons', held in Pavia (Italy), and *B.Couture* co-organized the exhibition 'Re-Imagining Gibside Hall' for the **National Trust**.

REF2021 summary

Overall, this submission demonstrates a sustained upward trajectory in the research performance of the UoA13 at NU and is substantially different from the unit submitted in REF2014. We base this claim on (i) the quality and relevance of our research outputs, as indicated by citation metrics and the design awards obtained, (ii) the success of our research strategies, which have enhanced and will sustain our environment, our PGR community, and our infrastructure, and (iii) the significant contributions we made to the disciplines and to relevant policymakers. The breadth and calibre of our staff means that we are exceptionally well placed to address future challenges to the built environment and to continue producing agenda-setting research. Our unit leads activities such as the **IC3** and **BIMAE** and substantially contributes to projects such as **MOBIE**, which provides the underpinning for a vibrant and sustainable research environment into the future.