An Overview of eBusiness Impacts on Product Supply in Construction

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ABSTRACT
This paper synthesizes the many aspects of IT enabled change that are transforming the supply of materials and products in the construction process. It starts by characterizing the construction process in terms of the main aspects that influence IT uptake. The paper then explores changes enabled in the processes of the sector through the strategic adoption of IT and the web. This is characterized in terms of the pressures leading towards the standardization of processes and the collaboration and coordination of processes enabled by the web. Impacts on the structure and communication of design and construction information are then explored and the paper concludes by looking at the potential for changes in the efficiency of logistics through closer integration of information flows between the partners in the supply chain.

1. INTRODUCTION

Fully understanding the many ways in which the construction sector uses IT is difficult in part because of the complexity of the sector and also because of the limited amount of detailed research in this area. (Bjork, B. -C., 1999) This paper explores the most important developments that are transforming material and product supply in construction. Initially the main characteristics of the construction supply chain are examined. This is followed by a review of the key issues in relation to the transfer of information in the construction process. Finally the central issue of efficiency across the entire supply chain is considered.

2. CHARACTERISTICS OF THE CONSTRUCTION SUPPLY CHAIN

This first section looks at some of the key characteristics of the construction supply chain, a US$4.3 trillion industry, worldwide. Construction contributes some 7% of the total value of goods and serviced (GDP) in most OECD countries, however it is up to 12 to 14% in Japan and Korea (Gann, 2000) and if we add the entire construction related manufacturing cluster it represents close to twice these levels in any economy (DISR,1999). The characteristics explored in this section go some way to explaining why the sector has been relatively slow in its uptake of IT (Flanagan et al, 1998) and how the construction process has developed as a result of a range of industrial and market forces (Baldwin et al 1999).

2.1 Information

Increasingly, information is being recognised as a major part of the cost structure of many industries. In the health care sector, for example, it is estimated that information costs represents some nearly one third of the total costs in the supply chain. Intuitively, if the areas of information creation, transmission, storage and retrieval among all the parties are considered, it could be concluded that this would be similar in construction: the quantities of information are vast, the supply chain is highly fragmented and the level of complexity is high. Computers and, more recently, web-based technology offer the potential for great advances in transferring information accurately and quickly, in some instances approaching the goal of real time information flows. A number of studies (Betts, 1999) have indicated that IT has been vital

in assisting the construction sector to cope with the increasing complexity of its products as well as the increasing demands of its clients and regulators.

2.2 Fragmentation

The fragmentation of the sector is a challenge in itself. It has arisen from a number of pressures: *technical complexity* has led to tighter and tighter specialisation, the Taylorist drive for *production efficiency* has led to work being defined in smaller and more specialised packages and the *risks associated with employing labour* has led to a larger number of smaller organisations. However, fragmentation has its own risks and limitations. The *effective integration of tasks* becomes increasingly complex as the number of enterprises working on a project increases, *quality* becomes more difficult to manage as the number of interfaces among organisations increases and true *innovation* becomes more difficult to achieve across a fragmented supply chain than in a vertically integrated organisation. Furthermore communication between groups who hold different *goals, beliefs and even value systems* (Kalay, 2001) relies on the development of shared understanding.

2.3 Width of the supply chain

The width of the supply chain is a major factor limiting the sector's ability to innovate. The traditional market based, cost driven approach to contracting results in organisations having many alternate suppliers (wide supply chains) and thereby establishing relationships that are inevitably relatively shallow. Two issues are used to justify the cost based approach; one often raised in the public sector is that tendering is seen by many as the only way to guarantee probity, the other is that among contractors, the conventional wisdom is that cost competitiveness (that is achieved through tendering) suffers if business is done through long-term alliances.

It is interesting to consider that while post contract negotiations (including bid shopping) may achieve up to 5% cost reduction, experience has shown that in some high risk areas such as foundation construction, an alliance can yield as much as a 40% cost saving[1]. In contrast to attitudes in construction, in other industries partnering and alliances are seen as the best way to create value in the supply chain.

However, while tendering ensures the lowest price, in construction it is often less likely to give the best value for money. Why are these two apparently compatible ideals, price and value, in conflict? The reason is simple. Task definition in the design and building process is, to say the least, highly complex. And far too often the basis of tendering does not capture the true goals of the client. To illustrate this point take the case of structural design. Structural engineers can provide value in several different ways: fundamentally they must ensure the stability of what is being built, however, they may also optimise the quantity of materials being used and, at a higher level still, may help to optimise the overall construction cost by balancing the cost of materials, equipment and labour. In the fee tendering approach, if a client is seeking to save money on the fee he must specifically indicate the particular benefits being sought and provide a basis for measuring their achievement. Unless this is done, the fee saved will certainly be far outweighed by increases in construction cost.

[1] Informal discussion with John Findlay of STENT, a subsidiary of Balfour Beatty in the UK in August 2000.

2.4 Transaction costs

The reference to transaction costs is significant, though these are rarely understood or measured in the construction sector. In some sectors transaction costs have plummeted, while in construction, in many of the key practices, there has been little change. To illustrate the scale of change achieved elsewhere, in the last decade, bank transfers between accounts have dropped from US$1.27 for a teller transaction to US$0.27 for an ATM transaction to US$0.01 for an Internet transaction. Marosszeky et al. (2002) has reported a recent comparison of client project management costs, in Sydney, with the same client, under two different procurement arrangements. One an alliance project, and the other a similar sized project procured through a traditional design and construct tender. The costs were 2.8% for the alliance project and 9.2% for the D & C tender project. The variation of 6.4% is very significant when compared to the generally reported profit margins of less than 5% in the sector. Most clients do not even measure their costs in administering a contract, let alone benchmark them against different procurement arrangements.

2.5 Technology adoption rate

Finally, in technology adoption, the construction sector lags behind other industries in the adoption of IT enabled change. It has been estimated (Sauer et al, 1999) that while in construction most traditional processes have been automated, relatively few (10%) core processes have been re-engineered to align them with the potential of IT based technologies. And even fewer (0.5%) have been transformed through web enabled inter-organisational collaboration. While these are rough estimates, this is an indicator of slow change relative to other sectors; it also indicates that the potential for further change is significant.

3. STANDARDISATION OF INDUSTRY PROCESSES

In this section process change is looked at. The change from *traditional* industry processes that rely largely on the *skill* and *knowledge* of people to deliver satisfactory outcomes to industry processes that are more *fully scripted* and *standardised* is discussed.

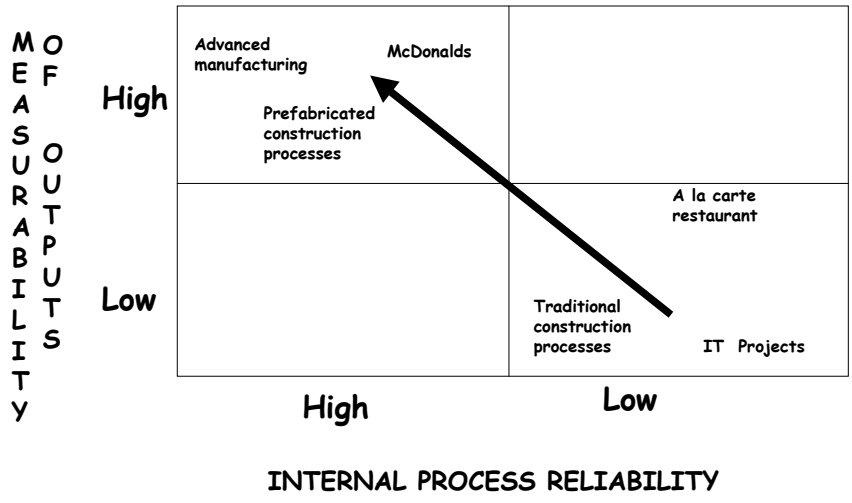

Figure 1: Process simplification[2]

[2] This figure was developed out of an informal discussion with Prof Phil Yetton UNSW AGSM in November 2000.

The two dimensions of change used in this discussion are *process reliability* and the *measurability of outputs.* The illustration below describes this transformation by referring to a few well-understood cases.

Processes in the bottom right hand quadrant are characterised in terms of low *measurability of outputs* and low *process reliability*. In these cases managements rely on the skill and knowledge of their people to achieve successful outcomes in what are very dynamic and often relatively unstructured situations. The trend among industry leaders, wherever possible, has been to restructure business processes in such a way that tasks can be standardised and outputs more easily measured. As part of this change, processes are codified and skills become more closely focussed around specific tasks, as processes are transformed, they move towards the upper left hand quadrant (see arrow in figure 2).

Hence the contrast between an a la carte restaurant and MacDonald's can be seen. In the latter case everything has been scripted and employees are highly trained in a sequence of relatively simple repetitive tasks. Meals are prepared in anticipation of people coming in, food is designed to have a longer shelf life, waiting times are controlled and product variety is limited. In the former, each meal is created and presented on demand, responding to special customer needs. The range of product is more diverse and response to demand relies on a higher level of craft skill and management organisation.

Construction projects differ widely and while some are in the top left hand quadrant, incorporating high levels of prefabrication, much of our work is in the bottom right hand corner with substantial site fabrication. This differs from market to market depending on the relative costs of labour and materials and the cost of keeping a site running.

The transformation of construction from a skilled, site-based process to one in which gradually more and more of the building is premanufactured and components are largely assembled on site is not dissimilar the *MacDonaldisation* of the restaurant. The major part of the entire production process is shifted from site to factory. The manufacture of components is through standardised, factory based processes. The benefits from working in a more controlled factory environment include the availability of better quality finishes and of more durable finishes that cannot be applied on site. Importantly, standardisation and repetition of production reduces the price of completed buildings. As a part of this transformation, site tasks have been simplified, thereby allowing faster construction cycles on site and reducing exposure to the risk of inclement weather.

A major challenge for construction is that this transformation of production processes is at a time when there is also a crisis in client confidence. Production changes have to be achieved without compromising customer satisfaction—rather it needs to be enhanced. For this, the reconfigured supply chain needs to be better integrated than the traditional process and greater focus needs to be placed on the:

- inter-organisational collaboration in the supply chain in order to promote better process integration;
- development of a client focused, reliable, value based culture within supply chains; and
- relationships across the supply chain, with a commitment to ongoing learning across organisations leading to an improved potential for product and process innovation.

4. WEB IMPACTS ON CONSTRUCTION PROCESSES

The internet offers the potential for process efficiency enhancement. Through the use of web based collaboration tools and the improved efficiency of simple market transactions much closer inter-organisational collaboration is possible, though it is noteworthy that current web based tools only cover a relatively limited area of project collaboration (Augenbroe et al, 2002). In addition, it improves the quality and immediacy of information flows while reducing transaction costs. It also has the capacity to enhance communication through semantically rich *representation* of information, enabling more effective *negotiation* between the participants (Kalay, 2001).

The construction industry has a vast array of transactions, ranging from the relatively simple to the extremely complex. In figure 2 the purchase of standard manufactured goods, such as bricks, falls in the bottom left quadrant while the design and construction of a facility through in integrated design team falls in the top right hand quadrant.

The bottom left hand quadrant, where both fulfilment and communication are simple, represents transactions that are defined by market mechanisms. On the communication axis, more information about options is available and transaction transparency is increased via the web. On the fulfilment axis, the improved matching of buyers and sellers and the aggregation of markets through hubs increases the capacity of the market. By simplifying both communication and fulfilment of transactions, the web has the affect of increasing the effectiveness and hence the potential of market mechanisms for an increasing number of transactions in the construction process.

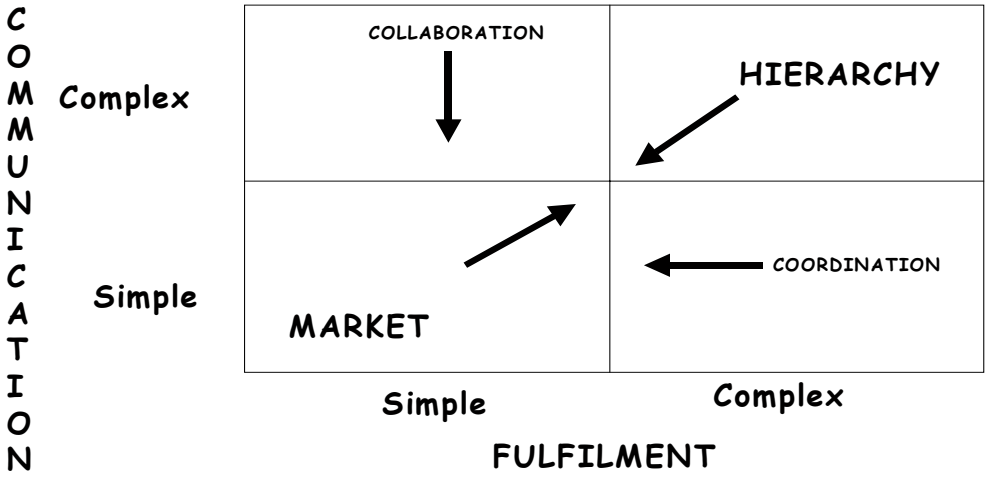

Figure 2: Potential of the web to influence competing processes[3] (Marosszeky et al. 2000).

Where both fulfilment and communication is complex, as it is in the design and construction of buildings and infrastructure, hierarchical organisations are well suited to achieve excellent

[3] This figure was developed out of an informal discussion with Prof Phil Yetton UNSW AGSM in November 2000.

outcomes. In these processes the information being communicated is both vast and complex and the fulfilment of transactions is negotiated and delivered through a highly fragmented team of specialists. Hierarchical organisations have been able to simplify the management of the myriad transactions between specialists within the design and construction team. Hence leading innovators have been large vertically integrated manufacturers such as Sekisui Heim in the Japanese housing sector and large integrated engineering groups such as Bechtel in the delivery of complex engineering projects.

Computer and web-based tools in the areas of coordination and collaboration have expanded the capacity of fragmented design and construction supply chains to compete more effectively with these traditional hierarchical organisations. Computer and web based *coordination* tools enable information sharing and the integration of information on shared models, with the potential to simplify communication and expand its scope to efficiently handle more complex projects.

At the same time computer and web enable *collaboration* tools facilitate the sharing of tacit knowledge, as well as concurrent collaboration throughout the design and construction phases. These tools also support processes of mass customisation in detailing and in fabrication.

Technological development is enhancing and strengthening both market mechanisms and the capability of fragmented design and construction supply chains. This is being achieved through different computer and web-enabled technologies. The overall effect is the creation of increasing flexibility in the structure of project organisations and in project delivery strategies.

5. DESIGN AND CONSTRUCTION INFORMATION

This section examines the implications of IT based technology for communicating information in the design and construction processes. Firstly, *specification writing* is discussed. In this area there have been changes that have the potential to greatly improve the quality of specification documents. Then the potential of *real time, accurate shared information* is investigated. And finally, the move towards *object-oriented technology* in design documentation is evaluated. All three areas promise to completely transform the information processes of the industry.

5.1 Specifications

Specifications complement drawings in defining what is to be built. As the available technology for construction has become more diverse over the past 50 years, drawings are less able to fully describe what is to be built. Therefore, there has been an increasing reliance on the specification to catalogue the detailed expectations of the designer.

Word processing and standard documents such as the Australian specification system (NATSPEC) have made it easier to produce good quality specifications. However, the often-argued drawback of generic documents is that, frequently, they lead to the production of a set of non-specific documents, and specifications must be project specific to be of value. Consequently, a challenge for specification providers is to prompt users to make their specifications as brief and as project specific as practicable. Unnecessary and irrelevant information obscures the important content that needs to be communicated.

There are two developments in IT based technology that have created new and more powerful possibilities for specification system providers and users. One is the potential to move from word processing generic documents to a *relational database* specification system. While this

technology[4] is not commonly used in the specification area, it will have important implications for the way in which specifications are used. It will also have very significant implications for the way in which project specific specifications will be structured. The second major development is the possibility to *hot* link sources of data. This can be provided in the first instance on CD technology and ultimately via the web.

Moving to relational database technology will mean that generic documents will be less likely to be used from project to project. The process of working with a database system is more likely to encourage specification writers to develop a project specific document since information is not held in a coherent generic format. When using relational database technology, specific information in relation to the myriad aspects of a building is held as carefully structured options in database cells. To construct a specification, the *specific* combination of information appropriate for *the* project is selected from the database—creating a custom made document.

The ability to combine information via *hot-linked* data sources further strengthens the specification writer's ability to customise project documents. This technology enables the writer to simply connect to the manufacturer's information provided either by a CD or via a web link. The technology enables the writer to select a product and import the manufacturer's recommended product specific specification text straight into their document. However for this to be effective, the structure of the information in the specification and the manufacturer's data must be structured on the basis of an agreed protocol.

Currently we are on the cusp of these changes; they have important implications for manufacturers and specification writers alike. For manufacturers this creates the opportunity to customise their information in formats that can be readily embedded into specifications. The importance of this is such that, for two similar products, specifiers are more likely to select the product with the better quality specification information, simply, because it is easier to specify. For specification writers, these technologies provide the opportunity to create information rich and project specific documents. In contrast to the current practice, the new technologies will encourage richness of data and specificity of information to a particular project. All in all these changes create a significant opportunity for manufacturers to position themselves in terms of the *quality* and *accessibility* of their product *information* as against the *quality* of their *products*. While this has always been a differentiator in the process of product selection, excellence in information is likely to become more rather than less important.

5.2 Real time, accurate information

For the question of real time, accurate information and information transfer among partners in the industry's processes, three developments are important: the emergence of shared databases on the web, the interoperability of software and the development of powerful, hand-sized technologies that enable accurate data to be captured and displayed in the field and rapidly communicated to all project stakeholders.

Shared databases have important implications for project processes and for process efficiencies, they are also extremely important for the information provided by manufacturers. Also the technology for effective, distributed product information via the web is rapidly

[4] It has been used by the Heinze Bandatenbank in Germany

developing (Coyne, R. et al 2001). Enriched product data will be embedded in drawings and in specifications and

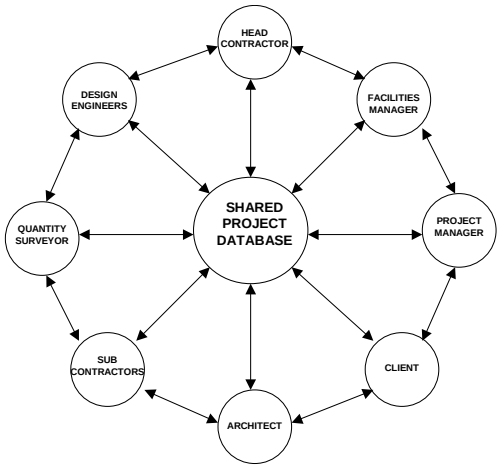

Figure 3: Web enabled shared databases

held on shared databases. From a process perspective they offer the opportunity for everyone to be looking at the same information and they enable the industry to move towards real time information and, most importantly, they create the potential for a common and shared body of project information. This promises to substantially reduce litigation in the sector, much of which arises from differences in the information that is held by the parties to a contract.

Developments in software **interoperability** continue to be a major issue, one that will affect the industry. Major internationally sponsored activities under the auspices of STEP and more recently the IAI (*International Alliance for Interoperability*) are leading to the definition of *Industry Foundation Class* (IFC) standards for the transmission of data between design programs. IAI development projects are creating common approaches in facilities management, structural engineering, engineering services, codes and standards and specification writing.

The other area of development that enables interoperability among software applications is the development of XML (eXtensible Mark-up Language)—(aecXML) in the US and (bcXML) in Europe. XML deals with interoperability in relation to data in word processing, spreadsheet and database applications. It was created to enable the reliable exchange of data embedded in richly structured documents to be communicated and interrogated over the web.

Current and recent work is finalising the development of internationally accepted taxonomies. While it is accepted that the technology underpinning interoperability is well advanced, the major challenges relate to contractual issues, to the ownership of intellectual property (IP) and cultural change.

Lead manufacturers are already developing all their product information, graphic and text, on the basis of international standards so that it can be most widely accessed by the design and construction community.

5.3 Hand held technologies

Another important area of change is the rapid development of hand held computers (PDFs), these promise to provide the basis of a much richer flow of information both to and from the

workface. Hand held computer technology is already enabling improved site data capture and transfer though this has yet to be fully exploited by the sector. These devices are rapidly becoming more powerful, are able to interface with a wider range of standard software packages and can be combined with a range of digital data gathering devices. For example, they can be used to combine text and pictures in a richer information set. They are already being used to record a wide range of site activity information: hours worked, percentage completion by trade package, site deliveries, creation of orders and defects.

For product manufacturers, the development of wireless application protocol (WAP) enabled devices, the next generation of hand held technology, heralds new opportunities in the communication of rich information about products and installation and specification details to the workface. This technology is currently available on telephones. Unfortunately, the small screen size of these devices imposes sever limitation on their application in the construction environment where a larger screen is essential. However as hand held devices become WAP enabled, they will have the potential to transfer real time valuable information to the workface.

5.4 3D communication

The design industry has to move from a vector past to an object oriented future, this will take a great deal of training, time and application (Bjork 1992, Eastman 1992, Fisher et al 1997, Wright et al 1992). This involves the move from 2D to 3D for the representation of designs. In 2D technology, plans, elevations and sections are separate assemblies of vectors, which need to be checked against each other to ensure consistency. In 3D technology, the representation is of a virtual object rather than a set of vectors. Plans, elevations and sections are merely different views of the object. In addition, with the use of object-oriented technology the properties of an object can be embedded so that when a user interrogates it, all the relevant information in relation to its characteristics, construction and FM information are linked. Once again this creates the opportunity for manufacturers to provide their product information in formats that can be readily incorporated in 3D design documents.

Finally, product modelling of entire projects is now possible using 3D and virtual reality (VR) software; these technologies enable realistic simulations of design, at an early stage in the project. This has the dual benefits of more certain client decision-making and improved design integration. Flat screen VR technology is rapidly developing and is anticipated on PCs within 2 years. Desk top *VR cave* environments are a recent development (de Vries, 2001) and they have reduced the cost of a 3D VR simulation environment from several million dollars to under $100,000. High quality product models from product manufacturers enhance the visual representation of the entire design and may become a differentiator in product selection.

6. SUPPLY CHAIN LOGISTICS

Constructed projects are delivered through extremely fragmented supply chains. This fragmentation defines the challenge of productivity improvement as the optimisation of the outputs of the *entire* supply chain, not just a single enterprise. Ultimately the weakest link in the chain limits the overall performance of the team. In this section the opportunities for improving the efficiency of the construction supply chain, especially from the product manufacturers perspective, is considered.

Research into costs in the electrical product supply chain at Eindhoven University in the Netherlands has shown that the relative costs of supply, manufacture and installation vary in

the extreme from product to product.[5] At one extreme, in the case of power point boxes, the transaction and supply costs far outweigh the product cost, while at the other, in the case of some high cost luminaires, the product cost is by far the greatest component of the overall installed cost. It is estimated that on average, as much as 30% of the delivered cost accrues after the product has been manufactured.

The main findings of the Eindhoven study, in relation to the cost of logistics, were that cooperation within in the supply chain will lead to the reduction of costs for some items. Furthermore, because of the wide range of cost structures, differentiated supply strategies are necessary for the optimisation of costs. It was also recommended that for different groups of product lines, delivery frequencies need to be varied, and the points at which stocks are held should vary from item to item. Finally it was found that information sharing throughout the supply chain is essential to enable opportunities for savings to be realised.

USBuild is a recent example of supply chain innovation to reduce the cost of logistics. The business model is that of a market aggregator. USBuild only serves large builders, and only standard house packages where the builder builds more than 100 identical units in a market[6]. The company uses a web based e-Business model to aggregate orders for certain items in the fit-out stage of houses. It picks-up from the manufacturer the week prior to delivery to site, repacks goods from different sources onto a single truck and delivers JIT in response to a telephone confirmation of the time of the delivery.

The implication for manufacturers is that different market aggregation mechanisms are likely to emerge around web-based technologies. This could affect their approach to the marketing and logistics of their products. In fact, it is conceivable that manufacturers could have a part in the development of new distribution strategies for the sector.

The other issue that is noteworthy is the trend to higher levels of prefabrication. The past 5 years, worldwide, has seen the increased use of sophisticated, prefabricated elements allowing simpler and faster assembly on site. Large manufacturers have the intellectual and financial capacity to participate in the development of such products and thereby can increase the value they add in the overall building process. Deeper relationships between manufacturers, fabricators and contractors have led to such innovations in the UK and Dutch building industries. These relationships are inevitably local and the potential of such relationships is worth exploring in every market. Closer relationships also create the opportunity for more efficient business transactions among partners in the supply chain, for example, self-payment, an innovation that is being introduced in a number of other business sectors.

7. CONCLUSION

This paper has drawn together a wide range of disparate yet related trends, all driven by IT enabled changes to the operations and capacity of the construction supply chain.

The main trends are to higher levels of prefabrication in production and more widespread and deeper collaboration between the partners in the supply chain. These strategies will yield lower costs through innovation in products and delivery processes brought about through closer partnerships and entirely new business models.

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[5] From informal communication with Prof Hans Wortman, University of Eindhoven in September 2001.

[6] From a presentation by John Taylor, one of the founders of USBuild at the ACCI Annual Dinner 2001.

There area number of significant implications for manufacturers:

- In an IT intensive world, the quality and richness of product and process information in itself can become a significant differentiator between products.
- Standards are emerging among the new information technologies and market reach will be maximised by the adoption of those standards, furthermore early adopters are likely to capture additional market share.
- New products and business models will emerge as a result of these technologies and manufacturers have both the intellectual and financial capacity to participate in their development. Furthermore it is in their interest to participate as they can then have more influence on shaping the future.
- IT enabled change has created the opportunity to drive down business transaction costs and this should offer manufacturers worthwhile opportunities.

Overall IT enabled change will have enormous influences on the processes of the sector, most of those are yet to unfold and so manufacturers along with other participants need wisdom and foresight to guide their investment and development choices.

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