

Institution: Nottingham Trent University (NTU)
Unit of Assessment: C13 - Architecture, Built Environment and Planning
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 Context and Structure</p> <p>NTU's submission to the Architecture, Built Environment and Planning Unit of Assessment (UoA) comprises 18.6 FTE staff from the School of Architecture, Design and the Built Environment. The School provides a broad range of undergraduate and postgraduate programmes in architecture, construction, property management, civil engineering and product design. Our research addresses key aspects of the creation and management of the built environment and its components.</p> <p>Implementation of our research strategy since REF2014 has delivered:</p> <ul style="list-style-type: none"> • a steady and sustained growth of research activity in the UoA with over 300 journal papers, 152 conference presentations, 50 book chapters, 2 authored books, and 2 edited books produced; • an increase in staff with responsibility for research from 11.2 FTE to 18.6 FTE in comparison to the previous REF period; • significant growth in research income from £865k to £3.355m; and • a three-fold increase in PhD completions from 13 to 40. <p>A significant development since REF2014 has been the establishment of three formal Research Centres, building on the four research groupings during the last assessment period. They are: Centre of Architecture, Urbanism and Global Heritage; Centre of the Built Environment; and the Product Innovation Centre. This structure reflects areas of research strength and provides clear alignment and integration of research and teaching in the School and has been the focus of targeted investment in research leadership and capacity.</p> <p>These Research Centres have driven the transformation of the research culture within the School. They are formal, cognate, and coherent research entities with clear leadership and review processes. They provide critical mass, enabling collaborative and dynamic team research to address changing societal and funder interests. Each Centre has a focused disciplinary purpose: disseminating its research through publications in world-leading journals; generating income through funding council awards and government grants; and co-producing distinct and demonstrable impact with end-users. Led by a Centre Director, they have membership ranging from professors to PhD students, enabling mentoring support for Early Career Researchers (ECRs) from experienced researchers and integrating PhD students into the research environment.</p> <p>The leadership and focus of the Research Centres have fostered collaboration across different subject areas within the School, crucially permitting researchers to come together to address key societal challenges that necessitate a multidisciplinary approach. The UoA has experienced staff turnover, but this became an opportunity by a combination of selected strategic external appointment and determined internal capacity building. For example, the appointment of Abdelmonem in 2016 enhanced the leadership in global heritage research, re-energising an area of established strength and leading to his leadership of this research at an institutional level. Further the appointment of Wu in 2020 brought strength in digital construction that has also been applied to serious gaming for prevention of gender-based violence during the REF period. Through internal promotion, Ianakiev has brought senior leadership on low energy housing and the reduction of fuel poverty.</p> <p>Centre of Architecture, Urbanism and Global Heritage (Abdelmonem, Chalal, Medjdoub, Mendoza, Soar and Souto). This Centre builds upon the outstanding heritage research undertaken in the School over the last two decades. It investigates the human aspects of</p>

architecture, spatial practices, urban heritage, material culture and the built environment within the ever-changing urban and social structures of contemporary cities which are forging new territories of interaction, innovation, creativity and analysis. A well-equipped Creative and Virtual Technologies Lab enables advanced digital media to explore the design and preservation of buildings. This Centre is pivotal to the national and international prestige of NTU's research priority on Global Heritage: Science, Management and Development.

Its reputation is reflected in grant successes (for example, £550k by **Abdelmonem** from AHRC and British Academy; and £35k by **Souto** from the Heritage Lottery Fund), widening international collaborations (Egypt, Jordan, Iraq) and public engagement in Nottingham using virtual platforms during the major redevelopment of Nottingham Castle. The Centre's research underpins an impact case study on smart preservation of urban and cultural heritage in the Middle East (REF3).

Centre of the Built Environment (Akib, Bull, Cutsforth, Ianakiev, Koblyakova, Manu, Mohammad, Pasquire, Sun, White, Wright, and Wu). Research in this Centre spans a wide spectrum from sustainable buildings and energy, to real estate economics and finance, lean construction, project management, procurement, and civil engineering. The overarching aim is to ensure that buildings and infrastructure are fit for purpose, resource efficient, and sustainable. The Centre generates new insights into technical, social, economic and management challenges facing the building industry which in turn inform policy-makers and provides knowledge and tools to building professionals. In so doing, its research builds upon disciplines that have been present since the School was created. The Centre plays a key role in NTU's strategic priority on Sustainable Futures.

The wide range of research areas has received funding of over £1m, including the REMOURBAN project (£800k, led by **Ianakiev**) on pioneering a sustainable urban regeneration model in the City of Nottingham. This interdisciplinary EU H2020 project, combining engineering with social science, and involving 22 partners across 7 different countries, developed sustainable energy solutions for social housing and is the basis of an impact case study (REF3).

Product Innovation Centre (Al-Habaibeh, Su, and four FTEs submitted to UoA D32). Research in this Centre spans both REF2021 UoA C13 and D32, covering design, manufacturing, and consumption of products. Researchers study the product life cycle from a multidisciplinary perspective, with special emphasis on resource efficiency and consumer needs. The Centre's aim is to contribute to global sustainable development goals, the economic competitiveness of UK industries, and the improvement of quality of life for individuals, local communities and wider society. Along with the Centre for the Built Environment, the Centre plays a key role in NTU's strategic priority on Sustainable Futures.

Reflecting their research contributions, members of the Centre within UoA C13 have wide connections with industry and international collaborations. This has supported grant successes, including circa £1m from the EU H2020 Circular Economy programme where the project CIRC4LIFE is led by **Su**, with a total budget of 6.3m euro and 17 partners from 7 countries.

1.2 Evidence of Achievement of Strategic Aims for Research and Impact

1.2.1 Achievement of REF2014 Strategic Aims

Three strategic objectives were outlined for this REF period in REF2014:

- (1) to develop a stronger research culture, evidenced by increased research funding capture and an increase in high-quality outputs.
- (2) to adopt a holistic approach to identifying research impact strategies for the grand challenges facing society, including sustainability and the low carbon agenda.
- (3) to work with the University's Doctoral School to increase the number of PhD students and therefore enhance the research culture within the School.

Success within the UoA is evidenced by achievement of these strategic objectives as follows:

- There is a strong and growing research culture in the School, illustrated by both the breadth and quality of its research activities. Significant strategic investment has led to a 66% increase, 11.2 to 18.6, in FTE for this UoA since 2013.
- During the REF2021 period, the total research income for this UoA increased by 287%, from £865,200 for REF2014 to £3,355,024. Income per FTE rose by 133%, from £77,250 to £180,377. £2m of the total was from highly competitive UKRI and EU H2020 sources.
- There has been a significant improvement in both quantity and quality of research outputs. The number of international peer-reviewed journal papers increased from 117 to 301 and 31.9% of these were published in the most highly-cited 10% of journals (SciVal).
- Sustainability and the low carbon agenda have become major research foci for the UoA. The impact case study “Developing Sustainable Energy Solutions for Existing Homes” exemplifies our success in this field.
- PhD and Professional Doctorate completions increased three-fold, from 13 during REF2014 to 40 during REF2021.

The success is underpinned by a combination of sustained investment and clear research leadership. The School Research Management Team is led by the Associate Dean for Research (ADR) (**Sun**), a role created for all academic schools at NTU since 2014. The Team also comprises the three Research Centre Directors (**Abdelmonem**, **Al-Habaibeh**, **White**) and Postgraduate Research Tutor (PGRT, **Souto**). The ADR is a member of the University Leadership Team and the Academic Research Leadership Team and collaborates closely with the Deputy Vice-Chancellor - Research and Enterprise. This wide engagement ensures the alignment of the School research and impact strategy with the institutional strategy - ‘Creating the University of the Future’ - which in 2015 adopted a theme of Valuing Ideas, encapsulating the research ambitions of the University (details in REF5a).

The Research Centre Directors have developed their leadership through additional specific responsibilities. **Abdelmonem** leads one of the five University research priority areas, in Global Heritage: Science, Management and Development. These priority areas underpin the collaboration across disciplines necessary to address the major challenges facing society. **White** is the UoA coordinator for C13 and **Al-Habaibeh** has an institutional leadership role as Director of the EU H2020 Extended University Alliance Doctoral Training Alliance in Energy, Applied Biosciences for Health and Social Policy programme (2018-2023) which is a collaboration between 12 universities in England and Wales with associate partners in Europe and Australia.

As Centre Directors, they lead development of research within their Centres and, along with the professoriate, collaborate with internal and external partners, provide opportunities for members of their Centres to participate in funding bids, and work in partnership with colleagues producing high-quality outputs. They review the Individual Research Plans of colleagues in their Centres to ensure that objectives are set and met and areas for development are addressed. All Research Centre Directors are engaged in joint research work with colleagues in their own Centre as well as working across other Centres.

Working in collaboration with research active staff, the Research Management Team is responsible for developing and implementing the School’s research and impact strategy. An annual School Research and Innovation Plan is developed which reviews achievements of the past year and sets objectives for the forthcoming year. Investment is targeted explicitly to support delivery of objectives and success is reviewed annually.

These Research Centres have been further supported by institutional investment of around £450k. This has been used to enhance their capacity and capability, support early career researchers with development of academic networks and bids, and to support C13 staff more broadly against agreed objectives, for example:

- **Souto** was funded to support the development of her work on the role of architecture in community empowerment.

- **Koblyakova** received resources to purchase data that gave access to information to support research on the Help-to-Buy scheme and to collaborate with the Scottish Government which is examining the implementation and efficiency of the scheme in Scotland.
- **Pasquire** was enabled to hold industry showcase events linking academics with industrial partners to develop external funding opportunities for lean project management research.
- **Ianakiev** received funding to support the analysis of the quality of life effects of his EU H2020 project.

1.2.2 Research Impact Strategy

Development of impact has been a key theme throughout the current REF period based on the UoA's strategy for REF2021 which aimed for greater engagement with partners in the design of research projects and investment in impact-generating activities within research projects. The UoA's REF2014 submission also identified sustainability and development of a low carbon society as a major new cross-cutting research focus and consequently a major focus for impact. Innovation in the approach to impact was central to this activity from the outset. The UoA has developed a range of sustainable mechanisms to help incubate the best impact from our research at all stages, and has targeted resources, including funds, studentships and staff time, towards prioritising impact pathways.

Since REF2014, the UoA has been successful in growing our research impact through the input of substantial external funding of around £2m being enhanced by local investment of £300k in impact through 5 internally funded PhD studentships: 2 in retrofit of existing homes and low temperature district heating (**Ianakiev**); 1 in energy efficient LED lighting (**Su**); and 2 in renewable energy solutions (**Al-Habaibeh**). Furthermore, this growth has also been made possible through a commitment to knowledge co-production throughout, with agencies acknowledged as the users (e.g. policymakers, public sector bodies delivering services, SMEs) of the findings shaping both research questions and dissemination. The delivery on the impact strategy integral to these research programmes can be seen in the impact case study on retrofit of social housing. Over 460 households benefited from warmer homes and simultaneously lower energy costs as a result of the research supported by the EU H2020 REMOURBAN project. For residents previously at risk of experiencing fuel poverty, the research enabled them to heat their whole homes without worrying about energy cost. Set within a deprived area, the project not only enabled improvements in wellbeing for residents but also enhanced the physical appearance of buildings. In conjunction with Nottingham City Council and Nottingham City Homes, the internally funded PhD research allowed for both the delivery and evaluation of impact with consequent lessons for wider use of the approaches.

Further evidence of important impact can be seen in: the work of **Koblyakova**, mentioned above, who worked with the More Homes and Better Homes Divisions of Scottish Government to frame the research; **White's** innovations in flexible office valuations (funded by RICS Research Trust) which has potential to change the real estate industry's approach to valuing this asset class; **Wu's** collaboration with Network Rail which led to a digital solution for automatic defect detection that has been applied to the maintenance of over 50 railway bridges; and **Abdelmonem's** collaboration with research users in Egypt, Jordan and Iraq which developed the impact case study related to policy change for architectural heritage in the Middle East.

1.2.3 Research Quality Strategy

In parallel with the emphasis on impact, the School has built a culture of research excellence. The Research Centres introduced above are a key part of this through the day-to-day, often informal, mentoring and support alongside more formal review systems. An internal peer review system has been put in place where all funding applications are reviewed by the Associate Dean for Research, and by internal reviewers when appropriate, to ensure quality bids generate improved success rates. Furthermore, an output review system has been introduced to collect evidence of output quality and to seek progressive improvement. A rigorous progression

monitoring system is in place to provide clear milestone checks and ensure timely completion of PhDs (see Section 2.2).

After REF2014, NTU created a more structured and transparent approach to the allocation of research time in order to support staff with the ability or potential to deliver high-quality research (REF5a). This is supported by the Individual Research Plan (IRP) system, where academics have an allocation of research hours within the workload planning process. Each IRP is assessed on capability to deliver at the requisite level based on previous performance across, for example, research outputs, impact generation, and research grant capture (with allowance for stage of career and other key equality and diversity characteristics). This performance-based approach to research-time allowances has led to the sustained increase in both quality and quantity of outputs.

The Annual School Research and Innovation Plans articulate the approaches outlined above and contain overall objectives for PhD recruitment, income generation, and support for research development of staff at different levels of career development, ranging from early career researchers to professors. The plans support the work of Research Centres which, in turn, enhance the development of quality outputs, funded projects, development of research impact, and enhancement of the research environment.

1.2.4 Research Ethics and Research Integrity

NTU is strongly committed to maintaining the highest standards of integrity and probity in the conduct of research. The University expects that all those engaged in conducting or facilitating research have an individual and collective responsibility to uphold the principles of research integrity which are set out in the Concordat to Support Research Integrity and apply to the whole research lifecycle.

Matters relating to research integrity, including research ethics, are overseen centrally (see REF5a) and managed locally. The University Research Committee, chaired by the Deputy Vice-Chancellor – Research and Enterprise, and reporting to Academic Board, is responsible for the development and monitoring of research integrity policies and procedures. The University Research Integrity Sub-Committee has responsibility for the implementation of the Concordat to Support Research Integrity and the production of a publicly available annual statement on research integrity, which is presented to Academic Board. A Code of Practice for Research; Research Ethics Policy and Procedure; Research Data Management Policy; and Responsible Metrics Statement provide the policy framework.

Robust scrutiny of projects undertaken by staff and PhD candidates in the School of Architecture, Design and the Built Environment is overseen by a committee including reviewers from the School of Art and Design and the School of Arts and Humanities, in addition to those from the School of Architecture, Design and the Built Environment. This approach ensures projects are scrutinised from different disciplinary perspectives which is a key issue given the multidisciplinary nature of the UoA. Undergraduate and Postgraduate Taught student research is also subject to ethical review, where needed, and this is undertaken by a committee operating at School-level.

Training resources are available to all staff and students in the form of online modules which cover issues of research integrity. This central resource complements training arrangements at local level, which are designed to meet the needs of specific ethics committees. Staff with significant responsibility for research provide annual positive confirmation of their commitment to uphold the standards in the Code of Practice for Research.

1.3 Future Strategic Aims for Research and Impact

The UoA's strategy for the next five years exemplifies its synergistic approach to research and impact. Further enhancement of the research culture and increase in capacity will be achieved, firstly, by determined improvements in process:

- Embedding a publications strategy that further enhances originality, rigour and significance of research outputs through collaboration, appraisal, and mentoring.
- Sustaining the growth trajectory of the UoA's research scale and quality with new appointments, external collaborations focused on the topics set out below and by delivering impact for stakeholders from a wider range of sectors.
- Enhancing the international profile and impact of key research themes by supporting ever more co-creation of research with external partners to address societal grand challenges.
- Developing collaborative networks that will further support development for early career researchers.
- Increasing research and impact funding particularly from UKRI through mentoring, appraisal objectives and engaging with the University's professional research support services.
- Strengthening research culture through engaging more academic staff in research and further integrating PGR students within our Research Centres.

Secondly, the strategy will be delivered by significant development of current areas of interest as well as the creation of new ones as issues facing research users change, opportunities for interdisciplinarity arise, and new staff are appointed. Thus, current research themes will expand in breadth and depth in the next REF period. Central to this rapid evolution will be major institutional investment in cultural heritage (**Abdelmonem, Mendoza, Souto**) underpinned by a £500k per annum commitment to increasing capacity and capability. This initiative, led by **Abdelmonem**, is the first of NTU Research Peaks to be launched and which exemplify NTU's approach to strategic growth of both research excellence and societal impact. This investment will recruit 3 early-career research fellows on a fast-track to an academic post along with several fractional professorial posts from renowned international institutions, thereby enhancing excellence, sustainability, and international reputation (REF5a).

The focus on low temperature district heating and low carbon housing (**Ianakiev**) will gain additional momentum and further support from deepened collaboration with Nottingham City Council as it seeks to deliver its espoused goal of being carbon neutral by 2028. This ambition is also a key part of the Universities for Nottingham (UfN) Civic Agreement which brings together the city's two universities, local authorities and health trusts, all of which have ambitious targets for carbon reduction.

There will also be developments in: sustainable energy for wellbeing (**Akib, Bull, Cutsforth, Chalal, Ianakiev, Sun, White**); mortgage markets and market liquidity (**Koblyakova, White**); housing economics and property investment (**Cutsforth, White**); and construction project management (**Manu, Sun, Wu**). Extensive collaboration with research users and academic partners as well as our multidisciplinary expertise will enable the UoA to spot and respond to future challenges brought about by technological and societal changes.

Importantly, these areas will be embedded within the three Research Centres. This will mean effective coordination of a spread of activities while permitting academics to work collaboratively within and across centres. This will support interdisciplinarity and thus the fulfilment of the complex needs of research users by providing them with innovative research-based solutions. Set within the wider University research support ecosystem, the Research Centres will provide the context and structure for meeting the objectives set for the next five years and the next REF period. They will continue to grow and evolve to match the research ambitions of the UoA and its external commissioners and partners.

2. People

2.1 Staffing Strategy and Staff Development

The UoA submission comprises 18.6 FTE. Just under 50% are professors, the remainder being lecturers with one (0.4 FTE) associate professor. Our submission covers five (4.2 FTE) female and two ECR staff members.

Investment in research leadership has been at the centre of our staffing strategy. During the review period, two strategic professorial appointments were made to expand our existing research strengths in global heritage (**Abdelmonem**) and construction management (**Wu**). The UoA also benefited from recruitment of internationally-leading researchers to strategic leadership positions. **Wright**, a leading expert in flood risk management and climate change adaptation, joined NTU as Deputy Vice-Chancellor - Research and Enterprise. **Bull**, who has a research track record in sustainable energy use, joined as the Deputy Dean of the School. **Sun**, an internationally-leading researcher in construction IT and project management, joined the School as Associate Dean for Research.

Another pillar of our staffing strategy is development support for existing staff. An Individual Research Plan is submitted by each member at the start of an academic year. As noted above, this articulates the key research objectives to be achieved and the resource support required. Members are supported with research time allocation, PhD studentships and pump-priming internal funding, depending on potential and achievement. Emerging research leaders are recognised with promotion against clear performance criteria. During this REF period, two members of staff (**Al-Habaibeh** and **Ianakiev**) have been promoted to professor and **Manu** was promoted to associate professor.

Investment in younger researchers has been manifested through four lecturer appointments during this REF period (two ECRs, **Chalal** and **Cutsforth**, one promoted to associate professor, **Manu**, and one senior lecturer, **Akib**). These young researchers add breadth and dynamism to the UoA. They are working with professors in their respective subject areas and contribute to integrating PhD students into the School's Research Centres. Since the previous REF, we have had staff turnover (Bandyopadhyay) and staff retirement (Hoxley and Sarshar); succession planning is an active consideration by the Dean of the School and the ADR to ensure sustainability and vitality of the research community.

The different sources of funding and broad interests of research users mean that researchers need to work in innovative ways with non-academic partners to ensure projects are funded and findings contribute to meaningful societal change. Evidence of achievement is captured through the professorial review process that is run bi-annually. Review meetings are held between the professor, ADR, Dean of School and the professor's head of subject. These provide opportunities to discuss performance and identify areas of strength and areas for further development. As the University places significant emphasis on enhancing research development and achievements, the Dean of School then discusses each professor's evidence of achievement with the Vice-Chancellor and Deputy Vice-Chancellor - Research and Enterprise.

The just over 50% of staff who are lecturers/senior lecturers in this submission benefit from consistent application of the NTU appraisal system (see REF5a). As a consequence, they have all had the opportunity to access support and to demonstrate evidence of producing research income and quality research outputs; in some cases they have already started to show significant impact. Each lecturer is associated with one Research Centre within the School and mentoring is provided by the Research Centre Directors. The annual IRP feeds into appraisal to ensure research objectives are considered alongside wider objectives.

An interim review and final review meetings are held with mentors to monitor progress and make necessary adjustments. Internal funding is provided to support research development; this has become an integral component in the Annual School Research and Innovation planning process.

2.2 Support Mechanisms for, and Evidence of the Training and Supervision of Postgraduate Students

The School has a growing and vibrant PhD community. Increasing the number of PhD students, currently at around 70, has been an explicit component of Annual School Research and Innovation Plans during this REF period. It has been supported by the University through 18 PhD scholarships that have been targeted to support research areas within the School and have helped attract high-quality PhD students through a competitive process. This University PhD bursary scheme has funded studentships with **Abdelmonem, Al-Habaibeh, Ianakiev, Koblyakova, Sun and White**. A further 4 students have been funded through the UoA's involvement in the H2020 COFUND DTA (see Section 4).

The University's Doctoral School plays a key role in supporting the development of PhD students by running training and development programmes covering generic skills related to undertaking and completing a PhD study. This includes a researcher skills development programme that includes live webinars, online learning resources and research engagement events. Furthermore, the Doctoral Employability Resource available on the Online Workspace provides information and activities to support students for job searching and future careers.

This training is complemented by more specific training within the School, for example research methods for specific subject areas. In addition, the School provides opportunities for career development for PhD students to become academics by providing teaching experience through contributions to UGT and PGT degree programmes. The Doctoral School liaises with PhD supervisory teams to provide support for all aspects of the student's PhD experience, from initial project approval, ethical approval, annual research progress reviews and transfer from MPhil to PhD, to the final submission of thesis to the University's institutional repository (iREP). Supervisory arrangements are governed by the School Research Degrees Committee that reports to the University Research Degrees Committee. All postgraduate research students are allocated a Director of Studies (DoS) and at least one other supervisor along with an independent assessor.

Weekly seminars, organised by the Postgraduate Research Tutor, are held for PhD students to present their research to other PhD students, supervisors and the wider School. In addition, further seminars are held with presentations from research active staff on a monthly basis. These seminars have proved very popular with around 70% of PhD students participating regularly, including during the Covid-19 lockdown period when they have run virtually. PhD Supervisors, the PGRT and the ADR also attend these.

During this REF period, there has been a significant increase (200%) in the number of PhD completions within the UoA compared with the REF2014 period. Two research-based professional doctorates were also awarded. The number of awards for PhDs and Professional Doctorates is reported in Table 1 below.

Table 1: Number of Research Doctoral Degrees Awarded by Academic Year.

UOA C13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
PhD	2	5	6	10	8	5	4
Prof Doc					1	1	
Total	2	5	6	10	9	6	4

2.3 Evidence of How the Submitting Unit Supports and Promotes Equality and Diversity

The School is a vibrant place to work, enriched by the diversity of perspectives, cultures and backgrounds brought by our students, staff, visitors, and local, national and international partners. Within all three Research Centres, we recognise that diverse teams encourage more

creative and innovative solutions to the development and management of the built environment and its components.

NTU was awarded bronze Athena Swan charter mark in April 2019 (see REF5a) and targets a silver submission in 2023. Supporting this, our School strategy aims at departmental Athena Swan submissions from 2022; application teams are currently conducting reviews, including cultural surveys on gender identification, promotion prospects and support, as a basis for developing an action plan for moving towards further gender equality. The School's Athena Swan champion ensures local funding and promotion panels are inclusive and diverse; monitors and reports EDI data related to equality of opportunity (funding, studentships and promotions awarded); and co-ordinates School-level EDI activities. These include six nominations to the Advance HE Aurora programme, events for International Women's week, Black History month, LGBT History month, the installation of an on-campus nursing room for nursing mothers, and maintenance of an EDI intranet with links to staff networks, policies and resources.

Recruitment across the School has transitioned, through gender decoding of recruitment materials and mixed-gender interview panels, to attract a more diverse staff pool. Staff training improves knowledge and understanding of equality and diversity within the workplace and we have introduced essential unconscious bias training for all staff. The Support of Academic Returners (SOAR) scheme funds up to £5k following a period of caring-related leave to support career pathway development.

In this UoA, 4.2 FTE (headcount 5) are women, one of whom is a professor (**Pasquire**) and the others are lecturer/senior lecturer (**Akib, Koblyakova, Mendoza** and **Souto**). Retirements in coming years will provide new opportunities for achieving gender balance; NTU has set a target of 35% of its professoriate to be female by 2025. 10 members of the UoA are from ethnic minority backgrounds, 7 of whom are professors, 1 is an associate professor, and 2 are lecturers. 4 members of the UoA are from other European countries.

Staff perception of EDI issues is very positive. For the main departments composing our Research Centres, the 2018 staff survey showed 77% agreement with *all* statements of equality of opportunity and protected characteristics, including "I believe the University is committed to equality of opportunity for all of its staff" (86%) or "I feel the University acts fairly, regardless of protected characteristics regard to development opportunities" (77%).

3. Income, infrastructure and facilities

3.1 Income

In a challenging and competitive environment, external research funding has been captured from a range of sources. These include EU H2020, AHRC, Royal Society, EPSRC, ESRC, British Academy, Innovate UK, charities and private companies. A total research income of £3.355M during this assessment period represents a 287% increase compared with £865k achieved for REF2014. This has been instrumental in building a strong and vibrant research culture. Table 2 below, shows annual research income generated during this REF period.

Table 2: Annual Research Income (£)

Year	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
Income	682,470	401,089	598,333	445,740	117,913	537,452	572,027

Major prestigious grants cover the School's research priorities of environmental sustainability and global heritage and include:

- EU H2020 - CIRC4Life: A circular economy approach for sustainable products/services (£1m).

- REMOURBAN: REgeneration MODEL for accelerating the smart URBAN transformation (£800k).
- zEPHYR: Towards a more efficient exploitation of on-shore and urban wind energy resources (£250k).
- AHRC– LABYRINTH: Conservation, Analysis and Virtual Reconstruction of Archaeological site of Hawara Pyramid and Labyrinth (£230k); GCRF Development Award: ENGAGE - Heritage Borders of Engagement (£56k).
- Royal Society Fellowship: An integrated framework of urban flood risk management under changing environment (£111k).
- British Academy: Sustainable Preservation of Cultural Heritage and Practices of Post-Conflict Mosul, Iraq (£294k).
- EPSRC - Wind farm Operation and Maintenance software development by using machine learning (£50k), Urban Flood Resilience in an Uncertain Future, (£60k).

3.2 Infrastructure and facilities

Research is supported by an expanded University Research Operations team and a full research lifecycle research information management system, Worktribe (see REF5a).

At School level, all staff within the UoA are located on the University's City Campus in the Maudslay Building or the adjacent Arkwright Building. PhD students are located close to their supervisors and laboratory facilities. Each student is allocated a desk and a computer workstation. The School provides further financial support for software purchase (if not already available), bid development, and conference participation.

During this REF period the School's strategic investment programme has provided £1.1m in infrastructure expenditure of which £510k has directly supported research.

Benefitting from institutional investment, a research space (300m²) in the Maudslay Building has been created which houses 10-15 researchers and visiting scholars. Main facilities include:

- A suite of photometry and colorimetry equipment for lighting measurement, including: (1) Luminance meter, Konica Minolta LS-100; (2) Illuminance colorimeter, Konica Minolta CL-200a illuminance colorimeter; (3) Two axis goniophotometer, Radiant Zemax PM-NFMS-0400; and (4) Integrating sphere, LightFluxColor LFC-150.
- A wind turbine gear train simulator, the first of its kind to run laboratory experimental investigations; a wide range of sensors and instrumentation equipment such as vibration, acoustic emission, strain gauges, force sensors, torque sensors, infrared sensors and cameras, data acquisition with high sampling rate; computer facilities and dedicated software for data acquisition, image/signal processing and artificial intelligence.
- A range of equipment for monitoring building energy use, including BSRIA Blower Door airtightness testing equipment; PULSE 60L airtightness testing equipment (ultrasonic); Hukseflux TRSYS01 Heat flux measuring system with thermal sensors; PCE -TDS 100 Ultrasonic Flow meter; Infrared thermometer; Loop Energy – Real-Time Energy Wi-Fi Monitors (Gas and Electricity); combined Temperature and Moisture Wi-Fi sensors.

In addition, the School has a range of design and engineering related facilities and technical expertise, including: Materials testing/light structures laboratory; a Concrete Laboratory; a Hydraulics Laboratory; a Geotechnical Laboratory; Structural testing equipment; Engineering Surveying; and 3D printing. Hardware available includes photometry and colorimetry equipment, real time energy Wi-Fi monitors, infrared thermometers, large light source performance characterisation equipment. These are available to our researchers and PhDs. The School has also invested in bespoke software and unique data sources to support research. The range of equipment types reflects the breadth of research within the UoA.

The School is also equipped with a Creative and Virtual Technologies (CVT) Lab, which is equipped with cutting-edge technologies including: visualisation technologies (augmented reality, mixed reality, virtual reality); tracking systems; HD video conferencing rooms; human computer interaction systems; audio devices and BIM/3D modelling/rendering software. The facilities support our research in global heritage preservation and virtual building design and construction.

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

4.1 Research Collaborations

Members of the Research Centres within the School have external collaborative networks linking them with other researchers, research users, and wider society. Collaboration is central to our strategy for building an international reputation, raising our profile, and supporting our impact strategy. An indication of the high level of research collaboration is the fact that 43% of the 301 journal papers published by this UoA involve co-authors from other countries, including China, Egypt, Finland, Greece, Iraq, Jordan, Spain, and the USA. Staff have participated in a wide range of international conferences and symposia. These have led to successful research collaborations that have raised the profile of NTU in these subject areas. During this REF period, members of this UoA have been active in participating in and leading international consortia in tackling some of the global challenges facing the modern world.

For example, **Su** leads, as the project coordinator, a consortium of 17 partners from 7 EU countries for a 6.3 million Euro H2020 project (2018-2021) on circular economy lifestyle.

Ianakiev collaborated with 21 partners from 7 countries in the H2020 REMOURBAN project (2015-2020), which aimed at showcasing sustainability and future cities. In addition to academic partners, the project also involved collaboration with research users and made a real world impact, as presented in one of the impact case studies in this UoA.

Abdelmonem has established an extensive collaboration network on global heritage research, with collaborators from the Universities of Leeds, Durham, Birmingham and Leicester in the UK, Sousse University (Tunisia), University of Wasit (Iraq), University of Baroda (India), as well as research user organisations in Egypt and Iraq. The collaboration led to successes with 5 AHRC grants (£553k), including a Global Challenges Research Fund Network Plus, and one significant grant (£300k) from the British Academy. Work in this area is also presented in an impact case study.

Another example of national research collaboration is by **Wright** on Urban Flood Resilience with the universities of Nottingham, Exeter, Cambridge, Newcastle, Heriot-Watt, Cranfield, West of England, and the Open University. Internationally, **Wright** is collaborating with the Chinese Academy of Science Institute of Geographical Sciences with the support of a Royal Society Advanced Newton Fellowship for Professor Qihong Tang.

This UoA is engaged in collaboration with other universities in the training of PhDs through two H2020 Marie Curie Actions funded programmes. The 'Extended University Alliance Doctoral Training Alliance in Energy, Applied Biosciences for Health and Social Policy' programme (2018-2023) is a collaboration between 12 universities in England and Wales with associate partners in Europe and Australia, which aims to develop 83 internationally connected early-stage researchers with interdisciplinary and intersectoral skills and experience. The 'Towards a more efficient exploitation of on-shore and urban wind energy resources' programme (2019-2023), with 13 partners from 9 countries, provides a Europe-wide multidisciplinary PhD training platform that supports the development and application of advanced meso/microscale atmospheric models and the assessment of the impact of real terrain and local atmospheric effects on the predicted aerodynamic performance of windmills, structural dynamics and noise emissions.

This UoA encourages staff visits as a means of forming research collaboration. During this REF period, 18 staff were supported to visit 23 overseas institutions and 10 visiting scholars from 9

international HEIs have been hosted. These staff exchanges helped to expand the international collaboration links of the UoA. Examples include: the appointment of **Medjdoub** as a visiting professor at Huazhong University of Science and Technology, China (2017-2020) and the establishment of a joint research centre on virtual and creative technologies; a researcher exchange programme between NTU and Harbin Engineering University, China led by **Su**; **Al-Habaibeh** acting as a mentor to early career researchers at the Federal University of Goiás, Brazil; and **Mendoza** visiting National Autonomous University of Mexico and organising joint research workshops on the reuse of 20th Century Concrete Shell Structures in Mexico.

The UoA supports staff to attend international conferences; 152 presentations were delivered by UoA members. Staff were also active in organising international conferences, such as, the 4th Conference on Mechanisms, Transmissions and Applications (**Su**), 2019 International Conference on Energy and Sustainable Futures (**Al-Habaibeh**); the annual International Conference on Construction and Real Estate Management (**Sun**); 2019 International Group for Lean Construction Research Conference (**Pasquire**); 2020 International Association for the Study of Traditional Environments (**Abdelmonem**); the 17th International Symposium on District Heating and Cooling (**Ianakiev**); and the Seventh International Conference on Flood Management (chaired by **Wright**, with 400 international attendees).

4.2 Networks and Partnerships: Relationships with Key Research Users

Original research undertaken within the UoA has developed links with, and benefited from co-creation of research with, a wide range of partners. This applies to a wide range of research within the UoA. Key research users in **Abdelmonem**'s research include heritage bodies in the Middle East (Ministry and Department of Antiquities in Egypt and Jordan respectively) and the Mayorality of Baghdad, Iraq. This relationship was reinforced by a visit to the University of the Iraqi ambassador's representative in 2018. In addition to government bodies, **Abdelmonem**'s research also incorporated working with SMEs and raised their profile with authorities in their home countries. **Ianakiev**'s work with Nottingham City Homes (NCH) and Nottingham City Council strengthened relationships between local government, the social housing provider, and the University. This has supported further successful bidding to Siemens supporting a PhD studentship (**Ianakiev** and **White**). The direct benefits of this research to householders have been beneficial to NCH winning further funds for sustainable energy improvements in their housing stock. **Koblyakova**'s work on the Help-to-Buy scheme has led to the development of relationships with research users in the Scottish Government and the Central Bureau of Statistics in Israel. It has also developed research outputs with members of the Central Statistical Bureau. **Souto**'s research in public participation on the role of architecture in society has supported her successful bid with Nottingham Cathedral to the Heritage Lottery Fund. **White**'s research on flexible offices has led to deepening relationships with RICS who accredit degree programmes in the School.

4.3 Wider Activities, Contributions to the Research Base, Economy and Society

Members of the UoA have contributed to their research fields not only by academic journal outputs but by a range of activities such as keynote speeches, conference organisation and chairing, membership of learned societies, acting as reviewers for UKRI and international funding bodies, and contributing to editorial boards of academic journals. UoA staff have presented 17 keynotes at international conferences; have been chair and/or co-chair for 10 conferences; and contributed to scientific committees for over 50 events. Staff in the UoA contribute as either journal editors or members of editorial boards to a wide range of academic journals. **Su** is editor-in-chief for the International Journal of Design Engineering. **White** is the Economics Editor/Advisor to the International Journal of Housing Policy as well as being on the editorial and executive board of the Journal of European Real Estate Research. **Wright** is Senior Editor (Engineering) of Wiley Interdisciplinary Review on Water. UoA members have been guest editors for International Journal of Hydrogen Energy (**Al-Habaibeh**); International Journal of Architectural Research (**Abdelmonem**); International Journal of Materials and Product Technology (**Su**); Key Engineering Materials (**Su**). In addition, NTU staff also serve on editorial boards of 15 academic journals.

UoA members assist research funders through peer reviews. **Al-Habaibeh** and **Sun** are members of EPSRC Peer Review College; **Abdelmonem** is a member of AHRC Peer Review College. **Su** is a member of Overseas Review College for Research Grants Council of Hong Kong and Research Council for Natural Science and Engineering, Academy of Finland; he was also a Member of the review panel of '973 projects' programme of Chinese Ministry of Science and Technology. **Al-Habaibeh** is a member of the Said Foundation Scholarship panel. **Sun** is a member of RICS Research Trust assessment panel.

Members of the UoA play leading roles in numerous academic and professional bodies, including Executive Director of European Real Estate Society (**White**), Director and Trustee of Lean Construction Institute UK (**Pasquire**), Task Group Leader for IEA-DHC TS2 Annex (**Ianakiev**). **Abdelmonem** is an elected patron of the Home Renaissance Foundation, London. **White** is an assessor in REF2021 sub-panel 13. He was a member of the RICS Leaders Forum on valuation of flexible office space (May 2019).

Economic and societal impacts are reflected in work on smart preservation and management of urban heritage in the Middle East (**Abdelmonem**) and in sustainable energy solutions in local authority housing (**Ianakiev**). Both are reported as impact case studies in REF3.

Abdelmonem's work on preserving heritage is valuable to society particularly in regions of conflict. To address the challenge of heritage preservation, Abdelmonem collaborated with Middle Eastern governments to develop digital platforms for heritage preservation to address the increasing vulnerability of heritage sites and create alternative mediums for community-led income generation and growth of the heritage economy in light of a sustained decline in international travel to the region. Abdelmonem has influenced government policy and built capacity within SMEs and government departments by embedding digitally supported heritage preservation practice.

In **Ianakiev's** research on sustainable energy for local authority housing, making homes warmer improves the quality of life for residents and reduces energy costs. Households who were fuel poor were lifted out of fuel poverty making significant differences to their lives. The networks developed by this research impacted on the supply chain for SMEs involved in the production of sustainable energy products leading to the development of more cost-efficient methods of housing retrofit and therefore increasing the size of the potential market for these products. The outcomes have been very well-received by Nottingham City Council and were influential in setting out their plans for a carbon neutral city by 2028.

Beyond the REF3 case studies, analysis of supply chains is evident also in project management (**Pasquire**). This has suggested different approaches to the management of supply chains in research with Highways England, impacting on cost and delivery times. Analysis of homeownership costs in research on the mortgage products (**Koblyakova, White**) has identified the relative profitability of standard variable rate mortgages for lenders and the role of the supply side in mortgage choice decisions by consumers.

The breadth of research within the UoA, the contribution members make to international research networks, their participation in and leadership of learned societies and in academic journal management, reflect their contribution to the research base and wider society.