CIB INTEGRATED DESIGN & DELIVERY SOLUTIONS (IDDS) RESEARCH ROADMAP

SUMMARY

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EXECUTIVE SUMMARY

Changes in the construction sector are creating opportunities in research to maximise the benefits of those changes and to continue the exciting developments in improved people skills, new processes and developing technologies. Many research centres around the world are investigating aspects of the current changes to drive their particular expertise forward. However, the CIB Integrated Design and Delivery Solutions (IDDS) priority research theme takes a higher-level view of the changes and then focuses down on a prioritised set of research targets. These targets have been investigated, re-focussed and validated over a period of four years through many workshops, conferences and meetings by a wide ranging group of representatives from approximately 90 industry and research organisations.

The outcomes of such research, once put into practice should be significantly shortened timespans from conception of need to occupation of new or revised structures. As time is money, the owners will get their investments into productive use sooner, which means a shorter payback time. In addition, there will inevitably be a reduction in construction costs as productivity increases. The improvements in reliable delivery and improved quality currently being seen in relatively simplistic use of Building Information Modelling (BIM) (compared to full IDDS) will inevitably continue its on-going trajectory of improvement. We should also consider the wider economic contribution to society that will stem from such improvements and, finally, and by no means unimportantly, the reliable modelling and delivery of sustainability at both the building and estate/area scale will significantly improve carbon footprints and other sustainable outcomes.

Whilst there are huge opportunities for early adopters, the primary risk will be the expansion of the gap between those working in this way and those who are not so advanced or who even refuse to progress. The opportunities to address the significant and widely varying wastes within the structure of the construction sector and within and across projects are huge and timely and industry is encouraged to become involved.

Full Report Prepared By

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1 For example, with reference to BIM: Although non-users dropped from 51% of the industry in 2009 to only 29% in 2012, more of them are hardening their resistance, especially among non-using architects where 38% say they will not use BIM. McGraw-Hill (2012) The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings (2007 – 2012)
A Case for IDDS Research from Sutter Health

At Sutter Health we have changed the way we contract for work, now using a single blended team of design and trade professionals from the very beginning of design all the way to the first day of operation of the completed facility. We give that team the responsibility and authority to manage the risks that they control and the profitability of their respective companies is determined by how successful they are in doing this. In return for those companies putting all of their profit at risk, we undertake to not put the companies themselves at risk by guaranteeing to reimburse them for all of their actual costs. Thus Sutter Health takes on the catastrophic downside risk of our projects and manages this risk through establishing integrated, collaborative relationships with our project partners.

Many wonderful things have evolved from this grand conceptual shift in our thinking around contracting. We are getting our projects built on budget; more remarkably we are getting them built on time; and most remarkable of all we are getting 100% of the scope we requested at the start delivered to us at the end. That last factor is the great elephant in the room – so many projects can be dressed up as on time and on budget by colluding with our teams to cut our scope, degrade our visions for the project, or by just one more visit to the board to beg for more money and time. No owner, designer or builder has any incentive to talk about this with the outside world. The only people this gets discussed with are the people inside the system. They may deny it at the speaker’s podium or in their marketing brochures, but they’ll wholeheartedly admit it’s true at the bar.

The success at Sutter Health happened because of the change in the way we contracted. That change required the team to overhaul most of their standard practices and behaviours. They had to find a way to track performance against the owner’s goals, to develop a single BIM from thousands of separate files, to plan work as a single team and to ensure their contract partners would not fail. – They had to undergo fundamental cultural change. All of those changes were made not just because they are the right things to do but also and critically because you can’t be financially successful under this contract model without them. That’s why this contractual change is so important. It establishes a market for everything you are about to undertake to create.

Right now it is only the leading visionary thinkers in the market that are after the tools, information flows, processes and cultural transformations you are about to spend years creating, but the market place in general is not. Because of the way the vast majority of the projects in the world are contracted there is no unarguable, hard-nosed financial need for visionary change. Therefore I urge you to undertake, as part of your broad research program in support of visionary change, the establishment of an IDDS-based conceptual model of what it means to deliver any capital project successfully. If you do that you can then move on to test existing contracting models and find the behaviours those models incentivize and establish what the best-in-class contracting model is. Of course, feel free to test Sutter Health’s Integrated Form of Agreement contract against it and let me know how it does 😊

If you do this you will be helping to seed the wholesale transformation of the capital delivery market and this will cause thousands of people with billions of dollars to beat down your door for all the fruits of your research - because they are going to need all the outputs from the IDDS Roadmap research programme to be successful within that contract model.

Heed the entreaty of the winged goddess of victory herself and “Just do it”.

Digby Christian
Regional Program Manager, Sutter Health, Facility Planning & Development
This global priority theme is aimed at transforming the construction sector through the rapid adoption of new processes, such as Integrated Project Delivery (IPD) and Lean Construction and procurement, together with Building Information Modelling (BIM) and automation technologies, using people with enhanced skills in more productive environments.

The development of IDDS is about radical and continuous improvement, rather than development of a single optimal solution.

The construction sector is undergoing the most significant changes it has experienced in over a century. It is during this change that construction practitioners and researchers have a very real opportunity to influence how the construction sector is transformed and assist its transition into a progressive and productive sector ready to meet the challenges of the next quarter century. Some of the drivers for change, enablers, barriers & opportunities are summarised on the next page.

The focus of the Integrated Design and Delivery Solutions (IDDS) CIB Priority theme is on pursuing a vision of a revitalised sector through the rapid adoption of new processes, developing a workforce with enhanced skills and supported by information and knowledge technologies. The goal is a sector where people practice more collaborative and communicative processes, supported by pervasive, but nearly transparent, knowledge and information based technology. These professionals will be working towards continuous improvements across every phase and significant task of the project: conceptual planning and making the business case; all parts of design, supply chain, construction, commissioning; operation; retrofit; and even decommissioning and capturing the lessons learned into subsequent projects.

IDDS has been developed as a grounded concept through workshops and consultations with academia, industry, governments and clients on five continents over four years. Several hundred people have been consulted and prominent academics and industrialists from around the world have been involved in focussing and nurturing the research theme.

Significant societal and technological influences are driving changes in the sector. Portable connected technology has penetrated the construction site and back offices, bringing unprecedented opportunities for the rich information exchange. Construction materials and systems have also evolved significantly, often with ambitious targets for new levels of performance measured in terms of immediate cost, ease or time of installation, energy requirements, healthy environments and sustainability. The amount of off-site fabrication has also increased.

Despite these influences, significant obstacles prevent a smooth transition into a new construction paradigm. Technology capabilities, such as Building Information Modelling (BIM) -enabled applications, are advancing so fast that experienced workers with traditional skill sets are hard pressed to keep abreast, while the sophistication and complexity of the designs that can be created using these new tools is also becoming a challenge. In turn, BIM has enabled improved information flows through a project and greater opportunities for collaboration (such as through the use of Integrated Project Delivery (IPD)). However, the commercial pressures on software vendors to differentiate development tools and data formats inhibit the exchange of information, particularly between professional specialisations.

Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects.
Another significant obstacle to progress is the entrenched adversarial nature of the industry; IPD and similar collaborative approaches are used on only a minority of projects. Contracts in common use focus on identifying responsibilities and liabilities, limiting information exchange and majoring on the consequences of failures. Also, projects are often broken into fragmented, serial phases where opportunities to collaborate and optimise results are lost. Specialist professional indemnity insurance also reinforces such resistance.

Traditional approaches typically mean that many issues that could have been prevented through early broad stakeholder involvement are discovered much later, at great expense, at the workforce. Vertically integrated organisations and some influential progressive companies have overcome this by assembling a collection of educated partners who they prefer to work with on collaborative projects.

To have the maximum impact, this transformation of the capabilities of the sector needs to be holistic and based on knowledge capture, processing and reuse. The three imperatives of IDDS are shown, together with the research areas that need to be further enhanced and/or adopted to render the vision real. Although this period of change is being enabled by new technologies, which in turn are enabling new processes, it is only where we see true collaboration between people and their organisations that significant improvements in both project productivity and quality occur.

Having explained the drivers and some of the interactions, it is essential that we focus down to a smaller number of research targets that might be achievable; these are shown below. Whilst targets three and four concentrate on assisting in the changes which are already underway in various places around the world and to variable extents and success rates, one and two are focussed down on improving the value delivered by IDDS in the real world. These are described further below.

**STATE OF THE ART**

There are many centres of expertise, both in research and in practice in some of the areas of IDDS but there are very few or none which encompass the holistic IDDS.

The construction sector is by no means homogenous and currently displays a very wide variety of levels of sophistication, varying dramatically within and between regions and countries. Even in companies that are generally recognised as leading edge, their approach can vary significantly between departments and across projects, often depending on the interests or knowledge of the client to drive adoption of advanced approaches on any specific project.

Progressive companies and some larger integrated firms are bringing together more key stakeholders and major or key sub-contractors earlier in the projects to identify sources of risk and opportunities, and synergies and trade-offs between solutions to multiple performance requirements.
Communication between stakeholders is done digitally, including through BIM. Project practices are more integrated and continuous and often involve design-build or design-build-operate paradigms, there are more opportunities for off-site manufacturing and fabrication of system assemblies, panels, and even entire modules. More holistic approaches to management, such as Lean Construction, also contribute and are effective in reducing unreliability and waste, whilst improving health and safety.

Various leaders of the industry have gone significantly further in each or several of these aspects. A few practice IPD (or similar) as an active process in individual projects with select clients. Such collaborative approaches are supported in the USA by contract templates typically published by the Association of General Contractors of America or American Institute of Architects. Under these contracts multiple parties agree to, and are given incentives to strive collaboratively for more optimal solutions to the project goals. Companies employing such frameworks have usually adopted BIM as their preferred medium for knowledge transfer during the project, and most large construction firms have or are adding BIM capabilities to their product lines, although often on an individual project basis, rather than as standard practice. A side effect of large contractors and clients increasingly using or calling for BIM (see overleaf) is that less progressive companies are slowly being exposed to BIM functionality, as they have to upgrade their software and fit in with new business processes imposed from higher up the supply chain. Leading suppliers are also beginning to contribute useful models of their products into the sector for inclusion in models of facilities, simplifying specification and sourcing of their products.

Projects using Virtual Design and Construction (VDC), supported by BIM technical capabilities, have delivered significant added value in coordination between major physical systems and their designers and installers due to its solid 3D model representation aspects and parametric properties and attached information. VDC has also greatly improved client understanding of the impact of decisions on the final deliverable through easily understood rich visualisations of design variants and their effects. Further developments in BIM standards and technological support are pushing towards better capture and encoding of the non-geometrical attributes of building system elements such as makes, models, warranties and installation dates needed in specifications and facility management tasks.

The use of digital building models has allowed a few companies to implement active processes and custom technology to capture and reuse construction knowledge and lessons learned between projects. However, there remain significant obstacles to broader attempts to preserve many aspects of contextual knowledge in transactions, e.g. the reasons for decisions. The bulk of codified knowledge remains trapped in professional silos and throughout the supply chain for reasons of “competitive advantage” and because of limited standards/capabilities for the management of professional knowledge in general. Many aspects of more mundane and current construction knowledge that would benefit from sharing also remain isolated by limitations inherent in existing broad representationational BIM standards or formats, including Industry Foundation Classes (IFC) and Construction Operations Building information exchange (COBie). These limitations include the inability to represent appropriate levels of detail for simulation or analysis during design and the lack of representations for details pertinent to specification, manufacturing, assembly, erection and incorporation of building systems from numerous construction trades, including cast in place & pre-cast concrete, MEP systems and solar power systems to name a few.

Our construction landscape is changing rapidly; most noticeably the science of creating and maintaining our assets is undoubtedly entering a new digital renaissance, one that is driven by the need for new efficiencies both in capital & operational expenditure (“totex”) and increasingly altruism around our carbon solutions.

The UK HM Government Construction Strategy (GCS) is leading the way in terms of seeking 15-20% lifecycle savings through a series of client driven interventions. ....

.... BIM in the UK has very much become a verb, a way of working collaboratively, and one that heralds a cultural change….Ultimately we will, in time, move from the foothills of collaboration to integration....

The CIB Integrated Design and Delivery Solutions (IDDS) Research Roadmap sets out to establish these key integration themes and help ensure a collegiate framework for researchers as we set out to better this already great industry.

David Philp MSc BSc FRICS FCIOB FGB
Head of BIM, Mace
Head of BIM Implementation (seconded) HM Government
Professor Glasgow Caledonian University, Scotland
Chair BIM2050 Group (for young professionals)
IDDS
Integrated Design & Delivery Solutions

Norway: Satoshi has led on the development of ISS guidelines.

Finland: Arguably world leader in BIM, responding to the use of BIM for interopability recently been updated into national standards (COS). Cremona.

Japan: Major government initiative on reducing errors and costs through BIM, providing standards, guidelines and specifications for interoperability and related issues.

South Korea: Major programme on the mandate of BIM, progressing.

China & Hong Kong: One of the first major BIM mandates implementation (2010). Hong Kong Housing Authority BIM guidelines. South Korea, 2012: To build the Digital City. Government is strongly supporting BIM.

Sweden: Late 2012 five Swedish collaborations in promoting BIM.

Denmark: Several state organisations are promoting BIM taking advantage of the use and benefits of BIM.

Germany: Some adoption of BIM, although not widespread.

Netherlands: BIM required for public projects. BIM is being adopted, and communications being developed.

France: BIM mandated for public projects. France has high uptake of BIM, with the main contractor and a huge construction supplies company as early adopters.

UK: Government mandated Level 2 BIM and an asset information in public projects by 2012.

Canada: Looking at adapting/adopting the USA’s NFMS-US.

Australia: BuildingSMART leading on the implementation of BIM, encouraging the use of BIM, including teaching at Universities.

New Zealand: Government in early stages of exploring BIM. Approaches for implementation of BIM.

China: Government actively supporting BIM development and implementation.

Singapore: Automating code by 2012, encouraging the use of BIM, including teaching at Universities.

USA: Many Government, client organisations, and States have adopted BIM standards (e.g., Federal Administration and US Army Corps of Engineers). Many large projects (e.g., GMH) have adopted BIM but, many rely on their preferred software. Public sector (Department of Defense) have been the leaders in the BIM uptake for the past 10 years. Project Delivery also gaining traction.

IDDS (Integrated Design & Delivery Solutions) provides a holistic solution for the delivery of sustainable building projects.
An exemplar for improved project performance can be seen in the Castro Valley Eden Medical Center. Approaches and resultant achievements include:

- Eleven party Integrated Forms of Agreement (IPD)
- 100% of profit was at risk versus a 50% share of any savings
- Truly collaborative relationships
- Whole team meeting every two weeks for two days
- “All kinds of misunderstanding were uncovered”
- Abandonment of ‘design intent’ as an end in itself
- Lean Construction
- Building Information Modelling
- Need to deliver 30% faster to beat regulatory change (seismic)
- Triple le victory: on budget; on time; and with all goals intact

(Personal correspondence, Digby Christian, Regional Program)

Early signs of really advanced and paradigm shifting construction technologies are also emerging, taking construction well beyond the current limited use of off-site modular manufacturing and into a potential for flexible industrialised construction. For example, innovative, scaled-up additive manufacturing processes, such as the concrete 3D printing development programme at Loughborough University (UK) (right, courtesy of Loughborough University) provide scope for increased architectural complexity and yet potentially offer hugely reduced work processes, once scaled up for on-site robotic arm deployment.

At the city scale, excellent models already exist for cities such as Stuttgart, Germany and Yan Tai, China and many others are in preparation. Whilst most concentrate on geometries, some (e.g. Salford, UK) go to the extent of embedding a huge range of sociological information, providing a level of understanding of social structures and interactions which would otherwise be far more difficult to assimilate.

**Perceived Problems & Challenges**

Educational institutions are beginning to provide BIM programmes, although no industry standard exists for recognising or even certifying the programs or accrediting the graduates, or in terms of Continuing Professional Development (CPD) standards. In fact, there remains considerable debate as to the nature and scope of new BIM-related roles in the industry. Even as these BIM programmes become more established they need to be extended to meet IDDS goals that require construction professionals with far more knowledge management and communication expertise than is common today. For professionals to be effective in monitoring their own performance and to be able to strive for improvements will require measures and supportive tools for benchmarking quality, design integration, life-cycle impacts and completeness of captured knowledge against references or previous work. This feedback needs to be dynamic through tools like dashboards or regular generated reports. With respect to sector practitioners, significant cultural change also needs to be part of realising IDDS goals of creating a cooperative, knowledge preserving and sharing industry, instead of one characterised by adversarial interactions and knowledge hoarding. There is also a need for further education of site workers in terms of understanding BIM versus drawings, collaboration and re-skilling. It also becomes feasible to adjust later-delivered items to reflect ‘as-built’ pragmatic changes (and typical deviations from design, such as pour depths and floor levels) by correcting the ‘as-built’ BIM. Significant re-work can thus be avoided. This, together with enhanced design and build-ability would typically also reduce the opportunities for end-of-project claims – this could have a very significant effect on the many small contractors and they need to be educated accordingly.
As the manufacturing industry has shown, integration and collaboration can lead to dramatic improvements in the quality and time required to realise ever more complicated products. However, they have also shown that dramatic improvements can also continue to be found using lean principles and automation, where appropriate. There is a Lean Construction initiative and its relevance to the goals of IDDS is significant. Efforts need to be made to embrace its principles, even as the construction sector is transformed by the pervasive incorporation of digital enabling technologies.

Following on from this, greater supply chain integration becomes a possibility and there are many current attempts at building BIM object libraries to assist with the incorporation of ‘real’ components earlier, rather than using space reservations. (This is controversial in itself as it is often seen to be better to delay supply competition, though with limited true understanding of the overall balance of costs to a project or, more particularly of whole-life costs.) Industry Foundation Classes (IFCs) are increasingly used (but not always) to provide a level of common understanding across these modelled artefacts and components. However, greater development of and investment in IFCs would be of great advantage to the global construction industry, opening up a huge potential market of suppliers. Integration of sub-contractors of widely differing skill levels, particularly at a time of such radical change, introduces additional performance risk within projects. There is an urgent need for education and knowledge sharing through case studies to facilitate this change.

Knowledge capture and re-use within projects is helped greatly by the use of BIM, but not if a new model is created at each stage of the process and embedded data, information and knowledge is lost in doing so. In the USA, Mortensen has developed a knowledge-sharing network and Turner has its ‘BIM University’; however, there is a great deal more knowledge sharing research and implementation to be developed.

Silo mentalities prevail and document-based information exchange across professions and throughout supply chains ensures that information and, particularly, any associated intelligence, coordination and agility is either corrupted or even lost. Unified solutions are not at a stage when real knowledge sharing and knowledge development is supported for the design, construction and operation stream(s). Considering that “each model is an abstraction for a purpose”, the underlying data, information and knowledge in the shared models should cover all the intended purposes, and enable addition or subtraction as necessary for a particular purpose or stage, but not lost to the project as a whole, including for the life of the delivered building, infrastructure or artefact.

Knowledge can also be seen to be very specific to one market/ contract type/ or project type or size. Commonly, significant new clients (i.e. government agencies) demand statistical evidence as to whether BIM is even appropriate to their own needs. More case studies and, particularly, meta studies are needed to provide such evidence.

In terms of wide area and city scale modelling there is some difficulty in the fusion or at least interoperability of data and information, not least because Geographic Information Systems (GIS) and BIM have developed on separate paths.

The Open Geospatial Consortium is working towards greater interoperability; however, BIMs frequently contain attached parameters that may have no equivalence or import mechanism in the GIS world. Various efforts are continuing, including the development of a CityGML extension called GeoBIM and expansions of the IFC linking BIM and GIS. In reality cities may very well wish to research and/or integrate currently unforeseen attributes – not only geometric ones. It is therefore important that objects and attached data may be stored and at least be available
for future purposes. Conceptual ‘digitalCities’ might include existing Victorian-developed cities to be modelled at very high Levels of Detail over time, as well as modern cities, such as currently being created in China, and which might be modelled from the outset. Federated or integrated information could then be used, for instance, for modelling information flows, aggregate human behaviours or infrastructure decay and replacement rates.

**Leading Centres**

In general, the leading centres of building information technology are perceived to be currently in the Nordic countries (e.g., Tekla and Solibri) and the USA (e.g., Autodesk, Bentley, Vela Systemes and Vico). However, there are also capabilities in the rest of Europe, such as Nemetschek/Graphisoft (Germany/ Hungary) and Dassault Systemes (France), as well as many smaller companies, such as Asite, CAD-DUCT and Navisworks (the latter two both now Autodesk) (all UK), and Construction Virtual Prototyping (Hong Kong). This list is far from exhaustive and the software market place will undoubtedly change over the next few years as new capabilities are developed and companies acquired or merged.

In terms of Lean Construction, the California-based International Group for Lean Construction (and its regional satellites elsewhere in the world) and Lean Construction Institute represent the focus. However Lean Construction is spreading widely around the world, as exemplified by, for example, Grana y Montero in Peru or Sutter Health in the USA. Lean Construction currently represents the key process change in construction, although there is scope for further process development as whole-life design, construction and operation develops. BIM and Lean Construction used together offer the sort of holistic process approach that other industries commonly take for granted. Integrated Project Delivery (IPD) pulls these approaches together to form and facilitate an overall project contract process. IPD is currently very much centred in the USA, as explained further below.

Although IPD can be seen as a legal structure and framework process, it is also very much a catalyst for collaborative working, which may be argued to have commenced in Australia with Alliancing, although the Heathrow Terminal 5 project in the UK was also clearly very advanced. The Florida contractor-created IPD process was further developed through the Lean Construction Institute and American Institute of Architects in California before being developed as a national standard by the AIA. Other USA frameworks such as the Association of General Contractors’ Concensus Docs and Sutter Health’s Integrated Forms of Agreement are also currently being used in the USA. The UK Government BIM programme now has a very large task group (largely industry-donated) to develop some similar framework, together with multi-decade project insurance; this and all the previously mentioned frameworks are intended to break down barriers and to foster collaboration between parties and people. Whilst IPD does not seem to need BIM (see Illustration above) in practice BIM is typically an integral facilitating mechanism for IPD projects; Lean Construction is also slowly increasing in adoption in IPD, with the Last Planner process having been used as the integrated process between multiple designer specialisations. Early work at Technion (Israel) and the University of Salford (UK) on integrating Last Planner with BIM, in terms of both data and visually, points the way towards future enhanced project management toolsets

In terms of sustainable construction, the International Code Council’s International Green Construction Code can be seen as a key guide to moving construction forward in that way, particularly in the USA.

Academia and research centres have many foci of excellence, including the earliest contributors and guides to this project. VTT in Finland, CIFE at Stanford University, the School of Computer Science at the University of Auckland and the School of the Built Environment at Salford University came together to help guide the development of IDDS through consultation with experts in research and practice around the world. The early team has since expanded and now includes many more organisations shown at Appendix 2. Current additional research centres include Delft University of Technology, Queensland University of Technology and Virginia Tech.
FUTURE SCENARIO

Broad development and adoption of IDDS concepts is expected to transform the construction sector. In particular, projects will be delivered collaboratively with teams striving for optimal facility performance, realised using sustainable construction methods and materials, thus minimising the total life-cycle cost of the project in terms of money and the environment.

The future capabilities of the sector can be broken into four categories: Collaborative Processes, Enhanced Skills, Integrated Information and Automation Systems, and Knowledge Management. Collaborative processes will involve the biggest societal change in the sector with serial processes being replaced by vertically integrated collaborative processes (characterised by information flowing freely and effectively between all stakeholders) amongst “virtual” enterprises that exist for the duration of the project, and even across projects. Complete planning and monitoring of project progress will eliminate waiting time and “making do” with incorrect materials. The skills of trades people will develop as they participate in integrated work processes using advanced tools to contribute their work to the collective effort, and observe the impact of their contributions virtually on the other team members’ work. They will leverage and add to repositories of the shared knowledge built from past projects, as it applies to the current requirements. Advanced tools and knowledge of major work processes will allow them to evaluate multiple alternatives and select the best for the work process and product.

DEVELOPMENT STRATEGY

Realisation of the above scenarios will required concerted and focussed efforts by many stakeholders in the construction sector but will also be founded on broader societal and technology changes already in evidence today.

Development of New Practices, Processes and Tools. The construction sector represents a particularly challenging domain for deep collaboration given the short-term nature (the period of one project or less) of most collaborations, and the adversarial nature of the relationships. Better standard practices and processes need to be developed that promote collaborative efforts on projects. Industry organisations and governing bodies need to participate in developing these practices and formalise them with documentation, training, and to embody their principles in contractual documents.

The skills of trades people will develop as they participate in integrated work processes using advanced tools to contribute their work to the collective effort, and observe the impact of their contributions virtually on the other team members’ work. They will leverage and add to repositories of the shared knowledge built from past projects, as it applies to the current requirements. Advanced tools and knowledge of major work processes will allow them to evaluate multiple alternatives and select the best for the work process and product.

IDDS
Integrated Design & Delivery Solutions

Five-Year Vision

- Wide use of clash detection/ avoidance and visualization
- BIM adoption commonly required (regional differences)
- Wide use of project websites and cloud computing to enable real-time collaboration
- Many suppliers provide parametric objects for use in design
- Limited industrialised/off-site module preparation
- Handover documentation commonly delivered digitally
- Use of modified existing contracts – covering digital construction documents
- Country/region governments issue IDDS compatible procurement requirements
- Joint architect/engineering degrees in demand
- BIM (BIM+) literacy expected from large contractors and architects and engineers
- Digital construction literacy increases in medium and small supply chain companies
- Rapid modelling used to incorporate existing structures and monitor as-built variation
- IFC used for certifications, conformance to regulations and access to archived data
- CityGML as a standard basis for modelling urban forms

Ten-Year Vision

- Regional life-cycle carbon accounting enforced
- Design visualisation commonplace at workface
- Semi-automated scheduling and procurement
- Electronic planning and handover documentation
- Single point contracts will be used extensively
- Insurance becomes commonly project based
- Tender notification services/systems fully digital
- Governments accept digital models for all approvals
- Entire workforce is digitally technology-savvy
- Joint AEC degrees are demanded, and a necessity
- IDDS may become mandatory
- IDDS applied to wide-areas of urban-infrastructure
- Growing emergence of GIS and BIM+ models
To complement these practices, tools are needed to robustly and transparently support and promote knowledge sharing and collaborative development within individual projects amongst stakeholders with diverse objectives and roles. Positive engagement of Project Management bodies would be beneficial to the development of appropriate processes to foster IDDS, whilst tracking of new technologies, such as off-site manufacturing and construction design and build automation will ensure that IDDS develops optimally.

**Expanding Skills and Collaboration.** Deeper project collaborations allow for project teams to strive to achieve greater immediate value in projects. Many of these improvements will be found through the broadening of traditional discipline foci to consider integrated designs. This is likely to require the involvement of non-traditional stakeholders, such as suppliers. Suppliers will need to take a proactive approach to integrating their information and requirements into early project documents and will have to extend their own skill sets to achieve this. In fact the whole team will require access to the shared knowledge and enhanced skills needed to effectively perform integrated work processes. Clients should also be educated as to the different risks and opportunities of IDDS, as should owners, maintainers and occupiers.

**New Standards and Interoperability.** Creating, documenting and sharing these more sophisticated and integrated designs will require further development of existing BIM standards to ensure that knowledge covering all major processes is seamlessly exchanged. This advanced semantic interoperability will be overwhelming without more defined “views” of information appropriate for specific classes of applications and particular classes of application and standardised processes. With the whole industry communicating through digital documents, the regulatory and inspection activities will also need to be updated to work with the same documents instead of 2D drawings; integrated information and automation systems thus become more possible and holistic.

**Knowledge Development and Transfer Systems.** To go beyond the immediate and achieve more value over the entire life-cycle of a facility will require the development of easier (and probably automated) ways to capture, codify, store and re-use knowledge to overcome transitional organisations and workforces.

**RESEARCH CONTRIBUTION**

The development strategy documents a wide range of changes that will impact over the next decade as IDDS develops and takes hold in the industry. However, the research underpinning for the majority of these changes is still in a fairly formative state. For each of the expectations there are numerous possible approaches to be explored with little consensus on which approach will give the desired outcome and the greatest level of benefit. Even where approaches have been researched, many of the identified solutions are sub-optimal and unlikely to be acceptable to those in the industry.

A difficulty in progressing the research to support the proposed development strategy is that, as with the core notions behind IDDS, it needs a cross disciplinary approach. The strategies draw upon research founded on deep understanding of the impact of several disciplines alongside the building and construction fields. Research development and approaches from fields such as Computer Science, Organisational Psychology, Management Science, Law, etc. have to be brought to bear. Researchers capable of doing this are those who can move beyond consideration of research within the silo of their specialist domain and who hold a more holistic view of the impact of their work.

This research challenge fits well with the principles and approaches taken within CIB. With the priority theme pulling together researchers from across a wide range of task groups and working commissions there is already the notion of cross-disciplinary working to address the research problems being identified in IDDS. It is also clear that some of the specialist task groups and working commissions already draw upon the literature of other domains in tackling the matters core to their members. However, **engagement with industry is vital** in order to gather data from case studies, to validate ideas, and to test new approaches.

**RESEARCH AGENDA**

The IDDS research agenda is focussed on four interconnected priority research targets. Each of the targets leads towards a well-defined outcome for the industry. Some of the targets may be familiar but all are recast in terms of IDDS and its potential for the industry. Progressing the research agenda for each of these targets will require a mixture of pure and applied research to ensure the validity of results within practice. The four research targets...
are: developing improved sustainability models and measures; defining the Built Environment Information Fabric (BEIF); improving current practices; and engendering cultural change and knowledge management and dissemination.

**Developing Improved Sustainability Models and Measures**
Significant changes are required to past approaches and the levels of information available for decision-making. This mid-term goal of IDDS will require research in the following areas:

- A more coherent approach to sustainability.
- Demonstration of the return on investment (ROI).
- Improved simulation models to more correctly predict as-built performance.
- Human Building Interfaces (HBI) to provide feedback to human occupants of facilities and engage them in sustainable operations.
- Incorporation of individual human behaviour into resource modelling and control.
- Models for process, physical and functional waste.
- Sophisticated approaches to measure and model re-use and recycling.
- Promotion and standardisation of sustainable architecture programs across the world’s universities.

**Defining the Built Environment Information Fabric (BEIF)**
The ability to incorporate information from multiple disparate sources enables a significant step up in the ability to comprehend a built form within the complete context of its placement in the environment. An information fabric that extends the context of information from that clustered around an individual building through to city scale models will be required to solve emerging infrastructure network problems and facilitate integration of traditionally disparate domains. The scope of information sources envisaged would encompass councils and territorial authorities, transport authorities, utilities, land information resources, geotechnical resources, environmental resources, climate resources, etc. Example applications include support for contingency planning, mitigation, response and recovery, and for the modelling of traffic, energy and water (and pollution) flows and wider area sustainability modelling and planning. The fabric should use the building as the context but integrated into its surroundings. The concept of BEIF should be seen as a mid to long-term goal of IDDS and will require research in the following areas:

- Understand approaches to improve the operation of the building.
- Reworking approaches and notions of modelling, not just on the installation scale, but planning the pathway and integration into the geographic scale.
- Protocols to turn a model into a base of information, or knowledge, for users.
- Systems that will manage the long-term coherence of facility information.
- The evolvability of systems consuming building information.
- Standards and agreements to support the very basic underlying structures of the information fabric.

Development of systems allowing the processing and understanding of data within the models, especially that flowing from sensors over the life of a building, to associate context and develop formalised knowledge about the building. The data, information and imputed knowledge will need to be communicated effectively back through to users through effective visualisation paradigms.

**Improving Current Practices**
Numerous studies and implementations show that fundamental process improvement, such as industrialisation of construction and supply chain integration, is neither readily adopted in the sector nor easy to get right. However, such radical change is essential in order to achieve significant improvements in cost effectiveness and waste and energy reduction. Improving current practices should be seen as a short to mid-term goal of IDDS and will require research in the following areas:

- Further adapt industrial design processes for the product and its manufacture.
- Collaborative approaches to design.
- Construction improvement through simulation and information integration.
- Supply chain improvement, in particular the expansion of electronic tendering and supply.
- Impacts of technology development, including human-computer interaction, location awareness and whole-life data use.
- Electronic submission and approval systems.
- Improved facilities management, building management systems and BEIF integration.
Engendering Cultural Change & Knowledge Management and Dissemination
Even in projects where there is no collaborative legal framework, early use of BIM is showing a breakdown in traditional adversarial relationships. Engendering cultural change should be seen as a short to mid-term goal of IDDS and will require research in the following areas:

• Industry and enterprise business re-modelling.
• Legal frameworks that projects run under.
• Changes to the insurance frameworks.
• Developing new and expanded roles within the industry.

It is essential that A/E/C industries capture knowledge and re-use it both in practice and education, so that we can improve at the pace of the leading edge participants, rather than at the pace of the slower majority. Improving knowledge management and dissemination should be seen as a short to mid-term goal of IDDS and will require research in the following areas:

• Development of a new pedagogy for integrated design and construction curriculum.
• Develop new design roles that integrate conceptual design and technical implications.
• Automated business process modelling, considering copyright and security.
• Improved semantics and interoperability descriptions.
• Improve project collaboration of distributed project teams through team mental models and computer supported collaborative working (CSCW).
• Knowledge management needed for technology transfer.
• Develop a dissemination and diffusion model within the industry.
• Improve the economic performance management of the built environment.

….the development of a Built Environment Information Fabric is of particular promise. The linkage between GIS, city modelling and various data sets is a huge challenge but will greatly help our understanding of the world and how best to develop and manage how to build it.

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This Research Roadmap has been developed to both provide a thematic signpost for the many CIB research groups and to encourage others, especially in industry, to become involved. Should you wish to discover more, please either visit the CIB website at www.cibworld.nl or refer to the more comprehensive Roadmap in Publication 370. For research leaders involved in your own country, please contact one of the following.

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