

<b>Institution: 10007140 Birmingham City University</b>
<b>Unit of Assessment: UoA 13 Architecture, Built Environment and Planning</b>
<p><b>1. Unit context and structure, research and impact strategy</b></p> <p><u>Overview and Research Structure</u></p> <p>The Built Environment cluster at BCU is an established centre for research in the built environment and planning, with specialisms in placemaking, construction and environmental sustainability. The wider Built Environment grouping is one of two departments within the School of Engineering and Built Environment (EBE), which alongside the School of Computing and Digital Technology (CDT) comprises the Faculty of Computing, Engineering and the Built Environment (CEBE), through which research activity is strategically coordinated. Research from BCU's Birmingham School of Architecture is returned to UoA34 (Art and Design).</p> <p>We have made returns in Built Environment and/or Town and Country Planning to every periodic assessment since RAE1996. Since REF2014 we have made strides in achieving a sustainable critical mass for research. Then, we returned 4 FTE to UoA16 (Architecture, Built Environment and Planning), with 21.4% of the submitted outputs ranked as 4* and 42.9% of outputs classed as 3*; one of our impact case studies was ranked at 3*. Now, our research community stands at 11.4 FTE independent researchers with significant responsibility for research (SIGRES), along with seven emerging researchers (that is, staff working towards independent researcher status), and 17 postgraduate students.</p> <p>A combination of staff turnover and recruitment of eight new researchers has enabled us to form three distinct research groups, bringing fresh thinking to existing staff with strong industry-based experience:</p> <p><u>1. Property, Planning and Policies</u>, led by <b>Higgins</b>, brings together academics across the University to focus on the complex interrelationships between people, space and the environment. Aiming to contribute to public and professional understanding of the core concept of place in modern society, its applied research is focused on a range of contemporary themes relating to real estate, sustainability, planning, design and development. This is delivered through a portfolio of applied interdisciplinary research, knowledge exchange, education, community engagement and advice for decision makers and policy makers at all levels. The Group has three core areas, namely 1) Property, Space and Capital, 2) Planning, Governance and Communities, and 3) Building and Urban Sustainability, where multidisciplinary research brings sustainability perspectives to bear on questions of real estate, landscape, spatial planning and governance, as well as buildings, environments and occupiers. Research within the first area (<b>Higgins, Lee and Mayouf</b>) is focused on studying the real estate landscape. The second area (<b>Carter, Gullino and Larkham</b>) covers a broad range of spatial planning and governance issues, focusing on both built and natural environments. The group is interested in how environments originate, develop and change, the processes by which they are managed, and the stakeholders, organisations and systems involved. Research in the third area of Building and Urban Sustainability (<b>Lee, Boyd, Mateo-Garcia, and Higgins</b>) centres on buildings, environments and their occupiers from a sustainability (economic, social and environmental) perspective. Research includes direct observation, modelling and simulation. Outputs are designed to offer advice and solutions to occupants, owners, designers and developers in order to achieve sustainable buildings and spaces that are both environmentally and financially sound.</p> <p><u>2. Transforming Building Life Cycle</u>, led by <b>Cheung</b>, advances knowledge related to the building life-cycle through the application of digital technology and process transformation as well as the application of novel management approaches. Research in the group explores the adoption of digital technologies: Building Information Modelling (BIM), internet of things, machine learning and virtual reality; the applications of innovative planning, design and construction approaches</p>

such as lean manufacturing and integrated project delivery, and the interfaces amongst human, building and the living environment. Overall aims are to improve construction health and safety, productivity and building performance, to reduce fuel poverty and CO<sub>2</sub> emissions, to improve the wellbeing of building users, and build intelligence, connectivity and future-proofing to our living environment. This grouping has, in turn, three sub-groups. Construction and Digital Technology (**Boyd, Cheung, Edwards, Mayouf and Patlakas**) studies the potential of applying digital technology to the building life cycle in order to transform service provisions and practices; Innovative Planning, Design and Construction (**Boyd, Cheung and Patlakas**) addresses industry needs by rethinking the people, process and technology in the building life-cycle, and developing evidence-based practical new approaches to create value. Intelligent and High Performing Buildings (**Boyd, Cheung, Edwards, Monica Mateo-Garcia, and Lee**) is focused on the underlying challenges in delivering intelligent and high-performing buildings, and develops potential solutions so as to create better living environments.

3. Global Environmental Challenges (Interdisciplinary Group with UoA12-Engineering), led by Professor Melville (UoA12), focuses principally on energy and water related issues, scoping long-term sustainable solutions in partnership with industry, businesses, citizens and experts. The Bioresource and Bioeconomy subgroup explores Biomass cultivation and processing (e.g. algae) for energy and high value products and materials, and the Bioremediation of water and wastewater by characterisation, pre-treatment/ pre-processing and optimisation of technologies for Anaerobic Digestion. The Water, Environment and Communities sub-group brings together Proverbs, Ioannidou, Fournalis and Wu from UoA12 with **Lim, Larkham, Boyd and Gullino** to work on sustaining resilient communities under environmental challenges relating to water. One strand of research is on methods for improving the quality, supply and management of water, improving resilience to flooding and water runoff including property level responses and adaptations, storm water runoff, agricultural runoff, mine drainage and industrial by-products runoff. Technical and analytical tools used include Hydraulics and fluid dynamics, Modelling and control, Structures and materials, Water distribution and engineering, and Water quality testing and analysis, including tracer studies. Another strand examines the development and implementation of appropriate water policy at national and regional levels. This includes the associated governance arrangements to support effective planning and implementation of blue/green infrastructure to support the development of healthy environments.

Overseeing strategy and operations for the cluster is the Built Environment Research Directorate, chaired by Professor Athwal, CEBE Associate Dean for Research and Innovation, with Professor Fournalis as EBE School Director of Research Strategy and School UoA lead for REF2021, and Associate Directors for Research Degrees (**Larkham**), Impact (**Boyd and Cheung**), and Outputs/Environment (Dr Ioannidou, from UoA12). The Directorate is supported by a Technical Officer. Meeting monthly, it determines and reviews UoA strategy, sets plans for implementation, and considers the allocation of Faculty funds to support equipment purchases, PhD scholarships, and travel and conference costs.

#### Research Aims and Achievements 2014-20

The strategic growth outlined above reflects the University strategy described in REF5a. Following our modest submission to REF2014, the decision was taken to build research capacity, with five aims in view: (i) achieve critical mass of staff to create a balanced and sustainable research cluster (ii) leverage the University's developing infrastructure – as explained in REF5a – to increase the volume and range of external grant capture (iii) build a sustainable doctoral community to encourage the exchange of ideas and nurture the next generation of academic talent (iv) mobilise impact opportunities to tackle important societal challenges, and (v) nurture a culture within our cluster based on values of strict integrity, peer review, and career development.

Against those aims, we claim the following achievements:

Aim	Achievement
Critical mass of staff	Growth from 4 to 11.4FTE staff returned with significant responsibility for research
Volume/range of grant capture	Projects with DfMA-Innovate UK (£233k), Highways England, UK Government Agencies, (£175k). Significant KTP Income.
Doctoral community	Growth from 4 PhD completions for REF2014 to 13 for REF2021; growth in enrolled students from eight to 17.
Impact opportunities	Case studies reflecting major national priorities in housing and sustainability, and a major project that steered HS2's design policy towards careful integration with the landscape and initiated an urban National Park for the West Midlands (WMNP).
Nurture research culture	New protocols for peer review, staff support, career planning

### Enablers

*Critical Mass.* Our growth has been driven by targeted recruitment campaigns in 2015, 2017 and 2019 for academics with high-quality research profiles, leading to the appointment of eight staff who qualified for SIGRES. They have joined existing staff consisting of three research professors (**Boyd, Larkham** and **Edwards**), a Reader (**Carter**), and seven Emerging Researchers (i.e. those awaiting qualification for SIGRES). Together, this balanced constituency forms the three Research Groups that create the quality, volume and impact of our research. Based on disciplinary coherence, each group allows a critical mass of researchers to work together on projects and via jointly supervised PhD projects, many of which are created in consultation with or in collaboration with companies or public sector organisations. Teams of researchers from within a single group, across Built Environment groups or from other departments both internal or external to the University, come together to bid for funded projects that develop and apply their research to achieve societal impacts within defined timescales. There are particularly close partnerships with other BCU research groups: in the Engineering Department with Computational Modelling, and Sensors and Control; in the School of Computing and Digital Technology with Data Analytics and AI, Cyber Physical Systems and Digital Media Technology (DMTLab); and in the Birmingham School of Architecture with Critical Artistic Thinking in Design (CATiD), which has a significant shared membership with the Planning, Governance and Communities subgroup. Research group activities include programming of the Department's research seminar series, developing funding applications, formulating research equipment bids, hosting symposia and conferences, and providing a context for visiting scholars.

*Grant Capture.* Measures to support income generation have included enhanced support from the University's Research, Innovation, Enterprise and Employability (RIEE) professional service (as described in 5a), including bid development workshops; development of robust internal peer-reviewing process for significant research bids, involving an internal panel that meets regularly. These have helped the UoA in successful capturing of significant Research Income (with indicative projects such as: DfMA-Innovate UK with **Cheung**, £233K; Highways England, UK Government Agencies, with **Edwards**, £175K. There has also been significant KTP Income (Excelsior Panelling with **Edwards**, £144K).

*Doctoral Community.* PhD research is supported by Faculty fully sponsored PhD studentships (20 Faculty Sponsored studentships over a period of 3 years, of which 6 are to students associated with this UoA) and 2 studentships awarded to this UoA by the University Scholarships scheme, and 2 studentships part-funded by industry. Provision has been made for a regularly scheduled supervision training programme including the SEDA-accredited

Communities of Practice. These measures have helped to achieve 13 PhD completions within this REF period, so bringing on the next generation of academics and strengthening industrial partnerships.

*Impact.* A number of initiatives have been introduced to support researchers in developing, identifying and capturing evidence of impact arising from their research. Workshops and training in impact to support staff in the UoA and across the wider faculty have been provided by external consultant Saskia Walcott (Walcott Comms) and Professor Mark Reed (Newcastle University). Staff mentoring is also provided on an ongoing basis from research group impact leads who also organise further industrial visits and specialist workshops. The Water sub-group, for example, has organised two day-long workshops (2018 and 2019) with regional organisations and stakeholders in the Water based industry and community to identify areas for collaboration and impact.

*Research Culture.* As part of our research group meetings we have developed work-in-progress sessions to support the writing of publications. An Internal and External peer review system for outputs has fostered greater maturity in our research, as evidenced in the range of work and the number of journal publications produced. UoA submitted staff deposited 225 journal, 71 conference and 36 other outputs (such as book chapters and technical reports) in the BCU Open Access repository during this REF period, including the 28 Outputs submitted for REF2021.

#### Ensuring vitality and sustainability of impact supported by interdisciplinary working

A major facilitator of interdisciplinary working for this UoA has been, and will continue to be, the STEAM (Science Technology Engineering Arts and Mathematics) programme which, as noted in REF5a, has since 2016 been developed to support work across disciplinary boundaries. Our cluster has been a leading participant engaging in STEAM initiatives such as the STEAM Conference, STEAM scholarships and STEAM Fellows schemes. This strand of activity will intensify when BCU STEAMhouse, a new £70M building, opens in December 2021 with parts of the CEBE Faculty being relocated there, sharing it with incubation spaces and other established corporate tenants. A further facility, STEAMhouse India, will yield significant opportunities for international collaboration.

By its nature, much of our research is demand-led and involves interdisciplinary working with industry partners and research users. Thus impact most often arises from the co-creation of research carried out in those partnerships. As outlined in REF5a, partnership development is supported by the RIEE professional service department that co-ordinates cross-university support for Knowledge Transfer development and delivery, commercial support for IP, commercialisation and consultancy, and leads on public and community engagement, including events and outreach. They provide support to academic staff to facilitate pre-award collaborative funding and broker partnerships across local authorities, Local Enterprise Partnerships (LEPs), the West Midlands Combined Authority, stakeholder groups and private sector industry partners. RIEE provide 4 dedicated staff who support the impact development work of the CEBE Faculty: an Impact development support officer, a KTP development officer and two partnership managers, one of whom specialises in the sustainability sector.

Further opportunities are engendered through our Industry Advisory Board. The Board consists of 17 Industrial members with representation from Architecture, Planning and Construction Companies such as Konstrukshon Ltd, IG Masonry Support Ltd, Faithful+Gould, Highways England UK, Bouygues UK, Rider Levett Bucknall (RLB), Arcadis LLP, and MAC Construction Consultants.

Interdisciplinary working with partners including end users is intrinsic to our strategy and the selected impact case studies demonstrate the success of these approaches to achieving impact.



ICS 1. *Financial and efficiency improvements from socio-technical digitalisation of costing and procurement in the built environment*: Industry-funded research highlighted the need for long-term supply chain partnership in the fragmented construction industry and proper representation of costs, such that Small and Medium Enterprises (SMEs) are more secure and effectively managed. National contractor Willmott Dixon and its subcontractor NG Bailey have improved costing and procurement strategies, saving them hundreds of thousands of pounds since 2018. The research has also been disseminated by workshops to most large UK housebuilders and their supply chain. This work has been recognized in the Procuring for Value report from the UK Construction Leadership Council which has been adopted for value-based procurement by the Construction Innovation Hub and within UK government departments.

ICS 2. *Integrated Landscapes: Seeing the Bigger Picture*: research into an holistic understanding of landscape as being based on the relationship between a community and its territory set a new cultural agenda to position landscape as a strategic mechanism for sustainable city region transformation. It steered HS2's design policy towards careful integration with the landscape and initiated an urban National Park for the West Midlands (WMNP). The research influences the West Midlands Combined Authority's current sustainability agenda, the direction of long-term social and economic regeneration in the Black Country and underpinned the course for the Black Country being awarded UNESCO Geopark status.

### Research Integrity

Our strategy is supported by robust and rigorous processes across the Faculty to ensure our research endeavours and activity are held to the highest standards in terms of compliance with ethical obligations and standards whilst ensuring integrity with regard to legal and professional frameworks. CEBE has a well-established ethics committee that stipulates that 'All those engaged with research have a duty to consider how the work they undertake, host or support, impacts on the research community and on wider society'. Every research project must receive ethical approval prior to commencement. Integrity is maintained in line with the Research Integrity Concordat and we follow all of the processes and governance structures at Faculty and University level as set out in the REF5a Institutional Statement. As noted in the REF5a, this UoA is fully compliant with the Concordat on Open Research Data, and receives support from the designated Open Access Officer.

### Future Faculty Strategic aims (2021-2027)

As noted in REF5a, BCU's future research strategy will (i) further improve research quality (ii) ensure research underpins core learning and teaching, and (iii) foster innovation, social/cultural benefit, and economic growth, geared to the needs of private, public and third sectors. During the last REF period this UoA has built a sustainable foundation of strong, discipline-based research groups supervising a significant number of PhD students and producing research outputs through highly valued outlets. For the next REF period we have defined four key strategic aims:

- Consolidate and continue to grow these groups via recruitment and development of our current emerging researchers (50% increase in staff with SIGRES to 18), PhD completions (to 20) and PhD students enrolled (to 26).
- Increase the vitality and quality of the research groups' operation and activities by systematically taking on best practice from within the university and from the wider sector.
- Be recognised as partners of choice for interdisciplinary projects in Construction with more focus on Digital, and the evolving Green Economy with more focus on developing Resilience in Communities under the challenges of Climate Change; thus increasing research income by 50%.

- Increase the reach and significance of our research and impact activities by greater engagement and leadership within BCU STEAMhouse to build multi-disciplinary projects and with STEAMhouse India (see section 4) for international activities.

## 2. People

In 2016, two of the four staff returned to REF2014 left, giving us the opportunity to restructure Built Environment research at BCU the better to support the strategically identified Construction and Environmental Sustainability domains. Thus we have recruited eight talented researchers to work alongside our existing researchers and industry-experienced emerging researchers to establish our three research groups.

Through the successive rounds cited in Section 1, we made one strategic leadership appointment in **Higgins**, who came to us from RMIT University, Australia, with extensive industry and academia experience in the Pacific region. His remit was to provide leadership in the area of Real Estate. We also made three mid-career appointments. **Cheung** came from Oxford Brookes University to bring leadership to BIM; **Gullino** from Salford University to enhance our work in spatial planning; and **Patlakas** from Southampton Solent, bringing expertise in structural civil engineering and architecture. New early career researchers, distributed evenly between our research groups, are **Lim, Mayouf, Matteo-Garcia**, and **Lee**.

These have joined our three existing Professors **Larkham** (urban planning), **Edwards** (safety aspects of plant/machinery) and **Boyd** (construction and environment), as well as **Carter** (environmental governance and interdisciplinarity) and seven emerging researchers, who are supported and mentored work by their more research-experienced colleagues. In summary, our UoA profile consists of four Research Professors, four mid-career and four early career researchers, seven emerging researchers, and 17 doctoral students: a proportionate balance of experience to which we intend to add during the next cycle.

### Staff development strategy

The primary aims of our staff development strategy are to:

- maintain and expand a vibrant and supportive research community;
- make transparent allocation of workload and responsibilities;
- support academic staff at each stage of their research career, including clear progression pathways;
- provide the mechanism to support emerging researchers who are already recognised as practitioners/enterprise active to pursue PhD study and develop practice-based research.

Led by the the UoA Research Directorate and reporting to the EBE Research Committee, this strategy has been operationalized through the research group structure that promotes the cross-fertilisation of ideas, via a variety of dissemination mechanisms including hosting biweekly seminars, research group meetings, attendance and active participation in symposia and conferences.

Workshops are organised to support colleagues in peer review activity, practice-based research, producing research outputs, and applying for career progression. Staff benefit from a two-stage review process for both funding applications and publication submissions: firstly in a peer-to-peer process, both receiving and giving advice, and secondly gaining feedback from expert review by senior colleagues and external advisors.

We actively encourage participation from staff at every career stage in all aspects of our research groups' activities, and promote an open, transparent, collegiate atmosphere. Where possible, we seek to minimise the effects of hierarchy through co-location of group members in

our open office accommodation. We provide transparent annual competitions for all researchers to apply for their projects to be awarded Faculty-funded PhD Studentships (typically 10 annually throughout CEBE) and for the Faculty Small Research Equipment scheme (typically £65k per annum). All researchers, including PGRs, can apply to our Conferences and Networking Mobility Scheme (typically £20k per annum) for consideration at monthly Research Committee meetings.

Our research culture is maintained by a transparent allocation of research workloads and responsibilities. As outlined in the REF Institutional Code of Practice, all academic staff complete an annual Personal Research Review that is considered by the Research Directorate (all of whom have taken Avoidance of Unconscious Bias training). Judged against University defined criteria, staff qualifying as having Significant Responsibility for Research (SIGRES) are awarded 0.25FTE, 0.35FTE or 0.5FTE of time to devote to research activities depending on demonstrated research productivity and career seniority. The total salary cost in 2019/20 of this allowance for the 12 staff with SIGRES was £334,158. Research time allocation is a ring-fenced entitlement recognised through BCU's Workload Allocation Model (WAM) framework. Additional time is allocated to account for PhD supervisions, externally funded research, knowledge exchange projects, pilot project awarding funding, or sabbaticals. This model protects research time as a departmental priority.

Additional specialist support is available to staff depending on the stage of their research career:

*New Staff.* All the Department's research active academic staff members are involved in recruitment, enabling newly recruited staff to be quickly inducted and aligned in appropriate research groups so that they are able to fully participate in the Department's research culture. All new staff are assigned a mentor through the research group support activities, and supported to produce annual professional research development plans. New staff are given priority in the consideration of Faculty-funded PhD studentships and access to the university supervisor training programme.

*Emerging Researchers* who do not have a PhD are mentored by senior research group colleagues to develop a proposal; currently, two Department academic staff members are undertaking a PhD with their fees covered by the Faculty and a 0.2FTE time allocation. Academic staff with a prior career in industry are mentored to help them build upon their industrial experience and evolve a research career, potentially via the PhD by publications route.

*Early Career Researchers* are encouraged to present in Faculty Research Seminars and Workshops; they have access to a research group-based mentoring scheme and are offered co-authoring and funding opportunities, working with senior colleagues.

*Mid-Career Researchers /Associate Professor/Research Professors* are supported through bespoke workshops (including for promotion and professorial confirmation application), underpinned by a mutually supportive faculty-wide mentoring scheme. A number of sub-groups have formed within the established research groups; the emerging leaders of each sub-group are coached to succeed the current group leads or develop the sub-group into an independent research group. During the census period, two colleagues in our cluster have been promoted to Reader or Associate Professor primarily for their research (on Readers and Associate Professors, see REF5a). There has been one promotion to Research Professor.

### Research Students

As noted above, there has been an increase in the number of PGR students during this REF period from eight in 2014 to 17 in 2020. The number of awards has also increased greatly from 4 during the REF2014 period to 13 in 2019/20. That improvement has been driven by substantial Faculty investment. Each year over this cycle, the Faculty has committed £530k to support full bursaries for 20 students, as well as a further 30 fee waivers or part-waivers.

These awards have been prioritised to support projects supervised by early career research staff, most of whom have been newly recruited.

PGR recruitment is pursued through a variety of channels: publicising opportunities via academic mailing lists, publicity to current UG and Masters students (helped by strong growth of our taught Master's programmes during this period); advertisements in official websites (findaphd.com and jobs.ac.uk) and via industrial partners). Postgraduate research students are recruited nationally and internationally, and are funded through a range of mechanisms including Faculty and University (STEAM) scholarships. Formal applications proceed from review by two academic members of staff, to interview by three academics.

The PGR lifecycle is overseen by the Director of Research Degrees and managed by three Faculty based research administrators from the University's Doctoral Research College (DRC). All students undergo a University-led induction that then divides into faculty and school levels. All new PGR students undergo formal research training as part of our career development support to them. Within the School, they are required to complete a PGCert in Research Methods which covers generic and built environment specific research skills. Additional generic training is provided via the DRC, which has a wide range of courses related to research and personal development. All PGR students are allocated a supervisory team comprising a first supervisor, one or more second supervisors and in some cases additional external (industrial) advisors. Beyond their supervisory team, students attend workshops with – and have regular contact with – the Director of PGR Studies, who is available to them for additional or alternative academic and pastoral support. Support is also available from the DRC and from the University's Education Development Service (EDS).

All PGR students are offered opportunities to develop their teaching skills and supplement their income through Visiting Lecturer and Demonstrator schemes. Training is provided through dedicated Teaching for PGRs modules and through training within the School (providing subject specific guidance, for example in running lab sessions).

We view our PGR students as full members of our research community. All PGR students are provided with a desktop or laptop computer and a desk within the same open office area as the academic staff and leader of their research group. This ensures they are fully immersed in the workings and culture of their group, and facilitates opportunities for research discussions with fellow students and academic staff, including supervisors, further to those that take place in scheduled sessions. Doctoral researchers attached to our cluster regularly present their research at the monthly research seminars, and participate in Faculty open days, which gives them the opportunity to present their research to pupils from under-represented groups. Funds are made available on a competitive basis for students to attend conferences. Each student has been funded to attend at least one conference during their studies. PGRNet is a university wide network of PGR students and a student rep from this UoA is appointed to represent student issues to DRC staff, the Director of Research Strategy and most crucially at Faculty Research Environment and Degrees Committee.

**Progress monitoring:** full time PGR students produce progress reports at 12 months, 24 months and 30 months, with six-monthly reporting thereafter until completion. At the end of each academic year, FT PGR students undergo a formal assessment for progression, involving the latest written report, oral presentation and a viva voce examination by at least two independent assessors. Students who have difficulty at this stage are proactively supported in developing and delivering a research and study plan, overseen by the Director of Studies and the DRC. Arrangements for part-time students are similar but with appropriately longer timeframes.

PhD supervisors are required to participate in the Faculty's supervisor development programme before being eligible to supervise. This ranges from attending a supervisor development day, through to undertaking the University's Communities of Practice supervisor training programme, which results in a SEDA qualification. Supervisors can also attend examination workshops in order to prepare them for examining PhDs internally and externally. PRES results over



successive years indicate strong levels of satisfaction with our various arrangements for supporting doctoral students.

#### Equality, Diversity and Inclusion (EDI)

The School has a strong commitment to equality, diversity, and inclusion and is in full compliance with established EDI principles. The University's EDI Committee was set up to establish good practice across all Faculties. For CEBE, it is chaired by the Associate Dean for Student Learning Experience & Academic Quality, and has representatives from all staff and student levels. The group meets monthly and leads on initiatives to address diversity issues locally and in the sector. The Faculty supports and implements EDI policies in Employment Policy, Trans Policy, the Equal Opportunities Policy, Maternity, Paternity, and Adoption Leaves for all staff, whether research or teaching focused. Alongside the EDI committee, School staff are encouraged and supported to engage with groups within the University such as the Black, Asian and Minority Ethnic (BAME) Steering group, the Disabled Steering group, the Mental Health and Well-being Network, and the LGBT+ Staff Network.

In line with BCU's code of practice, all academic staff may apply for SIGRES status, including WAM remission and resources to pursue a research career. Applications are assessed by colleagues who have undertaken Advance-HE EDI training (including Avoidance of Unconscious Bias). As noted above, the same training is provided to our internal REF peer-review panels, which include a balance of senior (professorial and reader level) and junior researchers, aiming for gender and ethnicity inclusion wherever possible.

Among Cat-A staff in CEBE, 40% have identified as BAME, higher than the BCU average of around 25%; while 5.6% have declared a disability, which is close to the BCU average of 5.2%. Meanwhile 76% of Cat-A CEBE staff are male compared to the BCU average of 48%. Gender is a particular issue for our discipline, recognised nationally for STEM subjects, and steps are being taken to redress the balance. BCU was awarded the Athena SWAN Bronze Institutional award in recognition of its commitment to advancing gender equality through a four year Action Plan (2016-2020). CEBE is currently applying for a departmental Athena SWAN award. The School has encouraged and supported our female academics to participate in women leadership development programme such as the Aurora Leadership Program funded by Higher Education Academy. We also seek to ensure that our internal processes and culture are conducive to creating an environment in which female academics and practitioners can prosper and reach senior positions. We require that gender diversity issues are explicitly considered in all appointment and promotion panels. Flexible and part-time working is supported for parental/caring responsibilities. Research seminars are held within office hours for the benefit of colleagues with childcare responsibilities.

BCU's Programme for Women Achieving Excellence in Research (PoWER) provides a series of monthly sessions aiming to inspire and support female academics, building their skills, knowledge and confidence to increase research capacity and capability.

From UoA13 staff submitted to REF2021, three out of 12 are women: a Reader (**Carter**), an Associate Professor (**Gullino**) and a Lecturer (**Mateo-Garcia**). Other female staff hold senior academic leadership roles CEBE: Professor Hanifa Shah is the Pro-Vice-Chancellor & Executive Dean and 3 of the 6 Heads of Department in the Faculty are women.

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

#### Strategies for research income generation

As discussed in Section 1, our strategies for research and impact are very often intrinsically linked by co-creation of research with industry and end-users. That is reflected in our funding and income generation methods. The research groups provide centres of disciplinary

excellence, while our defined Impact Areas help interdisciplinary teams to coalesce to address major industrial and societal issues.

CEBE has developed three cross-Faculty Impact Areas to provide co-ordination and development in addressing (i) Digital Productivity in Manufacturing and Construction (ii) Smart Cities and Sustainable Environments, and (iii) Smart Health. This UoA has provided leadership in the first two of those areas. Each Impact Area has at least two co-directors from across the Faculty, a designated business development support manager from the University's Research, Innovation and Enterprise Service, and an impact representative from each Research Group in the Faculty.

Each Impact Area has a responsibility to:

- Establish a strategy for funding and impact in the innovation area based on research groups' expertise
- Carry out business development activities such as engaging with regional, national and international networks with a focus on regional priorities through membership and partnerships with groups such as West Midlands Combined Authority, Birmingham City Council, Birmingham and Black Country LEPs and Chambers of Commerce, Highways England, and major construction companies such as Engineeria, Jacobs, WSP, Balfour Beatty, Kier, JCB.
- Create and maintain a pipeline of funded projects
- Monitor and run innovation projects

The University's RIEE provides the overall comprehensive organisational infrastructure to support research and impact, as outlined in REF5a.

Our cluster's Research and Impact Strategy relies upon and delivers applied research close to market needs, particularly those of the construction sector, as typified by the award of Innovate UK grants. One collaborative award and three KTP projects with a cumulative £734K of grant funding to BCU were awarded during the REF cycle to support research and development. For the companies involved, the results were improved products, processes and profitability. Principal funded projects have been as follows:

- Excelsior Panelling Systems, 2018-2020, Innovate UK-KTP grant funding of £144k to embed advanced digital technology into the supply chain, 'downstream' to manufacturing process and 'upstream' to seamlessly integrate rich geometric and semantic information into an architect's digital building design (**Edwards**). Final report received an assessment from Innovate UK of outstanding.
- Morrison Utilities (MUS), 2019-2021, Innovate UK-KTP grant funding of £228k, to support MUS to develop and foster a radical cultural transformation in Health & Well Being within the utility sector, optimising employee work-life balance, and using big data and computational intelligence techniques to develop novel workplace initiatives (**Edwards**, but postponed during recruitment stage due to Covid considerations).
- Stenprop Limited, 2019-2021, Innovate UK-KTP grant funding of £176k, to introduce technological and cultural innovations that can lead to a paradigm shift in the relationship between tenant and landlord – to customer and service provider and thus transform the company into a leading service provider for the multi let industrial sector (**Higgins**, but not started due to IP considerations).
- DfMA Houses, 2019 to 2021, Innovate UK project no. 104798, £973k project value, £186k grant to BCU, Collaborative knowledge-based (Design for Manufacture and Assembly) DfMA approach to building cost-efficient, low-impact and high-performance houses. (**Cheung / Patlakas**)

- Highways England, 2020, have awarded a grant of £175k to recruit two fully funded PhD Studentships in the area of Safety in Highways Construction (**Edwards**).

Engagement in these projects, with both small and large companies, serves to inform the research groups of key strategic needs in Built Environment/Construction related industries, and thus to drive topics and priorities in their research agenda, for example by directing the choice and definition of projects that are offered for PhD recruitment.

Other projects, generally with smaller grants, have addressed the environmental sustainability agenda. Carried out with collaborators in other departments and universities, such projects were funded by sources including ESRC, EPSRC, British Council/Newton Fund and Royal Institute of Chartered Surveyors. An example is ESRC Project Reference: ES/M006522/1, 2014-2016, grant value £59k: Maximising the Impact of Games as Effective Participative Tools: The Rufopoly Resource Kit (**Carter**).

For the whole census period, UoA13 has earned £1,111,000 from a variety of externally funded sources.

### Facilities

Funded projects and the many related PhD projects ongoing in our cluster are supported by excellent research facilities in the Millennium Point building. In 2017, a University-funded £6.5m re-furbishment saw the installation of a new maker area, engineering labs and associated equipment, including fully equipped Hydraulics and Geotechnical labs. Of particular relevance here is the Geotechnics and Soil Mechanics Laboratory Space, which is equipped with Plasticity Index equipment (Liquid Limit Test – Casagrande , 24-0425 Grooving tool and gauge B.S, 24-0410 Liquid Limit device BS with Counter. C/W Metal Grooving Tool & Test Gauge, Liquid Limit Test – Cone penetrometer, Plastic Limit Set, Moisture Content apparatus, Unconfined compression test apparatus, Dry Compaction Testing). The Hydraulics Laboratory is equipped with specialised equipment to permit measurements of friction loss in pipes, 2.5 metre flow channel, Venturi meter, and a hydraulic bench.

The Environmental Lab offers a wet lab/pilot facility and a microbiological lab offering state of the art analysis and testing of environmental samples, as well as scientific evaluation of lab scale and pilot scale technologies and processes using an analytical suite for measuring a range of physical, organic and inorganic parameters, featuring X-Ray Fluorescence, GCMS, Calorimetry, Spectrophotometer, Microscopy.

Workshop facilities have further benefitted from £420k invested in seven new machines from XYZ Machine Tools. Our maker space is equipped with a laser cutter, 3D printers, and a variety of electronic components such as motion, proximity, and humidity sensors. Further labs provide access to electronic equipment for signal measurement and analysis, and a Scanning electron microscope.

Cross-Faculty initiatives (synergies between School of Computing and School of Engineering and Built Environment) permitted the establishment of a high-performance Computing cluster (with an associated Faculty investment in excess of £100k), dedicated to computational research.

Most recently (2020) our strategy has delivered funding to allow an expansion of the research facilities in the School of Engineering and Built Environment, through our partnership in the establishment of the Department of Education funded Greater Birmingham & Solihull Institute of Technology (with associated funded awarded in excess of £1.1M for capital equipment) that will permit the commissioning of further state of the art research facilities.

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

##### External Collaboration

We have implemented policies and mechanisms that facilitate the development and success of research collaborations, networks and partnerships:

- Dedicated partnership and engagement managers within RIEE who provide intelligence and support engagement with research partners on a regional, national, EU and now with an increased emphasis on wider international opportunities.
- Organisation of workshops and industrial visits with industry and other stakeholders in research group interest areas
- Regular opportunities for Faculty funding of conferences as well as international study and field visits.

The result has been has growth in our UoA of collaborative research projects both with national and international relevance. 83% of the UoA research projects have national collaborations while 17% of research have an international collaborator.

As noted in Sections 1 and 3, a core feature of our research and impact strategies is to support the Construction and Environmental Sustainability sectors. We have done that by joining research collaborations with companies in all parts of the construction supply chains, and with governmental and community organisations. Two strong examples of how that has been achieved are given in our impact case studies. Other examples of how our staff have interacted with beneficiaries, made wider contributions to the economy and society nationally and internationally, and carried out interdisciplinary research, are as follows.

The KTPs referred to in Section 3 demonstrate impact with individual companies whilst the Innovate UK Collaborative *Transforming house construction using Design for Manufacture and Assembly(DfMA)* project is being carried out in collaboration with Walsall Housing Group, Hadley Group, Northmill Associates, Qm Systems and Energy Systems Catapult. **Cheung** and **Patlakas**'s research in the Innovative Planning, Construction and Design Research sub-group has helped improve productivity and performance through a newly developed platform based design and production approach for offsite houses, optimised via a knowledge based software tool. Hadley Group have adopted this approach to develop new panelised, volumetric and hybrid offsite products and are currently building five modular houses. They have reported a 5-year production plan of 485 modular houses, which is predicted to save £14m in life cycle cost out of a forecast £66m contract value of their modular house product, and save 66 kilotonnes of CO2 emissions.

**Edwards**'s research has helped to enhance the health, safety and well-being of plant and machinery operators throughout industry internationally. His research on Hand Arm Vibration Syndrome has led to published vibration data and management guidance that are currently used by the UK Ministry of Defence and US Department of Defense when training staff exposed to vibration from power tool usage; and, in the UK, by Balfour Beatty Utilities Solutions (BBUSL) and A-Plant, Speedy Hire and GAP (who between them represent 80 percent of the UK plant and equipment hire market). **Edwards** has also researched plant machinery stability characteristics in partnership with major construction contractors (Costain), OEMs (JCB), utilities contractors (Morgan Est., Morrison Utility Solutions (MUS) and BBUSL), utility companies (Scottish and Southern Electricity) and hire companies within the supply chain (including Flannery Plant Hire and A-Plant). In a testimonial (2019) from Brand Safway (a major global supplier of safety equipment to the construction industry) on his machinery stability research, their Project Controls Director has commented that 'since implementing these changes, we estimate that related safety breaches and associated costs have reduced by as much as 25% last year – perhaps totalling tens of millions of Euros in prevented costs.'



**Mateo-Garcia** and **Boyd** are supported by leading UK home builders, Barratt Developments Taylor Wimpey, Redrow; and Midland Heart Housing Association on two PhD projects tackling overheating mitigation and indoor air quality improvement in new build residential developments in the UK.

Examples of engaging with diverse communities and publics is provided by the work of **Carter** and **Larkham**. In the ESRC funded Rufology project (see Section 3), **Carter** and collaborators created the Participology set of resources ([www.participology.com](http://www.participology.com)) that allow stakeholders in sustainability projects to engage communities and stakeholders in more lively and effective ways. The resource set has been used by the following partners: Royal Town Planning Institute; Royal Institution of Chartered Surveyors, DEFRA, Natural England, Natural Resources Wales, The Scottish Government, David Jarvis Associates Ltd, Northumbria University, Newcastle University, University of Salford, University of Nebraska-Lincoln, United States, Swedish University of Agricultural Sci, University of Adelaide, Australia and a number of UK local authorities and schools. **Larkham's** work on the history of planning demonstrates the need for meaningful public engagement during the modernization of urban spaces and infrastructure, and the need to build capacity for participation among the public as a precursor to successful engagement. During this REF period **Larkham** has contributed to 9 books or book chapters, as well as a public lecture at Gresham College on Re-planning London that has garnered more than 20k views on Youtube.

The UoA has an active policy of encouraging national and international collaborations, typified by study visits (**Edwards** in Australia, USA and South Africa; **Higgins** in Australia, New Zealand and China; **Gullino** in Italy). Other examples of International Collaborations include QR CGRF funded projects with a diverse community in South Africa, and Solar Irrigation Pumps work in India. In mid-2021 BCU is opening STEAMhouse India in partnership with the Indian conglomerate Hero, close to one of their manufacturing sites. This will provide a base for further engagement with construction and environmental sustainability sectors in India that can make enormous contributions to world CO2 reductions.

#### Service to the Discipline

Three academic staff members act as international peer reviewers for EU grant proposals, while two professors have visiting professor appointments with overseas Universities. In the census period the School has hosted two international workshops, while five members of academic staff have delivered keynote presentations in international congresses. 12 academic staff members are reviewers for peer reviewed high impact factor journals, while four members of staff act as members on advisory bodies.

Specifically, **Edwards** has been Visiting Professor at Kwame Nkrumah University of Science and Technology, Ghana; University of Johannesburg, South Africa (currently being considered for a Distinguished Professorship); Deakin University, Australia; recently offered Adjunct Professorship at University of Southern Australia, Adelaide, Australia. He has given keynotes at the Third International Workshop on Systems Thinking in Infrastructure Development, Huazhong University of Science and Technology, Wuhan, PR China (5-8th December 2018) and the CIDB Postgraduate Research Conference, Industry 4.0, University of Johannesburg, South Africa (28th-31st July 2019). His achievements have been recognised with the award of Outstanding Reviewer of the Year (2018) for services rendered for Journal of Construction, Engineering and Management, American Society of Civil Engineers (ASCE), and with a rating as an 'internationally leading academic' by the National Research Foundation, South Africa (B1 rating).

**Higgins** has served as RICS West Midlands Committee Member; *Pacific Rim Property* Journal Editorial Member; *Property Management* (Emerald Journal) Editorial Member. He has given keynotes at the ARBREX Conference May 2019 ('Innovation and the Built Environment Professional: Can A Robot Do Your Job?'); and the RICS Stratford Forum Nov 2019 ('The Rise and Rise of Multi Let Industrial Buildings').

**Larkham** is the Editor for *Urban Morphology* (Journal of the International Seminar on Urban Form), an ISUF Council member and Executive Committee member. He has served as Editorial Board member for each of *Journal of Urban Design*, *Urban Design International*, *Planning Perspectives*, and *Sustainability*, and been an Editorial Adviser for *Revista de Morfologia Urbana* (Portugal). He has delivered keynotes at conferences in Porto (September 2019) and Stockholm (October 2019) and been an invited contributor to the AHRC Heritage Policy workshop, Leicester (November 2018). He is a member of the External Advisory Board for the Swedish School of Planning, Karlskrona.

**Cheung** has since 2007 acted as external assessor for proposals for Hong Kong Earmarked Research Grant (equivalent to EPSRC/ESRC grants in the UK) and peer reviewed for *Automation in Construction*, *Construction Management and Economics*, *ASCE Journal of Management in Engineering*, and *ASCE Journal of Management in Engineering*.

**Carter** received the Chair's Award, Royal Town Planning Institute (RTPI) West Midlands (October 2018), for the 'Planning Game' project which she led, using the Participology resource and additional research to develop the Place Makers board game. She played a major role in the development the National Ecosystem Approach Toolkit (NEAT; <http://neat.ecosystemsknowledge.net/>), which was shortlisted under the 'Innovative Practice in Decision-Making' category of the Royal Town Planning Institute (RTPI) Planning Excellence Awards. She has also served as Associate Editor (Socio-Economics) of the journal *Environmental Values* (since 2011), hosting the annual Board Meeting at BCU. She has been BCU's representative on the Regional Activities Committee of the RTPI, West Midlands Region, since 2015, and is a member of the European Society for Ecological Economics (ESEE) and the International Society for Ecological Economics (ISEE) (since 2017).

**Gullino** has delivered the following invited talks: (2017), Civic Crowdfunding and the Negotiation of New Urban Public Spaces. Stories of Citizen-led Micro-regeneration from London and Milan (Incubators Conference – Urban Living Labs for Public Space, KU Leuven 10-11 April). (2017), 'How can mothers of preterm babies adapt to the big wide world?' (St Thomas' Hospital London, 19 May). (2017), 'New mothers' experience of the urban environment with their preterm infants involve complex social, emotional and psychological processes' (University College London Hospital, 9 March). (2017), 'Urban conflicts: 'sink' estate regeneration plans in London' (Politecnico di Milano, 27 January). (2016), 'The participatory spatialities of health care design' (Politecnico di Milano, 14 May). (2016), 'First-time mothers of preterm babies; experiences of the transition from home to urban environments' (King's College London, Department of Perinatal Imaging and Health, 27 April). (2015), Re-imagining concepts of planning through the experience of people dying in cities (University College London, Bartlett Research Exchanges, 23 March). (2014), 'Implementing patient and public involvement (PPI) in paediatric research' (Biomedical Research Centre, Great Ormond Street Hospital and Guy's and St Thomas' NHS Trust Foundation, 19 March). 'At the crossroads: spatial planning, health and parent-led research' (King's College London, Centre for the Developing Brain, 7 March).

**Lim** was on the Editorial board for the International Symposium on Civil and Environmental Engineering (Malaysia, 2018).