Building a Client-Orientated, Knowledge-Based, Value-Driven Industry

A scoping-study of the research agenda relative to the issues facing the built-environment construction industry in 2020

National Platform for the Built Environment
CONSTRUCTING EXCELLENCE

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Andrew Edkins - UCL (co-author)
Hedley Smyth - UCL (co-author)
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John Findlay - Balfour Beatty
Richard Saxon - Consultancy for the Built Environment (CBE)
Bob White - Mace
Jim Meikle - Davis Langdon
Bethan Morgan - Constructing Excellence
Peter Whittington - BERR

Funders

ARUP

ATKINS

Balfour Beatty

Balfour Beatty
Infrastructure Services

mace

Taylor Woodrow

DEPARTMENT FOR BUSINESS
ENTERPRISE & REGULATORY REFORM

Foreword

This report tackles a subject of immense breadth, complexity and importance to our industry and wider society. Developing greater client orientation is central to the way we will live and operate in a decade or so. By becoming a knowledge-based industry, we will learn effectively from past successes and failures in order to deliver a better-built environment.

All too often, our industry has not sufficiently understood and responded to clients' long-term needs. By identifying this subject as critical to its strategic development, we have begun to take responsibility for addressing this issue.

This study describes a number of priorities that need to be addressed to move the industry towards a client orientated and knowledge based one. It outlines a vision of an industry delivering tangible social, economic and environmental value to our clients and to wider society. It is a 'call to arms' to our industry, which we would do well to heed.

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 report is one of three commissioned by the National Platform for the Built Environment to scope out the research agenda for the built-environment construction industry (BECI) regarding the issues relating to its delivery capacity and practices that it will be facing in approximately 10 to 15 years' time – say 2020.

We began by identifying the 'critical change issues' affecting the BECI, looking initially at issues which had affected the recent past – 1980 to the present (Section 3 of the report), and then the future – the present to 2018-23 (Section 4). A number of issues, concerns and themes arose out of this extended analysis (Section 5). We then interviewed over 20 leading figures in the industry and held two workshops representing owners, consultants, contractors, suppliers and others (Appendix 1) in order to identify potential research topics relative to the industry's perceived needs circa 2000.

The industry in ten to fifteen years time will in many ways not be dissimilar from todays. However we see four factors as being dominant at that time (Section 6): climate change; demographics (affecting both the nature of demand on the BECI products and supply of an appropriately skilled work force); funding; and technological developments (particularly an increase in intelligence at all levels of the built environment: materials, components, buildings, cities, regions; and organisations), much of which will originate outside of the BECI. These dominant factors imply:

- The need to take a more integrative, interdisciplinary, whole life-cycle view of building development, delivery and operation – this calls for a systems oriented, holistic approach to project work;
- A focus on technology adoption;
- New knowledge management practices;
- Opportunities to improve the industry's competitiveness.

Over 200 research topics were identified relative to these themes (Section 7). These topics were then prioritised first into a long list of 17 topics and then into a short list of approximately six topics (Section 8). This short list is as follows.

1. *Examine the **Systems Integrator/Integration** role/function relative to 2020: what, why, who, how, economics, skill base, tools.*

*1.a. Establish an **owner-oriented governance life-cycle methodology.***

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2. *Develop **integrative quantitative models** combining requirements, POE, project delivery, and Facilities Management/Operations data into 'what good looks like'.*
3. *Define the 2020 **education and skilling** needs; and the **professions**' and **insurance industry's roles.***
4. *Examine the impact of **ICTA, robotics, off-site manufacturing, and intelligent materials on the supply chain**.*
5. *Examine **procurement** options and limits: e.g. of a specification-based approach; of relationship approaches.*

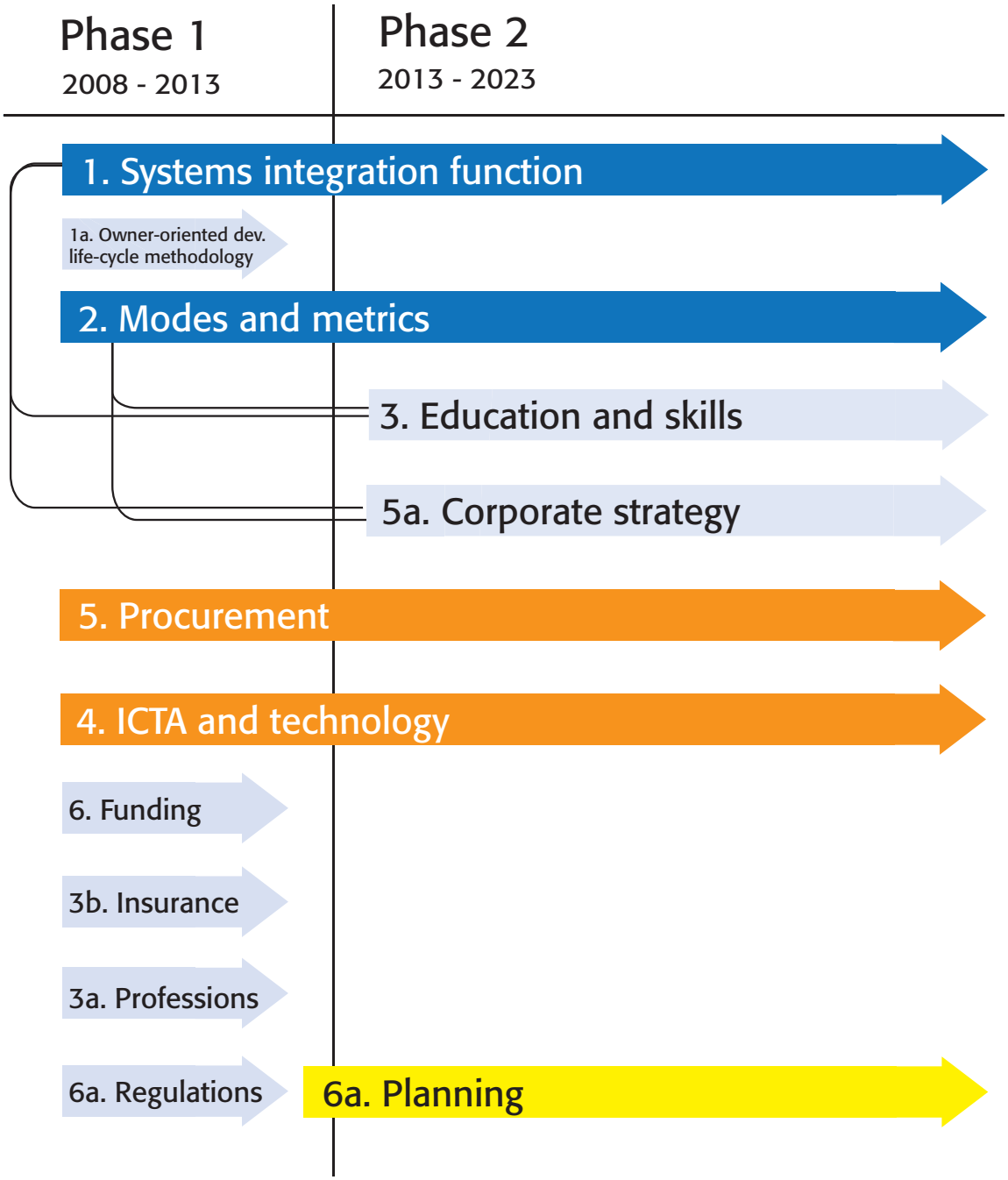
*5.a. Explore the **corporate strategy** implications of all the above: on the firm, international players, competition, competencies and education.*

6. *Explore the implications new **funding** requirement and mechanisms.*

*6.a. Explore **2020 Planning and Regulations** needs.*

We then reviewed what research was being performed in these areas (Section 9) before proposing a sequence of research activities to be considered over the next ten to fifteen years related to each of them (Section10) – see Figure ES.1, over. This list is offered not as a Plan to be formally administered so much as an indicative agenda.

Figure ES.1: Proposed research implementation schedule



1. Introduction

This study essentially addresses the delivery issues that face the BECI. The other two National Platform studies are on:

- ICTA – Information and Communications Technology and Automation – to facilitate knowledge capture and application, and improve understanding of client requirements;
- Reduced resource consumption - moving from waste elimination and cost savings to added product value, especially to meet sustainability requirements.

One of the key National Platform objectives is to have an industry-led pre-competitive research programme endorsed by a significant part of the built environment sector. Thus the objective for this study is to encourage the industry to address this topic as part of its own, rather than its clients', agenda.

Specifically, this scoping study aims to:

- Address key issues already raised by the National Platform, as described below;
- Identify and describe previous work and current initiatives in this area;
- Identify research gaps and describe associated research opportunities.

A number of issues have been identified by National Platform working groups as central to the newly emerging built environment construction industry. These include:

- Greater understanding of the clients' business needs (moving well beyond the traditional construction-client relationship), focusing on outcomes and employing systems thinking – systems definition, requirements elicitation and stakeholder analysis;
- A focus on:
  - Economic, environmental and social conditions and needs
  - Improved data and decision support systems, particularly with respect to (whole life) sustainability
  - Optimizing value balance (outcome focused) and associated trade offs;
- Better understanding and exploitation of existing knowledge bases, educating the whole supply chain through knowledge management and organisational learning;
- Greater use of retrospective demonstration reviews – addressing the issue of whether improved processes result in better product and performance in use and overall outcomes;
- Making better use of outcome performance measures.

The underlying theme, as identified in the EU Strategic Research Agenda of the construction industry (see Section 5.2.2. below) is to develop an industry that is actively engaged with client requirements, and those of wider stakeholder groups. It envisages constructors as solution providers, embracing consultancy, finance, design, build and operate to achieve value-based outcomes.

The study connects an EU perspective (focussed on the benefits to the EU Citizen) with a UK-centric concern about the built environment construction sector taking more responsibility for its own destiny through owning and engaging research.

2. Methodology

2.1 Clarifying the study brief

We began by clarifying the study brief. The initial title of the study was *Building a client-driven, knowledge-based industry*. We felt that there were aspects of this title that merited clarification. Questioning each phrase of the project title, we agreed with the National Platform that:

- 'Client-driven' should become 'client-orientated' to reflect the built-environment construction industry taking responsibility for its destiny;
- 'Building' should mean 'creating and developing' – recognising where we are now, our context;
- 'Industry' is a catch-all for various sectors that comprise the built environment – and recognising that there will be particular points of interest amongst some of those that constitute the industry members;
- 'Knowledge-based' means using knowledge more cleverly and appreciating the opportunities that knowledge management offers, particularly in making better decisions.

During the course of the study we also decided to add 'Value-driven' to reflect the importance of value in the industry's thinking.

2.2. Identifying key trends, not building scenarios

The obvious first step in looking at the future is perhaps to build scenarios of future possibilities. This had recently been done for construction by, for example, the RIBA (Foxwell, 2003). We felt however that scenario building had a double disadvantage: it could 'box one in' to the selected scenario(s) and simultaneously distract one from focusing on the items and issues that were really determining the nature of the upcoming change (Harty et al., 2007). We therefore proposed instead to identify 'critical change issues' affecting the Built Environment Construction Industry (BECI), looking initially at issues which had affected the recent past, say 1980 to the present, and then the future, the present to 2018-2023. In general we followed the methodology proposed by Ratcliffe and Sirr (2003), as shown in Figure 1.

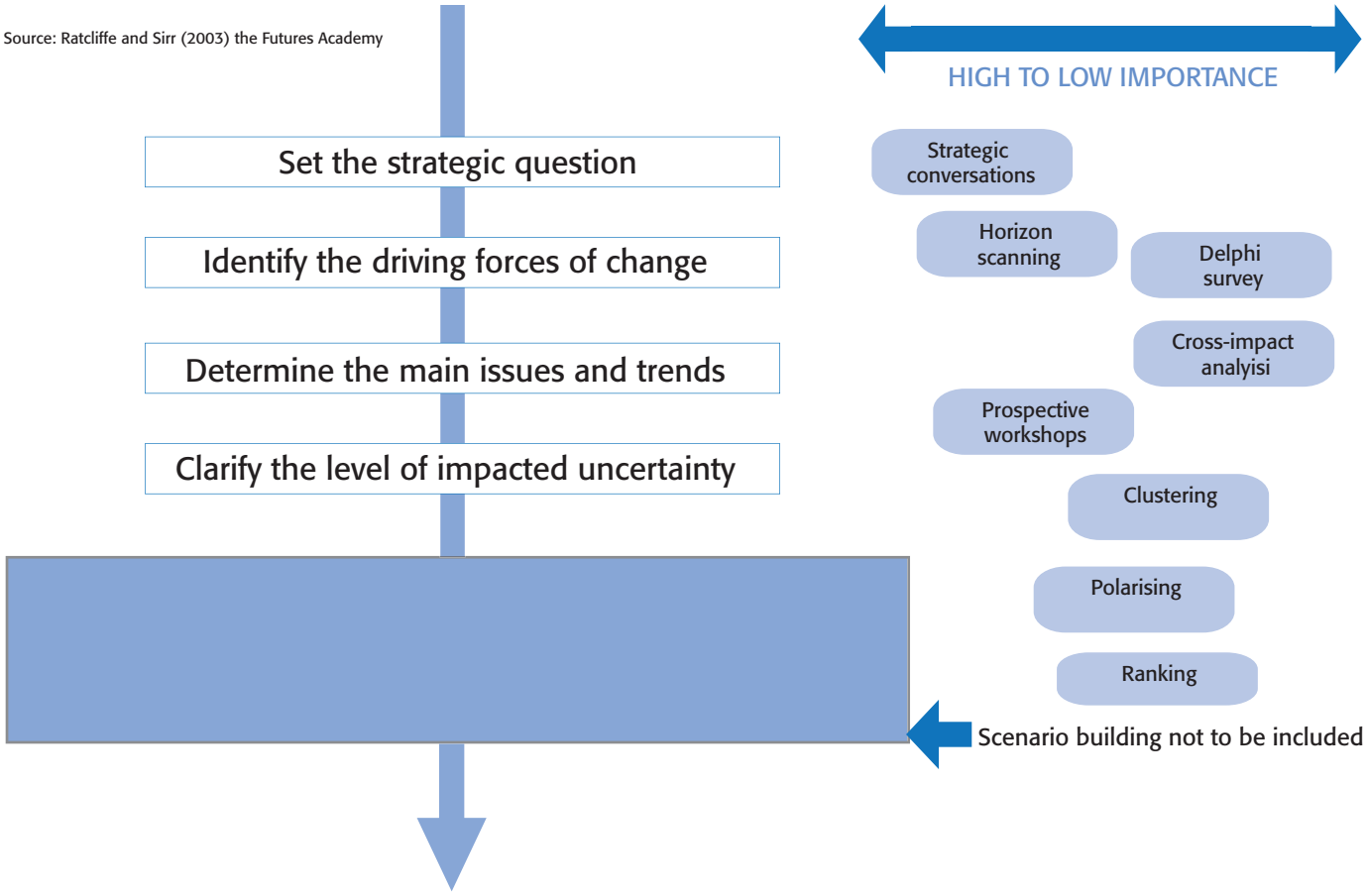


Figure 1: Study methodology with respect to identifying future trends and issues

We looked at the BECI through three lenses, as shown in Figure 2:

- The general state of the world (a STEEP analysis, i.e. looking at Social, Technological, Environmental, Economic and Political factors) – an outer lens or circle;
- The specific characteristics and needs of the sectors that comprise the BECI;
- The pan-sector set of issues that affect the BECI 'industry'.

2.3 Data Collection and Model building

We believed that expert views are important and are expressed differently in singular (as gained for example from one-on-one interviews) and collectively (via workshops) and we therefore proposed getting data via both methods, as well as from literature. As a result, we conducted over 20 interviews on various aspects of the study and held two workshops. A list of those whom we interviewed is given in Appendix 1

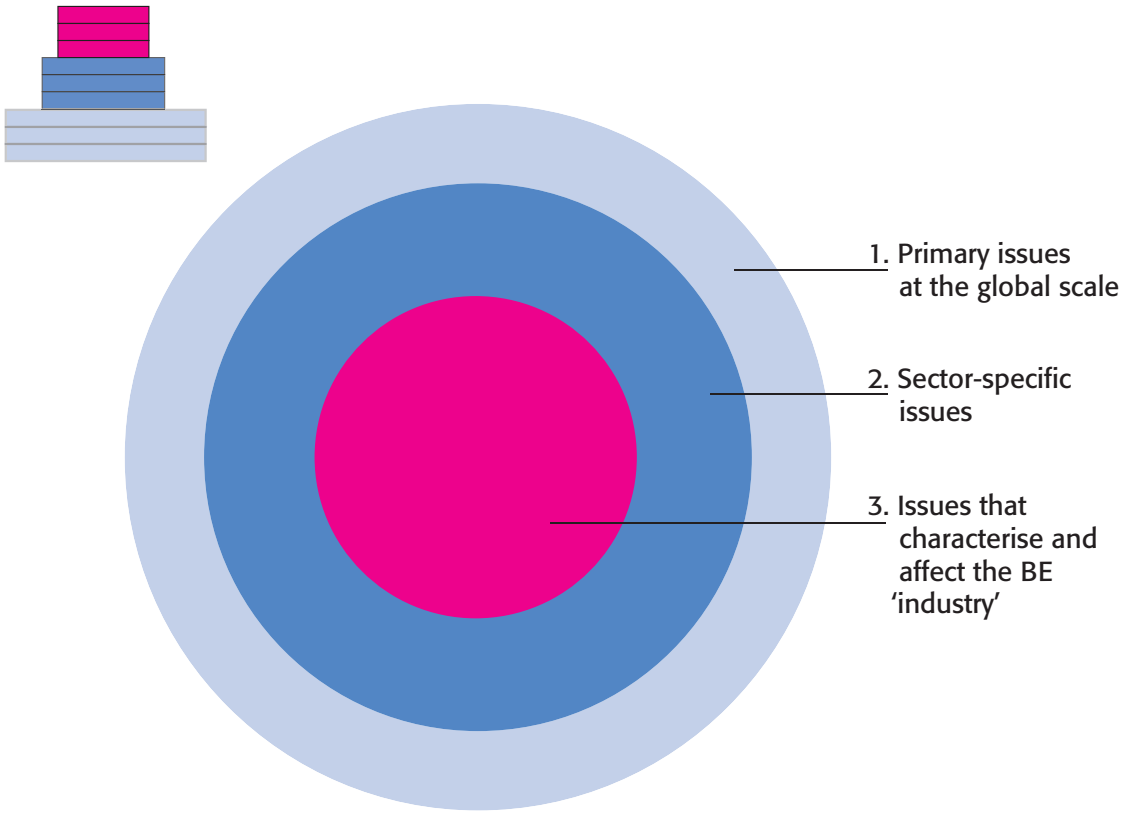


Figure 2: the three levels of analysis of issues affecting delivery in the Built Environment Construction Industry

From these interviews, workshops and the literature review we:

- Identified what we believe will be special relative to the topic area in 2020 (+/- 3 years);
- Identified over 200 research topics relevant to:
  - A client-oriented, knowledge-based, value-driven approach
  - The special challenges of ~2020;

- Identified where research is going on and where there are gaps relevant to the above;
- Developed:
  - a set of proposed research topics
  - a programme for industry to undertake this research.

We began by identifying significant trends and issues relative to the 'delivery management' nature of this study that have been prevalent since approximately 1980.

Social: In the most advanced (T1) economies, a move away from the nuclear family model and increased social fragmentation. Rise of T2 economies such as Brazil, Russia, India, and China (BRIC). Increasing globalisation.

3. The recent past: Trends and issues, 1980 – Present

Lesser Developed Countries (T3) struggling, particularly in Africa and South America.

Technological: Rise of ICT (Information and Communications Technologies) in the home and the workplace. Materials now complex and natural-synthetic hybrids. Rise of the car and air transportation.

Economic: Adoption of forms of social welfare capitalism; companies are economic engines, governments and states set the regulatory and competitive backdrop.

Environment: Sustainability becoming a major issue. Concern about resource depletion/extinction and impact of pollution.

Political: End of the cold war and narrowing of the primary political poles; reduced power of the unions (in the UK); polarisation between centralised and decentralised planning; rise of the European Union.

3.1. Scene setting: The Built Environment Sectors, 1980 – Present

Commercial: Complex schemes, mixed use. Concern about being green-lean-mean; leading developers taking a more demanding client-management role. Tenants and occupiers wanting to off-load property problems. Design increasingly seen as value-adding, and securing supply chains now makes good business sense.

Housing [all forms]: Dominance of owner-occupier (more of private/part-private and less of fully state provided); over-demand and under-supply leading to issues of affordability (general) and availability (regional). Capacity targets in South East. Land availability an issue. Greening the stock is desirable.

Governmental [health, education, civil defence, military, State administration]: Rise of PFI, PPP and derivatives – government moving from prescriptive input specifications to procuring procurement vehicles – Building Schools for the Future (BSF)/military training. Shift from build-&-forget separated from building maintenance separated from refurbishment, to various acronyms such as DBO (Design, Build, Operate), DBFO (Design, Build, Finance, Operate), BOOT (Build, Own, Operate, Transfer), FM (Facilities Management). Implications are potentially profound, but are still fragmented – even within PFI (Private Finance Initiative) and PPP (Public Private Partnership). Design previously much maligned, but now highly regarded and sought.

Retail/Industrial/Leisure: Out-of-town, car-centric centres have come, are here, but are increasingly recognised as not being the way forward. Manufacturing industry increasingly seen as second place to the service

sector (centralised [e.g. financial services] and distributed [e.g. call centres and hairdressers]).

Transport infrastructure: Dominance of roads and air, but these becoming increasingly congested and polluting; stress on ageing rail systems and huge costs for building, and operating, rail.

3.2 Scene setting: The BECI 'industry', 1980 – Present

We identified a number of factors regarding the delivery context of the BECI from 1980 to the present, as listed below. We grouped these into three classes: those relating to the general BECI delivery context, the principal actors operating in the industry's delivery, and its processes.

Context

Planning: Planning laws and regulations have been strongly influenced by central government policy and local government interpretation. This has allowed significant variation, and the growth of specialist consultancies which have allowed major schemes to progress. Laws and regulations have grown to be ever more complex, driven by professionals and experts. Strong political push is often needed at central or local levels.

Building Control: Primary concern has been technical compliance to ensure secure and robust built environment products.

Health, Safety and Security: Primary concern focussed on death and serious injury and a drive for enforced compliance through the use of punitive measures and external enforcement.

Contract forms: Significant developments have occurred from traditionally linear and contractually transactional procurement approaches towards a broad range of procurement options that reflect both differing approaches to risk management and the diversity of players involved, from the serial and professional, to the infrequent and naïve.

Process

ICT: Significant step changes have occurred in the use of technology from analogue 2-D to digital 3-D. Most major changes in IT have been developed outside the BECI sector, with better distributed computing ability

mirrored with improved communication systems. Whilst traditional approaches (manual trades and paper based communication) are still present, there is far more evidence of automation and electronic communication, although interoperability of various systems remains problematic.

Manufacture /Assembly technology: There have been great improvements in the ability to link CAD information to CAM production and thereby improve accuracy and reduce both error and waste. This has taken place not only at the component level, but has also been developed for off-site manufacturing where both panelised and volumetric systems are increasingly used. Improvements in materials and techniques have made for cleaner and often drier processes.

Delivery forms: The traditional sequential contracting approach gave way to the introduction of the professionalizing of construction (fee based) and the introduction of specialist project and programme management.

The product: Traditional design solutions have been dominant, but there have been many innovations in design, materials, technologies, and techniques. With the exception of the ubiquitous rise of self-cleaning curtain wall glass, buildings still typically look as they have always and are made from brick, concrete, steel, and wood. There has been a dominance of the capital expenditure project, separated from the operational budget, but the gap between the two has been closing.

Actors

Supply-side organisation(s): There has been a sea change from mass employment in large organisations to both self-employment and the rise of the distributed supply chain dominated by various levels of sub-contracting organisation. This fragmentation of the supply base has resulted in the sector being more flexible to changing market requirements, but has also led to a reduction in investment in areas such as research and development and long-term training. The established use of supply chains increased transaction costs in line with the number of contracts used.

Skills

General management – A greater reliance on general management skills has emerged due, in large measure,

to the increased organisational complexity of projects and fragmentation of the supply chain.

Technical –.The focus has been more on manual skills, whether in the drawing office or on site.

Labour Relations: The demise of mass employment in single organisations and unionised labour representation has seen a decline in the formality of labour relations.

Clients: Whilst there has always been a great range of client types, in almost all areas clients have come to be better informed and to have higher expectations in terms of both the service and product delivered.

The Professions: The professions have persevered despite the challenges raised both by increased dominance of the managerial specialisms and clients becoming more capable.

4. The future: trends and issues, 2008 – 2023

We then moved on to look at future trends and issues, again, first looking at the general social, technological, environmental, economic and political influences, then at individual sectoral demands, and finally at influences specific to the BECI itself.

4.1. Scene setting: The general backdrop, 2008-2023

Social: Changing demographic profiles. Significantly different push/pull drivers for migration. Security (fear of: terrorism, crime; implications of new forms of war) a rising issue. Food & water supply becoming increasing stressed. Pressures building for the adoption of increased sustainable living. Life-long learning. More affluent T1 life styles; increasing poverty in T4 (hopeless) nations (and some sliding from T3 to T4).

Technological: Rise of knowledge-based products and services. Smart products – from clothes to buildings to cities. Improved data interoperability and ubiquity. Changing impact on transport, e.g. cars as we know them. Decline of fossil fuels: Energy security drives fission/fusion/hydrogen/other? Benign/inspiring architecture.

Economic: Global competition and consumerism, (fluidity of purchasing, supply). Changing sources of funding. Move to more agile markets and organisations. More volatility and less predictability.

Environment: Climate change - prevention of (inevitable) storm/flood damage, rising diseases (e.g. malaria), impact on food and habitation patterns. Combating further CO_2 emissions becomes a major preoccupation (BE formation and operation, electricity generation, transportation). Changing habitation patterns. More attention to issues of resource shortages coupled with elimination of undesirable output (waste, pollution).

Political: Rise of Russia and China; Mid East; nuclear and bacterial weapons.

Energy security. Immigration control. Counter terrorism.

4.2. Scene setting: The Built Environment Sectors, 2008-2023

Commercial: Drivers: 'smart' development, sustainable cities; systems development; connectivity & "connexity"; Corporate Social Responsibility (CSR), political & social cohesion: green development, social exclusion, affordable housing; climate change; places, products & processes: funding, value, professional behaviour & alliances, PPPs; security: tall buildings' future; demography: growing numbers, aging, moving; quality of life: virtual living, fun work; Concerns/Options: Philosophy: sustainable urban development, CSR, quality of life; Framework:

internationalisation, information revolution, ethical investment; Location: changing nature [location] of work, competitiveness, connectivity & logistics; Form: mixed-use developments, energy for organisational behaviour conservation and localised production, safety & security; Function: fun-factor, flexibility & adaptability, access & affordability.

Housing: Drivers: Need to upgrade stock to provide more dwellings, more flexibility, greater energy efficiency/ less CO_2 emissions. Radical new designs required. Role of the car and flooding. Land availability and affordability issues. Dominance of owner-occupier (regional). Concerns/Options: Increased off-site manufacturing, standardisation of production management on site; greater complexity of development pipeline, especially regulatory issues.

Governmental [health, education, civil defence, military, State administration]: Drivers: continued pressure on expenditure and diminished role of government as client in the absence of concerns about war or civil unrest. Concerns/Options: continued reliance on private finance and emphasis on service specifications. Government as reduced procurers yet increased regulators. Emphasis on value and service – holistic (e.g. Whole Life Costs), but also focussed (briefing & design, delivery, post occupancy, dismantlement).

Retail/Industrial/Leisure: Drivers: Out-of-Town, car centric centres unlikely to be the long-term way forward. Increased emphasis on people-based service and internet shopping. Change and flux of demands in warehousing to echo and accommodate these structural shifts.

Transport infrastructure: Drivers: ageing rail and road systems, capacity/ congestion [demographic push] on all forms; major investments required. Concerns/Options: integrated 'systems' approach to planning and execution. 'Intelligent' traffic (all forms) management. Upgrade major project management skills.

Utilities (water, fresh & foul, power): Drivers: under-capacity, centralised and fixed, polluting, inefficient, aged. Major issue on future energy sources. Concerns/Options: Huge investment in new power capacity. Potentially major skills capacity issue. Need for systems approach to planning and delivering new capacity.

4.3. Scene setting: BECI delivery re, 2008-2023

As for 1980 to the present, we grouped the BECI delivery factors into three classes: those relating to the general BECI delivery context, the principal actors operating in the industry's delivery, and its processes.

Context

Planning: Planning laws remain of critical importance to the development of the built environment and are under pressure for the social, economic, and environmental impact they have on proposed schemes and areas. Simplification of the complex web of laws and regulations has commenced to avoid a one-approach-fits-all prevailing attitude and to speed the decision making for both simple and very complex schemes.

Building Control: Increased range of building regulations to ensure conformity to many diverse sets of requirements. Of the many additions, the most profound is the need for strict compliance with environmental performance.

HSS: Significant expansion of the area to include many long-term occupational health issues. Emphasis is on behavioural issues associated with working safely and to promote good health. This has resulted in some improvement in HSS performance, but the topic remains a great concern.

Contract forms: There remains a diverse range of contracts to choose from, but there is growing emphasis on the form of relationship that is expected by the contracting parties, with longer-term partnership or alliance forms of contract relationship being seen as a very significant factor for success. This success is shifting from the inputs provided, to the output produced, or even the outcomes achieved. There is, however, evidence that the shift from transactional contract to relational contract is not either easy or a guarantee for successful outcome.

Process

ICT: Increasing ubiquity of IT data leading to problems of information overload and value dilution. As greater 'intelligent' processing is developed, so more value will be able to be extracted from ever increasing volumes of data. Much of this data will be able to be generated and transmitted automatically allowing, for example, the latent potential in Virtual Reality to be realised. Major challenges in interoperability and in model building across the many dimensions which constitute modern operations/facilities based construction.

Manufacture /Assembly technology: The rise of new materials and automated production and assembly (further development of MMC: Modern Methods of Construction) will allow more complex products to be built both commercially viably, safely, and whilst meeting increasingly high environmental performance criteria, e.g. waste and carbon footprint.

Delivery forms: Continued moves to, and challenges around, managing the full life solution that some leading clients/ PFI/PPP players are seeking. This requires the management of both the strategic 'front-end' where the issues are around strategic problem/requirements identification, through to the operational 'back-end' where continuous delivery of appropriate service gives way to retirement and disposal of the asset.

The product: Rapidly increasing awareness of environmental issues, both in terms of energy consumed by the built element (in production and operation) and the ability of the built element to withstand potentially highly variable environmental conditions. In operational terms, clients are seeking appropriate levels of ongoing and future performance, which increasingly stresses robustness and adaptability.

Actors

Labour Relations: Growing general awareness of the need to balance the needs for improved working conditions with the need to remain competitive, particularly in such a wide labour market as represented by the widened European Union. This balance is typically being struck at the local level, with law/regulations providing only a degree of enforceable provision.

Skills: Decline in the need for trade craft skill, with need for flexible skills. Significant increase in the need for specialist management skills has resulted in the growing number of specialist management experts. Emphasis on life-long learning. knowledge, and management. Process and technological improvements shift the need for technical skills to be far more IT-based in design offices and orientated to site-based assembly rather than site-based creation.

Supplier organisation(s): Continued restructuring to differentiate suppliers in the top market tiers towards asset /income /professionalisation driven and super/mega subcontractors as main contractors with differentiation specialist skills; increased global ownership with London as a main world cluster for the professions and overseas ownership of contractors/suppliers; supply chain integration (often not extended whole way). The transaction costs associated with distributed supply chains countered with the use of networks or clusters of supply based organisations who seek to work in an aligned manner where possible. Some clients further this by creating long-term alliances, but often this is at first tier only. This emphasises the need for consistency of behaviour and relationship, and the ability to continuously deliver acceptable performance.

The Professions: Dealing with two types of challenge with varying degrees of success. 1) the rise of the various externality issues such as sustainability and the challenges and opportunities in new technologies; 2) the need for the professional disciplines to coordinate with each other to deliver more appropriate, higher value solutions. Both require increased interdisciplinarity. Question whether professions' power will not erode.

Clients: Many more clients are aware of the impact that their built environment element will have on the wider environmental, economic, or social systems. They are demanding more and seeking greater assurance or evidence about a range of issues, from sourcing of materials, to long-term performance of the built element. The more sophisticated clients adopting systems approach to whole-life management and value-based relationships.

5. Common themes, issues and concerns relative to circa 2020

From the above analysis we were able to identify a number of common themes.
These are summarised in Figure 3.

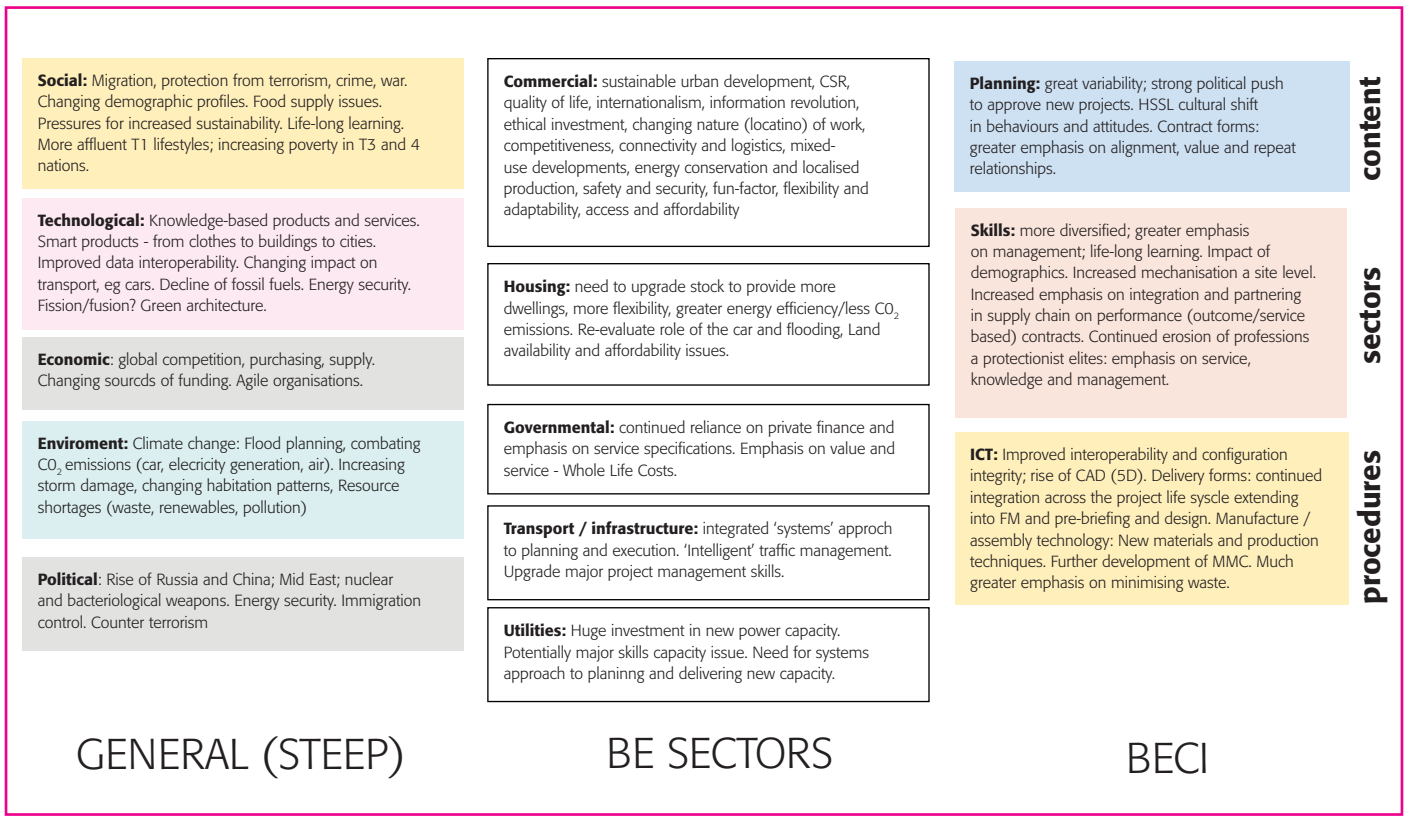


Figure 3: Summary of principal themes, issues and concerns affecting the BECI in 2020

These themes, issues and concerns clustered around the following drivers:

- Sustainability [Social, Economic, Environmental, Food]
- Climate Change [CO_2, Flooding]
- Security and Safety [Terrorism, Energy, Food]
- Corporate Social Responsibility [Ethics, Governance]
- Quality of Life [transport, leisure, work]
- Energy sourcing and emissions
- Waste and resources management

- Flexibility, adaptability, agility
- Intelligence (ICT, knowledge, learning) – communities, organisations, individuals; "24-on"
- Improved management of development & delivery
- Up-rating of skills
- Better front-end planning/definition
- Other, e.g. funding, Whole Life & Value based decision making, Service delivery, etc.

5.1. Development of the 2020 research agenda

From this list, a number of research issues, concerns and trends arise in consequence:

- The advantages of adopting an holistic, systems approach to overall planning and delivery.
- The value of seeing the delivery 'life cycle' as an integrated whole, form front-end definition through design and build delivery into operational services
- The importance of sustainability and stakeholder engagement
- The need for high quality management and technical expertise
- The importance of delivering value-for-money, and of doing this best through aligned supply relationships and integrated, relationship-based contractual/ organisational development & delivery forms.
- The need to assure an appropriate skills-/ labour-supply base.
- The opportunities promised by effective organisational and individual learning, both from projects and on a life-long basis.
- The enormous opportunities ICT offers, and the promise of intelligent products (from nano and materials, components, buildings and cities; and services).
- The need to continue moves being made in off-site manufacturing and in gaining efficiencies through more effective lean management and waste management

We then compared this list with National Platform's original list, namely:

1. *Client behaviour and expectations (including outcomes, value, design)*
2. *Knowledge*
3. *Systems approach*

4. *Requirements management*
5. *Stakeholder management*
6. *Sustainability*

This produced a consolidated list of what we saw, and took to be, our working list of opportunities and issues relative to the BECI delivery circa 2018-2023:

1. *Addressing environmental issues.*
   - Accommodating climate change/ reducing CO_2 emissions.
   - Improving sustainability – environmental, social, economic.
   - Managing waste.
2. *Providing an holistic understanding of, and response to, client and user needs.*
   - Adopting a systems-based approach to overall requirements definition and delivery.
   - Promoting integrated/aligned relationship-based contractual/ organisational development & delivery forms.
   - Providing increasingly integrated life cycle services from the Front-End, through delivery, into operations.
   - Promoting a whole life approach.
   - Encouraging effective stakeholder engagement.
   - Promoting a value perspective and Value-for-Money culture.
3. *Providing the necessary quality of management and technical expertise.*
   - Ensuring an adequate skills/ labour supply.
   - Developing the knowledge-based abilities of the sector.
   - Maximising learning: organisational and individual, life-long.
4. *Optimising ICTA.*
   - ICT technological developments.
   - Intelligent products and services.
   - Improving off-site manufacturing.
5. *Other, e.g. regulatory control, market pressures*

5.2. Comparison with recent similar forecasts

As a reality check, we then compared this list with the research agendas recently proposed by E-CORE and the Strategic Research Agenda.

5.2.1. E-CORE (2005)

E-CORE – the European Construction Research Network - was launched in October 2001 as an EC funded Thematic Network under the FP5 Programme "Competitive and Sustainable Growth". From then until March 2005, E-CORE provided an electronic reference point for construction research at a European level, providing an 'umbrella' for individual research interests and for specialist networks related to construction to come together and share ideas and opportunities. A major objective for E-CORE was to develop a strategy for European construction research. (Note that the remit of this strategy was broader then the delivery focus of this study.) The industry was characterised as needing to be:

- Focussed on value: 'performance' oriented using lean production,
- Environmentally responsible,
- Innovative & continually learning,
- Stakeholder oriented.

The implications of this focus were seen to result in the following traits, each of which suggested research directions.

- Service delivery: specification based performance; continuous improvement.
- Relationship contracting, trust, organisational learning, tighter educational linkages, developing people.
- Performance metrics, better performance modelling, better operational feedback.
- User requirements tools, better linkage to models of outputs/outcomes.
- ReducedCO_2 emissions through better design; buildings as net generators of energy (though not of CO_2); environmental impact assessment tools.
- Water saving measures; better understanding of flood protection requirements; ditto high winds.
- More flexible, better value-for-money housing.
- Whole life cost orientation.
- New, more intelligent materials [nanotechnologies].

- ICT: virtual modelling of outputs/outcomes, 4D construction modelling, interoperability.
- Waste/Lean; more sophisticated off-site fabrication and delivery; recycling waste.
- Better working environments.
- Protocols and regulations in support of all the above.

5.2.2. The EU Strategic Research Agenda (European Construction Technology Platform (2005)

The Strategic Research Agenda (SRA) was established by the European Construction Technology Platform (ECTP) in 2005 to address the research needs of Europe in the field of construction over the next 25 years. It was created following a high-level report, "Challenging and Changing Europe's Built Environment", which was endorsed by the High Level Group (HLG) of the ECTP in 2005, which outlined a vision for a sustainable and competitive construction sector by the year 2030.

The SRA Vision 2030 document presents a construction industry that is increasingly client/user-driven, sustainable and knowledge-based, and proposes two interlinked

key goals to achieving these:

- meeting client/user requirements;
- becoming sustainable.

The Strategic Research Agenda proposes a set of research priorities that are organised around these two principal goals. The Agenda has been prepared by the ECTP Support Group with relevant contributions from the Focus Areas and various National Construction Technology Platforms. It was approved by ECTP HLG on the 22nd of November 2005.

The SRA proposes that "by 2030 Europe's built environment is designed, built and maintained by a successful knowledge- and demand-driven sector, well known for its ability to satisfy all [sic] the needs of its clients and society, providing a high quality of life and demonstrating its long-term responsibility for mankind's environment. Diversity …is embraced; good employment opportunities; companies engaged in R&D and competitive locally, regionally and globally."

The SRA makes, in our opinion, a big claim on the presumed sophistication of the client. Clients, according to the SRA (paragraph 4.3.1) supposedly have become knowledgeable sophisticated customers buying from

other industries: time-cost-quality/scope is the minimum and, it is asserted, not unreasonably, they want value above that to solve organisational and policy issues and address broader societal issues. It is evident however that many occasional procurers of facilities are uninformed clients and users; nor is it clear that most regular procurers are sophisticated in organisational learning, knowledge management, in leveraging the most effective relationships in and value from the market. As a result, we believe that the BECI will need to place high priority on having requirements elicitation skills and will need to own the responsibility for deploying them effectively.

The SRA identifies the following research areas.

- Meeting Client/User Requirements:
  - Healthy, safe and accessible indoor environment
  - A new image for cities
  - Better use of underground space
  - Mobility & supply through more efficient networks.
- Becoming Sustainable:
  - Reduced resource consumption
  - Reduced environmental and man-made impacts
  - Sustainable management of transport & utilities
  - A living cultural heritage
  - Improved safety & security.
- Transformation of the Construction Sector:
  - A new client-oriented knowledge-based construction process
  - ICT and Automation
  - High Added-value construction materials
  - Attractive workplaces.

Each of these areas has the following research implications

- Meeting Client/User Requirements:
  - Planning policy re urban sprawl
  - 3D GIS models.

field sites, supported by holistic decision-making tools

- New, intelligent, integrative asset management systems (e.g. transport)
- New threat assessment tools (e.g. re terrorism, flooding, etc.).

- Transformation of the Construction Sector:
  - Requirements management tools
  - Performance-based standards
  - Whole life management
  - Knowledge management approach
  - Customer-oriented design approaches
  - World-class delivery chains, using 'industrialised processes' and new models
  - ICT: interoperability, visualisation, sensing, programmable materials
  - Intelligent, easy-to-install and de-mount materials, life-cycle oriented

The check against the E-CORE and SRA proposals did not lead us to alter our list of potential research issues relative to the BECI delivery agenda circa 2020. This therefore became the basis of our structured interviews.

6. What's So Distinctive in 2020?

The National Platform asks us to focus on the potential research issues circa 2020. What will be so special about this date?

Societal change generally happens along a continuum: hopefully the period 2018-2023 will not be unusually dramatic with major step changes. Nevertheless, based on all the above, on our analysis, and on the conclusions of our interviewees and workshops, we believe that the following four factors could be dominant in shaping the BECI in and around 2020. The most significant factor relates to climate change, not just as it is in 2020 (though this is significant enough) but in what must be being done to prepare for the next 30, 50 or more years. Two factors relate to resources – people (both in shaping demand on the built environment and influencing production) and money, both in the amount required and the form it is supplied in (state funding, private finance, etc.). And the last factor: technology developments – technology push.

Environment

- Climate change
  - The IPCC (Intergovernmental Panel on Climate Change) warns that greenhouse gas emissions must peak by 2020 if the worst chances of climate change are to be avoided. But the real impacts won't be on us till 2050+: we must be working on 2050+ scenarios in 2020!

Resources

- Demographics
  - Ageing and immigration: an aging population, a more extended family profile, and more pressure from immigration will create further heavy demands on housing and infrastructure.
  - In addition there will be continued implications for the BECI workforce in terms of sourcing of labour, skills, and off-site construction.
- Funding
  - Much of our infrastructure, including housing, is old, environmentally unfit, or otherwise in need of upgrading and replacing; and many PFI schemes at the end of their design lives. There will be massive needs for new and reconfigured infrastructure and housing (Booz Allen Hamilton estimate over $40 trillion over the next 25 years, $9 trillion in Europe (Doshsi et al. 2007))

Technology

- Increasingly intelligent buildings and cities
  - ICTA intelligence will make user/built environment increasingly sophisticated, pushing the importance of better understanding the user interface.
  - Improved intelligence should be making itself felt at all levels, from nanotechnologies, through larger materials, components and systems, to buildings, communities, and to whole cities, regions and countries.

The EC SRA is to the point on CO_2 emissions [Section 4.2.1]: "By 2050 the majority of new EU buildings produce zero CO_2. 100% of the building stock are retrofitted. Energy consumption of the BECI is reduced by 50% and CO_2 emissions by 75%." This will require, inter alia, "integrated life-cycle processes for flexible buildings and infrastructure "… including] integrated design, construction, FM, de-mountability, waste removal, etc.

These four factors, combined with all the others, create, we suggest, a need for an industry that:

- Takes a more integrative, interdisciplinary, whole life-cycle view of its work – leading to a systems orientation to project and product definition and development, and operation.
  - One result of which is to require more informative metrics and models of the overall building 'system' and its components being developed and 'operated'.
  - Another is to focus better on eliciting and delivering clients', and users', real needs.
  - And another is to have more comprehensive, owner-oriented governance models to hand (less design-oriented than the RIBA Plan-of-Work, and less Procurement-oriented than the OGC Gateway process);
- Pays due recognition to developments in technology, but recognises that many of these originate outside of the BECI, for whom therefore the challenge is less technology origination as technology adoption;
- Acknowledges the need for better 'knowledge management' capabilities in the industry, but in doing so raises the question of the roles of:
  - the professions in providing this, not least given the new interdisciplinary, holistic environment that we believe will be required to address the external challenges of climate change and infrastructure reconfiguration,

- the insurance industry in not constraining real 'lessons-learned' reviews,
- education in supporting the industry intellectually;

▪ Sees that this new landscape offers new opportunities for the industry to restructure and improve its competitiveness.

The potential research issues facing the industry around 2018-2023 are now examined in Section 7 and then prioritised and shaped in terms of this loose scenario in Section 8.

7. 2018-2023 research issues

Before attempting to list potential research issues relating to the BECI circa 2020, we should note the need really to segment recommendations. The field is too big to be treated as homogenous. Segmentation should be by:

- Sectors
- Refurbishment versus new build
- Large projects/firms versus not large
- Experienced clients versus not experienced.

Segmentation remains an aspiration for this report however. It is beyond its scope in terms of time or resources. What we are building towards is a broad agenda which hopefully will serve as a menu of potential research issues related predominantly to delivery circa 2018-2023.

Having generated almost 200 research suggestions through our interviews and workshops, we grouped these topics in a post hoc classification into four major areas:

- Tools, techniques and technologies
- Capabilities
- Knowledge
- Regulation and planning

We now consider each of these in turn. The following bullets represent, largely, proposals made by interviewees or in workshops.

7.1 Tools, techniques and technologies

7.1.1 Requirements & Modelling

We require a much better understanding of what helps users perform better. We need to be able to build models of "what good looks like" based on 2020 Whole Life Cost (WLC) data. We must learn from Post Occupancy Evaluations (POEs). Also, we need to know better when to use specification-based procurement.

- We need improved **Post Occupancy Evaluation methodologies**, particularly in light of 2020 conditions – energy, CO_2, waste, etc.
- We need research on how the **insurance industr**y can allow **real learning** from POEs. (PI is a major constraint in getting empirical evidence on failures)

- A major research thrust from POEs should be to build up more **quantitative model**s. (The insurance industry will need to understand better the risks it is insuring.) These models should encompass 2020/2050-relevant Whole Life Cost data (e.g. relating to 2050 climate change conditions).
- A specification approach is alright in theory but can be expensive and lead to poor quality design: we need to **know better when and where to use performance based procurement.**
- We need **integrated modelling capabilities** integrating 2020 Whole Life Cost data (which will be quantitatively and qualitatively different from say 2010-2015 due to the evolving and worsening climate situation), decision-making tools (Design Quality Indicators (DQIs), Critical Success Factors (CSFs), sustainability data) into planning and visualisation tools – tying whole-life data into models of 'what good will look like' – see SRA 4.2.1,2,3.3
- Robust project **delivery metrics** should be a sine qua non: how feasible is this?

7.1.2 Whole Life Costs

2020 conditions need modelling, particularly re refurbishment. This needs to be FM-based

- **Whole life costs: 2020 requirements need modelling**, e.g. of building stock and economics of O&M.
- **FM** needs to be better articulated. There are research issues of technology, data availability and perception. This is where integration – a more holistic, Whole Life Cost/Value-based view – must start. Currently there's too little emphasis concerning the current stock. Start with refurbishment.

7.1.3 Value

Value is like risk: complex and contextual. For 2020, we must focus on O&M/FM with respect to the 2020/2050 period, and on the relationship with risk & benefits.

- Value needs to be better articulated. We need to start with **operations** feeding into design and construction through FM. We need to work out how to **make explicit the value dimensions and risks** which are /are to be embedded in them. How to calculate value in terms of social capital? How should risk and opportunity be integrated with value?
- Moving from cost to value is not the real issue – both will remain important. We need to understand better the **risk (predictability)-benefit relationship c**lients face (knowledge- and client-orientated).
- We need to shift awareness of Whole Life Costs/Value data from a "cost" to part of the" intellectual asset" base.

7.1.4 ICTA

As well as interoperability, ICT's role in modelling, visualisation, and manufacturing (off-site, lean) needs developing and assessing.

- We need **integrated modelling capabilities** integrating 2020 Whole Life Cost data, decision-making tools [DQIs, CSFs, sustainability data] into planning and visualisation tools – tying whole-life data into models of 'what good will look like' – see SRA 4.2.1,2,3.3
- We need to address issues of **collaborative prototyping and data sharing**
- What role can ICT play in facilitating the interfaces for **JIT** ordering, production and delivery?

7.1.5 Materials

Intelligent materials will impact the whole user-supply chain relationship. Also need to look at lean, robotics and CO_2 implications.

- We need to understand better the implications of **intelligent materials** to the user and the supply chain
- We need to look at the Off-Site Fabrication (OSF) interface with sites and utilities for integrated **lean/ just-in-time (JIT)** solutions to installation of services and components; and how to strengthen OSF with the design professionals, scoping just-in-time agile production with creativity
- Need to examine scope for low cost global OSF versus **carbon implications**.
- Past predictions for a step-change via **robotics** have proved false: we need to research value of robotics in controlled OSF environments.
- The economic criteria in relation to increased **productivity** (including 24 hour working) and quality control require in-depth consideration.

7.2 Capabilities

7.2.1 User/client needs

We need greater clarity on **who the real clients/ users are**, what their needs are and know how best to elicit these.

- We need greater clarity on who the real clients/ users are and what their needs are. (SRA is naïve on this we feel.) We need better client/ user satisfaction indices. We need research into facilitating **client**

self-awareness for making explicit their requirements and expectations; it's absolutely more than just tools.

- How should **briefing** take greater cognisance of **'unintended users'** – e.g. building occupiers who were never even on the radar? How can we extend briefing to better take account the environment and other '**externalities**'?

7.2.2 User/client methodology

We need to replace the RIBA Plan of Work (which, quite understandably, is design orientated) as the default process guide with something more comprehensive in management and governance terms, and which is client oriented.

- A comprehensive project development, delivery, operations product development **life cycle methodology** needs to be established to become the default reference guide for clients/sponsors and project members in place of the RIBA Plan of Work.

7.2.3 Systems Integration

There is space – and need – for a function for, and/or an approach to, managing the elicitation of client/user requirements and the development and delivery of appropriate holistic responses.

- **What kind of industry structure/organisation is needed** to service a Whole Life Value/Costs-performance-based, specification-based approach to project definition? Will it be definition alone or definition and delivery? What **kind of firms** would be operating there, what will the **economic model** be, the skill/educational base, professional support? (There is quite a long way to go beyond the current PFI consortium led approach.) If the skill base is partly process, partly behavioural, partly substantive, what should be the **technical discipline base** - designers, builders, other (analysts)?
- How relevant a model are the US Architect/Engineers (A/Es): what can we learn from positing their analogue in building? Will the new A/E (Systems Integrator) provide **cradle-to-grave 'assured' service**? What will this take? Robust project **delivery metrics** should be a sine qua non: how feasible is this?

7.2.4 Procurement

Should we be testing different delivery models appropriate to 2020 needs – e.g. re using a specification-led approach, for housing, re Relationship Management?

- A specification approach is alright in theory but can be expensive and lead to poor quality design: we need to know **when and where to use performance based procurement**.
- Should there be market testing of the relationship approach (Latham, Egan): what are the limits of procurement-led changes and companies' scope for managing organisational behaviour?
- Should we be trying new delivery models for housing (e.g. from mixed use development)?

7.3 Knowledge

7.3.1 The professions

Our knowledge base is quite inadequate for 2020: it needs major updating, sponsoring and owning. What, and which, should be the holders and proponents of this new Systems Integration knowledge base?

- Assuming we are moving towards an integrative, client-centred BECI model, **who will be the holder of this knowledge**: firms or/and professions? Which **professions**? What should the role of the professions be?

7.3.2 Corporate Strategy

2020 will require new corporate responses: much work can usefully be done to explore the implications to core competencies, economic models, competitiveness, etc.

- What kind of **industry structure/organisation** is needed to service a Whole Life Cost/Value-performance-based specification-based approach to project definition etc. (see 7.1.1)?
- **Corporate strategy** work is required to help contractors move from a predominantly task-orientation working environment to a client-orientation one, and to transition from relational contracting to relationship management
- **Contractors' risk and technical profiles** are changing, so too is their ownership and competition: work is needed on assessing this and better shaping their core offerings and competencies.
- What will be the impact of new approaches to BECI development and delivery mean to global competition/ global cooperation?

- What will the implications be to the **insurance industry** (Professional Indemnity)?
- Ditto regarding the **HEIs** (Higher Education Institutes)?
- There is a need to help companies take the lead in addressing sustainability by incentivising change which works effectively and in good time.

- Are different forms of organisation (e.g. John Lewis partnership) needed for 'buy in' and internal integration in order to facilitate broader integration?

7.3.3 Education & Skills

This new situation will demand new skills and educational programmes, including new research paradigms.

- What are the **skills** required for this new client/user oriented, Whole Like Cost/Value performance-based, systems integration situation? **Model what these are, how long it will take to develop them** and what the **educational/ learning & development programmes** should be. What will be the **organisational/professional home** for them? What do we need to do to engage the consultants, developers, educators and others needed to mobilise the required systemic, holistic, managerial and organisational skills? What changes are required so that professions and universities aren't barriers to change? (See SRA 5.5)
- We need new **research paradigms** for addressing 2020 issues: researchers are working off 2005 paradigms: what are these? (More holistic, interdisciplinary/ multi-professional/industrial, systemic (but circa 2010/2020 not 1970 – complexity, new economics, soft systems, industrial, etc.)).

7.3.4 Knowledge brokering

Where will knowledge lie? How will/should it be made available?

- The whole sector needs a consistent/comprehensive approach to **knowledge broking** on a global scale to transfer and accelerate knowledge awareness and application. At present it is ad hoc. What would this entail? Will it yield competitive advantage in a global market for clients and BECI sector alike?
- What forms will client- and knowledge-orientated systems take, linking to integration issues?
- Government's approach to **regulations** must change. What is the role of knowledge in this? How can the Government impose housing standards if 70% homes are occupier-owned? Regulation needs to be integrated – planning, building control, local fire officer ruling, heritage/listed building/conservation. – at a single point.

7.3.5 Socio-technic issues

Where will knowledge lie? How will/should it be made available?

- We must identify ways of **developing appropriate client-orientated behaviour.** Improvement started with specific innovations, has shifted to (softer) continuous improvement but must address fundamental attitudes and culture. "Unless we deal with the people issues, all this is pretty meaningless".
- While there is much new research around information, organisation, technologies and tools, but application will only be effective if social attitudes are appropriately engaged. A **socio-technic framework** is needed to understand how best the technical recommendations can best be applied.

7.4 Regulation and Funding

7.4.1 Regulation

The research outputs need promulgating in their social context.

- Regulatory issues will be at the heart of this tension: how will they have to change? Will regulatory regime have to be more facilitative, more evidence based?
- Understanding and managing **refurbishment** will be central: we need to understand the 'incentive issues' better: how and when refurbishment happens; what are the issues that will drive appropriate refurbishment (financial, regulatory, risk, fashion, etc.)
- Should houses be required to have a regular **'MOT'** [compare with HIPS]?

7.4.2 Planning

The nature of planning – frameworks and, particularly, the nature of decision-making, will need re-thinking for 2020 needs.

- A critical set of **planning issues** will be the tension between top-down command and regulation and bottom-up democratic **decision-making.** Will there need to be more top-down direction and control? For example: automatic planning approvals within pre-designated zones?

7.4.3 Funding

There will be massive new funding needs: how will these be met and how will they affect performance?

- There needs to be a major programme of **evaluation of PFI/PPP projects**: is this possible given commercial sensitivities?
- Will we see the demise of PFI/PPP? (Many 30 year contracts will be ending.) How therefore will we be **funding** social and technical infrastructure?

8. 2020 Top Research Priorities

This long list of topics was then rationalised into two lists – the second being a shorter version of the first. The long list, of 17 items, is shown in Figure 5 on the following page. The list below, in Figure 4, is a shortened version of the Figure 5 list, having about six major research topics

1. *Examine the Systems Integrator/Integration role/ function re 2020: what, why, who, how, economics, skill base, tools, etc.*

   1.a. Establish an owner-oriented governance life-cycle methodology.

2. *Develop integrative quantitative models combining requirements, Post Occupancy Evaluation, project delivery, and Facilities/ Operations Management data into "what good looks like".*

3. *Define the 2020 education and skilling needs; and the professions' and insurance industry's roles.*

4. *Examine the impact of ICTA, robotics, off-site manufacturing, intelligent materials on the supply chain.*

5. *Examine procurement options and limits: e.g. of a specification-based approach; of relationship approaches.*

   5.a. Explore corporate strategy implications of all the above: on the firm, global players, competition, skills and education

6. *Explore the implications new funding requirement and mechanisms.*

   6.a. Explore 2020 Planning and Regulations needs.

Figure 4: Short list of 2020 BECI 'delivery' research topics relative to 2018-2023

1. *Establish the real user/client: how can we better elicit and define their needs?*
2. *Develop Whole-Life Cost/Value tools and models: these should be developed with regard to post 2020, FM-based data and operational models.*
3. *Develop Value-based tools, paradigms, and data.*
4. *Examine the implications of Post Occupancy Evaluation (POE) data with respect to 2020 operating conditions.*
5. *Establish an owner-oriented project governance life-cycle development methodology to supersede the RIBA Plan-of-Work.*
6. *Examine the Systems Integration function/ Systems Integrator role with regard to the challenges of 2020: what is it, why is it necessary, (is it necessary), who would do it, how, what are the economics of the function, what skill base is necessary, what tools, etc.*
7. *Develop integrative quantitative models: models which integrates requirements, POE, project delivery and operational (FM/OM) data to show "what good looks like".*
8. *Examine the impact of intelligent materials on users, clients, and the supply chain*
9. *Develop production enablers – ICTA, robotics, off-site manufacturing – and examine the impact on the supply chain.*
10. *Examine procurement options: specification-based; limits of relationship approaches,*
11. *Examine new roles for the professions with respect to 2020 (e.g. as knowledge holders).*
12. *Explore corporate strategy implications of all the above on the firm, international players, competition, skills and education.*
13. *Define the 2020 education (HEIs) and skilling needs.*
14. *Define the impacts on and of the insurance industry: e.g. on full and frank POEs, on the ability to learn from mistakes, on getting real Whole Life Costs, etc*
15. *Explore BECI knowledge brokering system options*
16. *Explore 2020 Planning paradigms*
17. *Explore accelerating 2020 Regulatory environments*

Figure 5: Long-list of 2020 BECI 'delivery' research topics relative to 2018-2023

9. On-going Research in the Priority Areas

We were asked to identify where there is research going on in these six or so priority areas. The following list is not by any means exclusive.

1. Systems integration role/ function	Bristol	Risk Uncertainty Management for Infrastructure Systems
	Reading	Innovation in through-life service delivery
	Loughborough	Improved Construction Business Processes – design chains for value delivery, procurement-led cooperation, stakeholder management and value. Simulation of new customer-focused ways for delivering products and service
	Salford	Re-valuing Construction Client briefing, Process improvement , Design and procurement management, construction and project management, partnering and collaborative Working , Integrated quality and risk management, Value Management ,Tools (electronic) to improve user-engagement in design.
	CE	Value
	Nottingham Trent	Project integration
	UCL	Management of projects; major transport projects Systems Engineering FM
	Stanford	Global projects
	Manchester	Management of Projects + soft systems
	Imperial	Projects, Systems and Innovation
	Nanyang Technological University	Systems Management and construction
1.a Owner-oriented life-cycle methodology	CIC	CIC Services booklet

1. Quantitative models – what good looks like	Loughborough	Whole Life Value User-centred product and service delivery in the built environment industries' capabilities to meet differentiated user requirements
	Dundee	Whole Life Costs
	Bordas	POEs
	Herriott-Watt	Decision Support for low Carbon design
	CE	POEs
	Delft	Real estate decision making models. Asset value creation
	CIBSE	Whole Life Costs
	BRE	Benchmarking, Energy, Health-Checks, DQIs, Whole Life Costs
	VTT	ICT models and tools for decision-making and life cycle planning
	CRC	maintenance models (through CIEAM)
	QUT	Building Performance (Sydney Opera House)
2. Define 2020 skills/education needs	Loughborough	Management of Human Resources – knowledge, life-long learning, skills and training
	Salford	Education in the Built Environment :E-Learning, Industry engagement with education, education supply chain (recruitment and retention), women in construction, knowledge management
	CITB/ CSSC	Manpower forecasts
3a. The professions	ICE	Professional skills
	Manchester	Role of the professions
3b. Role of insurance		

4. Information and Technology [incl. materials]	Reading	Intelligent Buildings Research Group. Materials Mechanics and Biometrics. Manufacturing Process and Process Modelling
	Loughborough	Advanced ICT applications, Innovative Construction Technologies ,Safety, mobile IT
	BRE	Intelligent Buildings, MMC
	VTT	Manubuild – open building manufacturing, Construction processes and production methods
	QUT	Design, infrastructure, smart systems
	UCL	Virtual reality; spatial modelling
	Stanford (CIFE)	Organisational modelling N-D CAD
	BERR/Ce	Avanti program
	Salford	Process protocols, product models, knowledge-based systems, modelling and simulation and integrated computing environments.
	BERR/CIRIA	Off-site building
5. Procurement	Reading	Innovative procurement
	UCL	Supply Chain Management; Relationship Management
	Birmingham Business School	Supply Chain Management and projects
	BRE	Lean
5a. Corporate strategy	Reading	Human resource management and the culture of the industry. Migrant and transient workers, Construction sector competitiveness
	MIT	International corporate strategy
	HUT	International operations of construction companies. Service procurement, organising and strategies. CRM in Construction and FM.
	Salford	International competitiveness
6. Funding implications	UCL, Delft	Public Private Partnerships
6a. Planning and Regulation	UCL	Regulations implementation
	BRE	Services
	Lancaster, Salford, Sheffield, UCL,	Vivacity 2020: design tools for the 24 hour city

Note:

- The Systems work needs to be seen as engineering as well as management, behaviours as much as technology. What we are talking about here is a discipline of managing the front-end of projects, from an early understanding of the client's needs, with full appreciation of the 'system's' required operating characteristics, which then goes on to develop and manage the project (if indeed it proceeds) in an integrated, holistic manner, through design and construction into operations.

  Intellectually, systems integration is probably the hardest of all the six areas to grasp. The systems approach stresses seeing entities (systems) as 'wholes' (holism) with properties emerging at different levels (hierarchy and emergence), and with parts (subsystems) managed at and across their boundaries (interfaces). The approach was largely developed between the 1950s and the 70s. Most of the work since then has been less about developing original concepts and tools – with the notable exception of soft system methodologies (Checkland, 1999; Checkland and Scholes, 1998, Wilson, 2001) – than about application, either in a conceptual sense, for example in innovation, supply chain management, organisation theory, learning, or in 'hard' scientific and engineering terms, as in say meteorology, agriculture, software, transport and many other fields.

  Systems engineering is a particular branch of the systems approach which prima facie ought to be relevant to creating the built environment (Oliver et al., 1997; Stevens et al., 1998). It has been described as "a robust approach to the design, creation, and operation of systems. In simple terms, the approach consists of identification and quantification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of the best design, verification that the design is properly built and integrated, and post-implementation assessment of how well the system meets (or met) the goals" (NASA, 1995). It combines management with design, concentrating particularly on the front-end in assessing information, defining effectiveness measures, creating models, performing trade-off analyses, and creating build and test plans. The International Council on Systems Engineering's sequence of development would not be unfamiliar to construction but is addressed from a systems perspective: a 'mission concept of operations' (CONOPS), a systems requirements document, statement of work, request for proposal and contracts data requirements list should all be developed 'in the pre-concept phase' of a project's development, according to the INCOSE handbook (INCOSE, 2004).

  These are difficult areas however, as a recent CIA study illustrated (Meier, 2008). Requirements management for example is an area of real practical difficulty. Whereas traditional systems development models advocate that requirements should be fully identified before design can begin, there is increasing recognition that often this is not possible and instead there is either a more progressive elicitation, comparable to Blyth and Worthington's strategic or progressive briefing (2001), or a quicker, shorter define-test cycle as in Agile software development (Leffingwell, 2007).

  The Built Environment sector has not really, with the exception possibly of Planning, really engaged formally with systems thinking. Few firms are applying systems engineering in construction. This said, there is undoubtedly a strong current in the Built Environment industry for more holistic, interdisciplinary approaches to addressing the issues it faces (CIB, 2005), as evidenced perhaps by the Strategic Forum's 2012 Construction

Commitments (client leadership, integration, etc.). A systems approach would be highly appropriate conceptual underlay to such moves. Lawrence & Lorsch's work on differentiation and integration (1967) and the early sociotechnic work of, for example, the Tavistock Institute and its studies of the construction industry (Higgon and Jessop, 1966; Tavistock, 1966) are also pertinent. All, including systems thinking, are theoretical substrata of 'the management of projects' view of the discipline of developing and delivering projects in which projects are treated holistically and the front-end definition is recognised as being typically both undermanaged and simultaneously the place where value is most created or future problems created (Morris and Pinto, 2004).

In any case, we believe an early piece of required work should be to investigate the relevance of these ideas and techniques to the challenges of 2020. There is no major research on-going, as far as we can see, on the role of the Systems Integrator – what there is is either on systems engineering, integration, or management of projects with a systems perspective (e.g. Yeo, 1995).

- There is essentially no research going on regarding an owner-oriented governance orientated life cycle. (Again pertinent to the 2012 Construction Commitments). Probably not a lot is needed. One wonders why this has not been tackled heretofore.

- Comprehensive metrics and modelling is widely and strongly seen as a major upcoming research area, described by one professorial interviewee as the one real insight from this study, and by another as a Fairy Godmother wish. The latter interviewee stressed the importance of expert professional subjective judgement and warned against machine-like reliance on metrics for decision making. In our experience, most people would like in the first instance just to have useful data. The facts are we don't have many good models or data on how the end product – the building – will perform (how capex and opex trade-off), especially in the context of 2020's environment. If we don't have 'whole process' or 'whole product' data (systems thinking again), we can't be in control; and we won't be able to learn and improve.

- The treatment of Knowledge Management has proved interesting. Knowledge Management and Organisational Learning have been major academic research areas over the last ten to fifteen years (Bredillet, 2004; Sense, 2008) yet there is a perception that despite the huge interest in it, the insights have been relatively small. Certainly we now recognise the importance of tacit knowledge as much as explicit, and hence the importance of communities-of-practice (Wenger, 2000) and reflection on, and in, practice (Schön, 1991). Rather than addressing these as academic topics, our interviewees suggested a more consequential approach: for example, what are the roles of the insurance industry in constraining lessons-learned or the professions in providing needed interdisciplinary knowledge. Or what knowledge should education be teaching (and how) circa 2020? There is no real research on the future curricula of construction education that we are aware of. If correct this is astounding! There is no real research on the impact of insurance on innovation and learning.

- There is no major research on funding. There are only the beginnings of a programme of evaluating PFI and PPP projects. This surely has to come to the fore given their prominence, both past and to come, and at times real difficulties.

- Regulations and Planning has work going on but it is not oriented towards delivery issues.

10. Proposed Sequencing of the Research

We are asked to suggest an implementation programme for the priority topics. Figure 6 proposes that topics 1 and 2 (Systems Integration and Models & Metrics) should begin immediately, in Phase 1 of the proposed programme of research. They are fundamental to the future work. Topic 1a (the owner-oriented life cycle methodology) is a relatively short piece of work and could likewise begin immediately.

- The Systems Integration programme would be a multi-year, new research dimension, both in its own right, also influencing other research programmes.
- Models and Metrics would also be a multi-year research programme, again representing a major new research direction.
- Procurement and ICTA and Technology are essentially already on-going programmes.
- The potential of research around funding, the role of insurance, the professions, and regulations should all be evaluated with some initial, more detailed exploratory work. This should happen in Phase 1 of the research programme. Further work, if appropriate, could follow in Phase 2,
- Research on the implications of all the above, but particularly of Systems Integration and of Models and Metrics, on Education and Skills, and on Corporate Strategy, would naturally follow after the initial research findings had begun to appear, and would therefore be most appropriate in Phase 2 (2013-2023).
- Research into the 2020 implications on BECI delivery of Planning would similarly be in Phase 2,

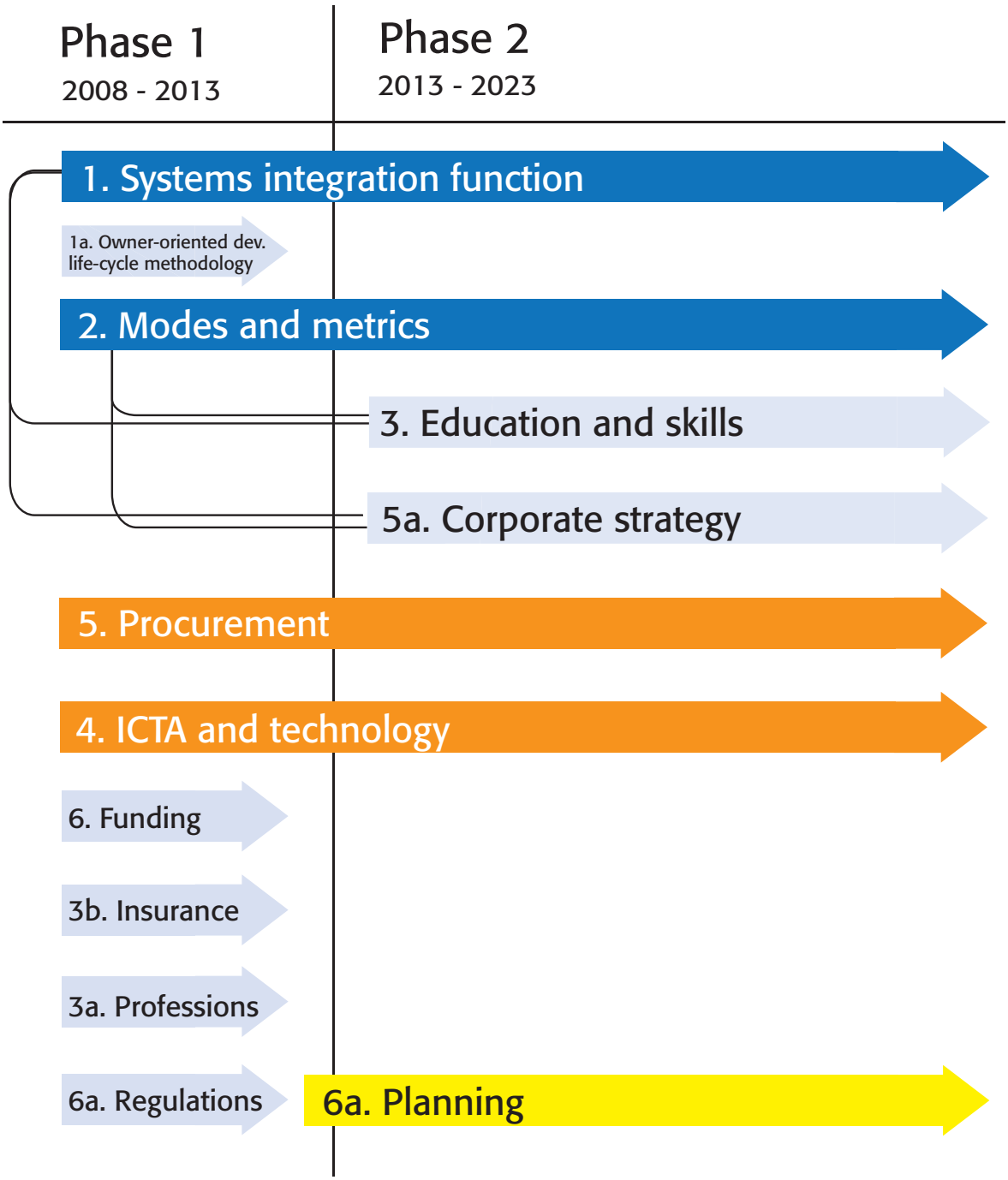


Figure 7 suggests some specific tasks and timings within this broad sequence.

TOPIC	RESEARCH	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Examine the Systems Integrate role in the context of 2020	Clarify expectations of the role, its benfits and barriers to implementation															
	Action research on issues and benefits in practice															
	Compare broader relevance of systems integration approach to the new BECI paradigm															
1a. Establish an owner-oriented governance life-cycle methodology	Develop a methodology (replacing Plan-of-Work) showing how practices should be deployed															
	Action research on its implementation															
2. Develop quantitative , integrative models and metrics using POE. WLC and FM data. With front end requirements and specifications so we can model "what good looks ike"	Exploratory studies on (a) the systems architecture (b) the data integration issues															
	Build examples of how operations data can integrate with Front-End decision modelling and these then feed into requirements, briefing and specification packages.															
	Investigate how these vary according to different design, procurement and construction routes.															
3. Define the 2020 education (HEIs) and skills	Assess the implications on skills and education of systems integration, integrated data modelling, interdisciplinarity, special impacts of 2020+. Look at different pedagogic delivery models.															
	Trial and formally evaluate exemplar programmes															
3a. Review the roles of the professions re the 2020 environment	Define the needs for professional bodies - knowledge brokeringm independent advice. Look at the efficacy with which they are doing this. (Action research?)															
3b. Review the role of insurance in constraining learning and innovation	Exploratory study on the challenge to the professions of the interdisciplinary knowledge base needed for 2020															
4. Examine the impact of ICTA, robotics, off-site manufacturing, intelligent materials on the supply chain, skills and education, and C02 emissions	A steady stream of ongoing work. Much of the research in this area is done by people outside of the industry: construction reacts to this.															
	The socio-organisational implications of, and on, developments should be assessed - eg on skills and education & C02 emissions. This will be an on-going theme but may benefit from periodic focussed study															
5. Examine procurements specification and relationship approaches	The impact of systems integration and integrated models and metrics.															
	Better understanding of the constraints on these on a specification/output led approach to procurement. And on the use of a relationship-based approach.															
5a. Explore corporate strategy implications; the firm, global players, competition, skills and education.	ad hoc and reactive															
6. Explore funding mechanisms' implications	An initial exploratory study. (This could be an extension to the nCRISP Pearce report)															
6a. Engage with emergent and potential 2020 planning paradigms and Regulatory environment	Re Regulations, there should be initial exploratory studies to look at. Eg a strategic review of carbon targets, policies and technologies for new and existing housing over the next 50 years; & a programme of more rapid, better quality research to support policy (implementation)															
	There should be initial exploratory /scoping study of Planning needs: eg demand vs approval regimes (local, regioanl, national, zoning, major projects)															

11. Conclusions

Forecasting is always difficult, particularly with regard to the future. Yet ten to fifteen years hence is not long away. And whilst one might be naturally sceptical of the forecasts, the degree of consensus amongst those interviewed and in the workshops in identifying tomorrow's issues has been notably high.

An industry luminary, exceptionally well informed about the industry's current research, commented that our lists of Sections 7 and 8 were quite different from the agendas that are generally been worked on. Section 9, the list of on-going research in the priority areas, might challenge that view however. There are pockets of activity, in some places quite substantial; but what is lacking is articulation and focus. That, really, is what this exercise has very much been about: gathering evidence to signpost a research agenda for 10 to 15 years out.

The agenda discussed in Sections 7 through 9 is not offered as a programme to be administered in some directed, planned economy manner: a new National Programme. It is, instead, an indicative agenda relevant to (a) the delivery side of the Built Environment Construction Industry (b) the factors we have identified as being particularly important to this industry circa 2020.

If the list is vulnerable, it is probably here, in the factors we identified as important in 2020. It is not so much that we may have got them wrong; it's rather that there may be others, or there may be different priorities. In any event, the list is cogent we believe. And as the commentary in Section 9 made clear, there is high agreement on the importance of models and metrics; few can doubt technology, or procurement; there are several topics which seem obviously appropriate for initial checking out (education and skills, the professions, insurance, corporate strategy); perhaps only Systems Integration is the intellectually difficult one.

But that's what research is there for: to investigate. We hope this exercise helps stimulate not just researchers but the whole industry to do just that: think, study, and prepare for the future!

Appendix: List of those consulted

THOSE INTERVIEWED

- David Adamson, UrbanBuzz
- Derek Baillie, LandSec
- Professor Peter Barrett, Salford University
- Professor Tim Broyd, Dundee University, Halcrow
- Keith Clarke, WS Atkins
- John Connaughton, DLE
- Professor Roger Courtney, UCL
- Professor Andrew Dainty, Loughborough University
- Professor Will Hughes, Reading University
- Professor Jim Meikle, UCL, DLE
- Professor Alan Penn, UCL
- Simon Preston, Network Rail
- Martin Ong, BAA/Arup
- Professor Yvonne Rydin, UCL
- Ken Shuttleworth, MAKE
- Karin Stockerl, Housing Corporation
- Don Ward, Constructing Excellence
- Jeremy Watson, Arup
- Bob White, Constructing Excellence
- John Worthington, DEGW

WORKSHOP 1

- Paul Warner, 3DReid
- Mark Sowter, Head of Environmental Construction, Tesco Property Services
- Martin Ong, ICT & Automation Working Group
- Pat Bowen, ConstructionSkills

- Rennie Chadwick, Taylor Woodrow and National Platform Support Group
- Beth Morgan, Constructing Excellence
- Roger Courtney
- Jim Meikle

WORKSHOP 2

- Nick Smith, LandSec
- Dave Rowe, Keltbray
- Derek Heffernan, Cyril Sweet
- Ivan Williams, MACE
- Ellis Walker, WSP
- Nicola Kelly, Sir Robert McAlpine
- Steve Lester, WTPartnership
- Mark Cubitt, DLE
- Malachy McNamara, Buro Happold

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