

CIB White Paper on IDDS
Integrated Design & Delivery Solutions



Publication 328

ISBN 978-90-6363-060-7

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CIB Publication 328

ISBN 978-90-6363-060-7

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Integrated Design & Delivery Solutions

This global priority theme is aimed at transforming the construction sector through the rapid adoption of new processes, such as Integrated Project Delivery (IPD), 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.

Introduction and Use of this White Paper

CIB is developing a priority theme, now termed *Improving Construction and Use through Integrated Design & Delivery Solutions* (IDDS). The IDDS working group for this theme adopted the following definition:

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.

The design, construction, and commissioning sectors have been repeatedly analysed as inefficient and may or may not be quite as bad as portrayed; however, there is unquestionably significant scope for IDDS to improve the delivery of value to clients, stakeholders (including occupants), and society in general, simultaneously driving down cost and time to deliver operational constructed facilities. Although various initiatives developed from computer-aided design and manufacturing technologies, lean construction, modularization, prefabrication and integrated project delivery are currently being adopted by some sectors and specialisations in construction; IDDS provides the vision for a more holistic future transformation. Successful use of IDDS requires improvements in work processes, technology, and people's capabilities to span the entire construction lifecycle from conception through design, construction, commissioning, operation, refurbishment/ retrofit and recycling, and considering the building's interaction with its environment. This vision extends beyond new buildings to encompass modifications and upgrades, particularly those aimed at improved local and area sustainability goals. IDDS will facilitate greater flexibility of design options, work packaging strategies and collaboration with suppliers and trades, which will be essential to meet evolving sustainability targets. As knowledge capture and reuse become prevalent, IDDS best practice should become the norm, rather than the exception.

The IDDS working group prepared this white paper to support discussions of IDDS at the CIB IDS 2009 Conference and then updated it, based on questionnaires and feedback from the conference. It is structured based on the major elements of IDDS from the definition. The working group will use the paper to facilitate further discussions of current conditions related to each element of IDDS and to

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further elaborate the forecast conditions, gaps, and the IDDS development, collaboration and deployment strategy.

The paper begins with a vision of exemplary IDDS to realize the full potential benefits, and then describes the current state of four key topics: collaborative processes; enhanced skills; integrated information and automation systems; and knowledge management. The paper concludes with a summary of the benefits of IDDS and the actions required to realize these benefits. Figure 1 shows, for those with involvement in the vital precursors to IDDS, how we view IDDS as the next logical progression for the improvement of construction sector performance, particularly in the light of whole-life sustainability imperatives, new facilitating technologies, and emerging skills. These precursors include

1) product modelling and computer-aided engineering, 2) ISO 10303 (also known as STEP: Standard for the Exchange of Product Model Data), 3) Industry Foundation Classes (IFC), and 4) Building Information Modelling (BIM).

We identified potential uses of this white paper by five audiences: industry and clients; CIB and the broader research community; other industry associations and organizations; educators and trainers; and technology providers. Industry stakeholders and clients can use the white paper to assess current capabilities and define viable paths and steps to achieve IDDS. CIB and the broader research community can use the white paper to broadly coordinate and cultivate research to stimulate a holistic approach to achieving IDDS.

Other associations and industry organizations, such as buildingSMART International, the American Institute of Architects (AIA), and the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE), and the Finnish State Properties (Senaatti-kiinteistöt) can use the white paper to increase understanding of the future benefits for their members and plan necessary actions to realise these benefits. Educators and trainers can use the white paper to refine learning objectives for IDDS professionals and develop course materials to support these learning objectives. Technology suppliers can use the white paper to guide planning for future investments in IDDS products.

Various elements of IDDS are currently being explored in largely isolated parts of academia and industry, and by certain enlightened clients. These early adopters are discovering enhanced ways of delivering and gaining value over the full life cycle of the facility. IDDS should yield greater gains for the early adopters and provide a roadmap for others. However, IDDS will also challenge traditional industry structures and contractual processes as it both highlights current inefficiencies and facilitates their resolution, making the most of the work forces' collaborative intelligence.

IDDS seeks to complement modern agility and flexibility with integration spanning from design intent to successful commissioning, operation and maintenance. IDDS signals radical change, though also emphasising the need for continuous improvement, in order to achieve agile design and development, coupled with lean delivery and operation for sustainable use and reuse. Such change will transform construction, simultaneously drawing on lessons from better integrated and innovative industries, although retaining the best aspects of individual design.

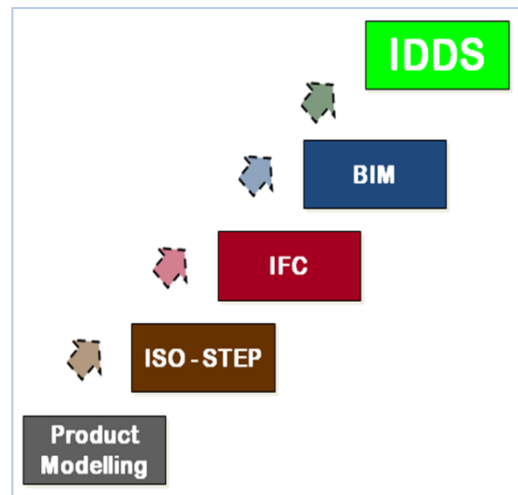


Figure 1. The Evolution of IDDS

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Visions - Outputs from the CIB IDS 2009 Workshop

- Construction will be like manufacturing: very lean, very low defect, very efficient, very integrated from the materials to the final product, as the client receives and uses it. Digitally modelled, simulated, controlled and maintained.
- True collaboration of distributed teams enabling system and service integration at all levels throughout the building life cycle.
- Suitable technology that allows leveraging improvement in processes and people – technology is invisible and does not drive the change.
- IDDS means realization of sustainability ideals. The industry will be informed by performance-based evaluations of the new materials, assemblies and buildings as well as existing ones.
- Progressive and aware owners will require performance at a level which's requires integration. They will specify the end and not the means! Progressive firms will realize this market demand and meet these expectations with the best means.
- Projects conducted with multi-criteria focus on the complete life cycle. Integration of all parts in the projects' design and construction with better performance (documented) delivered
- The industry will be 30-50% industrialized construction
- The change from production information to production 'dashboards'. The use of decision support system and automated design analysis and approval. The design of a more responsive lifecycle originated built environment. More functional design in response to user requirements and needs.
- Demanding customers define their needs together with professional designers. Designers give the well-analysed guidelines and parameters for construction processes. An effective supply-chain fulfils all technical requirements precisely by utilising shared information and optimised processes.

A direct implication of this is that IDDS will expand the construction workforce beyond traditional roles and remove geographic barriers as online training, design and collaboration are developed. Furthermore, as construction becomes more industrialised and integrated there will be increased opportunities for remote manufacture, operation and even maintenance.

Vision and Main Elements of Exemplary IDDS Delivery

Future IDDS. Successful use of IDDS involves changes in each of the project phases: conceptual planning and making the business case; all parts of design, supply chain, construction, commissioning; operation; retrofit; and decommissioning. For each of these phases, key changes in the structure and culture of the project team, including the firms that contribute its members, create a favourable context for IDDS. Examples of these changes include: a team approach; support for innovation and tolerance of failure; strong lateral linkages and decentralized decision making; networks of commitment; and new forms of contracting, transparency and risk management (including insurance models).

This favourable context allows integrated work processes, facilitated by advanced information systems, shared models, and involving people with special skills, both in terms of trades and professions, and management and leadership.

Above all, the future IDDS needs to support and foster learning and continuous improvement internally and across the sector through the use of knowledge management and iterative feedback. Our vision of the effects of these elements on a future exemplary IDDS project is described briefly below. The cultural change required to achieve IDDS may be challenging, especially in the development of trust within what is currently an often risk-shedding and distrusting sector. However, sufficient successful integrated projects have been delivered to prove that such transformation can occur. Those organisations and partnerships which embrace such change wholeheartedly and early are likely to achieve significant business advantage.

Integrated Work Processes. Effective implementation of IDDS results in integrated work processes for each phase of the project, and throughout the full lifecycle of the project. Prior to construction the team completes: 1) integrated planning to implement the project, rather than specialist priorities throughout; 2) integrated design to allow evaluation of multiple alternatives and coordinate functional and spatial interfaces; and 3) integrated supply chains to provide timely technical expertise, commissioning and subsequent operation and maintenance services, including delivery of full definition of system performance requirements and specifications, and coordination of completion,

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Processes: Recommended Actions from CIB IDS 2009 Workshop

Short Term	Medium Term	Long Term
<ul style="list-style-type: none"> •Experiment with modifying existing processes •Optimal holistic processes •Identify best practices •Processes are model-based •Loop between what to be changed and why => how to change => carry out => evaluate 	<ul style="list-style-type: none"> •New modular processes to support new business models •Evaluate and identify points for maximum ROI (is the process worth it) •Demonstrate best practices and show impact •New procurement models •Process efficiency analysis 	<ul style="list-style-type: none"> •Flexible and configurable processes •Professional guiding societies that inculcate best practices •Performance based procurement •Processes are driven by project information and action needs

Possible Barriers: stovepipe mindsets, current project management tools, lack of understanding, too little evidence, current contract models, current roles and practices, risk avoidance, rigid legislative measures and rules

Required Enablers: dissemination/understanding of process benefits, successful case studies, visionaries who think out of the box, believers in change, benchmarking, higher profit margins that allow experimentation, environmental and energy demands

commissioning, and handover for operation and maintenance of the building or plant systems. Further future benefits may result from the adoption of new approaches to work processes now being developed in other sectors, such as ‘holonic’ development and production (modularized, transferrable, partial solutions and processes, partial/interim product assemblies) and self-learning factories.

Technologies. A set of technologies and capabilities for collaboration and automation are essential for project teams to implement the integrated work processes identified above. These include: modelling of design intent, multi-disciplinary performance analysis, building geometry data, merged with construction site data, and delivery of the as-constructed facility model; 4D visualization; virtual prototyping; transparent, interoperable and reliable data transfer with third party applications; automated propagation of changes and integrity checking, and computer aided manufacturing and assembly. The deployment of these technologies will require open systems architectures and sharing and coordination of appropriate views of data included in the models. The integrated facility model (usually a combination of distributed information resources) becomes the means of ensuring coordination, agility and integrated work processes throughout the full lifecycle, reducing risk and waste. It can also be used to support reporting to and decision making by higher management.

Technologies: Recommended Actions from CIB IDS 2009 Workshop

Short Term	Medium Term	Long Term
<ul style="list-style-type: none"> •Develop toolkits to allow for experimentation •Identify appropriate standards •Develop technology and demand for it in parallel •Simulation and experimentation •Product model 	<ul style="list-style-type: none"> •Develop modular tools •Share standards •Standard data models and interfaces •Solutions for flexible and adaptable architecture •Shared model 	<ul style="list-style-type: none"> •Develop a holistic framework supporting flexible processes and modular tools (plug & do) •Development of technology that interacts with the user •Develop interfaces to standards •Information models for the Build Environment will support the full integrated decision making over the full lifecycle •Open BIM

Possible Barriers: competitive commercial interests versus open source and knowledge sharing, too many standards, too much focus on technology and not construction, short term business relationships, cost and time of developments, legacy solutions

Required Enablers: critical mass, demanding client, organisation and regulation of rules and functions, collaboration between different stakeholders, convergence of standards, interfaces to standards, experimentalists

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People: Recommended Actions from CIB IDS 2009 Workshop

Short Term	Medium Term	Long Term
<ul style="list-style-type: none"> •Inform people •Educate and encourage to experiment •Incentives for goal orientation •Publicise financial benefits of working together •Life-long learning •Education on systems integration and holistic ways of thinking 	<ul style="list-style-type: none"> •Encourage to implement and review •Peer-review and recognition •Companies nurture new competencies •Develop tools to support the formation of generalists using education as a priority task •Stakeholder engagement in use of tools and visualisation of results 	<ul style="list-style-type: none"> •Communicate •Encourage to demand •Collaborative social workspaces •Rewards for learning and sharing •New career paths •Create core group of people with deep and broad skills in delivering IDDS •Encourage to demand training and tools for IDDS

Possible Barriers: narrow mindedness, lack of motivation, conservatism, liability, professional communities lobby to preserve traditional roles, lack of "practice-oriented" inertia in universities

Required Enablers: incentives for learning, demonstration projects, trade organisations, education, life-long learning

People. Project teams pursuing exemplary IDDS need people with special qualifications, particularly in terms of an underlying adaptability and willingness to explore multiple skill sets. Many people with such attributes will require only a minimum of motivation but will depend on a facilitative and supportive management and business culture in order to thrive. These begin with technical and collaboration skills and a commitment to a team approach. The training and development of integrated team members gives them an ability to understand the work processes of the other specialists on the team along with the shared knowledge essential for integrated work processes. Several roles are critical for successful IDDS, including technical champion, integration champion, model management, and knowledge management. For each, the individual brings knowledge, enthusiasm, and commitment to make IDDS work and realize the project benefits but, above all, a personal attribute of being able to assimilate multiple inputs and develop a holistic view of what is best for the project.

As knowledge resources and capital are developed, essential long-term partnerships will form, providing some of the workforce stability needed for integrated design work processes and improved construction productivity. Such changes will also facilitate the opportunity for broader adoption of continuous improvement seen in other industrial sectors, improving training, motivation and skill, and consequently, collaboration and health and safety outcomes.

Main Elements of IDDS

The following sections further describe each of the four main elements of IDDS. For each element, the description includes current conditions and a brief summary of expected future conditions and gaps to achieving IDDS. It should be noted that the development of IDDS will drive the adoption of new attitudes and structures for managing and integrating risk and responsibilities, and will eventually push against current regulatory strictures, delivering improved performance of all project objectives throughout the lifecycle and greatly facilitating advances in project and area-based sustainability. IDDS will affect the delivery of individual projects but will also provide scope for area integration of the built environment.

Collaborative Processes across all Project Phases

Current conditions. There are examples where first tier contractors operate in an integrated manner on individual projects, or where temporary joint ventures are established, though these remain comparatively rare, despite seeming to offer financial, time and delivered quality benefits through more integrated processes. Even rarer are examples of vertically integrated supply chains and work packaging strategies that support IDDS; unfortunately, the culture of distrust and litigation prevails and

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impedes experimentation and progress with these new paradigms. What does exist is often at the initiative of exceptional individuals, though examples of clients forcing such an approach (for example, through the use of framework agreements) do exist.

In general, silo mentalities and cultures 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. Thus decisions are frequently made autonomously without multi-disciplinary participation, and in the absence of holistic or comprehensive and accurate knowledge. The use of an iteratively and incrementally developed design, pulled from an end user or client perspective is virtually impossible within current structures, or at least rarely achieved. Such collaborative approaches, linked with an effective knowledge management system would facilitate options design and engineering, based on alternatives which build both on prior knowledge and on topical alternatives.

Designers, engineers and advisors often need to collaborate although rational formal procedures on how to integrate by collaborating are often lacking. Collaboration mechanisms are typically reliant on the particular coordinating responsibilities of the main designer, although these vary and may be informally defined. 4D CAD and BIM are now often used to integrate design information and reduce design errors (artefact collisions and functional requirements, etc.); however, unified solutions are not at a stage when real knowledge sharing and knowledge development is supported for the design, construction and operation stream(s). In the case of integrated procurement routes, Private Finance Initiative (PFI), or similar procurement methods, designers, engineers and advisors are starting to collaborate with contractors and suppliers more often. These types of procurement model facilitate effective team communication and collaboration and iterative integration of stakeholder ideas and feedback. There is some research evidence that such procurement approaches can yield improvements in *time* and *cost*. However, the lack of tools to measure and benchmark *quality* and *design integration*, as a value to be achieved, hampers proper measurement of any quality improvements

Future Conditions with IDDS. To effectively transform to efficient, end-to-end and vertically integrated processes through the use of IDDS will require both structural and process changes, as set out below in this white paper. Improved design and delivery through better coordination and integration will remove the most costly categories of waste in the construction sector – waiting time and ‘making do’ (i.e. finding workarounds when all planned pre-requisites are not available).

Additionally, information technology tools must provide increased capability for knowledge sharing and development, rather than for just information exchange, aggregation and storage. This will prevent non-ideal adaptations of pre-existing designs and stimulate the efficient – in terms of needed multidisciplinary design iterations – creation of design value. A key input to these models must be a shared understanding of integrated design value as a deliverable of the team.

Gaps to Close. A thorough analysis of the project and supply chain process improvement opportunities and their individual and combinative effects will indicate the most efficient transition path for the sector to achieve IDDS.

IDDS should deliver better value, not only in terms of time and costs, but value-in-use. The latter should also encompass architectural values, including the design integrity of the spatial, functional and technical performance of the resulting buildings. IDDS requires a paradigm shift of all those involved, including clients, operators and other stakeholders, as well as architects, engineers, constructors and

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their supply chains, in order to deliver integrated solutions, in preference to today's norm of sub-optimal, single discipline-based, aggregated solutions.

Enhanced Skills

Current Conditions. Members of current project teams often bring skills that are focused on design disciplines, construction trades, or other functional activities, such as project entitlement or materials management. The increased performance requirements and complexity of constructed facilities require additional specialists and increase the need for integration skills. Multi-skilling is rare and document-based thinking is prevalent.

Appreciation of linkages between work products in different functional areas, and the ramifications of this interdependency is limited. Compared to prior projects that used consistent work processes to deliver simpler facilities, fewer people can decipher what is important and develop coherent strategies for integration to realise project objectives over the full lifecycle. Experience-based judgement is declining. Few people understand advanced information technology and its implications for integration. Professional development does not keep pace, and few organizations support the development of integration skills. The potential for specialization traps discourages individual investment in learning about new technology.

Future Conditions with IDDS. Future projects that make effective use of IDDS will require managers, engineers, specialists, suppliers, builders, and operators who bring shared knowledge of major work processes on the project, together with skills to integrate these work processes. Project managers tasked with integrated projects will seek out staff with shared technical knowledge and integration experience as key selection criteria. The increased availability of integrated data and information, along with knowledge of prior projects and current requirements, will foster integrated work processes both between and within specific project phases and major activities. The information and knowledge resources and the integration skills of the project team will allow evaluating a number

Industry Challenges - Outputs from the CIB IDS 2009 Workshop

- Development of guidelines for new roles and responsibilities, including changed delegation of responsibility, risk management, change management, and commitment management.
- Identification of appropriate methods and metrics for changing organizational culture and structure.
- Identification of "weak processes" and recognized problems in current practice and their root causes.
- Sharing of insights and knowledge on achieving IDDS.
- Development of BIM reference processes for different project or facility types.
- Understanding of "Standard Work" for maintaining and leveraging the new technologies and processes.
- Transformation of engineering standards into "processable" information, knowledge resources and federated data dictionaries.
- Redefinition of procurement modes, contract models, shared information and shared risk.
- Technology transfer from and to other industries, e.g., shipbuilding, aerospace, agriculture (heavy equipment), entertainment.
- Identification of new roles, their longevity and training requirements, and novel career paths.
- Refinement of collaboration contracts and insurance schemes.
- Greater supply chain refinement and integration, and development of long-term partnering; development of new procurement models.
- Offering of exemplar projects for research.
- Development of motivational mechanisms to ensure the inclusion of buildings materials manufacturers within IDDS.
- Adoption of trust models (e.g. Reliable Promises / Promise-Based Management).
- Expansion of knowledge sharing on a mid to long-term partnership basis.
- Development of on-site monitoring for future process optimisation; development of process management as a core skill.
- Recognition and embracing change as an opportunity.
- Learning from other sectors; e.g. concurrent engineering.
- Embracing industrialised construction with mass-customisation.
- Development of improved integration of sustainability modelling.
- Consideration of new models of intellectual property management, e.g. open/ public general licence. Understanding of the implications of co-evolved design and clients' long-term model access needs.

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of alternatives for the work process and product of each major functional activity for the project. This will result in increased effectiveness in meeting all types of project objectives.

Gaps to Close. Making the transition to IDDS will involve developing the shared knowledge and skills needed to effectively perform integrated work processes. This will require actions by each major functional area represented on the project team, as well as by researchers and educators. Owners and project managers will need to create a project organization and context that fosters IDDS, including using this capability as an important criterion in selecting team members and the timing (typically earlier) of their involvement. They will also need to insist on a lifecycle view of projects to ensure that earlier work processes will provide the information and knowledge needed for later project phases. Design engineers and technical specialists will need to grasp the major advantages that IDDS can provide and broaden their traditional discipline focus to view an integrated design as the only acceptable solution. Suppliers of permanent equipment and engineered materials will need to adopt a proactive approach to integrating their information and requirements into early project work processes and accepting integrated solutions that are best for the project.

Builders will need to view IDDS as an opportunity, not a burden, and make sound early input to key project decisions that will allow use of beneficial methods, such as increased offsite work and automation. Operators will also need to get involved early and make their requirements to support operation and maintenance known and considered in project decisions; even to the extent of subsequent retrofit options. Researchers and suppliers of information technology can continue to increase the capability and usability of integration tools, further considering the data, information, and knowledge required by each of the project team members and activities. Educators can take advantage of integration tools as potential learning resources, giving the students the dual advantage of gaining experience with work processes and technology for IDDS.

Integrated Information and Automation Systems

Current Conditions. Limited degrees of integration, either through the supply chain or along the design path, are supported by current BIM and analysis commercial products. These approaches are typically vendor-specific and tie together a small number of design tools (in comparison to the thousands available in the marketplace) which are unlikely to be the complete set required by any particular grouping of professionals involved in a construction project, let alone a fully integrated team. Creating a wider integration platform usually requires uniquely qualified individuals to be available in one of the companies involved in the project. The IFC product model data standard cuts across CAD vendors and offers limited interoperability for only a subset of design and construction processes, and yet requires individuals with special qualifications in each company to ensure the integrity of data exchanged. Due to the limited number of applications supported in current BIM environments, or with interoperable interfaces, the practice of manual re-entry, and checking of data between applications is both necessary and common. Using current interfaces for automated information exchange can often result in loss of information and no guarantee of the semantic integrity of models being exchanged (let alone retaining the design intent). Information management with current BIM and interoperability solutions is typically by a document management system, in which a complete model is exchanged and information is managed through interrogation of the different versions of the complete model being passed between project participants.

With a few exceptions, current value chains for materials and component supply and for construction operations at the project site remain fragmented and individually optimized. Paper specifications and drawings define the technical requirements and configuration for the products of fabrication and

Research & Education Challenges - Outputs from the CIB IDS 2009 Workshop

- Identification of the sources and types of value(s) for a variety of stakeholders, and the added value and ROI of using IDDS.
- Impact assessment of IDDS on whole life energy use and sustainability.
- The extent of possible and desirable of interoperability levels to IDDS (including from differing business perspectives). Investigation of any open systems applicability (both in terms of software, and in terms of opposition to a closed system).
- Investigation of a rationale for a reference IDDS conceptual system; and then definition and development of such a system.
- Development of a roadmap from BIM to IDDS.
- Identification of boundaries and synergies with other initiatives, such as Integrated project Delivery/ Virtual Design and Construction, Lean Construction and Holonic Production.
- Identification of issues and resolution of issues of risk and liability management (including change authorities and audit trails), and of information sharing and security.
- Development of an IDDS Storyboard/ Roadmap.
- Analysis of business change management implications, and implications for the education and training of staff. Such change has been shown to be particularly problematic for senior staff.
- Industry needs analysis.
- Recognition that IDDS is a continuous improvement programme; not a single goal.
- Skills, learning and training needs analysis and development of joint educational materials for design and construction. (Utilisation of IDDS as a new integration-oriented education platform).
- Closure of the gap between what industry says it needs, actually needs and what education delivers (it takes several years for students to graduate and needs change during this period). Increase educational agility.
- Meta-analysis of exemplar projects, and comparison of effectiveness versus traditional models.
- Identification of appropriate novel tools and processes.
- Development of a taxonomy of IDDS.
- Investigation with industry of methods of certification of new skills and abilities.

construction, but do not facilitate integration of the physical work processes. As a result, opportunities for considering detailed fabrication and assembly during design, performing this work at the best location, and making use of appropriate levels of automation are largely lost, lessening the effectiveness of project delivery. In addition, these fragmented work process often do not produce the data and information needed for the remaining phases of the project lifecycle, let alone provide 'as built' (compared to 'as designed') feedback to subsequent stages. Nevertheless, the possibilities of interfacing BIM component specifications directly to computer-aided manufacturing and automated assembly are already being used in isolated cases.

Future Conditions with IDDS. Interoperability will be ubiquitous in the industry when practitioners do not need to understand the complex and sophisticated technology underlying their software tools. This will provide a seamless connection between software tools gathering and updating the view of information required for any particular process in the project. Specialised software coders will not be required to develop and manage project-specific information exchanges. An interoperability manager from the project team or partnering companies will establish the best approach for project use of the software tools and for information delivery, sharing and handover.

As described in the vision and elements of IDDS delivery, integrated work processes and information technology will bring major advantages during the planning and design phases of projects. This will continue into the delivery and operations phases in two major ways. First the benefits from integrating information-intensive work processes during the design will extend to the members of the value chain responsible for materials supply, construction and commissioning, and operation. Second, integrating the physical work processes for fabrication, installation, and commissioning of new facilities will further increase the overall performance of the project. This integration will facilitate designing for fabrication and assembly, performing physical work at the most effective location, coordinating this work to best meet project objectives, and developing the data and information needed for the downstream phases of the project lifecycle. However, more fundamental

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performance improvements will accrue from the dense and accurate information transmission between flexible production resources, when linked with iterative and incremental design to form an information view of construction. Information must flow efficiently from the direction of functional utilisation and client/ stakeholder requirements backwards, as well as from the design(er) forwards, within a carefully optimised design information architecture. Only then can physical activities be optimised and integrated in a holistic manner.

How will these integrated physical work processes take place during project delivery? They will begin with the products of integrated design, especially models that include both technical requirements and geometric configuration. Analysis of the scope of work using these product models along with construction process models will include evaluating multiple alternatives for the location of the work and for the methods of fabrication, installation, systems completion, and commissioning. This will result in the work plan that best meets the project objectives, using the optimal combination of physical work processes in the shop and at the project site. These integrated processes will also provide data and information regarding as-fabricated and as-built conditions (in a sufficiently timely manner that subsequent design stages can be re-optimised), along with the required quality documentation.

Integrated work processes during project delivery will greatly enhance the teams' ability to complete the project in accordance with the owners' objectives and priorities for cost, schedule, quality, safety, and sustainability. Performing the work at the best place using the best process offers major opportunities for performance improvements related to each type of objective. Examples of the benefits include: decreased cost and schedule from designing for the unique fabrication and assembly requirements and conditions of the project; increased safety and quality from working in the manufacturing environment; decreased cost from automation; decreased work scope, cost and schedule for field construction; and designs and constructions which are optimised for whole-life utilisation as well as for the construction and commissioning phase.

Gaps to Close. Reaching this future state requires further significant work on many aspects of information science and semantic interoperability developed over the last two decades. The data dictionaries and information models which underlie IDDS information exchange will require significant development to cover all major processes. A major effort will also be required to define the information views (including for visual management) required by particular classes of application and standard processes. Sophisticated approaches to model and view-based information management are also required to cope with project structures and the processing times common in the industry. Software developers will need to put significant resources into ensuring the adequacy of their products to exchange semantically consistent views of buildings, and into maintaining configuration management and decision integrity and traceability. The new software tools will also need to tie into knowledge management systems within companies and for the industry.

A very significant gap is the current reliance of 2D drawings for transfer of 'official' information. Solving this problem will require change by clients and regulatory authorities, as well as the IDDS supply chain. Eventually the IDDS model must itself become the basis for contract in terms of design, build and operation. Accommodating the different levels of technology adoption and competency across the various sectors and regions of the industry, by providing viable increments to new capabilities, is a key challenge in moving these principles from the few leading organizations to a majority of the construction industry and its stakeholders.

Whereas information must be timely, accurate and relevant to particular users, knowledge should be retained and analysed for wider use, and should not be discarded because of lack of apparent current

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applicability. This tension means that information should be temporarily suppressed (typically at the information technology - human interface) to prevent information overload, but should not be purged from the underlying dataset. Another related tension arises from the existence of proprietary information and the associated need for security to manage access to that information.

Governmental Challenges - Outputs from the CIB IDS 2009 Workshop

- Realignment of regulation with the new IDDS reality, to ensure an efficient, effective, sustainable and safe delivery of public and private built environment.
- Recognition that emerging BIM Standards must evolve.

Leading suppliers of materials and components for construction are moving toward partial integration and automation of engineering, procurement and physical manufacturing and assembly work processes. In some firms this includes extracting information for fabrication from the design model. Further progress will require providing more complete design information models for use in planning and integrated physical work processes throughout the value chain for materials and components, in construction, and during the facility use and maintenance. Another gap is more comprehensive planning and management tools to allow full evaluation of alternatives for integrated physical process during project delivery. Further development of these tools will allow sharing of data and information for a broad range of work tasks during and following project delivery. Examples include: detailed configuration for all engineered materials, size and other constraints on fabrication and shipping, plans for material handling and flow to the workface, most beneficial sequences of installation, acceptance criteria for inspection and measurement, requirements for quality control documentation, priorities for systems completion and commissioning, and technical requirements for operation and maintenance. The adoption and customization of an appropriate information architecture for any given project will become as essential as the construction architecture to ensure that design information waste (inaccurate, incompatible, unavailable or untimely information) is minimised. Reusable template information architectures or patterns could be an objective of IDDS research.

Knowledge Management

Current Conditions. Typical firms have limited standards for knowledge management, dictated by management or legal staff without internal experts' and wider stakeholders' contributions. These standards provide little opportunity or encouragement for employees, regardless of position, to provide feedback for their further improvement. Systems and procedures that do exist are usually administrated by management, not distributed expert staff. Codified knowledge within the typical firm exists within individual groups (discipline, trade, function) and is seldom shared with those in other domains or upstream or downstream partners in the name of "competitive advantage". Corporate culture tends to hide, rather than directly address and resolve problems that have occurred on its projects. Capture and reuse of project knowledge is limited to reuse of personnel. There is also a failure to recognise and transmit the true training and learning outcomes required from the education sector.

Future Conditions with IDDS. Applying knowledge management, as done in a few leading firms, includes codifying, using and constantly updating critical knowledge and business processes based on on-going internal and external stakeholder feedback as "best practices" and "lessons learned" over the full lifecycle of the project. Employees are rewarded for their input and corporate culture encourages documentation of knowledge. Problems and solutions with multi-company, multi-disciplinary or multi-phased implications are captured in narrative forms. The focus of these activities is concrete actions or the creation of reusable and potentially automatable "processable rule-sets".

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Gaps to Close. Achieving knowledge management requires effective and easy ways to capture and represent the knowledge as rules to be automated, and lessons to automatically remind employees about. The transitory workforces, temporary management structures and distributed sites of construction projects require automated collection of data and processing into intelligence. The retention of design and supply chain change ‘audit trails’ and their integration with near-realtime monitoring of status (e.g. through RFID tags or on-site LIDAR scanning) could provide valuable knowledge. However, a mechanism is needed to embed contextual narrative into such a project history. Corporate culture must also transition to value staff ideas, encourage reuse and openness between groups, and build practices based on stakeholders’ feedback. Industry leaders can also prompt and help educators to better prepare graduates for taking advantage of the knowledge available in progressive firms. The gains achieved through IDDS are likely to foster longer term business relationships that encourage sharing and growth of knowledge capital and make this process both more probable and less problematic.

Involving Stakeholders to Realise Wholelife Value

As discussed above, the adoption of IDDS by the construction sector has great potential to yield value to both companies in the sector, and to clients of the sector. That value can only be measured in context of these stakeholders and will take the form of savings in time, costs, and materials; improved quality and performance of the facility; product optimisation/customisation; and enhanced reputation. Topical influences of wholelife sustainability can only be modelled, delivered and monitored through the adoption of IDDS. However, this improved delivered value will not come automatically or without significant challenges.

Although identified gaps have been split into industry and research/education topics (see panels earlier) they cannot be effectively viewed or addressed in isolation but rather in terms of their potential influence on the construction sector’s processes/practices, adopted technologies and people. As illustrated in Figure 2, any attempts to fill gaps identified in one element will necessarily impact, directly or indirectly, all three industry foundations. Apparent gains in one foundation can be more than offset by consequences or lack of preparation in others. Identifying and addressing specific consequences of changes is non-trivial and cannot be done without heavy participation of sector stakeholders. Hence IDDS requires strong linkages between researchers and stakeholders to cooperatively recognize specific needs; co-develop solutions and updated learning and training packages; and apply the results on a continuous and ongoing basis.

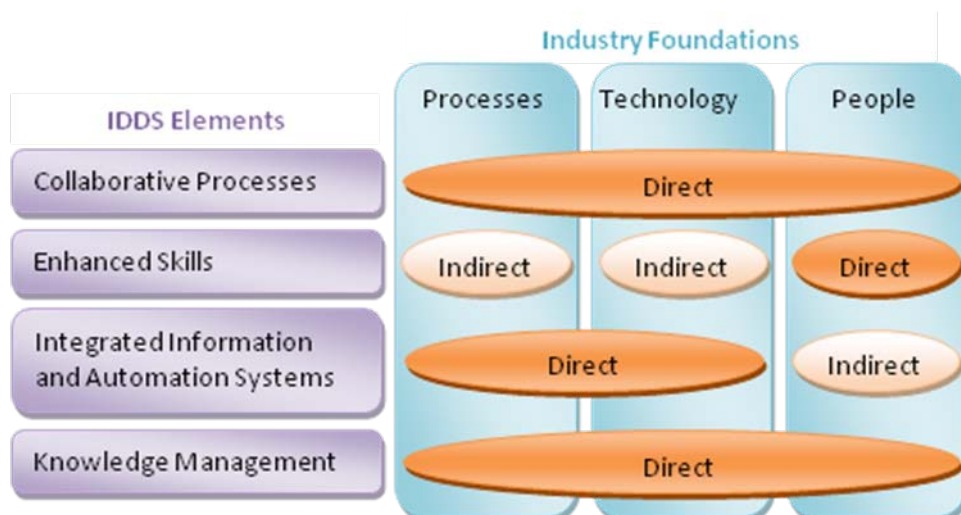


Figure 2. Impact of 4 Key IDDS Elements on Industry Processes, Technology and People

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Next Steps for Developing IDDS

The CIB World Building Congress, to be held 10-13th May 2010 in Salford, UK, will provide a platform for further development of IDDS and will be the ideal launch platform to engage the wider CIB community. The next steps should be to prioritise the research agenda by predicted impact, risk and horizon, and to develop a roadmap for each of the IDDS elements against the industry foundations.

Specific priority actions are listed below:

- Development of a CIB IDDS programme plan,
- Identification and engagement of key processes, technologies and thought leaders, whether in construction, other sectors, or research and development,
- Development of a research and deployment roadmap,
- Identification of motivational imperatives, incentives and of leadership within each of the audiences described above.

Acknowledgements

This White Paper has been prepared on behalf of CIB to drive forward the global priority research theme of Integrated Design and Delivery Solutions in the construction sector. Bob Owen of the University of Salford, UK, Mark Palmer of NIST, USA, John Dickinson of NRC, Canada, and Bob Tatum of Stanford University, USA have led the finalization of this White Paper. Contributions by Abdul Samad (Sami) Kazi of VTT, Finland, Robert Amor of University of Auckland, New Zealand and Matthijs Prins of Technical University of Delft, The Netherlands, have also significantly helped to shape the paper. A number of other international experts have also contributed to the work by submitting comments on earlier versions of the paper.

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CIB Publication 328

ISBN 978-90-6363-060-7