Building Information Modeling and Integrated Project Delivery: What is the future?

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Abstract

The current state of practice in Building Information Modeling (BIM) has made significant progress over the last decade in integrating the design and construction processes. Current contractual relationships such as Integrated Project Delivery (IPD) arrangements are also making inroads into a more integrated process of combining design and instruction. However, both developments are still in a state of infancy.

This paper explores best practices through a current analysis of the state of practice in integrating design and construction through BIM and new contractual arrangements as well as the current limitations to functional integration. The referred limitation comprises an analysis of how aspects such as sustainable/green construction and conservation design can be better integrated into BIM, including lean construction to maximize value reduce waste. This paper explores this process, chiefly addressing issues of liability, particularly as such models gain greater usage by the Owner during the operational and maintenance phases of a facility.

It concludes with possible avenues that the construction industry needs to explore in the greater strategic integration of design and construction.

1. The development of Building Information Modelling

Addressing the Issue of integration of Building Information Modelling (BIM) and Integrated Project Delivery (IPD) requires a good definition of the term “design.” Design can be viewed as a “continuous integrative process of recycled, calculated ideas and decision making that yields an optimum result toward a set of objectives” that can be applied not only to the design of the built environment but to anything.

In the construction industry the phenomenon of lagging in technology can be part of the nature of the process. The discipline is bound by such restricted conditions with significant penalties that allow little if any scope for innovation and application in the process of building or designing. A significant amount of innovation keeps taking place when it comes to materials and the detailing of elements. To the process of design on the other hand, innovation entails risks that Architects, Engineers, and Constructors prefer to avoid. This risk aversion mindset was so dominant to the development of Computer Aided Design that from the beginning we found designers and decision makers using the computer as a tool for some electronic form of drafting instead of as an autonomous decision making agent that could return optimized results to its user. In fact the quantitative power of the computer was minimized...
to the vectors that define line drawings which in turn become conventional Construction Documents in two-dimensional printed format. Spreadsheet software packages that could produce numerical results that decision makers would use were running side by side with the CAD programs, allowing the users to transfer information back and forth in a fashion similar to the way that a calculator would be set on a drafting board one decade earlier. That was essentially a transformation of the computer to an electronic “drafting board”.

In a rather inhibited manner, during the early to mid 1990s large software companies like Bentley integrated special additional packages that incorporated specialized aids to the use of 3D design. Those were not necessarily aids that would facilitate an elaborate and systematic plan of action with a global scope for a project. Instead those were aids that would facilitate rendering processes in three dimensions, and produce some quantitative outcomes related to quantities. At the same time other software developers produced CAD programs that were designed to be specifically used for the design of buildings but again that was in terms of arranging together built elements without proactively taking into account issues related to financing, cost control, energy control, etc. ArchiCAD, Cheops, MiniCAD, and a number of others would be applied toward the conventional architectural design. One of the developers of Cheops, a company in Southern France specifically said, “You cannot design a shoe with our software.” Nevertheless, quantities and some specific qualities of the materials used were incorporated in order to restrict issues such as building a wall perpendicular to an existing window. At the same time, the Aerospace industry saw the possibility of use of computers as a design aid that would allow them to generate three dimensional forms of aeroplanes. The phenomenon of the Guggenheim Museum of Bilbao opened new horizons to the vision of how computers can be used and the results edited and manipulated, from one software package to another. Yet the integration was more of a task for the end user, translating one document from CATIA to AutoCAD, cutting sections of the three dimensional model and generating drawings that could be used for the actual construction of the designed result.

At present we still see a number of software developed, that integrate to BIM/CAD packages that can produce analysis of designed elements of the built, but not proactively informing the user or optimizing possibilities before the design is produced. The iterative process of decision making still relies upon the end user rather than the computer.

At that stage we saw a series of advancements at various directions but not in an integrated or easily integratable manner. Files could be imported or exported from one specific program to another, usually with a significant loss of important data, and most of the times with unavoidable transformations that would render the process of transfer marginally efficient. In a fashion similar to the operating systems wars of the late 80s and early 90s, products of one company would be formulated to function well with the allied products. It was left to the end user to apply the strength of every available program and reach a point where the information would be transferred to another.

A visionary thought would be the following: Instead of an integrated single package which can be too heavy for the computing power of a standard personal computer, we should aim for an integrable package that allows external applications to communicate and generate the result that will be governed by the user. Each application can yield the desired result as computed to be an optimal solution, edited by the user, and integrated to a finalized product. That will lead to an “automated total design process” where parameters can be adjusted dynamically, as a metric governed by an end user whilst the computer returns results that can be tested at any time within a virtual 3D environment. The term “Total” may stand for integrating pertinent parts, allowing the end user to manage the importance of the encompassed parameters and accordingly direct the processes to be followed. An early example could be the integration of specialized applications such as the algorithm that generates Tensegrity structures in a 4D virtual environment (Charalambides & Liapi, 2005).

2. The development of Integrated Project Delivery agreements

The development of IPD is hardly modern. Most of the principles underlying the integration of the project team are derived from W. Edwards Deming’s work with Toyota in the 1950s. His work on productivity
improvement and optimization in management through the use of systems thinking is in contrast to the current practice of fragmentation of construction disciplines. The continued fragmentation of the construction process which often leads to adversarial relationships has lead to significant customer dissatisfaction and contributed to the development of more cooperative relationships including IPD.

There has been a long-held concern that the industry is underachieving because of low profitability and the current emphasis on cost as the exclusive selection criteria for design and construction (Egan, 1998, Colledge 2005). There is a need for government-led initiatives to improve cooperation. Additionally, there is too little capital investment within the industry, no emphasis on research and development and little emphasis on training. More than one third of clients are dissatisfied with both contractors and consultants because of the lack of coordination and unreliability regarding time, cost and quality performance. It has been suggested that these concerns should be addressed by the development of an integrated project process based on four key elements: product development, project implementation, partnering the supply chain, and production of components. Five “key drivers” for effecting this change are committed leadership, a focus on the customer, integration of the processes and teams, a quality driven agenda, and a commitment to people. Partnering has been especially championed as a mechanism for removing confrontation from the procurement process. The benefits accrue from the development of closer working relationships over longer periods of time, and the sharing in gained efficiencies from such a relationship.

Owners are becoming more definitive in their demands for more reliable outcomes of the construction process. These demands include: improved decision-making to reduce poor design decisions, improved contract documentation to eliminate the extensive use of RFIs in the building process, improved preconstruction estimating, improved procurement, expediting and scheduling, improved coordination between design and construction, improved cost-efficiency through a value-based approach, and improved closeout documentation.

A working definition of IPD as a project delivery approach is that it “integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste, and maximize efficiency through all phases of design, fabrication, and construction” (AIA 2007a). In its most effective form IPD should go well beyond just a more collaborative agreement between Owner, Designer and Constructor to include other consultants, subcontractors and vendors who become stakeholders of the entire project process (AIA, 2007b).

However, it must be acknowledged that, as yet, no clear single definition of IPD exists. It is unclear whether IPD is to be considered as either a philosophy of project delivery or a required multi-party contract. It has been defined as operating at one of three levels of collaboration: Collaboration Level One or “Typical” where collaboration is not contractually required, Collaboration Level Two or “Enhanced” where some contractual collaboration is required, and Collaboration Level Three or “Required” where collaboration is required through a multi-party contract (NASFA et al., 2910). The first two levels may be regarded as more philosophical than contractual in nature. Indeed, some opponents of the use of IPD as a contracting method argue that integrated delivery is a process and operational framework which may be achieved under other better tested forms of contract including design-build and at-risk construction management (Post, 2010). In such instances early involvement of the main parties is possible and the collaborative environment may be enhanced by the use of BIM and other virtual design and construction tools.

At a minimum, Level Three IPD requires that the Owner, Designer and Constructor all sign the multi-party agreement, and often, other project team members considered critical to the project success are also brought into the agreement. However, there exist problems with such arrangements in that there are few insurance products to cover multi-party contracts, and those being developed are project specific and expensive (Post, 2010). There is potentially a lack of competitive selection of contractors and usually no guaranteed maximum price when the contract is enacted. The waiving of one’s right to make claims against other team members will likely render any liability insurance dysfunctional and inoperative.
Some have suggested that IPD should be a process that does not include the client in order to maintain the ability to make claims against the team’s liability insurance (Wang, 2008). Such arrangements include one of the prime team members being the lead organization, having a conventional contract for the total package with the client and forming an IPD relational pact with the other major team members, as defined in Figure 1 below. This pact includes an open book approach between the team and sharing of the “pain or gain” of the project success via the use of a target style of agreement. It would seem that such an approach, while having some merit, is at best Level Two IPD as defined above.

![Figure 1: IPD Relationship without Client. (Wang. 2008)](image)

In the United Kingdom, successful use of what is called third generation partnering has become common, even among public sector clients (Wright, 2006). In such arrangements an Owner uses the services of a select group of Designers and Constructors for all of their work. Over time this limited pool of resources develops strong collaborative working relationships that encourage innovation and efficiency. Successful performance is measured through the establishment of Key Performance Indicators (KPIs) which allow the client to benchmark the team’s performance. If the team maintain good scores on the KPIs, then their services are retained. Such arrangements use conventional contracting instruments, though often they will involve target pricing to encourage greater attention to the bottom line.

Care must be taken, though, in not overstating the power of partnering agreements, including IPD. Such agreements are not necessarily a panacea to solve all problems in construction relationships: they can fail. There are four main reasons why partnering alliances are unsuccessful, their success depending on the ability to effectively mitigate these problems (Wright, 2005):
• the failure to establish clear goals, operating procedures or responsibilities with no concrete measures of success;

• a clash of management styles or business cultures, or the emergence of internal interpersonal problems which frustrate the progress of the alliance;

• a lack of trust or mutuality where one partner perceives that the other is gaining an unfair advantage through the alliance; and

• changes in one of the partner organizations which reduce its commitment to the success of the alliance.

It may be seen from the foregoing that IPD is still in the development stage. In most instances, though, it is an attempt to involve the constructor and other parties in the project process at a much earlier stage than has been conventional. The degree to which it should be viewed as a philosophy or a contractual instrument is still under considerable discussion. However, there is strong agreement that this IPD in either approach is enhanced considerable by recent advances in BIM technologies. The integration of BIM and IPD, while still embryonic, is likely to form the keystone of future improvement in project delivery in construction.

3. The integration of Building Information Modelling and Integrated Project Delivery

In many ways the drive towards the greater use of BIM and IPD has been forced on the industry by Owners’ demand. Owners are becoming more demanding of the construction industry, including the heed for improved decision-making using digital models; improved contract documentation to eliminate the use of the RFIs during construction; improved preconstruction estimating; improved procurement, expediting and scheduling; improved coordination of the design and construction phases of the project; improved cost-efficiency through a value-based approach; and improved closeout documentation through the use of laser scanning and digital models. Drivers for the increased use of BIM and IPD include: a shift toward globalization of the product supply chain in the construction industry, the need for increased productivity in construction and the consequent low profit margins, the demand for greater sustainability and the need to reduce the environmental impacts of construction, and the increasing complexity of the building process.

BIM and IPD are complementary tools: BIM facilitates the integration of information and provides a single platform for the storage and retrieval of data, and IPD provides a framework to integrate the shared goals and values of the project participants. The basic principle of both BIM and IPD is the provision of knowledge integration (AutoDesk 2008). Since IPD relies on the collective expertise of all project stakeholders particularly in the early stages of design, the consequences of design decisions can be understood earlier in the process and thus more readily ensure project success. The use of BIM to capture this project knowledge can create a better, more integrated understanding of the project, enabling clients and their IPD team to more effectively assess how project options align themselves to the desired business goals. Satisfying owner demands is at the heart of the both the use of BIM and IPD process.

A recent report (Young et al. 2009) has indicated that 70% of companies adopting BIM see positive returns on investment and achieve a better than expected value on their work. They achieve competitive advantage by marketing new business to new clients, offering new services with BIM, and helping a company maintain repeat business with past clients. Extensive use of BIM results in improved productivity by reducing rework, reducing conflicts and changes during construction, and the improved ability to detect potential clashes during the design phase.

Architects, Engineers and Constructors are responding to Owners’ demands by adopting new processes, including collaborative partnerships, and utilizing new technologies. New tools and technologies are key enablers of the integration of design and construction (AutoDesk 2008). These include:
• BIM design tools to provide platforms for integrated processes built on coordinated reliable information and resulting in enhanced coordination, fewer RFIs and change orders, and less rework.

• 3D and 4D visualization for enhancing scope definition, stakeholder engagement, and decision making.

• Model-based analysis using BIM-based data and digital analytical tools to understand project energy consumption, structural performance, cost estimates and other inferential reasoning from the design while it is underway.

• 4D modelling for coordinating construction and increasing the reliability of schedules.

• Fabrication from 3D models resulting in elimination of shop drawings; better tolerance, lead time, and safety; and faster field assembly.

• Model-based bills of materials providing faster, more accurate takeoffs for cost estimating, energy analysis, etc.

• Laser scanning to capture existing (as-built) conditions that can be combined with BIM to provide reliable as-built models.

It is clear from the foregoing that this integration of BIM technology and IPD is being fuelled by increased Owner demands for a product where the design and construction process is typified by a more cooperative and nonadversarial relationship among the members of the project team. This is being enhanced as Owners realize that the industry now has better tools to achieve this harmony. They demand better value for money and less wastage of resources as the new norm for the construction industry.

4. Suggestions for the further development and integration of BIM and IPD

As stated at the beginning of this paper and outlined in the previous sections, the integration of BIM and IPD is still very much in its infancy. Still more can be achieved to improve this integration and improve the industry’s image regarding the provision of its Owners with greater value for money. These areas for improvement include: the greater use of BIM during the design phase, a greater integration of the parties involved in construction, more emphasis on the operability and manageability of BIM tools, the greater incorporation of green and sustainable design, and the use of lean construction techniques into the process. Suggestions for this are outlined below.

a. Greater Use of BIM during the design stages

BIM is a natural evolution of CAD. Construction professionals, and more specifically designers, have started to recognize the value of information technology, using computational power of what is available rather than transforming the computer to perform in digital format what was analog drafting in the past. The process can be accelerated through the accumulation of information and the generation of methods of assessment and decisions to be taken. BIM is still in a stage where users give input and it is simply recorded into a file that can be viewed in virtual 3D space. The computation power of IT in conjunction with the information that can be accumulated should allow the computer to act as an autonomous decision making agent that implements resolutions into designed forms and generate reports on process for the users to review. At an early stage it can be anticipated that a series of smaller tasks can be performed, slowly leading to an expanded environment where the users will feed the information to an open computational network. This will allow the computer to perform assessments and process a design from the stage of pre-project planning to the construction documents, and even in robotics control.
according to a schedule produced and dynamically adjusted throughout the whole operation (Charalambides 2008).

b. Greater integration of all construction parties

The role of the “architectus,” a title awarded to Brunelleschi for constructing the dome of Florence, an individual who would assure the Vitruvian ideals of “Firmitas, Utilitas et Venustas” (Stability, Utility, and Beauty) has been disseminated to that of architect, engineers of all the disciplines, project manager, code inspector and any other emerging specialty. This series of professionals of different disciplines need to work in partnership in order to combine their specialty toward a teleological objective, with each discipline having its own portion to contribute. Like in all types of groups and organizations, acquired momentum and often seniority of individuals, lead to unavoidable tensions and lack of effectiveness in collective effort. These conditions result in a significant decrease in the collective IQ compared to that of the individuals who form the group (Senge, 1990). Transforming each such group into a “learning organization”, although ideal, it is not always feasible. Thus, constructing an agenda of priorities and generating metrics for decision making would be more and more difficult, tending toward impossible as the above mentioned disciplines continue to diverge toward their own specific objectives. “Meeting of minds” may often occur, but on an everyday basis, a series of meetings with identical dynamics developed by parties takes place for most such processes. The variation of results depends on data and many times on the clarity of presented positions and parameters that have to do with the personalities of the players. The latter is the most dangerous aspect as persona should not become a factor in collective decision-making. This can become a significant delay factor in every process of the construction business. Many times meetings are held with a “democratic” attitude prevailing during the meeting although the decision has already been taken by upper management and the meeting is merely held in order to be kept on record, rendering the integration of parties input a mere shadow to the position of authority. It is however the experts that should be the decision makers; the distinction of the expert to that of the layman being nothing other than the accumulation of a body of knowledge that allows the establishment of correct parameters and information for decision making. The scenario of decisions already taken by upper management, render intense meeting conversations increasingly counterproductive, especially since the final decision is meaningless.

As Senge mentions in “The Fifth Discipline,” failure is more often caused by the system rather than because of extraneous factors; referring to the system of individual humans interacting. It is later denoted that by redesigning our own decision making policies we redesign the system structure (Senge, 1990). If we accumulate the know-how, we can update the databases and be experts before making decisions and taking action. Expertise, however, is not an established once and for all times attributed quality that individuals may possess for life, especially in a field like construction where immense funding amounts are disposed annually for research and development, making processes and materials more efficient. As data are always updated, human nature is intimidated by the unknown. In order to be experts, team members need to be believers in cause and objectives, and transform all the information into actions taken. The difference between reinforced growth to that of linear is that the growth of an organization – that we can also be translated to a system – is regulated by the pace of learning. Nevertheless, the level of expertise that can be anticipated by an individual is finite, and that is the reason the skills of the architect of the antiquity through the 19th century are represented today by a number of experts in specific aspects of the discipline, a cause that results in the need of collective work.

c. More consideration of operability and manageability in BIM development

What if this collective decision making body was to be facilitated by an unbiased process that resolves group dynamics using Information Technology. The use of developed software that integrates these disciplines in a preset assembly of processes is a near future reality. The more quantitative oriented disciplines of the engineers form a realm where biases would not easily form since data are objective. But the organization and establishment of metrics that lead to an undisputed result in decision-making may be a more complex structure altogether. This raises the question why computer is merely seen as a
“tool” that processes quantitative issues rather than resolving qualitative and quantitative issues simultaneously. It could easily transform processes and cycles of refinement pro-actively and engage into issues that are related to all the disciplines within the business of construction.

The construction industry is also still typified by the large number of documents generated and stored in interorganizational information systems. A large percentage of these project documents are generated in text format, which are readily capable of being organized to improve access to the information. Still many of current systems for document management in construction rely on manual classification methods controlled by human experts. Some algorithms have been developed to “mine” such texts in order to extract useful data on a particular subject (Caldas et al. 2002), which have met with success in information retrieval. There is, however, considerable scope for the development and incorporation of these software systems into the building information model.

d. Incorporation of green/sustainable design and construction

Like all aspects of design, the incorporation of sustainable, energy efficient design is becoming an integral part of the process. Although it has been argued that sustainable design may generate upfront costs that may or may not pay off eventually, with the improvement of technology and the constantly multiplying resources and materials, sustainable design can be less costly, but particularly the concept of benefiting from the abundance of solar energy can be set at minimal to no cost.

![Solarium, an interactive program for the design of building form and orientation for optimal solar energy use. (J. Charalambides)](image)

Many software packages are available for an extensive analysis of a designed form. The objective presented in this paper however, would be met if the analysis is produced before the form is finalized. Instead, a ratio of initial dimensions and orientation from the very beginning would be a more efficient method for the designer to follow, allowing analysis and only minor adjustments to be made if necessary at a later stage.
Green BIM is seen as an emerging trend. In 2005 only 2% of construction used green construction techniques, but this trend upwards has grown steeply since. Currently, industry practitioners are just beginning to tap into the full potential of BIM to achieve green building objectives. Future steep growth is anticipated in the use of energy performance simulation to produce more environmentally sustainable buildings (Bernstein et al. 2010). However few tools exist to achieve this better than other existing technologies. It will need a significant push from Designers to develop analytical tools that can readily translate and handle the great amounts of data contained in BIM on an efficient and productive way. The use of BIM for green construction is well understood by architects, but more client engagement is needed to capture the time and cost savings of BIM during the design and construction of green buildings, and to effectively use BIM during the operation and maintenance phases of a green building.

e. Use of lean construction practices for waste reduction and maximizing value

Lean Construction as defined and developed by the Lean Construction Institute (LCI) has been in existence since 1997. The two cornerstones of Lean Construction are maximizing value and minimizing waste in the total construction process (LCI, 2007). Lean Construction is a production management-based approach which has grown out of the manufacturing design, supply and assembly processes. The project delivery system is a concurrent engineering process utilizing the simultaneous design and production of the facility. Control is defined and an interactive way rather than just a performance monitoring role. Quantifiable performance measures are derived to assure an atmosphere of continuous quality improvement. The reliable release of work between specialists in design, supply and assembly assures that value is delivered to the customer and waste is reduced. It is particularly effective on complex projects and projects with a high degree of uncertainty. It challenges the norm that there must always be a trade off between time, cost, and quality.

In this sense, BIM and IPD are natural partners of Lean Construction. All champion the need for greater integration of the project process through earlier involvement of all the construction team, the need for greater enhanced communication between the parties, and an open buy-in to the risks and rewards of being a project participant. The open-book approach and equitable approach to risk sharing of IPD coupled with the ability of BIM to integrate all of the building information and the desire of Lean Construction to maximize value to the Owner while minimizing waste are all potential avenues for the construction industry to gain greater competitive advantage.

5. Conclusion

The above narrative has acknowledged that great progress has been made over the last decade in providing a more integrated approach to construction than has been its reputation over the past century. Increasing customer dissatisfaction over the past few decades with the construction industry’s ability to provide a product in a nonadversarial and cooperative environment has been recognized by some leading champions of the construction industry. This has been outlined by tracing the development if BIM and the increasing use of IPD as a project delivery system by reviewing the work of previous researchers in these areas. It has been noted, though, that much more could be done to improve the ability of the construction industry to provide excellence in the designed and constructed product. The bottom line, after all, is providing Owners with a product that not only meets their needs as they envision them, but to address issues that Owners would not have considered, in optimizing the process and maximizing the efficiency and effectiveness of the result. Beyond that, the final work should be produced in an efficient method that alters the whole concept of the design process as it was perceived until recently.
References


NASFA et al., (2010): *Integrated Project Delivery For Public and Private Owners*, A Joint Effort of the National Association of State Facilities Administrators (NASFA); Construction Owners Association of America (COAA); APPA: The Association of Higher Education Facilities Officers; Associated General Contractors of America (AGC); and American Institute of Architects (AIA).


