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Institution:	Loughborough University
Unit of Assessment:	C16 Architecture, Built Environment and Planning
<p>a. Context</p> <p>The Unit is within the multi-disciplinary School of Civil and Building Engineering (CBE), which has a 70-year history of delivering successful, practice-relevant research. This is founded upon our college origins, where academic studies were dovetailed with improving industry performance, resulting in a strong Institutional culture and symbiotic relationships between research and practice. In the period 2008-13 our research addressed some of society's most complex and pressing needs. The types of impact included: new technologies and processes to aid the design, construction and operation of buildings (<i>economy, commerce or organisations</i>); strategies and models to reduce building energy demand and improve construction efficiency (<i>environment</i>); healthier and more productive workplaces; improved health and welfare of those constructing and inhabiting buildings (<i>health and welfare</i>); a more robust regulatory environment; a stronger evidence-base for policy formulation; greater public awareness/better prediction of the effects of climate change (<i>public policy, law and services</i>); all with crossover into impacts on <i>practitioners and professional services</i>. These impacts arose from activities that cut across our two research themes of <i>Building Energy Demand</i> and <i>Construction Technology and Organisation</i> (see REF5), demonstrating their synergy and cross-unit collaboration. Our embedded approach to impact strategically aligns with Loughborough University's ethos of delivering 'Research that Matters'. Our knowledge production and dissemination activities are underpinned by a strong commitment to innovation and enterprise. This ensures that our research delivers value to industry, governments, regulatory bodies and civil societies worldwide by improving performance and competitiveness, influencing policy and enhancing societal wellbeing. Our two key groups of beneficiaries are: <i>industry</i> (especially clients, developers, consultants, contractors, product manufacturers and facilities operators); and <i>institutions & regulatory bodies</i> (central and local governments, professional institutions, improvement and regulatory bodies).</p>	
<p>b. Approach to impact</p> <p>As an entrepreneurial community we have the capability and resources to take successful research into practice; 65% of the staff returned have been employed in industry and our recruitment strategy seeks to continue to grow this vital source of know-how, end-user relationships and policy connectivity. As a result all our major externally-funded projects involve formal collaboration. Extensive networks of stakeholders shape our research and provide robust conduits to assure relevance and downstream impact. This provides robust pathways from research to our broad spectrum of stakeholder partners and beneficiaries. Commitments to supporting industrial take-up thus permeate our research and translate into extensive enterprise activity. The Unit's strategy for maximising impact comprises a mix of institutional mechanisms and School-based initiatives that collectively support impact-related activities. At the University level, enterprise forms the third pillar of core activity (alongside teaching and research) and is central to the University's 2016 Strategy. This requires the Pro-vice Chancellor for Enterprise to work in partnership with the University's Enterprise Committee, the Enterprise Office (EO) and each School's Associate Dean for Enterprise (ADE) to maximise the impact and utility of Loughborough University (LU) research. The EO supports secondments, proof of concept studies, enterprise fellowships, business case development, formulating contracts, IP protection/licensing/patenting and knowledge exchange. At the Unit level the ADE closely collaborates with the Associate Dean for Research, supported by a committee of 11 enterprise champions and an Enterprise Manager. They collectively identify and promote opportunities for research impact and knowledge exchange by fostering a culture and research environment that promotes and rewards collaboration, innovation and exploitation of research. Professional enterprise and media training form core components of continuing professional development activities and public impact and engagement are embedded through annual personal research plans, performance development reviews and promotion criteria as valued activities for all staff. Specific examples of unit and institutional support are described below in relation to our main pathways to research impact on our key beneficiaries.</p> <p>Significant impact arises from our strength and tradition of industry-focussed research, mainly funded by EPSRC, EU and TSB as detailed in REF5. The vast majority of our c.200 full-time</p>	

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doctoral students work directly with industry, of which c.70 work within our two CDTs that sustain collaboration with our key partners. The *Centre for Innovative and Collaborative Construction Engineering* (CICE) has secured three rounds of EPSRC funding (c. £12m in total) and supported 44 research engineers since 2008 in 33 sponsoring organisations to develop and embed new innovations in industry (e.g. AECOM, Aggregate industries, Amey, BAE Systems, Balfour Beatty, bam, BT, Buro Happold, Costain, E.On, Halcrow, JCB, npower, Tesco, URS, Vinci and Wates). The *London-Loughborough Centre for Doctoral Research in Energy Demand*, formed with UCL in 2009, has trained 20 students at LU with sponsors such as BRE, Centre for Sustainable Energy, the Department for Energy and Climate Change, Secure Controls, E.On, Unite Modular Solutions, Western Power Distribution and Willmott Dixon. Each student devises and implements a research programme that produces tangible impacts for their sponsor. Annual public engagement (including 3 STEMnet and 1 Eco-schools ambassadors) and impact demonstration activities are an integral component of the programme and a prerequisite of the CDT awards.

Steering Groups drawn from senior staff of stakeholder organisations advise all major EPSRC projects and the two Centres for Doctoral Training. They ensure the relevance of the research and offer pathways to impact across industry and policy communities as well as informing how we develop our approach to impact. Panellists include: Hunter Danskin (Chief Scientist at Department of Energy and Climate Change), David Adams (Technical Director, Willmott Dixon Energy Services); Dave Clarke (Head of R&D, E.ON); Prof Brian Collins (former Chief Scientific Advisor to BIS and Department for Transport); Hywel Davies (Technical Director, CIBSE); Elizabeth Ness (Group Sustainability Executive, Crest Nicholson); Jeremy Watson (Global Research Director, ARUP); Ant Wilson (Director, Sustainable Development Group, AECOM); Alison Mathias (Strategy Manager, Homes and Communities Agency); Charlie Law (Head of Environmental Management, BAM Construct UK); Miles Watkins (Director of Sustainable Construction, Aggregate Industries); Matthew Raybould (Director of Geotechnics, URS Infrastructure & Environment UK); Tim Embley (Group Innovation & Knowledge Manager, Costain) and Peter Woolliscroft (Non-exec. Director of Constructing Excellence).

Impact is also created through **contract research and consultancy** funded directly by stakeholders; the Unit conducted 73 funded projects since 2008, for 59 clients, valued at over £3.3m. Recent high-profile examples include work with Kingfisher Future Homes (£696k), part of Europe's largest home improvement retailer, to test technologies for their new Green Deal business venture; the Olympic Delivery Authority (£17k) to reduce building site accidents; Galliford Try (£2k) to verify the sprayed concrete design of the Olympic Canoe Slalom course; and the NHS Directorate (£30k) to develop new approaches to healthcare asset management.

Where opportune, research projects flow into **knowledge transfer activities**: since 2008 the Unit has exploited the EPSRC Knowledge Transfer/Impact Acceleration Accounts (£781k) and Knowledge Transfer Partnership scheme (£273k). Examples include work with SE Controls to develop novel ventilation control systems for building refurbishment, and Sandwood D&B to implement lean approaches to improve the construction of office buildings, both of which have been shortlisted for LU enterprise awards. Other examples include a prototype commercial process for 3D concrete printing, testing a framework and toolkit for adaptable buildings in architectural and engineering practices, and optimising healthcare infrastructure value for the NHS.

Our research has directly shaped political, legal and regulatory domains through our representation on British **Standards and other technical committees**. For example, 6 staff chair, or are members of Standards committees: Austin (CEN TC104/WG10 (Sprayed Concrete and WG11, Fibres for Concrete); Osmani (BS 8895, Designing out waste); Glass (BS 8905: 2011, Framework for the assessment of the sustainable use of materials and BES 6001, Responsible Sourcing of Construction Products); Ruikar (PD 7974-8:2012 Application of fire safety engineering principles to the design of buildings); Loveday (ASHRAE Technical Committees 2.1/2.5 on human thermal comfort/global climate change); and Mardaljevic (UK Principal Expert on Daylight, CEN/TC169 WG11 and revision Panel member for BS 8206: Daylight in Buildings). Furthermore, 48 **industry and policy reports** have been generated from our research since 2008. For example, Austin was the sole academic contributor to Constructing Excellence's 'Never Waste a Good Crisis' (The Wolstenholme Report) on industry reform. A Department of Energy and Climate Change report explored how trends in appliances affect domestic CO₂ emissions (Lomas, Firth), winning the LU

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Enterprise Award in 2012; they also contributed to the last three versions of DECC's annual UK Housing Energy Fact File, the key data source on the UK's housing stock energy performance. And Gibb contributed to the Health and Safety Executive's Donaghy report on fatal construction accidents, shaping emerging policy measures in the UK.

Staff lead several **industry networks**, including the School hosting the European Construction Institute, a self-funded membership-based institute of Europe's leading engineering construction organisations, set up specifically to exploit research throughout Europe. It is directed by Gibb (Royal Academy/ECI Chair in Complex Projects), with Unit staff sitting on Task Forces that act as conduits for implementation of our research, and comprises 32 global companies including BP, Shell, RWE, Amec, Foster Wheeler, GSK, Fluor, BG Group, CB&I and P&G. Other staff leading influential networks include Cook (Chair of IBPSA England and Secretary of the CIBSE natural ventilation group); Mardaljevic (CIBSE School design group); and Glass (Action Programme on Responsible Sourcing network).

Short courses, seminars and conferences targeted at our stakeholder **CPD community** increase the reach of our work. High-profile examples since 2008 include: Association for Project Safety (Gibb), ≈400 delegates/16 venues; Assoc. of Chief Police Officers (Bosher), ≈240 Counter Terrorism Security Advisors from across the UK; ICE Thomas Telford (Austin), 3 day design management courses, >160 delegates; and CII (Gibb), London 2012 H&S, 600 delegates.

c. Strategy and plans

Our 5-year strategy is to maximise the impact of our existing activities, extending the reach to new stakeholder constituencies and increasing significance by encouraging the highest quality of research in priority areas. Specifically, we will: (1) support the development of **more effective impact pathways** by mobilising a high-level user panel convened by our ADE, drawn from our existing steering groups and visiting industry professors (see REF5); (2) The new **Loughborough Centre for a Sustainable Built Environment (LCSBE – see REF5b)** will provide a vehicle for extending the reach and impact of our research; (3) benefit from the University **incorporating enterprise activity into academic contracts**, encouraging greater exploitation by all staff; (4) take full advantage of the opportunities afforded by the University's EPSRC Impact Acceleration Account to **fund technology transfer, staff secondments and dissemination**, enabling greater global engagement with our work; and (5) introduce new processes to **review the quality and potential impact of research proposals**, and prioritise support accordingly. In addition we will exploit specific commercial opportunities with strong industry momentum including: the 3D concrete printing process (Austin/Buswell - patent PCT GB 1118807.5) with Hyundai and Laing O'Rourke; the 'Zephair' low-energy cooling ceiling tile with Burgess Ceilings (Loveday - Europe and US patents EP1325266 and US7047752); building energy optimization software developed through TSB and licensed to IES Ltd (Wright); and the Kingfisher Future Homes project (Lomas/Loveday).

d. Relationship to case studies

Our impact approach detailed above is exemplified as follows. (1) The commercial potential of **ADePT** was identified before the current REF period, the spin-out Adept Management Ltd being set up by Austin through a *Gatsby Fellowship*, *relief from teaching* and a *secondment* supported by the University. This enabled Austin's on-going support for the development of novel software and exploitation of further research (e.g. *EO licencing* of VALiD to the company as a *consultancy* service) and *CPD* for many organisations through ICE's training arm. (2) The Unit exploited connectivity to the *Department of Health Estates and Facilities Team* to find new ways of delivering **quality healthcare estates**. *KTA funds* supported the development of the PAM Tool that now forms the basis of the DoH assurance strategy. (3) New techniques for establishing **accident causality** are having a sustained impact via *consultancy commissions* and *policy forums*. A *sabbatical* for Gibb extended the reach national/internationally through HSE, CIRIA, Engineers Australia and the Association for Project Safety and NIOSH in the USA) and *consultancy* for the Olympic Delivery Authority. (4) Lomas and Cook capitalised on *existing relationships*, built through CIBSE *working groups* and *consultancy* via the *Enterprise Office*, to advance the **design naturally ventilated buildings**. Cook subsequently used *KTP funds* to develop a new product for SE Controls who are now expanding into the building refurbishment market.