Institution: London South Bank University

Unit of Assessment: 13 - Architecture, Built Environment and Planning

1. Unit context and structure, research and impact strategy

1.1 Overview

Our submission presents the multi-disciplinary research done within the School of Built Environment and Architecture (SBEA) between 2014 and 2020. SBEA was established in 2014 as part of a structural transformation which saw the university's four faculties restructured into seven schools. This transformation created a strategic opportunity to bring together all research and subject areas concerning the design, development, and operation of the built environment under a new school. Interdisciplinary research is currently prioritised under four main themes:

- Architecture and digital fabrication
- Civil, building services engineering and acoustics
- Construction management, economics and integrated delivery
- Sustainability and resilient infrastructure and communities

Bringing together teams under these themes to foster an interdisciplinary approach to the built environment reflects our belief that global challenges necessitate multifaceted solutions.

SBEA research strategy was anchored around six pillars to enhance the research environment: **Quality and Integrity**; **People and Focus**; **Impact and Performance**; **Resources; Partnership and Engagements**; **and Communication** and **Improved Reputation**

SBEA's mission has been to create a vibrant research culture which produces world-leading, unique and impactful interdisciplinary research, contributing to socio-economic development and improvement in the quality of life in the UK and overseas. This is achieved whilst furthering our research under Unit of Assessment 13, delivered through its two research centres (and two research groups).

This is the first time LSBU has submitted a group in the area of research covered by UoA-13 to the REF, returning 32.2 FTE staff. This achievement in term of staff strength reflects our commitment to our key research themes and is supported by our on-going efforts to the grow the school's research environment through funding, new appointments, training, and other initiatives.

1.2 Structure

SBEA's research has been strategically organised under two research centres:

- Centre for Civil and Building Services Engineering (CCIBSE)
- Centre for Integrated Delivery of the Built Environment (IDoBE)

Two research groups were also created in 2018 with the ambition to grow into centres:

- Acoustic Research Group (ARG).
- Digital Architecture Laboratory (DARLAB)

This structure was developed to deliver on the research strengths, creating a critical mass for the Centres and a unified research environment for the School. These centres and groups enable the school's research mission to be attained. A strategic roadmap directs the progression of research in-line with this mission.

1.2.1 CCiBSE

CCiBSE has world leading expertise in Civil and Building services engineering (including past presidents of professional bodies) and is dedicated to developing and undertaking research that contributes to minimising the environmental impact and carbon emissions associated with development and operation of the built environment. This aligns with the UK Government's commitment to achieve net-zero carbon emissions by 2050 and supports the LSBU Group's

strategic commitments to the Sustainable Development Goals (SDGs) and UKRI's Clean Growth Grand Challenge.

The centre has also been at the forefront of developing industry skills and knowledge transfer using the school's CEREB facility. CEREB is a unique teaching, research and demonstration facility for the built environment which hosts research-based renewable and low carbon energy solutions.

During this REF period the strength of CCiBSE was enhanced through strategic appointments and investment in facilities, in Energy and System Modelling, Structural Engineering, Geotechnics and Interaction of Fluid with Structures (flood engineering in the coastal built environment).

CCiBSE currently comprises 20.2 FTE staff who work with over 20 partners.
CCiBSE's collaborations and flagship projects are described in sections 1.6, 4.2, 4.5 and 4.7.

1.2.2 IDoBE
IDoBE is committed to innovation in construction through enhanced business processes, and practices, project management and appropriate resources choice and allocation. IDoBE addresses the UK government's various strategies for the Construction Sector Deal, and works to obtain improvements in construction, focusing on Building Information Modelling (BIM) to improve the delivery of construction projects. The Centre's key research themes include: low productivity and construction waste, using knowledge, innovation, and digital transformation to improve cost certainty and predictability of construction projects. IDOBE also aims to address leadership challenges and the skills gap in the industry. The Centre's approach is to leverage knowledge from many disciplines to develop sustainable solutions to the challenges facing the built environment. IDOBE comprises of 12.0 FTE staff and works with several partners.

1.2.3 ARG
ARG focuses on the effects of noise on health, room acoustics, materials, metamaterials, and speech intelligibility. Aligning with LSBU/SBEA's real-world research impact strategy, ARG has worked with the following partners: Institute of Acoustics, CIBSE, Foster and Partners, Wandsworth Council, Henry Wood Hall, BBC, St Paul's Cathedral, Royal Academy of Music, Royal Opera House, Audio^3, Anne Kyyro Quinn, Aeropowder, and Imtech.

1.2.4 DARLAB
DARLAB aims to revolutionise architecture through the combination of digital technologies and physical building processes; and to develop criteria for a new system of structural logic which can be applied to architecture and is intrinsic to digital fabrication. It is underpinned by a digital robotic fabrication laboratory housed within SBEA. Its research focuses on additive digital fabrication techniques used for building non-standardised architectural components. By positioning material precisely where it is required, it can use digital, additive fabrication to interweave functional and aesthetic qualities into a structure. Aligning with the LSBU/SBEA strategy of enterprise with industry, partners include: Volkswagen Berlin, Titan Reality, Sound Display, European Space Agency and HAL Robotics.

1.3 Research and Impact Strategy
Real world impact is at the heart of our research strategy. This strategy was designed to:
1) develop vibrant research environment and ethos;
2) deliver research which informed policy and aided decision makers through the creation of guidance and standards; and
3) work with local organisations to deliver Industry Focused Impact.

This strategy was implemented through the setting of objectives to generate targeted,

measurable, impact. The research leads held one-to-one meetings with members of staff to understand their research development and delivery needs and to prioritise evidenced impact. Through our research output, internationally distributed newsletters, regular events, and our Industrial Advisory Board meetings we highlight our expertise and achievements and continuously provide opportunities for academics and stakeholders (industry, professional bodies and policy groups) to engage in our research.

1.3.1 Vibrant Research Culture and Ethos

An important commitment in the school's research strategy is to adopt an inclusive approach of building research into the activity and expectations of staff. This also aligned with the **SBEA Strategy-Quality and Integrity Pillar.** To achieve this:

- We developed the SBEA guide to research and included research in the staff workload model. Each year, staff members in SBEA are requested to complete the "Research and Enterprise Workload Form" to enable the leadership to include information on the research and enterprise components in their overall workload. The form collects information on the academic staff member's current research and enterprise activities, and plans for the coming academic year, including research output, postgraduate supervision, research & enterprise bidding and grants, and indicators of national and international esteem/Impact.
- We set up the school's research hub through which we run bi-monthly training workshops for researchers on topics ranging from how to identify funding opportunities to writing bids, conducting rigorous and original research, collaborative research, and dissemination of research (see section 1.6). This has resulted in increasing the number of research active Teaching and Research staff from 50% in 2013/14 to 75% in 2019/2020.
- Introduced an annual school research support fund and scholarships (see section 2.4).
- Provided structured mentoring for Early Career Researchers (ECRs).
- Increased research administrative support and dissemination platforms - we have centre newsletters, blogs and twitter.

1.3.2 Policy Impact and Influencing Practice

An important commitment of SBEA's research strategy was the **Impact and Performance** pillar, this section gives specific examples of policy impact including: **Gillich**'s research on the CEREB Policy Framework for implementing and incentivising multi-stakeholder, low-carbon solutions across existing buildings. This resulted in Gillich being seconded to the UK Department for Business, Energy and Industrial Strategy for 12 months in 2017 as Technical Energy Advisor in Buildings within the Science and Innovation for Climate and Energy Directorate. His research informed a £4.7 million UK Government programme (see Impact Case Study on Decarbonisation). **Shield's** research work informed Government policy on protecting the acoustic quality of schools – Acoustics of Schools: A design guide (see Impact Case Study on Schools). **Werna's** work has contributed to the UN Habitat World City Report 2020 – The Value of Urbanisation. **Chaer's** research contributed to the International Institute of Refrigeration 24th Informatory Note on Refrigeration Technologies "Containment of Refrigerants within Refrigeration, Air Conditioning and Heat Pump Systems". **Ebohon's** research contributed to UN Habitat World City Report 2016 and 2020-The Value of Urbanisation. **Ofori's** work has influenced and contributed to the construction industry in developing countries such as Ethiopia. **Eccles** research work informed the **RICS-Code of Practice** on Service Charge Management-2019.

1.3.3 Working with Local Organisations and Industry Focused Impact

Working with local organisations has put SBEA in a strong position to collaborate with centres of excellence and leading industry partners and business organisations. The partners include: **London Underground**, **Royal Opera House, National Rail** as well as SMEs such as **ICAX, Demand Logic** and **Sharps Redmore,** which have helped inform our REF impact case studies. For example: **Ford** and Dudley's (UoA12) research with **Demand Logic** has led to improvement of the company's software platforms, incorporating artificial intelligence into buildings management systems resulting in 10-30% cost savings due reduction of energy use and cutting CO_2 emissions by **37,000**t annually.

Over the last 2 years SBEA has supported Eight London-based SMEs to tackle barriers to innovation by providing bespoke research and development support through the Sustainable Innovation (**SI**) initiative (**SI** is made up of two projects, Access to Innovation (A2i), and Low Carbon London (LCLDN), which combine offer over £4million of funding from the European Regional Development Fund (ERDF)). For example: working with Skipping Rock Lab to develop their biodegradable water bottles as an alternative to plastic bottles as a means of environmental preservation.

The **Impact and Performance Pillar** was further strengthened through industry-focused Quality Related (QR) funded research (£120k annually). This has resulted in a total of 15 funded PhD scholarships. For example: work with **Brilliant Eye** produced research which directly informed the new IEC standard on speech (IEC 60268-16:2020); and research with the **Royal Academy of Music** informed British Association for Performance Arts Medicine (BAPAM) Hearing Conservation for Performance-Best Practice Guidance 2020. Collaboration with the **Bond Group** supported by (Department for Environment, Food and Rural Affairs) DEFRA, Innovate UK and the Technology Strategy Board (TSB) raised awareness of the challenges and opportunities of adopting circular processes within the retail sector and helped change the business model and solutions offered to their clients such as M&S, Morrison's, Sainsbury's, Waitrose and Asda. The behaviour change model produced has resulted in a significant reduction in embodied carbon and created 30 new jobs.

Chaer, **Paurine** and Maidment's REAL Skills and REAL Alternative research produced in collaboration with Institute of Refrigeration created better awareness of refrigerant leakage and emissions from cooling and refrigeration technologies, specifically, four e-learning modules on: environmental, cost and legal aspects of refrigerant leakage; management, maintenance, and good practice in minimising leakage. These pan-European training materials were made available in seven languages/countries (UK, Germany, Estonia, France, Netherland, Poland, and Greece). This created an Impact Case Study for UoA12 - Reducing refrigerant emissions, demonstrating our interdisciplinarity.

1.4 Research Strategy Successes

By following the SBEA research roadmap, the following have been achieved:

- **Research Leadership:** Our researchers have led four major projects worth £3.5m to LSBU and have been collaborators on further projects worth £3.6m.
- **Research Infrastructure**: Over £1.8m has been invested into the unit's research infrastructure. This included the creation of the Digital Architecture Robotic Laboratory (DARLAB), the Building Information Modelling (BIM) Hub and the Highways Laboratory. This aligns with the **Resources** pillar of the Strategy.
- **Research Esteem: Egbu** was the Chartered Institute of Building (CIOB) Vice-President (2017-19) and President (2019/20). He was also the coordinator of two CIB Working Commissions (W102 – Knowledge Management and Information in Construction) and W117 (Performance Measurement in Construction). **Shield** was the first female President of the Institute of Acoustics (2012-14); **Dance** acted as Chair of the Ministry of Housing, Community and Local Government for the Building Regulations Review for Resistance to the Passage of Sound (2017-20); **Ebohon** was Chair for the Advisory Board for Green Hub Africa (2016-20); **Werna** was Chair for Innovation and Knowledge for United Nations-Habitat (2019-20)); **Ofori** is Joint Co-ordinator (with **Egbu**) of CIB Task Group 95 on Professionalism and Ethics in Construction (2018 to date).
- **Awards:** Researchers and collaborations under the unit have won 15 awards and prizes, see sections 2.5 and 4.5 for detail.
- **Research Degrees:** 21 doctoral degrees have been awarded with a 33% increase in successful completions over this REF period of submission (August 2013 – July 2020). PhD registrations in the same period have tripled to 57 in 2019/20.

1.5 Examples of Research Centre/Group Achievements

The examples in this section illustrate how the goals and aspirations in these areas have been met or surpassed in the REF period, and provide a solid foundation for future goals and strategy:

CCIBSE Key Achievements:

- 98 indexed peer-reviewed scientific papers with multiple internationally leading joint authors.
- 15 PhD completions.
- £2.9m in research-related income to the unit.
- Won The Engineer: Collaborate to Innovate Award 2018 for the Balanced Energy Network (BEN).
- Awarded the Collaboration of the Year' award at the 2016 H&V News Awards for research work carried out by the School and Transport for London.
- Led the Climate Emergency Debate series 2019/20 and hosted the UK-Passivhaus Trust annual meetings.
- Received International Patent: Fire safety innovation for ventilated cladding panels.

IDOBE Key Achievements:

- 77 indexed peer-reviewed scientific journal publications.
- Knowledge Transfer Partnership for *Machine-based Learning for Analysis of Construction Data* with **RCIS** £220k.
- Organised and Hosted: International Conference on Professionalism and Ethics in Construction in 2018, under the auspices of Task Group 95 of the CIB after the Hackett Review of the incidence of the Grenfell Tower fire. Attendees: 102 from five countries.
- Developed a massive on-line educational course (MOOC) on sustainable construction, hosted by **CIOB** with over 30,000 active course participants from more than 100 countries.
- Won two international link research grants including the Newton Advanced Fellowship: *Harmonization of Construction Health and Safety Practices in the Southern African Development Community* £55K, which had real world impact in practice, and built research capacity and capability in many developing countries.

Acoustic Research Group Key Achievements:

- 22 indexed peer-reviewed scientific papers with internationally leading joint authors.
- Industrial PhD Sponsorship for four jointly funded research projects, £169K; and five PhD completions.
- National and international recognition including: A Higher Education Academy National Teaching Fellowship for Research Informed Teaching; Institute of Acoustics Tyndall Medal in 2014; and Institute of Acoustics Peter Barnet Award in October 2013; and Fellowship of the Acoustical Society of America in 2014.
- Design testing for the new Apple Headquarters in Cupertino, USA for Foster + Partners.
- Outreach activities to engage the public on acoustics with a Youtube video with 13M+ views, Callux entitled, “The Quietest Room in the World”.

DARLAB Key Achievements:

- Signed Memorandum of Understanding with Ministry of Sound, SCMGroup and Autodesk
- Secured funding for a KEEP+ Grant (£65K) jointly with the **ARG** to manufacture optimised acoustic panels with Titan Industries.
- Pilot project “Planetary Habitat Moon 2024” secured with the European Space Agency.

1.6 Support for Strategic Delivery

- SBEA’s collaborative research potential was reinforced during the REF period by a strategic initiative of an agreement signed with the Building Services Research and Information Association, (BSRIA) to establish the BSRIA-LSBU Innovation Centre. The aim of the centre is to address future issues for the building services engineering and

allied industries, providing thought leadership and delivering safe, affordable, and sustainable living to communities. (BSRIA is an international building physics testing organisation comprising over 800 member companies.

- Activities to foster the research culture were held, including: research hubs; away-days; sessions on research during scholarship weeks; focused meetings for early exchange of information on research themes; and support for 25 research internships during the REF period.
- A strategy to offer annual 'kick-start' funding (£40k available annually as part of the school's Internal Challenge Fund, please see section 2.4 for more detail). An example of the six projects funded in 2018/19 demonstrated the synergies that arise by bringing civil engineers and acousticians together to work on a sustainable material based on recycled glass beads that has excellent structural and acoustical properties (**McCann** and **Aygun**).
- To encourage inter-disciplinarity (40% of our research outputs were produced with collaborators from other disciplines, predominantly with members of UoA12), the strategy was to pursue funding from a broad range of sources, many of which are committed to the decarbonisation of the built environment. Examples include three BEIS funded projects (total funds over £ 4.2 million): Low Carbon Energy Innovation funding call creating the *Balance Energy Network* consortium; Low Carbon Heating Technology Innovation Fund for a project titled- *Endothermic Heating Technology Development; and Energy* Entrepreneurs Fund for the Home Energy for Tomorrow (HE4T), see section 3.1.1 for income detail.
- Another example of success in fostering interdisciplinarity is the £1.5 million award from National Institute of Health Research to develop a *Public Health Intervention Responsive Studies (PHIRST London)* project. The team is drawn from five of the university's research centres (in three schools). Going forward, our strategy will be to model the example of PHIRST London and develop collaborative projects on health issues across the university.

1.7 Future Strategic Goals

Looking forward, the key concerns in research in the built environment are the speed at which change occurs and how we influence policy and cultural value.

As a new UoA 13 we plan to build on our early successes and lessons. We will further align and integrate our work under the three broad themes of:
1) Energy and Architecture;
2) Health and Wellbeing; and
3) Delivery of Projects in the Built Environment to meet the needs of future generations.

This will entail building new and innovative strategic partnerships, particularly at the international level, such as with UN agencies and other development cooperation actors (**Werna, Ebohon**). We will continue to exploit our strong relationships with industry and professional institutions and will enhance our international collaborations. In the UK, we will influence policy and research agendas such as our work with BEIS (**Gillich**) and MHCLG (**Dance**).

We will continue to provide linkages between fundamental research, applied research, knowledge transfer and enterprise through our CEREB hub; and work with BSRIA and its members to develop high-impact research relating to net-zero carbon buildings and the built environment in general. This approach will deliver income, which we will invest back into research, and impact, which we will measure and continue to build upon.

Specifically, we will:

- Continue to provide resources to existing areas of impact such as investment in advanced facilities for Skills for Climate Change and Modern Methods of Manufacturing.
- Maintain and increase research outputs of international/ leading quality.

- Actively pursue and develop collaborations with world leading UK and international organisations, such as Foster and Partners and the Royal Opera House.
- Grow at least one of the Research Groups into a Research Centre through academic appointments, internal promotions, and investment in facilities and infrastructure.
- Support Government's policy formulation by providing relevant research on architecture and the built environment, for example around relevant aspects of COVID-19 and its aftermath.
- Attract collaborative/interdisciplinary funding to a value of £7m in 2020-27, a target of 100% increase in the current figure.
- Increase the number of PhD completions by 100% in 2020-27, to at least six per year.
- Further extend the reach of our research to include more developing countries.
- Strengthen the link between our research and our teaching demonstrated through the award of Higher Education Academy National Teaching Fellowships.
- Continue to support diverse start-ups and SMEs by undertake research into emerging services, processes and technologies to enhance the Built Environment.

2. People

As mentioned in section 1 People and Focus is one of SBEA research strategy pillars.
This section gives evidence of how quality and diversity are being promoted within the unit.

2.1 People and Focus

The People and Focus pillar has five strands, to:

- Increase the number of research-active staff in national importance areas of the Built Environment (performance, processes, and sustainability).
- Enhance succession planning by developing staff capacity, recruiting and nurturing staff members who are talented and experienced in conducting and applying research on the Built Environment.
- Develop our Research Environment and widen participation (such as increasing PGR numbers, and completions).
- Maintain research engagement, by providing structured training and mentoring, particularly for those at early stages of their research careers.
- Reduce the teaching workload for ECRs in their early years to give them time to develop their research area, as well as aligning their research with the SBEA strategy.

SBEA is committed to the University Research Concordat and uses it to support the career development of researchers. Information and training events are provided, overseen by a central Researcher Development Group. Currently **Kaluarachchi** is the main point of contact for the concordat and **Chaer** is a member of the university research committee.

The University is committed to equality for all, and values diversity and inclusivity. LSBU's Code of Practice for selection for REF2021 reflects the University's inclusivity, equality and diversity policy. It was circulated to all academic staff and has been fully implemented in this submission; this is exemplified by 61% of the submitted staff having a BAME background.

2.2 Staff Recruitment

Since 2014, in-line with the ambition of the SBEA Strategic Framework, we have increased research capacity by recruiting 24 academics (including 10 ECRs, four professors and four associate professors) in key strategic areas of the built environment. These appointments reflect international expertise thus supporting the School's Internationalisation Strategy developed in conjunction with the LSBU International Office. The new school management developed recruitment guidelines that consider understanding of contemporary research issues nationally and internationally, research record of accomplishment, research fit and research potential, and the potential to win funding and to establish or lead specific research areas.

- **Ofori, Ebohon, Udeaja and Ge** were recruited to professorial posts to grow and support research in Construction Industry Development, International Construction; Productivity in

Construction; and Professionalism and Ethics in Construction; Sustainability and Environmental Law, and Energy and Development in the built and natural environment,

- **Adamu** was recruited as an Associate Professor as part of the school's commitment to excellence in education and research relating to BIM.
- **Jin** and **Kangwa** were recruited to Associate Professor positions to strengthen the breadth of research on the built environment in the school. These Associate Professors providing a potential pathway to leadership as part of succession planning thus ensuring sustainability of the school.
- **Werna** was recruited as an Associate Professor from the International Labour Office (United Nations) to lead on strategies for innovative sustainable urban development solutions.

2.3 Staff Promotion

Promotion is available to all staff members in-line with the LSBU Academic Framework (see Institutional Statement). The process is centrally managed and runs every October. Staff attend workshops that help them to identify their strengths and potential training needs. Sixteen internal promotions were successful within this unit during this REF submission period, including:

- **Dance, Chaer,** and **Mavroulidou** were promoted to Professor.
- **Fong** and **Gillich** were promoted to Associate Professor, a part of SBEA's succession planning strategy.
- **Saber**, **Gomez-Agustina**, **Ye**, **McGovern**, **Shamas**, **Lopez**, and **Yebiyo** were promoted to Senior Lecturer.

Retiring staff with research profiles have been appointed to Emeritus positions and continue to work with our staff and doctoral students to develop relevant research, for example **Shield** and Gunn are supporting the research agendas of Acoustics and Geotechnics, respectively.

2.4 Staff Mentoring and Development

We have a structured mentoring system in keeping with the school's Strategic Framework. This drew upon the national Vitae Researcher Development Framework. Researchers develop a five-year publication plan and provide planned targets annually at their appraisals with their division heads and meetings the Director of Research and Enterprise.

Under the SBEA Internal Challenge Fund: Research and university-level Investment Pot funding, the school offers an annual competition for "kick-start" research funding to stimulate collaborative work in new areas. This fund provides support for: (a) small items of research equipment (£100k in 2014); (b) pilot research and enterprise grants (£40k in 2016); (c) collaborative research and enterprise bids (£15k in 2017); (d) enterprise internships (£6k in 2018/19); (e) strategic research on global challenges (£23k in 2019); and (f) projects under the internal challenge fund (£40k in 2020). This funding has benefited many of the submitted staff members, particularly ECRs, by enabling them to increase research output. This is in addition to annual funding for conference attendance for REF related outputs.

The University provides a systematic programme of research seminars and complementary skills training available to all staff and students. The school supports and promotes training workshops which are offered by the university for new supervisors.

The School offers Research Hub sessions. For example, in the academic year 2019/20 the school ran four workshops on bidding, grant opportunities, collaborations, and dissemination of research. The School also runs regular seminars during school away days and monthly workshops to encourage networking, foster interdisciplinary research and engender cross-fertilisation of ideas amongst researchers. These have helped to build a new research ethos. The school has championed pan-university and pan-sector brainstorming sessions to develop interdisciplinary research.

The school has benefited from the university sabbatical scheme which enables successful applicants to buy out time to cover teaching and administrative duties, thus providing them with time for research, preparation of output and bid writing. In 2018-19, **Gillich,** was awarded a

research sabbatical which enabled his secondment to **BEIS** where he helped to influence policy change at **Science and Innovation for Climate Change.** In 2019-20, two sabbaticals were awarded, to **Dance** and **Yebiyo**. **Dance** will chair the Building Regulations review for the Resistance to the Passage of Sound with the support of the **Ministry of Housing, Communities and Local Government**. The sabbatical enabled **Yebiyo**, an ECR, to spend time in Sweden and collaborate with researchers at KTH University.

We have also enabled researchers to gain knowledge on opportunities for collaboration and funding at national and international levels. **Aguda** was supported to participate in training as part of a ECRs delegation to Brussels to develop his EU funding skills and build networks.

2.5 Postgraduate Researchers

A key pillar of the SBEA Strategic Framework is to build a supportive, vital and sustainable research environment for its cohort of PGRs, and thereby, to improve the size, quality and diversity of its PGR population. Since 2014, with the strategic appointment of a PGR Lead (currently held by **Kaluarachchi**), the number of postgraduate researchers has increased from 18 to 57 during the review period. The UoA works with LSBU's International and Recruitment Offices to reach potential PGRs globally. Our PGR population is diverse; one-third are female, and 58% of all PhD completions have BAME backgrounds. Some 50% of PhD students are from overseas, and particularly, Middle Eastern and African countries, aligning with SBEA's internationalisation strategy and its commitment to equality, diversity, and inclusivity. The UoA has built strategic partnerships with several overseas institutions* including those in developing countries, such as The British University in Egypt, with which there is joint supervision of four PGRs. In 2020, the UoA introduced a new round of competitive PhD scholarships funded by the school. This created opportunity for more focused research and international access in line with the school's strategy. The best four proposals across the UoA's research centres and groups being selected.

The UoA provides PhD students with support that goes beyond the normal University provision to actively nurture them in a collegiate environment, building up a positive research culture from which they will develop a positive orientation and commitment to research integrity and professionalism. The Graduate Researcher Development Programme, which is managed through the dedicated Haplo online system, supports the delivery of training using Blackboard Collaborator for both our attending and distance learning PhD students. Haplo includes a subject-specific in-house training programme, and information on surgery time with the PGR Lead, and assigned personal tutors (who look after their welfare). The SBEA approach to PhD training and mentoring has been adopted by LSBU' London Doctoral Academy. This surpasses the formal supervision provided by each student's Director of Studies, and other supervisors.

In line with the research strategy of producing real-world impact, PGRs are encouraged to participate in applied research topics. This resulted in supporting nine match funded PhDs from the QR funds to the value of £120k during this REF period. Industry partners on this programme included: **The Royal Opera House, The Royal Academy of Music, London Underground, Hydromyx, Exergyn, Baykam, Brilliant Eye** and **The Bond Group**. These partnerships have strengthened SBEA's ties with industry and helped PGRs to produce impactful applied research. For example, the **Royal Academy of Music** demonstrated its commitment to research by providing funding for PhD students to investigate new architectural acoustics solutions. The partnerships have helped to develop SBEA's environment of research excellence as evidenced by two PhD students receiving the Acoustical Society of America Newman award 2016/17 and 2017/18; one student winning the Audio Engineering Society Bronze Award 2014; and the Institute of Refrigeration Ted Perry Award for research 2017/18. A former PhD student and research fellow, Dr Ina Colombo has become one of the leading female BAME engineering professionals; she was appointed as deputy director of the International Institute of Refrigeration.

Each student can benefit from the School's research funds to attend conferences (£500 per full-time PGR student annually, up to a total of £1,500; and half for part-time PGR student). Students are also provided with small items of equipment and consumables, including printing allowance.

This support has resulted in all successful PhD students producing at least one research output during their studies.

The LSBU CIB Students Chapter (361 members including PhD and other postgraduate students) was set up in 2015 to provide SBEA's postgraduate students with a forum for disseminating and sharing their research and findings, and to facilitate wider sharing of research among different CIB Chapters in the UK and overseas. This initiative is supported by the school through an annual budget of £5k plus organisational support for organising events and seminars. There are regular forums for students to present their research, liaise with industry and engage across disciplines. They can also participate in a range of student competitions and other activities organised jointly with The Royal Institute of British Architects (**RIBA**), **CIBSE** Young Engineers Network and **CIOB**.

The school has a long history of fully funded post-doctoral research fellowships. Five of these were provided in 2013-2016 awarded to **Gomez-Agustina, Gillich, Yebiyo, Paurine, Ali**. These post-doctoral fellows were developed to the point where they were able to take up permanent full-time academic appointments at LSBU. This demonstrates the sustainability of the school's research culture.

3. Income, infrastructure and facilities

Over the review period, the UoA has invested £1.8m to improve research capacity, with new laboratories and state-of-the-art equipment procured, enabling the unit to deliver outputs of an international standard. The unit has also expanded its portfolio of funded research, commercial contracts and resulting intellectual property. The diversity of the sources reflects our close links with industry and practice partners and professional bodies.

3.1 Income

Over the review period the UoA has been successful in directly winning research grants and commercial contracts with a total value of £3.5m and collaborating as co-investigators on projects with a total value of £6.9m. In securing these funds, our UoA has fostered partnerships with both leading sustainable innovation SMEs and world-leading organisations, and industry institutions such as **Foster and Partners, ICAX, National Rail, Royal Opera House, Tata Steel and European Space Agency.** This demonstrates our international reputation for applied research and development excellence, and our capacity to deliver timely high-quality solutions for the sector. Our portfolio of successful grants and contracts reflects our world-leading capabilities in architecture, building services engineering, civil and structural engineering, and construction management.

3.1.1 CCiBSE Research Income

CCiBSE academics have secured research grants and contracts totalling over £2.9m to the school. The range of successful projects and landmark achievements include:

- £2.9m (£600k to SBEA) Innovate UK-funded *Balance Energy Network* (Project- Funding-Number **102624**) consortium comprising LSBU and many low carbon specialist entities, which designed and installed the award-winning, world's first 5th Generation network on LSBU's Southwark campus. This has recently informed the decision of Lambeth Council approach to implement Heat Networks.
- £210k (£20k to SBEA) EPSRC funded *Energy Management and Analysis Exploiting Existing Building Management Systems Infrastructure and Data* (**EP/M506734/1).**
- Recently won £1m EPSRC-funded *H-2 Heat collaboration* (**EP/T022760/1**) with Brunel University, **HiETA**, Ricardo Group and Tata Steel on thermal energy transport using hydrogen technologies
- £181k (£27k to SBEA). EPSRC-funded project (**EP/R000298/2**) on *Bio-CO2: Power Generation and Heat Recovery* with Brunel, Entropea Labs and SWEP International.

- £559k (£147k to SBEA) *HE4T* collaboration with ICAX, Thames Water and Anglian Water to use heat exchangers to create high value energy from low carbon sources.
- £760k (£50k to SBEA) *Endothermic Heating Technology Development* with Minus 7 and ICAX to research hybrid solar thermal/PV/heat pump energy storage system.
- £38k funding and support from **London Underground** to research ground source heat pumps and their interactions with underground railway tunnels in an urban environment. This successful project has now blossomed into a much larger collaboration between LSBU, London Underground and energy providers, again demonstrating real-world impact.
- £185k (£100k to SBEA) MSCA-IF HORIZON2020 grant won with collaborators including **Network Rail** and Middlesex University on: *The use of Biocementation as a Nature-based Ground Improvement Technique*.
- £25k EU-funded *REAL Alternatives 4 LIFE* project investigating the potential of low emission refrigerants.
- More focused collaborations include: **Hydromx** to study heating systems using a nano-based heat transfer medium (£38k); **Exergyn** on heat pumps using shape memory alloys (£38k); **Basalt Fiber Tech** on sustainable basalt reinforcing bars in construction (£10k from **SI**); and **TopHat Industries** on off-site manufacturing and testing of modular timber for housing units (£27k).

These high-profile projects demonstrate the centre's ability to secure funding and contracts from research councils and industry organisations; the results also show our commitment to developing innovative solutions for a sustainable built environment.

Members of CCiBSE have also been active in developing intellectual property, demonstrating our strategic commitment to innovation, commercial awareness, and real-world impact:

- Following the Grenfell Tower Incident, a multi-disciplinary team was supported by the school to undertake research of a novel concept for fire control. This led to a new patent application (Patent No.1806000.4) for a fire safety innovation for ventilated cladding panels. The technology has attracted the attention of key fire protection manufacturers and funding from **TENMAT** who have provided materials for proof-of-concept testing alongside the SBUEL Proof-of-Concept fund (£13k). The patent has been extended to Australia and the Philippines, reflecting its potential in the international retrofitting market.

3.1.2 IDoBE Research Income

Over the review period, **IDoBE** has secured £293k in grants and contracts focusing on enhancing skillsets, managing waste and improving health and safety in the construction industry, thus promoting both social and environmental sustainability, and supporting the attainment of the UN Strategic Development Goals. Notable achievements include:

Machine-based Learning for Analysis of Construction Data, funded by a Knowledge Transfer Partnership with the Royal Institution of Chartered Surveyors (**RCIS)**, and in collaboration with the School of Engineering (£220k). This provided a web-based tool to address the skills shortage in the measurement and cost planning of mechanical and electrical (M&E) installations in buildings which was leading to the outsourcing of such services to Asian countries. This was in alignment with the UKRI's AI and Big Data Grand Challenge.

Collaborating with CCiBSE researchers and the Institute of Technology-Bandung Indonesia, IDoBE researchers secured and successfully delivered two Industry Academia Partnership Programmes from the Royal Academy of Engineering to address plastic waste in Coastal Indonesia (IAPP1617\38, total funding £41.4k and IAPP1\100054 total funding £49.6k).

Collaborating with Mangosuthu University of Technology (MUT) in South Africa, IDoBE researchers secured British Academy Newton Advanced Fellowship funding (NAFR1180168 total funding £55k)- *Harmonisation of Construction Health and Safety Practices and compliance in the Southern African Development Community*.

3.1.3 ARG Research Income

ARG has focused on jointly funded industry research. It has secured a total of £265k during the review period. The research has focused on architectural and environmental acoustics, especially on acoustics for the benefit of musicians. The breadth and profile of the group's research demonstrates the group's expertise and provides an example of the recognition and reputation for excellence of the UoA. The work has had impact in protecting musicians' hearing and teachers' voices. The group has researched novel materials to improve room acoustics and produced invaluable datasets for the wider acoustics research community. Some notable projects include:

- **The Royal Academy of Music (RAM)** provided £76k which was used to undertake audiometry to determine musicians' hearing, and develop novel dosimeters for use on stage, resulting in a new commercially successful product, **SoundBadge**. RAM supported the development and testing of new acoustic treatments including the sound absorbing mirror as well as inflatables as sound absorbers (recently installed in Henry Wood Hall to rebalance the acoustics). New methods developed were used to assess the sound exposure of the Choristers of St. Paul's Cathedral where it was determined that a new additional choir was needed; this was implemented in formation of the All-Girls' Choir (see Impact Case Study on Acoustics for the Benefit of Musicians). The research also informed the new British Association of Performance Arts Medicine – Guidance for Hearing Conservation for Musicians.
- **The Royal Opera House** provided £48k for research to develop metamaterials to improve the acoustics in orchestra pits. This research resulted in the design and prototyping of the world's first metadiffuser (see Impact Case Study on Acoustics for the Benefit of Musicians).
- The Quiet Project was a collaboration with **KSG Acoustics**, supported by an EPSRC grant UKAN (**EP/R00500/1**). This was a rapid response to measure and observe the effect of the first COVID Lockdown on the nation. It resulted in an exhibit on the National History Museum website entitled, "Nature: Liberated by Lockdown", and secondly, it has produced the largest environmental noise and soundscape survey (£35k).
- Medical measurement technology employed to study the relationship between vocal stress and acoustics; this initiative was funded by **Sharps Redmore** (£24k) and **Baykam** (£30k). The results were used to improve the classroom environment for secondary school teachers, informed *Building Bulletin 93*; and were reapplied in the design of practice rooms for opera singers.
- **Brilliant Eye** provided £15k for research to measure speech more accurately for reproduced sound systems; this informed the new IEC 60268-16:2020 standard for the objective rating of speech intelligibility by speech transmission index.
- **Imtech** provided £8k to characterise the acoustics of plastic ducting – now commonly used in industry; this research led to CIBSE forming a working group to study the characterisation of plastic ducts.
- **Foster and Partners** collaborated with ARG on the *Listening to London* Future Cities Catapult to create a wide area low-cost noise monitoring system utilising IoT technology, £12k.
- **Wandsworth Council** funded a £24k study on the effect of noise from the London Heliport on residents; this research was widely reported in the media owing to the community interest, enhancing the reputation of the UoA.
- **Siemens Mobility UK** funded a £4k project to review a voice/alarm system for the new Riyadh Metro in Saudi Arabia.

3.1.4 DARLAB Research Income

DARLAB is the newest research group, and it has engaged with multiple industry partners. It has secured £69k of research funding during the review period and over £150k of enterprise funding. Two of the research projects secured are listed below:

- KEEP+ Innovation Grant (£65k) was awarded to manufacture optimised acoustic panels with Titan Reality.
- A pilot project, "Planetary Habitat Moon 2024" secured with the European Space Agency (£3.5k)

3.2 Infrastructure

Supporting the Strategic Research Framework, the UoA has invested both personnel time and financial resources into developing a thriving research culture and effective approach to commercialisation of our research capabilities. In addition to securing income from grants and contracts, SBEA has implemented strategies that support our researchers to compete at an international level.

SBEA leverages the support, both financial and in-kind, of various units throughout the University, including QR budgets for the Research Centres, Technical Services budgets and technical staff, and funding and project management support for enterprise and innovation activities from the REI unit. All enterprise activities are assigned a business development officer to manage the financial and commercial aspects of industrial collaborations, with active professional project management.

The School's Research Committee oversees the direction and focus of research and enterprise of the UoA. The committee is formed of the Director of Research and Enterprise, the Dean, the Professoriate, the Head of Divisions, and the Heads of Centres/Groups. The committee meets monthly and offers flexible and responsive support for both research centre / group initiatives.

3.3 Facilities

SBEA has extensive specialist research facilities in which there has been substantial investment over the review period through various sources including the LSBU Research Capital Investment Fund (RCIF) scheme (over £1.5m) and Unit support (over £300k). In keeping with our commitment to produce research of outstanding/international-level quality, the UoA has created the BIM Hub, DARLAB and the Highways Laboratory. In addition, the UoA has procured fire testing apparatus, advanced digital image correlation systems, upgraded mechanical loading jacks, and advanced finite element analysis software packages. These investments not only enhance the outputs of our individual researchers, but also allow the UoA to outperform competitor institutions.

CiCBSE received £900k to improve a range of facilities. A new highways laboratory (with an additional investment of £20k) was built, and a concrete making laboratory upgraded (£180k). Investment in instrumentation for capital equipment included: surveying equipment (£230k), concrete and structures equipment (£60k, with about £5.7k from **TopHat** Industries consultancy), state-of-the-art advanced soil testing equipment for the soils laboratory (£75k from RCIF, £18k from the School, £28k from **Network Rail,** and £47k from **APEX**). An investment in fire testing equipment (£9k from SBUEL, £4k from the School) has upgraded the rig to British Standards. Industry-leading Abaqus analysis software has been purchased (£2.5k per annum) along with an investment in a Digital Image Correlation System (£43k), an upgraded large-displacement 50-ton loading jack (£37k) and a 30-ton universal testing machine (£86k). CEREB has been refurbished with upgraded IT and Building Management System (£25k).
ARG has the only acoustic laboratory in London and the South-East and has benefited from a total investment of £85k. The laboratory has had the reverberation and anechoic chambers refurbished (£25k). New cutting-edge instrumentation was purchased including impedance-based measurement equipment, audiometry instruments, vocal load monitors, and a laser vibrometer (£48k). Academic licenses for specialist research software have been purchased (£12k).

DARLAB was founded with a total investment of £250k from RCIF. These funds, together with an equivalent in-kind investment from industry, provided the opportunity to create an entirely new type of robotic laboratory to enable digital manufacturing in architectural research. The main setup consists of a multi-function robotic platform able to process different material with custom equipment and tools. DARLAB has received industrial sponsorship from **HITECO** (£10k) and additional school funds (£8k) to undertake experiments in subtractive and additive manufacturing.

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

SBEA's research strategy is to build multi-disciplinary collaborations to address bigger programmes of work with focus on issues of major international importance by establishing enabling structures:

- Drawing across the disciplines of the university as a partner such as the PHIRST London Centre;
- Creating a network of visiting fellows, to enhance multidisciplinary and interdisciplinary collaboration;
- Concluding agreements and undertaking joint research projects with international universities such as the **BUE;** and
- Becoming members of leading research networks such as the Association of Research in Construction Management (ARCOM), UK Acoustics Network, and the CIB.

4.1 International Collaborations

SBEA is a long-standing member of CIB. It has also joined Habitat-UNI, a network of universities promoted by UN-Habitat; and Alliance for Building and Construction (Global ABC) which is hosted by the United Nations Environment Programme (UNEP), fostering collaborations on environmental issues. It is also a member of Habitat International Coalition (HIC), an international coalition of not-for-profit organisations working on the social production of habitat.

The **BUE** collaboration encourages research across Civil Engineering, Building Services Engineering and Construction to create interdisciplinarity impact and knowledge sharing. Through the link with SBEA, staff members of BUE undertake doctoral studies at LSBU. Institutional links for knowledge exchange and academic collaboration were established with Blumenau University, Brazil. This has resulted in the book, "Social Ecological Resilience to Disasters: British and Brazilian Perspectives 2018".

At the individual level, **Chaer** has been collaborating for over 10 years with Prof. Goshashi from Azad University, Mashhad, Iran in research on desalination and nano-fluids. **Ford** and **Chaer** collaborated with industry and researchers from ITB, Indonesia on a project funded by the Royal Academy of Engineering (see section 3.1.2), which brought together architects, engineer, planners, policy makers, government organisations and local non-government organisations to develop an Integrated Engineering Model for Exemplary Waste Management and to address plastic waste in Coastal Indonesia**. Hong** runs hydrological modelling for water quality working with Choong-Puk National University Department of Environmental Engineering, Korea. **Kaluarachchi** is collaborating with researchers at University of Moratuwa in Sri Lanka to study the impact of COVID-19 on people with disabilities. **Kangwa** and **Ebohon** have established a collaboration with Mangosuthu University of Technology in Durban South Africa on the project on the Harmonisation of Construction Health and Safety Practices across the 16 member countries of the Southern African Development Community (SADC). **Mavroulidou** coordinated the MSCA-ITN EU research network involving 26 partners from academia, industry and regulatory organisations from eight countries. **Udeaja** is currently working with a multi-disciplinary team of researchers through an AHRC grant with the Jordan Centre of Excellence for IT and Heritage Promotion, Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat in India and the India Institute of Technology to explore how digital technologies can be

used to create awareness in the heritage field to improve conservation practices in both countries. **Ebohon** led the development of the MOOC on Sustainability in the Built Environment for Construction Professionals, which has attracted over 30,000 professionals from 100 countries. **Dance** participated in an EU Cost Action (DeNorms) which funded an exhibition of acoustic metamaterials in Coimbra, Portugal and with the support of UKAN put on the Symposium on Acoustic Metamaterials, Ischia, Italy 2019.

This range of collaborations has resulted in 20% of all research outputs submitted to this REF being a product of joint international research with diverse researchers from developing and developed countries including: Bahrain, Brazil, China, Egypt, France, Hong Kong, India, Indonesia, Iran, Jordan, Kenya, Morocco, Korea, Nigeria, Singapore, Spain, South Africa, and USA.

4.2 National Academic Collaborations

The success of our collaborations is evidenced by 50% of our outputs having joint authorship with researchers from other UK Higher Education Institutions. Staff are actively engaged in national research networks working with academic and industry partners. For example, **Dance** is the Special Interest Lead for Room Acoustics in the UK Acoustics Network (UKAN) which was setup to enhance interdisciplinary study. **Shield** has collaborated with University of Salford and University College London on acoustic design of schools by combining expertise in psychology (UCL) with acoustic surveys (Salford) and objective measurements (LSBU). This has resulted in the publication of the Acoustics of Schools: a design guide, published by the Institute of Acoustics 2015 (see, Impact Case Study on Schools). The BEN project is based on a pilot project on Cold Water Heat Networks undertaken with the SME, **ICAX**. It involved collaborating with Cranfield University on a Calcium Carbonate battery store, and with seven SMEs to build a campus-wide network using natural aquifers as heat stores (**Ford, Gillich**), see Impact Case Study: Decarbonisation. **Ford** is a founding member and ambassador of the Green Building Council University Forum and a member of the Knowledge Transfer Network Steering Committee for the Built Environment. **Ford** through CEREB has hosted the annual Passivhaus Trust meetings to further develop low carbon housing. **Dance** collaborated with the Dyson School of Engineering at Imperial College and Aeropowder through an **A2i** funded project, an innovative building material constructed from chicken feathers was tested at LSBU.

4.3 Visiting Appointments

Ofori, **Werna**, **Hong** and **Ge** have held visiting appointments during this REF period at prestigious national and international institutions. **Ofori** has been a Visiting Professor at Tsinghua University (the top Chinese university in science and engineering); and University of Science Malaysia, Penang, Malaysia; and is currently a Visiting Professor at University Tun Hussein Onn, Malaysia. **Werna** holds a Visiting Fellowship at Oxford Brooks University and at the University of Westminster. **Hong** is a Visiting Fellow at the Korean Institute Choong-Puk National University. **Ge** is a Visiting Professor at Guangdong Ocean University.

4.4 Professional and Civic Engagements

In keeping with the focus on applied research and engagement of LSBU, many of the staff submitted here have leading roles in advisory bodies and provide expertise to guide the development of policy or practice. For example: **Shield** was President of the Institute of Acoustics (2012-14). **Dance** is the chair for the Building Regulations Review- Resistance to the Passage of Sound for Approved Document E (2017-2020) for the Ministry of Housing, Communities and Local Government. He is also chair for the Institute of Acoustic Research Coordination Committee (2020). **Egbu** was Vice President of **CIOB** (2017-19) and President (2019/20). **Gillich** worked in UK Government's Department for Business, Energy, and Industrial Strategy (BEIS) Technical Energy Analysis division as well as sitting on the Energy and Industrial Strategy Scientific Committee (2017-18); **Ofori** and **Egbu** are Joint Co-ordinators of the CIB Task Group 95 on Professionalism and Ethics in Construction; **Ofori** is Deputy Chair of the International Board of the Infrastructure Transparency Initiative (CoST); **Ofori** is also a member of the Board of Trustees of Engineers Against Poverty, the UK charity; **Ebohon** is Chair

of the Advisory Board for Green Hub Africa. He also sits on the International Advisory Board of the UN-Habitat (2014-2020) which produced the World City Reports 2016 and 2020. **Ge** is Vice President of Commission-E1-Airconditioning for the International Institute of Refrigeration. **Werna** chairs the Innovation and Knowledge panel for UN-Habitat. **Udeaja** is the workshop convenor for ARCOM. **Adamu** sits on BIMAfrica.

4.5 Measures of Esteem and Leadership

Seven awards and two prizes have been won by scholars in this UoA during this REF period, these include the "Engineer: Collaborate to Innovate Award" in 2018 for the Balanced Energy Network; The Institute of Acoustics Tyndall Medal Award in 2014 **(Dance);** The Institute of Acoustics' Peter Barnett Memorial Award in October 2013 (**Gomez-Agustina**); Honorary Doctorate from Heriot Watt University (**Ford);** Royal Charter, International Research Award of the Worshipful Company of Constructors-2018 **(Adamu)**; and CONVR 2020 best paper award **(Jin)**. For the prizes, **Jin** received a prize for the most cited paper in the Journal of Resources, Conservation and Recycling; and a prize for the most outstanding reviewer in 2019 for ASCE's Journal of Civil Engineering Education. In 2020, **Estebsari** won the Manby Prize from the Institute of Civil Engineers.

The school has many scholars who are Fellows of professional institutions or learned societies. Most of these scholars play significant roles in shaping the research and development agendas within these organisations. The organisations include the: Acoustical Society of America (**Shield**); Chartered Association of Building Engineers **(Adamu)**; Chartered Institute of Building **(Ige, Jin, Ofori, Udeaja)**; Chartered Institute of Highways and Transportation (**Ali**); Institute of Acoustics (**Shield, Dance, Gomez-Agustina**); Institute of Refrigeration **(Chaer, Ge);** Institution of Civil Engineering **(Ali)**; Royal Institution of Chartered Surveyors **(Ofori);** Royal Society of Arts and Manufacturing **(Ebohon, Rossi)**; and Society of Project Managers, Singapore **(Ofori)**.

The UoA also has 22 scholars who are highly qualified fellows of the Higher Education Academy (**Adamu, Ali, Aygun, Chaer, Fong, Ge, Gillich, Gomez-Agustina, Hong, Ige, Jin, Kangwa, Lopez, Mavroulidou, McCann, Paurine, Saber, Shamas, Udeaja, Ye, Yebiyo**). **Dance** holds a National Teaching Award Fellowship, 2018 for research informed teaching.

Paurine has spoken at the UK All Party Parliamentary Group on the future of energy and natural resources in the developing world (2017) whilst **Dance** and **Chaer** were invited to attend meetings of Parliamentary select committees.

4.6 Contribution to the Academic Field

One-third of staff members are journal editors, special issue editors or members of editorial boards. SBEA has:

- Editors for the International Journal of Sustainable Development in Africa (**Ebohon);** and Journal of Sustainability (**Ebohon**).
- **Ofori** is on the editorial boards of many journals including: Construction Management and Economics; Engineering, Construction and Architecture Management; and Journal of Construction in Developing Countries. Other journals which include member from this unit on the editorial board include: 'Seminare - Scientific Investigations' (**Eccles**); International Journal of Disaster Prevention and Management and for the Construction Annual Review (**Kaluarachchi**); Journal of Environmental Engineering (**Hong)**; Journal of Sustainable Building (**Ge**); International Journal Management, Procurement and Law (**Jin**); Journal of Construction Research and International Journal of Construction Supply Chain Management (**Udeaja**); and Applied Acoustics (**Aygun**).

Editors for Special Journal Editions for; Frontiers of Engineering Management: City Infrastructure Engineering and Management (**Ofori);** and Nature Applied, Science Editor **(Ofori)**; Journal of Modelling Simulation in Engineering: Modelling and Simulation of Building Performance **(Ge**); and Journal of Energies: Alternative and emerging cooling and heating technologies **(Chaer)**.

Staff contributed to widely adopted books: The Book of Acoustics 2020 (**Gomez-Agustina**); Future Campus- Briefing and Design for Sustainability 2016 (**Ford**); Corporate Real Estate Asset Management Strategy and Implementation 2017 (**Eccles**); Reusing knowledge and leveraging technology to reduce design and construction costs 2015 (**Udeaja**); Construction Industry in Singapore-Improving the Performance of Construction Industries for Developing Countries-Programmes, Initiatives, Achievements and Challenges 2020 (**Ofori**); **Rossi** "Fibre Wonder" documents research work in digital and robotic architecture. For grant applications, one quarter of the staff are actively engaged as national and/or international reviewers: **Dance** acts as an international reviewer for MITACS (Canada) and as an EPSRC reviewer; **Chaer**, **Shamas** and **Aygun** are reviewers for EPSRC and UKRI; **Ebohon** and **Ofori** review bids for the National Research Foundation (South Africa); **Ofori** undertakes reviews of grant applications for the Australian University Grants Council and the Hong Kong University Grants Council; **Jin** is a reviewer for the Newton Fund Institutional Links programme and a reviewer of applications for grants for the American University of Sharjah (UAE). . **McGovern** is a peer reviewer for the Chilean government's National Fund for Scientific and Technological Development.

4.7 Research Media Exposure

The research produced by the staff members has been covered by the media. **Rossi** regularly produces novel structures which are exhibited around the world, for example Germany-Berlin (3 months 10,000 visitors), Austria-Linz (2 weeks, 5,000 visitors, China-Shanghai/ Beijing (2 months each, 50,000 visitors), Kazakhstan-Expo 2017 Astana-Future of Energy (4 months, 4m visitors) with media coverage in the areas of innovation, arts, and the built environment. **McGovern's** research has contributed to greater awareness of the risks of tsunamis; he has been interviews on the BBC. **Adamu's** COVID related work on aerosol spread indoors and ventilation strategy has gained media attention on the BBC and Soundcloud. **Dance** and **Gomez-Agustina's** work on noise emission from London Heliport received attention from the BBC. **Ye** and **Chaer's** work on airborne wind energy was referenced in *the Sunday Times*. **Ford's** research on energy was highlighted in Oman printed media and on Omen TV. Wide coverage in the print media in Nigeria of **Ebohon's** GreenHub Africa- the first environmental platform for dissemination of news and events on climate change in Africa.

4.8 Contribution to Society

CCiBSE research has focused on one of the Grand Challenges, decarbonisation of the built environment, and the ARG on another Grand Challenge, healthy ageing. The creation of more energy efficient buildings has emerged from the work with Demand Logic by data mining Building Management Systems to locate faults in buildings (**Ford**)**.** The BEN research has resulted in greater awareness of the potential to save energy by utilising underground aquifers and wastewater to connect buildings. This has also has advanced the frontiers of technology integration. The research concept and technologies are now being considered by Lambeth and Southwark Councils in London, and Bridgend Council in Wales (Phase 1 research on affordable heat networks for Bridgend Council was completed in 2020 and Phase 2 is currently being researcher).

CCiBSE and **IDoBE** research work with ITB-Indonesia (**Chaer, Ford)** has led to multiple impacts, including: a project to assess the requirements and academic impact of introducing collaborative multi-disciplinary working within higher education; local government in Bandung linking with manufacturers in China to develop a pilot plant with non-government organisations in Bali; and students and local communities in Indonesian have developed social enterprises resulting in local jobs.

IDoBE has led a British Council-funded project on the Harmonisation of Construction Health and Safety Practice (**Ebohon** and **Kangwu**). This has led to enhanced safety awareness and adoption of good practice contributing to the enhancement of the performance of the construction industries in 17 countries in Southern Africa and improvement of the wellbeing of the workforce. In addition, the publications, and findings from the ANDROID Network **(Kaluarachchi)** now act as a major knowledge base for disaster management strategies in

Europe and are incorporated into international mitigation strategies, demonstrating the breadth of our international reach.

For the Healthy Ageing Grand Challenge, research by **ARG** has shown that subjective pure tone audiometric tests could potentially be replaced with an objective Otoacoustic Emission Test based on our Royal Academy of Music study (**Dance**). The research of **Dance** and **Gomez-Agustina** on vocal alarm evacuation systems has been incorporated into the design of the new Riyadh Metro System through their work with **Siemens Mobility UK**.