EPSRC CENTRE FOR INNOVATIVE MANUFACTURING IN BUILT & HUMAN ENVIRONMENTS

OVERALL VISION FOR THE CENTRE

VISION:

The EPSRC Centre for Innovative Manufacturing in Built & Human Environments will catalyse a transformation of the Built Environment (BE) sector, through a deep understanding of user-needs and behaviours, that will drive the development of innovative design and manufacturing processes to sustainably optimise: social, environmental and economic value in use. The Centre will significantly improve:

- the ability of the sector to deliver functional benefits to clients and users with positive impacts in terms of their health, well being and effectiveness
- the environmental performance of the built environment in general and reduced carbon emissions in particular
- the competitiveness and economic performance of the construction sector and its beneficiaries

This will be achieved by consolidating fragmented uni-disciplinary knowledge and enhancing practices to monitor performance in use in order to create a robust and actionable evidence base. This is essential to inform continuous improvement in the sector's capacity to: design, manufacture and continuously support the optimal use of built assets. In doing so, the Centre will provide an internationally recognised resource for the UK BE sector that will stimulate new business models and increase its competitive presence in the global market place.

OVERVIEW OF MANUFACTURING RESEARCH CHALLENGES

A wide view of the UK construction sector (incorporating upstream and downstream activities to constitute the BE sector) shows that it encompasses up to 19% of UK GDP, with contracting alone employing 1 in 12 of the UK workforce[1]. Investment in the design, construction, repair and maintenance of our built assets provides a significant multiplier effect to the wider economy and underpins the overall well-being of society.[2] At the same time the creation and use of the built environment consumes 40% of UK energy, half of our water, one quarter of all raw materials, produces one third of landfill waste[3] and is responsible for almost one third of work-related fatalities[4]. There is therefore a need to maximise the value created for society through the built environment, whilst at the same time addressing practices and behaviours to reduce its resource and energy consumption. Against this background there is a collective acknowledgment within the UK that the BE sector needs to develop and nurture a whole systems approach to product delivery in order for it to become integrated, sustainable and competitive in the future.[5] To do this it must move away from out-dated, litigious, and restrictive ways of working to become a change agent that continuously creates and adapts the BE in order to maximise users' health, well-being and effectiveness.

> 'What is it about a building that helps enable successful use? How far do factors such as CO_2 levels, heating, lighting, classroom size and noise (individually and in combination) affect learning? Do we understand the anomalies between design intent and what is delivered? We need to better understand how people use buildings and factor this in at the design stage.'
> *Colin McKinnon* – Innovation Director, Buro Happold

The proposed Centre is well placed to tackle these challenges. It builds upon the strong foundations of the current Salford Centre for Research & Innovation (SCRI, existing EPSRC Innovative Manufacturing Research Centre) and strengthens this in combination with a powerful academic team from Loughborough University's IMRC and its associated Industrial Doctorate Centre. The academic team have substantial industry networks, and have been at the forefront of change in the construction sector for the past 10 years. In particular, the team's work on process improvement[6], lean construction[7], Building Information Modelling (BIM) and nD Modelling[8], Revaluing Construction[1] and Value and Sustainable Procurement[9] has played a key role in reshaping industry perspectives. In 2000 'process thinking' was still relatively rare but is now widely accepted[10], building information models were a concept and are now increasingly being adopted[11], the sector had a predominantly product perspective and now recognises its service and through life characteristics[12], and value procurement is widely embedded[13]. As a consequence our vision of a user-driven, integrated manufacturing process that maximizes value in use whilst reducing carbon emissions and resource consumption is now widely shared[5].

After more than ten years of strategic reassessment amongst industry leaders, the BE sector is now ripe to engage in research-driven innovation to deliver on these opportunities. This has two interactive foci: building an actionable evidence base of "maximising value in use" and, in this context "delivering whole-life solutions" and in so doing, further building the evidence base.

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[1]Revaluing Construction (2008, Blackwell Publishing); [2]The Effect of the Physical Environment on Mental Wellbeing (2008, UK Government Foresight Report); [3]Strategy for Sustainable Construction (2008, BERR); [4]Health and Safety Statistics 2008/9 (2010, HSE); [5] Research Priorities for Built Environment (2007, UK National Platform for the Built Environment), Strategic Research Agenda for the European Construction Sector: Implementation Action Plan (2007, European Construction Technology Platform), Building a Client-Orientated, Knowledge-Based, Value-Driven Industry (2009, UK National Platform for the Built Environment), Emerging Findings: Low Carbon Construction Report (2009, BIS); [6]A Generic Guide to the Design & Construction Process Protocol (1998, University of Salford); [7]An Exploration Towards a Production Theory and its Application to Construction (VTT, 2000); [8]nD modelling roadmap: a vision for nD-enabled construction (2005, University of Salford); [9]Interventions to Manage Trust in Construction Projects (2006, International Journal of Global Logistics & Supply Chain Management); [10]OGC Gateway Process: A Manger's Checklist (OGC,2007) ; [11]Integrated Design & Delivery Systems (2010, CIB White Paper); [12]International Examples of Service-driven Innovation in Construction (2007, NESTA); [13]Improving Public Services through Better Construction (NAO, 2005)

Maximising Value in Use: In practice, in 2010, the BE sector still has a project and product delivery focus, with a poor understanding of the value that it delivers in service and use. Maximising value to clients and society requires a deeper understanding of the sustainable benefits that are realised from the built environment in use. This depends upon an improved evidence base built on a robust understanding of the users' multi-sensory experience of the built environment and strengthened by the development of novel methodologies for engagement with a diverse range of users to help close the gaps between user desires, design intent and the final product in use. Finally, closing the learning gap between user-needs and associated value creation requires a much wider understanding of performance in use that moves from the current situation of post-occupancy evaluation of buildings as products, towards a wider assessment that incorporates stakeholder values, usability and the service that is delivered. [1]

The team assembled has been chosen to bring together leading authorities on each of the wide-ranging aspects of this challenge. *Prof Peter Barrett* leads the international research theme of Revaluing Construction with a particular interest in the links between Senses, Brain and Spaces. *Prof Marcus Ormerod* is Director of the SURFACE Inclusive Design Research Centre, focused on the development of novel solutions for user engagement in coherent and interlocking ways.

'The proposed research has the potential to transform the design process and ensure the environment we create is truly fit for purpose'
John Lorimer – Head of Capital Programmes, Manchester City Council

Prof Steven Emmitt is Professor of Architectural Technology, focused on design management with particular emphasis on interaction, stakeholder values, design value and usability. *Prof Dino Bouchlaghem* is Director of the Engineering Doctorate Centre for Innovative and Collaborative Construction Engineering (CICE), his current research interests include sustainable design and construction and Post Occupancy Performance Evaluation, an aspect that is strengthened by *Prof Paul Chung*. Paul is Associate Dean (Research) of Science, his research includes remote monitoring and control, enabling decision support and performance evaluation of built assets in use. *Carl Abbott* is Manager of SCRI, with research interests in life-cycle innovation and the adoption of low energy solutions in complex projects.

'By demonstrating how performance of people in buildings can verifiably change by up to 30% according to specific design criteria, Salford have added a new dimension that takes us beyond efficiency of building to effectiveness of building. We believe this is the next significant step in really unlocking Value in construction'
Chris Woods – R&D Director, Wates Construction

Delivery of Whole Life Solutions: While there is evidence of initial moves towards integrated design and delivery systems[2], current solutions are still project rather than people-centric, and improvement strategies lead to sub-optimisation at a production level rather than to systemic improvement. Meeting the challenge of moving towards a value creating, user-driven, manufacturing process therefore requires an adjustment of the product development, design & production process to ensure that user requirements drive closely integrated teams. This will demand enhanced technologies, such as BIM, that can support the assessment and holistic optimisation of the aspects of sustainability (social, environmental and economic). This will provide a crucial ability to simulate and verify in the design phase how well the building will fulfil user-needs. The implementation of such integrated solutions dictates an industry re-configuration including collaboration with extended operations and value chains leading to the development of new commercial tools and business models for success.

'As a means of enhancing the economic & social benefits, we need a lean focus on the product that delivers maximum value to the customer.'
Richard Saxon CBE – Consultancy in the Built Environment.

The research team for this aspect again illustrates the balanced portfolio of skills necessary for a systemic approach to the challenge. *Prof Lauri Koskela*'s current research interest is the fusion of lean principles with BIM implementation. *Prof Arto Kiviniemi* has a particular interest in integrated BIM and management of information throughout the building life-cycle. *Prof Naomi Brookes*' research focuses on understanding the relationships between stakeholders in the construction project management process and how these relationships support the information flows needed to enable clear communication of needs and values. *Prof Peter McDermott* leads SCRI's Procuring Value theme, his research interests include strategic and value procurement, integrated construction supply chains and construction industry development. He is also Research Director at the Centre for Construction Innovation. *Dr Steven Yeomans* is Research Manager at the CICE and former Chairman of the UK National Platform's work stream on ICT and Automation with research interests in strategic ICT enabled collaboration, collaborative working, web technologies and enterprise content management for collaboration.

LEADERSHIP QUALITIES OF THE DIRECTOR

Prof Peter Barrett is currently involved as Chair of the £4.95M EPSRC funded Innovative Manufacturing Research Centre, the Salford Centre for Research and Innovation (SCRI) and is the Director (PI) of the Framework for Innovation and Research in MediaCityUK (FIRM, total funding £3.3m). He is a member of the principal BE policy bodies, namely, the UK National Platform for Construction and the European Construction Technology Platform. He was PVC for Research (2001-08) at the University of Salford and is the immediate past President (2007-2010) of the UN-established International Council for Research and Innovation in Building and Construction. The proposed Centre will replace the current SCRI research centre and so the fact

[1] Usability of Workplaces (2010, CIB Report 330)
[2] Integrated Design & Delivery Systems (2010, CIB White Paper)

that Peter has completed his terms as PVC Research and CIB President means that he is now able to focus his energy to drive forward the development of this centre for Innovative Manufacturing.

UK NEED FOR A CENTRE

The move to the new model that the Centre's vision dictates, requires radical, systemic innovation. Consequently, although the industry desire for change is strong, the take up has so far been weak[1]. The Centre for Innovative Manufacturing scheme therefore presents a unique opportunity to enable industry transformation by mobilising an internationally renowned team whose combined expertise enables a closing of the loops between user-needs and preferences; through life design and delivery; and performance and value creation in use, thus enabling a systemic approach to the required transformations, driven and informed by a coherent portfolio of research activity. Furthermore, by bringing together two of the top rated research units in the built environment, the Centre represents a complementary combination of the best in the field and ensures impact from its research findings through its industry focused enterprise centres and from the industry based work and increased skills of the Engineering Doctorate students in the CICE Doctoral Training Centre at Loughborough and the Professional Doctorate at the University of Salford. The creation of this Centre will stimulate a departure from traditional thinking, focus the debate, act as a focal point for knowledge collection, permit the necessary research and development to be conducted, allow the identification of further research requirements, act as the catalyst for change, facilitate the creation and deployment of the necessary expertise required to influence policy and therefore lead the transformation of the industry into a modern, sustainable and innovative manufacturing industry.

CAPABILITY OF THE RESEARCH GROUP TO ENGAGE WITH USERS

Addressing the challenges requires new approaches in terms of research priorities and methodologies. The team assembled builds on the strong foundations of the existing IMRCs at Salford and Loughborough, combining experience of running such centres with a strict selection from amongst only the existing academics whose research focus is aligned with the new Centre's vision. This core group is then strengthened by academics from Salford and Loughborough who address previous research gaps around user engagement, sustainable design and integrated teams. As the detail in the Research Challenges shows, the investigators comprise a multidisciplinary team consisting of internationally leading academics that are positioned to tackle the major challenges identified by the Centre and that have a demonstrable record of academic excellence with industry and policy impact.

University of Salford
Centre Director: Prof Peter Barrett
Centre Chair: Prof Mike Kagioglou, Head of School
Carl Abbott: Current SCRI Manager
Arto Kiviniemi: Professor of Digital Architecture
Lauri Koskela: Professor of Theory Based Production
Peter McDermott: Professor of Construction Procurement
Marcus Ormerod: Professor of Inclusive Design

Loughborough University
Centre Co-Director: Prof Dino Bouchlaghem, Director CICE
Naomi Brookes: Royal Academy of Engineering and European Construction Institute Chair in Complex Project Management
Stephen Emmitt: Professor of Architectural Technology
Dr Steven Yeomans: Current CICE Manager
Paul Chung: Professor of Computer Science

The research team is strongly embedded in the international research community and the proposed work is explicitly fashioned to meet a significant international challenge, whilst also accessing complementary expertise across the globe. Examples of the international profile of the Centre's members are: the immediate past President (Barrett, 2007-2010) of the CIB (involving 2000 experts in 60 countries) and the co-ordinators of the CIB Working Commissions on Architectural Management (Emmitt) and Construction Procurement (McDermott) and the CIB Task Group on Recognising Innovation in Construction (Abbott). Dino Bouchlaghem and Peter McDermott are the editors of the International Journal of Architectural Engineering and Design and the Journal of Construction Procurement respectively. In Lauri Koskela and Arto Kiviniemi the team brings considerable experience of the VTT research centre in Finland. Lauri was a founder of the International Group for Lean Construction in which Prof Mike Kagioglou has also been prominent. Arto was until recently the Vice-President of Granlund, the largest building services engineering company in Finland. Naomi Brookes holds the Royal Academy of Engineering and European Construction Institute Chair in Complex Project Management. In addition to the over 40 industry members of the European Construction Institute other international partners that will collaborate to bring complementary perspectives to the research problems include: CSTB, Grenoble; SBR/Aalborg University, Denmark; Philips Lighting, Eindhoven; Salk Institute and ANFA, La Jolla, California (all deal with particular aspects of sensory perception and human interpretation of the built environment); MIT (Collaborative work on creative spaces), Stanford, California (Post Occupancy Evaluation); Hearthstone Alzheimers, Boston (design for alzheimers patients and clinical effects of good design); Berkeley, California (Lean Production); Technion, Israel (Lean Process and BIM integration); Aalto University, Finland (BIM Implementation) and Hong Kong Polytechnic University and Queensland University of Technology (Procurement & Industry Structure).

USER DIRECTION AND COLLABORATION

The proposed Centre is built upon the robust collaborative foundation of two existing IMRC Centres combined with the Industrial Doctorate Centre for Innovative and Collaborative Engineering (CICE). These Centres have established a successful and internationally recognised reputation for fostering outstanding industry collaboration with a wide range of influential

[1] Never Waste a Good Crisis (2009, Constructing Excellence)

companies from the construction sector. Both IMRC Centres are also greatly strengthened by additional funding (European, ESRC, AHRC, TSB, industry membership and consultancy) throughout the Technology Readiness Levels and through their partnerships with the Centres for Construction Innovation and Construct IT at the University of Salford and the CICE and European Construction Institute at Loughborough University. This has enabled an influential team of existing industry collaborators to be brought together to assist in the ongoing development of this proposal. Various individual meetings and three workshops have taken place since February 2010 with a final workshop hosted by the Dept of Business, Innovation & Skills which took place on the 16th June to refine and endorse this proposal. A future programme is planned in developing the proposal to the full stage. Taken together the existing IMRCs and Doctoral Training Centre have, over the previous 8 years, engaged in activity that has generated over £10m of in kind and cash contributions from industry partners. This is strengthened by an additional £7m of audited research impact from associated enterprise centres of the universities. It is anticipated that this level of industry investment will continue. The development of the proposal thus far has been characterised by its co-development with its industry partners and this will continue to be the ethos of the Centre once established. Key members of these organisations will therefore be co-opted onto the Centre's research advisory committees with a smaller steering committee consisting of leading external UK industrialists and international academics that will play a crucial role in critically appraising the Centre's activities.

The following have been actively involved in developing this proposal and have explicitly agreed to engage in collaborative research: Tristram Williams (BAM); Colin McKinnon (Buro Happold); Rennie Chadwick (VINCI Construction UK Ltd); Zara Lamont (Carillion); John Lorimer (Manchester City Council); Anthony Dillon (Willmott Dixon); Chris Woods (Wates Construction); Jon de Souza (Construction Clients Group); Neil Sachdev (Sainsbury's); John Findlay (JDF Works Limited), Richard Saxon (Consultancy for the Built Environment)

APPROPRIATENESS OF FUNDING MECHANISM

The challenges faced by the construction sector are long term and structural in their nature. The response requires new knowledge that can only be generated by long term user driven collaboration within a research environment that is embedded in a wider innovation system that drives impact downstream through adoption and application phases. In particular the Centre for Innovative Manufacturing funding mechanism will bring together a critical mass of the leading academics in the field, in a way that allows challenges to be addressed through linked and planned programmes of activity. This provides the ability to deliver against a long-term vision that is co-developed and recognised by industry, in a team-based manner. There will be two main elements to the Centre's activities: supporting platform activities and flagship research themes.

The platform activities will provide the supporting environment for the Centre's research and ensure that its findings create the maximum impact. In addition to the retention of key staff, activities here include: **Nurturing Collaboration** through the Steering and Advisory Groups, secondments to and from industry, international exchanges with recognised experts and networking with other centres. **Marketing and dissemination** which in addition to reports, websites, events and forums will further enable the development of interactive information exchanges (eg SCRI Live http://live.scri.salford.ac.uk/) through blogs and other interactive media. Additionally, platform funding will enable three types of research activity to occur. Firstly, **vision development** work which will raise industry expectations by enabling the identification of preferred futures and causes of current market failure. Secondly, demonstrating the possible, through **informing studies** that provide in depth analysis of international excellence. Thirdly, **rapid response** projects that arise from immediate needs identified within the Centre's flagship activities which will, where appropriate, bring in external experts.

As detailed in the research challenges, the Centre will pursue two flagship research themes: maximising value in use and delivery of whole life solutions. The funding mechanism will enable the research to tackle near and long-term challenges within these themes. Four main approaches will be employed. Firstly, **underpinning studies** that work to build an actionable evidence base around the holistic user experience. Secondly, **pilot studies** will be employed to implement manageable change in organisations and learn from the results. This leads to the third approach, namely **longitudinal studies,** that will play a vital role by enabling the Centre to monitor projects through their full life cycle, so closing the loop between user and design intent and performance in use. In parallel with these long term projects the Centre will, fourthly, employ transformational research approaches through **design science** aimed at developing new methodologies and techniques to proof of concept stage.

RESOURCES REQUESTED

The resources requested for the project are as follows: FEC Budget of £5.56m with an expected grant of £4.47m. The FEC Budget comprising: £1.34m Directly Allocated; £2.45m Directly Incurred; Indirect Costs £1.68m and £106k Exceptions. The Director and Co-Director have been allocated to the project for 25% and 20% of their time respectively. All other Co-investigators have been allocated 10% time allocations with Prof Kagioglou allocated at 2% reflecting his responsibilities as Centre Chair without direct research involvement. The RF allocation is equivalent to 540 person months of time. The distribution of the resources from the expected grant is in the ratio of £1.9m to the platform activities and £2.6m to the two flagship activities. The platform activity comprises of: Half the Director and Co-Director's time plus administration, other costs and the funded PhD students, together with approximately one third of research effort from the investigators and directly allocated researchers which will be allocated to the vision development, informing studies and rapid response projects. This provides the appropriate balance between flexible and responsive activity and planned programmes of work.