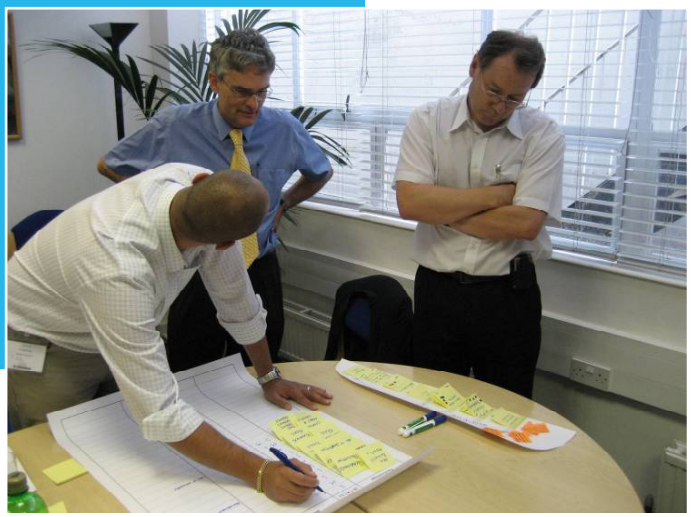
ICT and Automation (ICTA) Scoping Study Report



National Platform for the Built Environment
CONSTRUCTING EXCELLENCE

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ATKINS

Balfour Beatty

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Infrastructure Services

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Taylor Woodrow

DEPARTMENT FOR BUSINESS
ENTERPRISE & REGULATORY REFORM

Foreword

Sir John Egan's 'Accelerating Change' report in 2002 identified IT as a cross-cutting issue for the construction industry, and while we have seen great strides in the use of some technologies, take-up of other tools has been hampered by lack of industry input to their efficient development and deployment.

In June 2006, the National Platform's Strategic Research Agenda highlighted the key role that research into ICT and automation could play in supporting the future competitiveness of the UK construction industry. Since then, we have sought to flesh out this role. We have identified – from an industry-led perspective – what types of information, communication and automation technologies needed to be developed. And, perhaps more importantly, we have developed a vision of how they might be integrated together.

The future success of the UK construction industry in an increasingly competitive global market will depend upon the efficiency with which we create and reuse information throughout the design, construction and whole life management of our built assets. Innovations here will also support dramatic improvements in how we collaborate in the timely and efficient creation of a more sustainable built environment.

This is an ambitious, forward-looking report that should serve as a call to arms to everyone concerned about the future of our industry and our built environment.

Keith Clarke

National Platform High Level Group Chairman; Chief Executive, Atkins

Bob White

National Platform Support Group Chairman; Chief Executive, Constructing Futures

Executive Summary

This National Platform 'ICT and Automation' (ICTA) Scoping Study report is intended as a 'Call to Arms' for industry.

The strategic research programmes / roadmaps are the key section of this report (see *Section 2 – Strategic Programmes / Roadmaps*), and should be reviewed and updated periodically to ensure relevance and longevity.

The roadmaps were developed through a combination of work carried out by the National Platform ICTA Working Group, and through information gathering and analysis during two roadmapping workshops – held specifically for this Scoping Study. Additionally, a significant amount of desktop research was carried out to review a number of existing Built Environment roadmaps from other countries – this information was used to supplement the work carried out by the Working Group and workshops, and to highlight any commonalities.

In order to achieve the industry's long-term vision of itself, the 'ICT and Automation' priority area has identified the following five key research topics:

- *Collaborative Prototyping to Define and Deliver Client Requirements (Roadmap R1)*
- *Efficient, Seamless Sharing of Information Across the Built Environment Stakeholders (Roadmap R2)*
- *Ability to Interact with Real-Time Information Regardless of Physical Location or Timezone (Roadmap R3)*
- *Mass Adoption and Application of Off-Site Manufacturing, Automation and Mechanisation Processes & Systems (Roadmap R4)*
- *Well trained, well qualified workforce able to use the latest best practice technologies (Roadmap 5)*

By completing the research activities described in all five detailed roadmaps, and then integrating all these outputs into industry, the overall ICTA vision will be achieved.

To illustrate how the five themes might be integrated an example scenario has been devised:

Clients work with a multi-disciplinary team to use existing knowledge about their activities, anticipated future requirements, and industry knowledge about similar client needs to agree a brief - describing the organisational need for future facilities, and working on the principles of best whole-life value. As the brief is developed, additional team members are brought into the team as early as possible, and begin to use a virtual environment to prototype or model solutions which meet all the various dimensions of the brief – functionality, aesthetics, logistics, ease and safety of construction, operation and maintenance, whole life cost, sustainability, etc. Regardless of their location, all authorised project participants can interact with this virtual environment using various different computer hardware/software combinations, with the latest model version being readily available online, and over time being progressively populated to increasing levels of detail.

Once a consensus is reached about the finished form of parts of the facility, manufacturers and suppliers (already involved in the design process) reuse model information for offsite fabrication (perhaps extensively automated) of the required components in the optimum sequence for just-in-time delivery to the correct zone at the facility's location. Each component has an embedded device that carries all relevant information about its manufacture, material, service requirements, etc, and its arrival on site is, of course, automatically recorded. Once delivered, each component is swiftly and safely installed in its precise position by skilled site operatives - supported, where appropriate, by robot devices. All site operatives, project managers and other personnel wear small devices that monitor their exact position, giving warnings, where necessary, regarding the individual's safety and security. These wearable devices can also provide data about individuals' immediate surroundings (drawing on the embedded data in installed components and data stored in the virtual model), helping, for example, operatives to undertake site activities, with context-sensitive viewing tools (e.g. VR glasses) providing audio-video installation guidance. Those with managerial responsibilities can interrogate the online environment to get real-time updates on schedules, projects costs and other performance parameters – the same data also being available simultaneously to, for example, a client representative sitting in a remote geographic location – perhaps in another timezone.

As on-site processes are completed, the virtual environment is populated with as-built data that can be seamlessly reused for operation and maintenance purposes. The building model thus becomes a powerful asset management tool, linking the facility owner/operator with relevant suppliers or maintenance contractors, with all repairs or replacements automatically recorded. The actual in-service performance of building components is logged and can be interrogated by the owner/operator, manufacturers/suppliers, and by authorised professionals tasked with designing and delivering similar facilities for the same or (subject to confidentiality limits) similar clients. Similarly, any extensions, alterations or changes of use of the facility are also recorded for feedback purposes, and to inform future developments.

1 Introduction

1.1 'National Platform for the Built Environment'

Mission: The National Platform aims to demonstrate that research is a vehicle for industry transformation, and persuade industry that research is a core, business critical issue.

'National Platform' is an initiative to mobilise the whole Built Environment sector (see *Figure 1 - Three economic sectors form the Built Environment*) – contractors, authorities, architects and other designers, purchasing bodies, and the full range of suppliers, clients and users – to find a clear set of common industry priorities. (*See Appendix A - National Platform Strategic Research Agenda*)

Being industry-led, and supported by authorities, it will contribute to the forthcoming European and National programmes for research, development, innovation and demonstration of the built environment.

Consequently, National Platform seeks to influence and improve access to UK and EU research funding (through close links to ECTP – European Construction Technology Platform) to significantly increase the level of strategic, collaborative research in the UK Built Environment sector.

This initiative provides us with the opportunity to rethink the process of designing and building our environment, and to introduce a new approach to construction, thereby transforming the Built Environment into a competitive, responsible, knowledge-based, and client-orientated industrv.

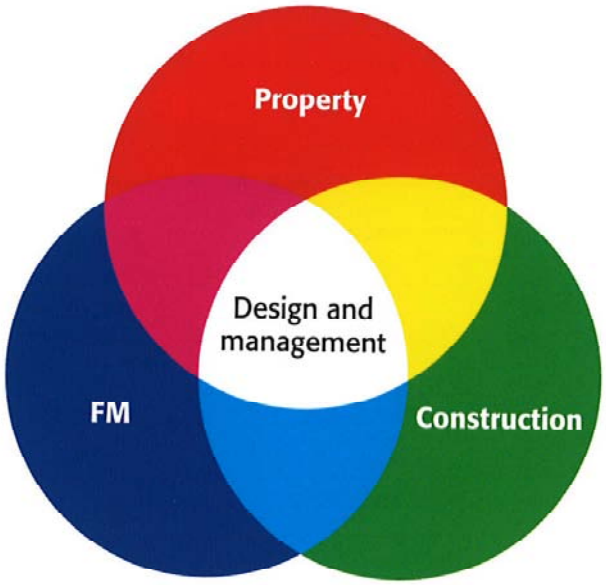

Figure 1 - Three economic sectors form the Built Environment

1.2 Background

In early 2006, the National Platform undertook a poll of members and colleagues, based on the European (ECTP) Strategic Research Agenda.

The key areas identified as high priority for the UK are:

- *Reduced Resource Consumption*
- *A new Client-orientated, Knowledge-based, Construction Process*
- *ICT and Automation (ICTA)*

Note: See *Appendix B – Glossary of Terms, for definitions of 'ICT' and 'Automation'* **(**and other terms and abbreviations used throughout this report).

1.2.1 Aims

An ICTA Working Group (see *Appendix C1 – Workshop Attendees for members*) was established mid-2006 to translate the National Platform's Strategic Research Agenda (see *Appendix A – National Platform Strategic Research Agenda)* into an industry-led prioritised research programme that:

- Supports the journey towards the UK industry's long-term (15 year) vision of itself.
- Influences the European (ECTP) SRA to ensure EU funding is available to meet the UK's requirements.
- Informs UK funding bodies' research programmes, easing access to these sources for stakeholders in the Built Environment.
- Encourages collaborative research projects (that collectively form a coherent programme of work).

1.2.2 Objectives of the ICTA Working Group

In consultation with industry, define themes and a supporting strategic research programme.

- Establish long-term (15 year) research objectives, and organise long-term research actions, that correspond with both market-driven innovation and long-term vision.
- Provide a research programme / roadmap for researchers and industry i.e. pave the way for research by establishing a clear set of directions and priorities.

- Accelerate the adoption, take-up, development, and research of emerging and new technologies that may revolutionise the Built Environment sector at large.
- Maintain close ties with the ECTP PICT (Process and ICT) focus area, and review and contribute to their SRA and Implementation Action Plan.
- Ensure alignment with the other two National Platform priority areas: Reduced Resource Consumption; and Client-Orientated, Knowledge-Based Construction Process (see *Appendix A - National Platform Strategic Research Agenda*).
- Propose longer-term resource - required to facilitate and monitor the development / implementation of research projects within the programme.

1.2.3 Initial Work Undertaken by ICTA Working Group

Work carried out by the ICTA Working Group prior to the commissioning of the Scoping Study (up to May 2007) included:

- Streaming of initial key areas.
- Initial discussion and clarification of the potential benefits, key requirements, potential research areas, existing good practice, and potential resources and members.
- Ranking and rating of themes, revised groupings, draft process and flow diagrams.
- Initial consultation with University of Salford to check assumptions, gaps, and potential overlaps.
- Consultation with National Platform, Constructing Excellence and DTI.
- Identification of the best way forward to achieve the stated aim and objectives, i.e. a Scoping Study.

Note: Initial work undertaken by the ICTA Working Group has been identified in *Appendix E - Summary of Existing Roadmaps and Workshops* under the column heading 'UK NP ICTA'.

1.3 Scoping Study

This ICTA Scoping Study was commissioned in August 2007 to:

- Produce a long-term (i.e. strategic) research programme / roadmap for the NP HLG to endorse for publishing.
- Identify and engage key stakeholders from industry and research through the research programme development process.

The Scoping Study will subsequently be used to help:

- Mobilise the whole built environment sector in a focused way.
- 'Pave the way' for research by establishing a clear set of common industry priorities.
- Accelerate the adoption, take-up, development, and research of emerging and new technologies that may revolutionise the built environment sector at large.
- Improve access to EU and UK research funding.

The Scoping Study has also addressed HLG feedback:

- Longer-term vision.
- Increased focus on automation.
- Not to focus on legal / contractual issues.
- Focus on industry's requirements (i.e. demand), rather than existing research (i.e. supply).

1.3.1 Desktop Research

In producing the Scoping Study, the following existing built environment roadmaps were reviewed to identify gaps, overlaps and synergies, thereby compiling a 'super-roadmap' (see *Appendix E - Summary of Existing Roadmaps and Workshops*):

- ECTP Strategic Research Agenda / Implementation Action Plan (Europe)
- National Platform ICTA Working Group's previous work (see Section 1.2.3) (UK)
- Strat-CON / ROADCON (Europe)
- Foresight – 'Constructing the Future' (UK)
- Construction 2020 – A Vision for Australia's Property & Construction Industry (Australia)
- FIATECH (USA)

1.3.2 Roadmapping Workshops

It was recognised that to ensure the above aims and objectives were met, roadmapping workshops with a broad range of industry delegates were required.

Adopting a roadmapping approach ensured that the resulting research programme:

- Addressed the entire context within which ICTA sits.
- Identified and engaged key stakeholders from industry and research in the research programme development process.
- Obtained industry endorsement of the resulting research programme / roadmap.

The 29 delegates that attended the two workshops were invited from a broad range of industry backgrounds (i.e. clients, funders, consultants, contractors, vendors, suppliers and academia), and were generally relatively senior individuals within their organisations.

The roadmapping workshops concentrated on ICTA as a means to an end, rather than the end in itself (i.e. focusing on the value that ICTA can bring).

They also focused on how ICTA can help address the increasing challenges of the UK Built Environment industry by:

1) Addressing strategic business drivers for the industry - i.e. High level / long term issues (over 10-15 year timescale).

2) Establishing which ICTA products, services and technologies are required to address these drivers.

3) Identifying the research that needs to be carried out to enable the development of these products, services and technologies.

Following the workshops, their outputs were analysed to consolidate and prioritise the 'super-roadmap' (see Section 1.3.1), thereby creating the National Platform ICTA Strategic Research Programme.

See *Appendix C – Roadmapping Workshops* for details of workshop attendees, the roadmapping methodology, the template used to present the outcomes, and photographs of the delegates in action.

1.3.3 Constraints and Assumptions

The key constraints and assumptions experienced during the delivery of the Scoping Study were:

- Tight delivery programme (especially over holiday season) – see *Figure 2 - Scoping Study Delivery Programme.*
- Limited workshop attendance by client bodies and construction suppliers.
- HLG feedback advised the Scoping Study to ignore the legal and contractual issues (assume these issues will be dealt with by others).

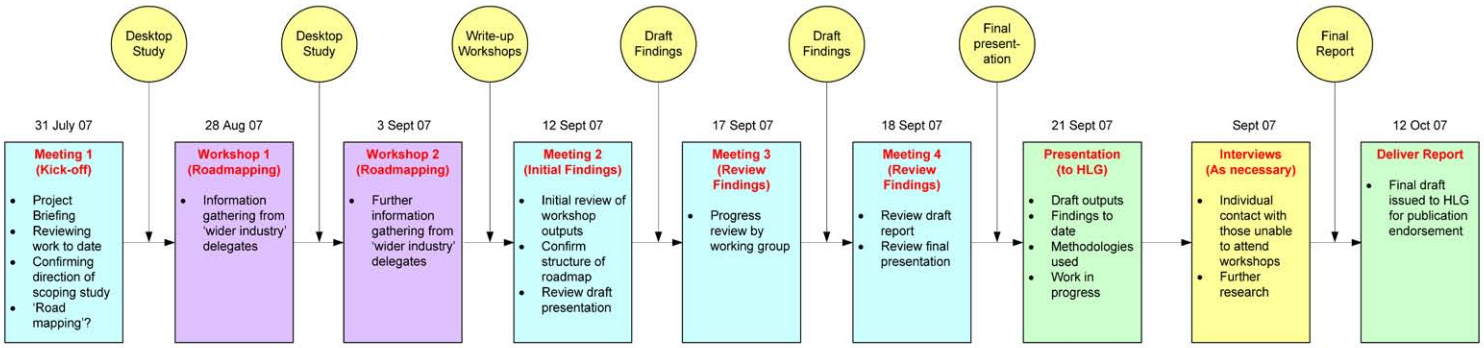

Figure 2 - Scoping Study Delivery Programme

2 Strategic Programmes / Roadmaps

2.1 Global Drivers of Change

Global economic competition has compelled many organisations to explore all possible options for improving the delivery of their products or services. This trend has also become apparent in the construction industry, with clients expecting a better service and projects that meet their requirements more closely. This has challenged the industry to become more efficient, integrated and attractive, both in the eyes of society and its potential workforce.

The global drivers of change, arising from social, technological, economic, environmental and political trends, which will influence the construction industry in the next fifteen years, can be consolidated into nine key drivers:

- Urbanisation, growth of cities, and transportation.
- Ageing population.
- Rapid technological and organisational change.
- Environmental and climate change.
- Shift from public to private.
- The knowledge economy and information overload.
- Technologies for tomorrow.
- People, safety and health.
- Vulnerability, security, corruption and crime.

In response, government, industry or research-led construction change initiatives have emerged in most developed countries which set out a vision of where the industry should head. For example, in the UK the key 'call to arms' reports include *Constructing the Team* (Latham, 1994) and *Rethinking Construction* (Egan, 1998). Sought after improvements, common to most of the initiatives, include reducing construction time and cost, defects, accidents, waste and operation and maintenance costs, whilst improving predictability and productivity.

Figure 3 - Construction Industry Drivers of Change illustrates these global trends which have led to the identified construction drivers, and instigated the targets for improvement. It is these intra-construction industry targets for improvement that have been taken to form the drivers for the ICTA Roadmaps.

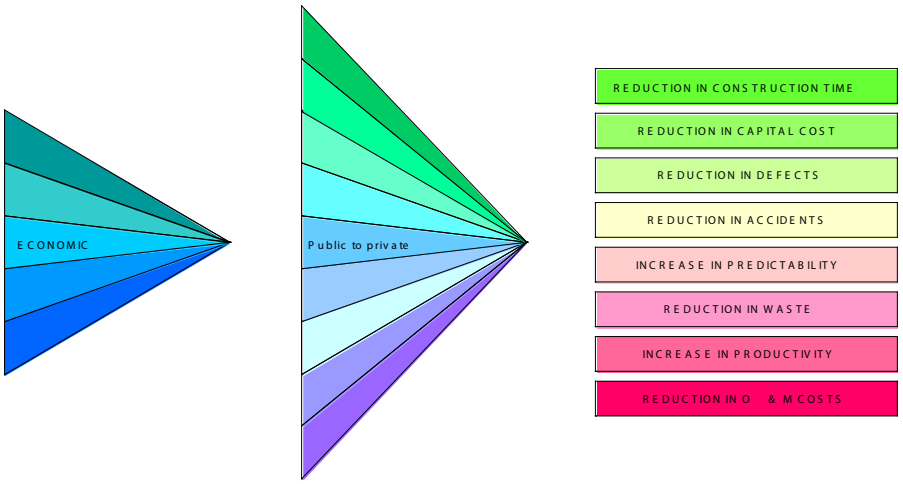

Figure 3 - Construction Industry Drivers of Change

2.2 Summary Roadmap

In order to achieve the industry's long-term vision of itself, the 'ICT and Automation' priority area has identified the following five key 'research topics' that must be addressed:

- Collaborative Prototyping to Define and Deliver Client Requirements
- (Achieved by Roadmap R1)
- Efficient, Seamless Sharing of Information Across the Built Environment Stakeholders
- (Achieved by Roadmap R2)
- Ability to Interact with Real-Time Information Regardless of Physical Location or Timezone
- (Achieved by Roadmap R3)
- Mass Adoption and Application of Off-Site Manufacturing, Automation & Mechanisation Processes and Systems
- (Achieved by Roadmap R4)
- Well Trained, Well Qualified Workforce able to use the Latest, Best Practice Technologies
- (Achieved by Roadmap R5)

Consequently, the National Platform initiative can firstly be subdivided into the three priority areas identified in Section 1.2 – Background, with ICTA being subsequently divided into the above five research topics (see *Figure 4 - Summary Roadmap*).

Note: NP ICTA headings have been mapped against ECTP headings to help identify commonalities.

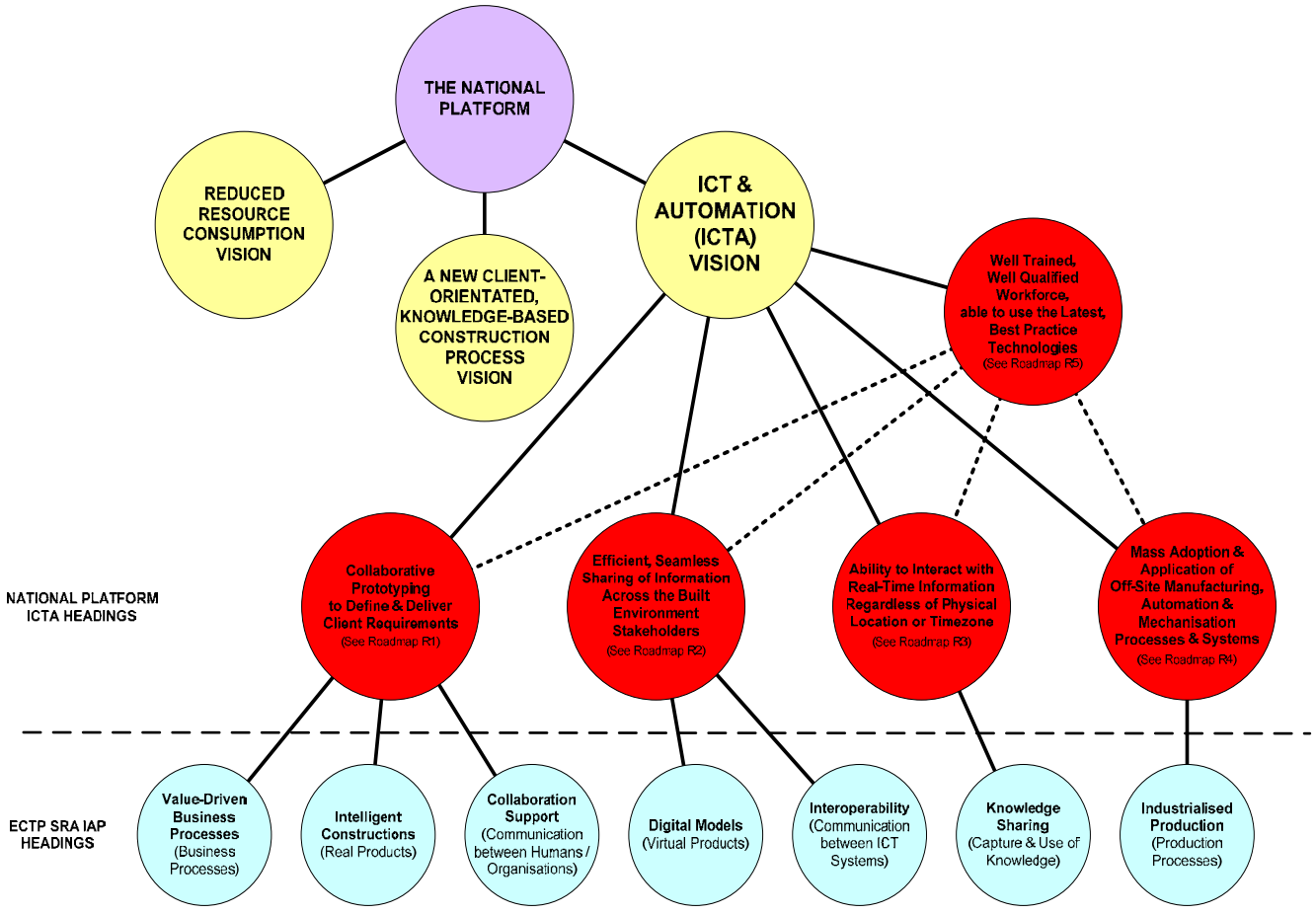

Figure 4 - Summary Roadmap

2.3 Detailed Roadmaps

Each 'research topic' has a detailed roadmap (see pp 12-16), which schedules out the products, services and technologies (blue boxes) that were identified by the industry as being necessary to address the key drivers (yellow arrow).

Subsequently, in order to deliver the products, services and technologies, the research and enablers have been identified in the green boxes (divided into short, medium and long-term activities).

By completing all five detailed roadmaps, the overall ICTA vision (see Section 2.4) will be achieved.

Important:

1) Although there may be a temptation to focus research efforts on developing the technologies, products and services, it was strongly emphasised by all involved that the 'people' issues (e.g. training, culture change, leadership) and 'process' issues (e.g. integration of supply chain and systems, contracts / legal) are key to bringing about effective change – see Figure 5 - Relative Importance of People, Process and Technology.

2) It is also worth highlighting that there may be significant benefits (time & cost) in adapting research / learning from other industries (e.g. more advanced manufacturing industries, such as automotive and aerospace) to the Built Environment – further research in this area is recommended.

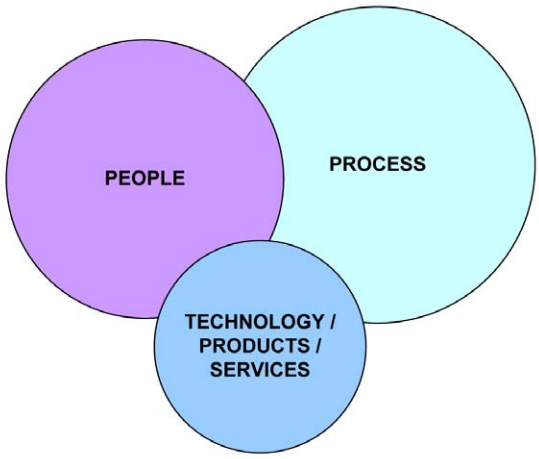

Figure 5 - Relative Importance of People, Process and Technology

There are some blank boxes on the detailed roadmaps (e.g. ICT Infrastructure roadmap). The reason for this is due to the fast-moving nature of some of these research themes (e.g. trying to map out IT infrastructure requirements more than four years from now was not considered worthwhile).

Finally in this section, to review the detailed source information that has been used in creating these roadmaps, and for the links / synergies with the ECTP SRA Implementation Action Plan, and other roadmaps, refer to Appendix E - Summary of Existing Roadmaps and Workshops.

Roadmap R1

See following spread.

For larger versions of the Roadmaps, please see the file entitled “ICTA Scoping Study Roadmaps_Large.

DRIVERS

- **Increase in predictability**
- **Reduction in waste**
- **Reduction in defects**
- **Reduction in capital cost**
- **Reduction in O & M costs**
- **Reduction in accidents**

PRODUCTS / SERVICES / TECHNOLOGY

	SHORT	MEDIUM	LONG
Intelligent Assets R1.1	• ICT to determine **optimum facility operating conditions**, and maintain operations within the performance envelope (i.e. energy efficient assets) • **Wireless and powerless sensors** that support interactive spaces - providing personalised, location and context-aware services	• **Remote diagnostics** and control (real-time condition assessment, predicting problems before they arise, and enhancing performance of the asset) • **Automated (& integrated)**, highly accurate capture of as-built data, to be fed into Asset Lifecycle Information System • **Embedded learning** / user support, and feedback to designers and planners • **User-aware working** / living / transport environments - access to information for optimising operations • **Personalised** location and context aware services	• **O&M decisions** and facilities management to be based on a fully integrated consideration of all lifecycle (e.g. environmental, cost) factors, supported by accurate, current, and complete data from ALIS • **Self-maintaining**, self-repairing facilities and systems will enable safe, secure, continuously optimised operations with near-zero downtime • **Adaptive systems** that learn from their own use and user behaviour, and are able to adapt to new situations without manual configuration, maintenance and support i.e. self-optimising systems • **Accurate prediction of asset performance** / improved energy efficient design
Advanced 'Next Generation' ICT Collaboration Applications R1.2	• **Transaction management** for electronic exchange of information to ensure documents meet a pre-defined level of legal validity (e.g. within an ICT contract), security (e.g. digitally signed), and trust	• Fast access to latest (**model-based**) information, anytime, anywhere • **Robust team interaction** e.g. information sharing and collaborative design	• **Seamless inter-enterprise integration**
Client Engagement Tools (Involvement, end-user satisfaction, value) R1.3	• **Requirements management tools (**to help with identifying & capturing the client's needs and allow them to transparently see how their requirements are transformed to best-in-class solutions)	• **Compliance assessment tools** (to ensure the final asset meets the customer's aspirations) • **Streamlined client approvals**	• **Decision support tools** e.g. to demonstrate to clients the performance of their asset before they decide to construct ('Try before you buy'); or to test alternative courses of action ('What if?' analysis) • **Customer-orientated configuration design**
Whole-life Assessment Tools (Cost, environment, society) R1.4	• **Building MOT's** (i.e. periodic independent inspections to check assets are performing above a minimum required standard) • **Socio-economic modelling** (to improve sustainable community development, predict effects of investment, and understand the system)	• **Whole-life costing tools** to include all environmental costs (to provide a clear business case for addressing environmental issues) • **Comprehensive eco-efficiency evaluation tools** for all stages of the asset lifecycle (providing ready assessment of environmental performance against best practice)	• Total lifecycle is supported by **ICT tools / services for whole-life decision making**, management & appraisal, by users, owners and society

Collaborative Prototyping to Define & Deliver Client Requirements

RESEARCH / ENABLERS

- Research & develop socio-economic models
- Requirements management - research ICT tools to capture the clients' requirements and transform them into technical solutions
- Research & develop use of active & passive wireless sensors, & RFID
- Investigate how to (most easily and economically) retrofit intelligent sensors / systems into existing building stock
- Research the use of transaction monitors to automatically compliance check electronic information / documentation across collaborative platforms
- Research and publish more forward-looking building regulations / design standards (currently based on retrospective data, that is becoming rapidly out-of-date due to current trends in climate change)
- Better understand, & communicate, the relationship between long-term lifecycle costs and initial facility costs
- Research & develop embedded intelligence in products & components
- Legal and contractual governance and agreements on practical procedures for ICT based collaboration e.g. model contracts
- Identify and address organisational and personal barriers to the adoption of ICT based collaboration (i.e. culture)
- Develop standardised management processes for ICT collaboration between designers, suppliers, contractors, end-users and other stakeholders

- **INTEROPERABILITY ENABLERS**
- **REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS**
- Compliance assessment - Research ICT-based verification tools, where technical solutions can be (automatically) verified against the set performance requirements (e.g. client's brief, design standards) ensuring there are no defects in the final product
- Use of BIM for client approval
- Research & develop ICT and methods for post-occupancy reviews
- Develop model-based process / workflow management: intelligent workflow aid; combining product model (PLM) with scheduling, resource planning (ERP) and progress monitoring
- Research & develop common platforms, networks and protocols for all systems in buildings to share
- Develop ICT to calculate energy used, and compare against design forecasts (from data model)
- Research methods for use, monitoring, operation and maintenance with intelligent embedded systems; user and context aware control; and ambient user interfaces e.g. integration of computing into the built environment to facilitate information gathering, such as visible energy use 'metering' (allowing occupiers to measure carbon footprint)
- Refocus from the purely technical to include the human element / attitude (i.e. technology is developing faster than human behaviour is changing)
- Facilitate a culture of co-operation and trust (e.g. partnering) between distributed teams, and encourage risk and reward sharing
- Create virtual communities using sophisticated applications based on WebDAV (Web-based Distributed Authoring and Versioning)
- Research & develop the design of workplaces for more efficient, collaborative and productive working

- **INTEROPERABILITY ENABLERS**
- **REMOTE WORKING & CONNECTIVITY TECHNOLOGIES ENABLERS**
- **ASSET LIFECYCLE INFORMATION SYSTEM ENABLERS** (i.e. data model for lifecycle of asset, with single point data capture)
- Research & development of new visualisation, virtual reality and communication tools / techniques, using shared integrated data models, enabling a 'value' & performance assessment of the asset to take place in many dimensions: e.g. energy consumption, visual impact, functionality, internal environment quality, safety, security, flexibility, operating costs and expect lifetime
- Develop optioneering capabilities e.g. climate change 'what if?' analysis (using model simulation, and based on rules and evidence)
- Research mass customised system concepts e.g. clients can order buildings like they now buy cars - selecting from a limited number of choices, creating widely different end results

DRIVERS

- Reduction in waste
- Reduction in defects
- Increase in productivity
- Reduction in construction time
- Increase in predictability
- Reduction in O & M costs

PRODUCTS / SERVICES / TECHNOLOGY

	SHORT	MEDIUM	LONG
Digital Models R2.1	• **Integrated nD models** (for use / development throughout the project lifecycle) • **Design software** based on digital modelling technologies (with visualisation and decision support tools)	• **Virtualised / simulated built environments** (incl. construction / manufacturing simulation) as standard service • **Product and production optimisation tools** • **Model based services**: new business opportunities enabled by model-based data e.g. design, analysis, estimation, visualisation, simulation etc. (computer-interpretable information allows highly specilised services using sophisticated software to become feasible)	• **Asset Lifecycle Information System** (i.e. a fully integrated solution in which the standards, models, etc. are created and developed for a specific asset) • **Virtual building model**, containing comprehensive as-built data of the building, delivered with building. FM is carried out using this model, e.g. automatic maintenance schedules
Interoperability (Availability of existing information for new purposes without re-entering) R2.2	• **Intelligent mark-up** • **Standard approach to BIM** over collaborative extranets (allowing distributed management of data model) • **Standards for data & metadata exchange**, object definitions & integrated model servers • **Single standard for data storage** throughout industry	• **Compatibility and interoperability of software** / systems that are being used throughout all stages of projects (e.g. design, procurement, manufacturing, construction, operation) • Migration from data/file exchange to **data sharing** • **Ontologies & open ICT standards** for semantic web-based communication throughout the supply chain • **Intelligent documents** (codes, standards, legislation)	
Integrated Processes (Design, procurement, construction, FM, PM, cost, risk, programme, etc.) R2.3	• **Model-based individual tools** e.g. risk assessment, design, etc.	• **Fully automated (model-based) procurement system** - seamlessly integrated with all other project systems e.g. design, PM, finance, controls, etc. (i.e. 'cradle to grave' integrated processes, tools & standards) • **Integrated project management**	
Knowledge Management R2.4	• **IPR protection** of complex, shared data	• Develop and maintain a **shared, industry-wide knowledge base** of reference information	• ICT for **capturing unstructured project data** & experiences, and transforming them into sustainable corporate assets

Efficient, Seamless Sharing of Information Across the Built Environment Stakeholders

RESEARCH / ENABLERS

- Establish mechanisms to ensure & maintain Intellectual Property Rights (IPR) for information input to shared databases
- Model data – research & develop methods, techniques & tools for assigning & maintaining IPRs for different components of the model data, and checking for secure transactions
- Research the collaborative manipulation of shared models using GRID-based and other technologies
- Develop, implement & embed data and metadata standards for information exchange
- Research use of BIM for business processes e.g. risk management, procurement
- Develop use of 3D model in planning process i.e. 4D (linked to master project schedule), incl construction planning
- Recognition of value of asset data in financial terms (not just the hardware / applications it runs on)
- Research sharing of structured (e.g. tables and databases) knowledge
- Develop the technical framework for both data management and information exchange that will be used by all business processes and applications
- Define the business processes involved in the project and facility lifecycle
- Develop the requirements for tools / models necessary to support the business processes
- Evaluate the tools / models identified in the marketplace and develop additional tools / models as required
- Need to re-engineer / reanalyse business processes for a data-focused environment, rather than being based around physical documents
- Develop a better assessment and understanding of risk
- Research how to use data models to phase work activities
- Develop nD modelling and grid computing for construction design
- Research methods for integrated BIMs and collaborative extranets to work together
- Develop legal and contractual governance of model data e.g. access and change rights at object and attribute level
- Research an integrated model-based standard, bringing together several currently isolated standards
- Develop a single standard for legal ICT working
- Establish practices for ownership of data, and liability for data integrity
- Demonstrate the true cost of poor interoperable working
- Establish legal aspects of objects e.g. IFCs: attaching attributes to objects, who owns the object, who has the right to modify attributes, etc
- Assess legal implications resulting from the introduction of ICT solutions to traditional practices, and adapt and develop the legal framework

- Create open standards as required for the data model and for business processes and best practices
- Develop fully integrated, semantic web & web services technologies i.e. additions of intelligence & annotations to web content to facilitate retrieval & interpretation by different applications (both human & computer-driven)
- Specify & develop infrastructures, model-based applications & Smart agents, which are based on open standards, grammar / syntax, ontologies & content
- Develop open object-orientated ontologies & model servers
- Develop 3D product definitions, and specifications (for automated procurement)
- Research method for using output from design systems to link with suppliers' network, and identify need for restructuring of the supply chain
- Research methods to integrate engineering, project controls, financial systems and procurement work processes and supporting tools
- Research model-based applications, and interfaces for communication with other applications
- Research & develop model checking tools - for validating model data against standards, regulations, design rules, contracts etc, with notification of identified conflicts and, when possible, suggesting corrective measures
- Define and develop an 'Integrated Model server' (providing common access to databases with geometry, for sharing product model data)
- Develop object databases e.g. product / component libraries (providing consistency and re-use of correct information)
- Research how to use information on construction products & materials (in the form of standard coded data e.g. IFC - Industry Foundation Classes) better
- Research whether DWF could be used as alternative to IFC
- Need technology take-up and feedback along the whole supply chain

- Develop real-time technical and schedule management tools (instant visibility of progress and variances), incl. the hardware, software and communication links, to allow real-time transmission of site progress to the 4D model
- Develop real-time cost management tools
- Develop a simple Facilities Management (FM) navigation tool to source key information
- Research & develop ICT for capturing unstructured project data
- Specify and develop fully digitised, unique and personalised, universal electronic cards, which will be shipped with the products, and manage the information structuring and integration for the product, and allow traceability of all parts of the final end product

DRIVERS

- **Increase in productivity**
- **Reduction in waste**
- **Reduction in construction time**
- **Reduction in capital cost**

PRODUCTS / SERVICES / TECHNOLOGY

Remote Working Technologies
R3.1

- **Enhanced 'telepresence'** / 'virtual co-location' / 'virtual site visits' technologies
- **Single comprehensive tool** (light and robust, with multiple applications) for mobile work (possibly 'wearable' device), which delivers just-in-time information in an optimal format
- **Digital pens / paper**

→

- **Completely digitised sites**, where intelligent terminals on machines and individuals give all site stakeholders ubiquitous context-based, geo-referenced and permanent access to information

→

- **Ambient access to all asset information** (stored within an Asset Lifecycle Assessment System) is available to all stakeholders, anytime and anywhere

→

Ability to Interact with Real-Time Information Regardless of Physical Location or Timezone

Connectivity Technologies
R3.2

- **Improved mobile / site networks** and systems for the efficient connection of mobile sites to corporate information networks
- Developed **WiMAX & Wide Area WiFi** technologies

→

?
(To be determined at future roadmap reviews)

→

?
(To be determined at future roadmap reviews)

→

RESEARCH / ENABLERS

- Investigate advanced possibilities offered by wireless or mobile communication technnology (incl. potential WiMAX and wide area WiFi)
- Research and develop enhanced 'telepresence' technologies, and implementing their wider use (both in the workplace and from home) – giving increased flexibility of working and reduced travelling
- Embed & promote the use of existing 'virtual co-location' technologies (e.g. video conferencing technology, webinars, etc.) in the industry
- Define & develop infrastructure requirements to support site working
- Research & develop better viewing capabilities for PDAs etc
- Research & develop remote management of data/process via PDAs etc

- **INTELLIGENT ASSETS ENABLERS**
- Develop GPS (or similar) to deliver data to on-site staff
- Research & develop a 'virtual site visits' capability (e.g. network of webcams linked to digital model of site, real-time BIM, etc.)
- Identification & development of 'new' human interface technologies

- **Further research / enablers to be determined at future roadmap reviews**

- **ASSET LIFECYCLE INFORMATION SYSTEM ENABLERS**

- **Further research / enablers to be determined at future roadmap reviews**

DRIVERS

- **Reduction in waste**
- **Increase in productivity**
- **Reduction in accidents**
- **Reduction in construction time**
- **Increase in predictability**

PRODUCTS / SERVICES / TECHNOLOGY

	SHORT	MEDIUM	LONG
Off-Site Manufacturing R4.1	• **Design for efficient manufacture** / off-site construction / pre-fabrication and pre-assembly, to be in common use	• **Efficient off-site manufacturing** and pre-assembly in widespread use	• **'Lean Production'** - automated design, factory production, and modular assembly in widespread use
On-Site Automation R4.2	• **Standardised construction processes and components** e.g. modular provision of customised (prefabricated) constructions, logistics, assembly & services • **Materials for automated manufacture** and erection	• **Completely digitised sites**, where intelligent terminals on machines and individuals give all site stakeholders ubiquitous context-based, geo-referenced and permanent access to information	• **On-site robotic assembly** (especially for hazardous or monotonous work) - providing safer (more controlled) working environments, and improved site working conditions
Intelligent Logistics R4.3	• **Embedded ICT in products**: Real-time traceability of materials & components on the construction site. Electronic 'how to build' information delivered with the product • **Real-time tracking** of construction plant & equipment to optimise site logistics	• **Integrated supply chain** / improved supply chain management (to improve procurement efficiency and performance, allowing 'Just in Time' logistics)	**?** **(To be determined at future roadmap reviews)**

Mass Adoption & Application of Off-Site Manufacturing, Automation & Mechanisation Processes & Systems

RESEARCH / ENABLERS

- **INTELLIGENT ASSETS ENABLERS**
- Adaptation of new concepts developed by other manufacturing industries (e.g. automotive & aerospace)
- Research materials to simplify, reduce cost, improve H&S, etc. for automated off-site fabrication and on-site erection
- Development & deployment of solutions (e.g. RFID) and services to identify & track on-site materials from delivery to in-situ. To include intelligent materials / products / smart coatings, capable of communicating location, orientation & condition for the lifecycle of the asset
- Define and document best practices for supply chain production, logistics, validation, and information flows to identify inefficiencies and bottlenecks and highlight improvement opportunities
- Produce construction automation guidelines
- Introduction of new services offered by satellites & GPS for site control (e.g. positioning construction equipment, and for monitoring works and their impact)
- Design new connection methods to enhance scope for automation

- **INTEROPERABILITY ENABLERS**
- **INTEGRATED PROCESSES ENABLERS**
- Develop logistics and process monitoring / management tools (incl. tagging technology) to automate tracking of actual v planned progress
- Research use of GIS to manage site data and logistics
- Investigate rationalisation of construction processes, with focus on off-site assembly of large, fully-fitted components
- Research the automation of construction plant & equipment ('Intelligent site vehicles' & robotics), and mechanisation of site activities aided by new automation and guidance technologies, including advanced embedded electronics
- Research process orchestration e.g. flow of resources for optimal build efficiency
- Integrate and automate supply chain work processes and job site delivery and tracking of materials and labour
- Research & develop distributed production management

- Research the transfer of Building Information Modelling (BIM) to manufacturing / virtual production
- Investigate the use of integrated data models (BIM) to facilitate modularisation

DRIVERS

- **Effective training and skills are essential to provide a well trained and qualified workforce, capable of transforming the industry - i.e. all other research topic areas are reliant on the success of this topic area**

PRODUCTS / SERVICES / TECHNOLOGY

	SHORT	MEDIUM	LONG
Training & Skills R5.1	• Effective **e-learning tools and concepts** for the construction sector • Flexible **e-learning courses** (for all levels and workstreams within the construction industry), resulting in recognised qualifications (could become new industry-wide training standards)	• Effective **'ICT in construction'** training modules • **E-Learning capabilities built into all ICT tools** so that continuous learning is supported as an integral part of the work	• **New career / employee qualification** for ICT data management • **Higher education courses** on 'ICT in construction' - context, underlying theories, models and methodologies (undergraduate and postgraduate)

Well Trained, Well Qualified Workforce, able to use the Latest, Best Practice Technologies

RESEARCH / ENABLERS

SHORT	MEDIUM	LONG
• Establish requirements for awareness, training, skills, and higher knowledge in construction generally (incl. ICT & automation) • Explore & develop methods of how to communicate / present what is already available to potential users, in particular SMEs (representing more than 90% of industry), where the ICT skills generally do not exist • Industry to work together with universities, professional institutions, and training professionals to develop new construction e-learning tools / courses	• Raise awareness of 'ICT in construction' in schools (to enhance attractiveness of industry and reduce negative culture by immersing early) • Industry to work together with universities, professional institutions, and training professionals to develop new construction e-learning tools / courses	• Industry to work together with universities, professional institutions, and training professionals to develop new construction e-learning tools / courses • Embed a 'learning' culture in the industry

2.4 The ICTA Vision

As described above (see *Section 2.2 – Summary Roadmap)* the 'ICT and Automation' priority area was subdivided into five key 'research topics' that must be addressed. By completing the research activities described in all five detailed roadmaps, and then by integrating all these outputs into industry, the overall ICTA vision will be achieved.

To illustrate how the five themes might be integrated, and to help convey the message to industry, the following example scenario has been devised:

'Built environment 2020'

Clients work with a multi-disciplinary team to use existing knowledge about their activities, anticipated future requirements, and industry knowledge about similar client needs to agree a brief - describing the organisational need for future facilities, and working on the principles of best whole-life value. As the brief is developed, additional team members are brought into the team as early as possible, and begin to use a virtual environment to prototype or model solutions which meet all the various dimensions of the brief – functionality, aesthetics, logistics, ease and safety of construction, operation and maintenance, whole life cost, sustainability, etc. Regardless of their location, all authorised project participants can interact with this virtual environment using various different computer hardware/software combinations, with the latest model version being readily available online, and over time being progressively populated to increasing levels of detail.

Once a consensus is reached about the finished form of parts of the facility, manufacturers and suppliers (already involved in the design process) reuse model information for offsite fabrication (perhaps extensively automated) of the required components in the optimum sequence for just-in-time delivery to the correct zone at the facility's location. Each component has an embedded device that carries all relevant information about its manufacture, material, service requirements, etc, and its arrival on site is, of course, automatically recorded. Once delivered, each component is swiftly and safely installed in its precise position by skilled site operatives - supported, where appropriate, by robot devices.

All site operatives, project managers and other personnel wear small devices that monitor their exact position, giving warnings, where necessary, regarding the individual's safety and security. These wearable devices can also provide data about individuals' immediate surroundings (drawing on the embedded data in installed components and data stored in the virtual model), helping, for example, operatives to undertake site activities, with context-sensitive viewing tools (e.g. VR glasses) providing audio-video installation guidance. Those with managerial responsibilities can interrogate the online environment to get real-time updates on schedules, projects costs and other performance parameters – the same data also being available simultaneously to, for example, a client representative sitting in a remote geographic location – perhaps in another timezone.

As on-site processes are completed, the virtual environment is populated with as-built data that can be seamlessly reused for operation and maintenance purposes. The building model thus becomes a powerful asset management tool, linking the facility owner/operator with relevant suppliers or maintenance contractors, with all repairs or replacements automatically recorded. The actual in-service performance of building components is logged and can be interrogated by the owner/operator, manufacturers/suppliers, and by authorised professionals tasked with designing and delivering similar facilities for the same or (subject to confidentiality limits) similar clients. Similarly, any extensions, alterations or changes of use of the facility are also recorded for feedback purposes, and to inform future developments.

3 Existing Research

3.1 Research Project Databases

This Scoping Study identified four key databases for starting to understand what ICTA research has already been completed, or is already underway.

These databases are:

3.1.1 VTT website for EU projects

This website contains listings of all 'Computer Integrated Construction' (CIC) research projects that have been / are being undertaken by the VTT Technical Research Centre in Finland.

It provides summary details of the project title, brief description, dates, research framework, and funding source. Furthermore, links to the individual project websites are also included, which allow access to full details (e.g. deliverables, partners, cost).

3.1.2 Engineering & Physical Sciences Research Council (EPSRC) for UK projects

EPSRC is the main UK government agency for funding research and training in engineering and the physical sciences, investing around £740 million a year in a broad range of subjects.

This website has a comprehensive search tool (including free text), and provides details of project title, project abstract, dates, principal investigator, partners, organisation, department, and cost.

It also provides details of calls for proposals, funding opportunities, funded grants, programme areas, and a funding guide.

3.1.3 Technology Strategy Board (TSB) for UK projects

The TSB is an executive non-departmental public body (NDPB), established by the Government through the DTI. Its task, operating across all important sectors of the UK economy, is to stimulate innovation in those areas which offer the greatest scope for boosting UK growth and productivity.

With a business-led panel of board members, an executive team and a business focus, the TSB will play an increasingly important role in the development of the Government's innovation strategy. Its primary aim is not the

creation of knowledge - where Government separately invests over £3 billion per annum - but the translation of knowledge into innovation and new and improved products and services.

The vision: for the UK to be seen as a global leader in innovation and a magnet for technology-intensive companies, where new technology is applied rapidly and effectively to create wealth.

The TSB website contains a searchable database of research projects, providing summary details, including project title, abstract, dates, partners, contacts, and cost.

3.1.4 ProQuest Dissertations & Theses Database (PQDT) (for PhDs)

With more than 2.3 million entries, the PQDT database is the most comprehensive collection of dissertations and theses in the world.

3.2 Research 'Centres of Excellence'

In addition to the above databases, UK 'Centres of Excellence', or 'Innovative Manufacturing Research Centres' (IMRCs), for ICTA research have been identified as follows:

- University of Bath – Innovative Manufacturing Research Centre
- Imperial College – Built Environment Innovation Centre
- Cambridge Engineering Design Centre
- Cambridge Institute for Manufacturing
- Cardiff University – Innovative Manufacturing Research Centre
- Cranfield Innovative Manufacturing Research Centre
- University of Liverpool – e-Business Research Centre
- Loughborough Innovative Manufacturing and Construction Research Centre
- Nottingham Innovative Manufacturing Research Centre
- Reading Innovative Construction Research Centre
- Salford Centre for Research and Innovation in the Built and Human Environment
- Warwick Innovative Manufacturing Research Centre

IMRCs receive five year block grants from EPSRC to be flexibly allocated between projects. This provides the UK's leading manufacturing researchers with a base of stable yet flexible funding, freeing them from the uncertainty and long lead times of project-based applications and enabling them to be responsive to the needs of UK industry and pursue strategic research themes as appropriate.

Each of these IMRCs has their own website that contains full details of the research projects that they are undertaking, and information of their individual areas of focus and expertise.

3.3 Reviewing Existing Research

This Scoping Study report does not analyse existing research - to identify gaps or synergies with the industry requirements – an activity that should be undertaken as part of the next 'implementation' phase.

However, during this Scoping Study, some existing research projects have been identified. This information has been included in ***Appendix F – Existing Research***, as a useful starting point for whoever is selected to implement the research roadmaps during the next phase. The appendix contains the following project details: description, organisation, department, cost, start and finish dates, and funding source.

4 Recommendations

In order to ensure that these roadmaps are adopted and embedded within the industry, and hence the required research is undertaken to achieve the vision, the following recommendations are made:

1) The publishing of this National Platform ICTA Scoping Study report should serve as a 'Call to Arms' for industry. (See *Section 5.3 - Dissemination*)

2) A 'programme office' should be established. (See Section *5.1.2 – 'Programme Office' Role*)

3) The roadmaps should be reviewed and updated periodically (suggest every 3 years) to ensure relevance and longevity.

4) It is important to ensure that all enablers are addressed, including those focusing on people & process issues (e.g. training, culture, contracts / legal) - without these being adequately addressed, the technologies, services and products are unlikely to succeed. (See *Figure 5 - Relative Importance of People, Process and Technology*)

5) Projects should include knowledge transfer from other industries, where it is considered that significant benefits could be gained for the construction industry in learning from other more advanced manufacturing industries (e.g. automotive and aerospace).

6) It is recognised that an extensive review of past and current research projects would take substantial time and effort, and may miss some research. Therefore, it is recommended that during the implementation stage the databases identified in Section 3 – Existing Research are used to establish the centres of excellence for relevant ICTA research, as identified in the roadmaps. The project co-ordinator should then liaise with these centres of excellence to ascertain and highlight the current research gaps and overlaps.

Also, when assessing new research proposals, the project co-ordinator's first point of contact (to avoid 'reinventing the wheel') should be the centres of excellence for that specific research area. (See *Section 5.1.2 – 'Programme Office' Role*)

In summary, liaising with the centres of excellence should provide the research project co-ordinator a clear view of:

- Existing research (and who is carrying it out).
- Required research that is not currently being addressed.
- Research that is being carried out that does not feature on the roadmaps, i.e. potentially research that industry does not need / want.

To aid the timely implementation of these recommendations, the ICTA Working Group has outlined their implementation proposals in *Section 5 – Implementation for the HLG's consideration*.

5 Implementation

This section provides the High Level Group (HLG) with a proposed implementation plan for ensuring the ICTA Roadmaps continue beyond 'just' a paper exercise, and support the National Platform's aim - to demonstrate that research is a vehicle for industry transformation through managing an ongoing programme of work.

It addresses the key components required for success:

- True, and continuously aligned, **industry requirements.**
- **Sustainable funding** to support pan-industry improvement projects.
- Active and willing **project participants**.
- Competitive and informed **bidding and partnering brokerage support**.
- A comprehensive, managed and supported **long-term programme of projects**.

And last, but by no means least, these five components must be supported by an ongoing **programme of dissemination**.

5.1 Business Model

5.1.1 Ownership

The criteria used to assess who is best placed to manage and support the ongoing programme of work were:

- Access to industry stakeholders and ability to ensure programme remains industry led.
- Access to, and knowledge of, potential sources of funding (i.e. EU Framework 7 and Technology Strategy Board).
- Track record in delivery of large programmes of research to innovation projects.

This led to the conclusion that Constructing Excellence was best placed to host the 'programme office'.

5.1.2 'Programme Office' Role

The role of the programme office is defined as follows:

- Maintain and support a programme of projects and re-examine on an annual basis to ensure alignment with industry requirements. Report on progress at HLG meetings.
- Liaise with the relevant funding bodies to influence calls to reflect construction industry requirements.
- Brokerage partnerships where required to augment project team skills or avoid duplication of effort.

- Understand bid requirements, both logistically and what would make a project stand out, and help manage the bid return process to increase the construction industry's chances of success.
- Ensure activities are disseminated effectively to all stakeholders through developing, implementing and maintaining a communications programme.

It is envisaged that the programme office will be resourced full-time by a secondee from industry, sourced from one of the HLG companies on a rotating 12 month basis. They will be responsible for the day-to-day running of the programme. They should be supplemented by a supporting 'chairman' role nominated from the HLG representatives, whose role is to act as a figurehead - to promote the programme and negotiate at a higher level as and when required.

5.1.3 Funding (Initial and Ongoing)

Initial seed funding should be sourced from the HLG membership, matched by funding from the Technology Strategy Board, to cover this resource for the first six months. The programme office should then become self-sustaining through re-investing a small percentage (say 5%) of the funds won to support programme projects. This will not only incentivise the programme office to be successful in their role of initiating projects, encouraging participants and winning funding, it will also provide a sustainable funding mechanism for as long as the industry actively pursues and needs support to participate in the long-term programme.

5.2 Project Participation

A vital component in the successful continuation of this strategic programme of research is to generate a pool of active and willing project participants. This will be achieved by an active programme of dissemination (see *Section 5.3 - Dissemination*), and through the ongoing success of the programme office.

To understand what will encourage participation we have examined what stops participation currently:

- Focus on short-term project requirements, and hence a lack of time to think of long-term needs.
- Lack of understanding of the funding mechanisms available to the construction industry.
- Perceived lack of construction industry success in securing these funds.
- Time taken to complete the funding application process, and lack of matched funding within organisations (as most competitions provide only up to 50% of project costs).

It is proposed that the programme office, as detailed above (see *Section 5.1 – Business Model*) should alleviate these barriers to participation, but it is recognised that an active champion role should be undertaken by the HLG, and the companies they represent should be seen to be availing themselves of the programme offices services.

5.3 Dissemination

Production and publication of this report does not mark the end of the ICTA project. It is important that this initial report be publicised and made widely available to all potential stakeholders, with future communications being managed by the 'programme office'.

As an ICT and automation project, it is recommended that a dedicated website be established to help manage communications. It is envisaged that this website will include the following features:

- Downloadable versions of the report, and supporting background information.
- Regularly updated pages describing the long-term programme of projects.
- Email links to the 'programme office', to individuals involved with the ongoing programme, and to participants in projects (on a reciprocal link basis).
- Weblinks to project websites and those of relevant organisations.
- Regular news updates on key developments, new projects, etc (including the opportunity to subscribe to RSS feeds and to e-newsletters).
- Online threaded discussion forums to allow interested parties to exchange views and ideas arising from the report.

Details of the report and the website will also need to be widely circulated through an integrated campaign combining conventional marketing (e.g. branding, production and distribution of final report in hard copy and electronic formats), public relations (e.g. media relations, event speakers, etc), and public affairs activities (e.g. lobbying, engagement with industry associations, academia, European institutions, etc) – all managed by the 'programme office'.

The dissemination process is more likely to be successful if it offers a compelling, but succinct, vision of the future of the Built Environment industry - clearly identifying 'what's in it for me' to potential stakeholders. To this end, this report includes a short example scenario – provisionally branded '**Built Environment 2020**' – to help explain where the initiative might lead.