Integrated Project Delivery for Construction

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Abstract

The ever evolving nature of a construction project requires a management process which not only facilitates changes and updates but actively seeks to reduce or remove them from the outset. Traditional construction processes are too segmented in their approach to collaboration between the main parties to a project namely the client, designer and builder. Instead of a traditional approach, the adoption of an Integrated Project Delivery (IPD) process provides a suitable platform for the open exchange of information between the parties and an overall streamlining of the entire project. A key advantage of an IPD process is the early concentration and assessment of the design and program for a particular project. This aspect relies heavily on the effective use of Building Information Modeling (BIM) which can be further utilized to provide construction quantities, detailed drawings and schedules. The research outlined in this paper highlights two separate construction projects in which an IPD process was applied. Both projects were carried out by a construction company which is transitioning from using a traditional construction process to IPD. It is envisaged that the information gathered can be used to establish a successful IPD system within the company and lead to influencing other companies to adopt the same process.

Key Words: BIM, Case Study, Design, IPD, Timber Frame

Introduction

The development of construction techniques requires the advancement of traditional construction methods to improve project standards. In an effort to improve project performance, the adoption of Integrated Project Delivery (IPD) is quickly increasing in popularity through involving all parties of the construction project at a much earlier stage. (Eastman 2011). This allows for greater control and planning for each project as collaboration between all members is the key to successful IPD-led design. Project efficiency and communication are essential in any construction project and traditional project delivery methods do not afford the same level of collaborative communication between the project team when compared to IPD (AIA 2007). There are however, cases where a breakdown in communication at any stage of the IPD process can lead to problems and difficulties once the project has commenced as is explained further in this research paper.

This paper presents two separate projects in which IPD was applied. Both projects were carried out by an Irish timber frame construction company (Company A). Each project entailed off-site construction and collaboration between clients, designers and contractors. Case Study 1 is a single storey 40m² (430.5sq.ft) pre-manufactured house extension while Case Study 2 is a 300m² (3229sq.ft) new build house. Due to the vast difference in size and design of both projects, an assessment of IPD from a cost comparison point of view is not feasible. Instead, both projects are used to highlight the positive effect of an IPD system on the construction management process of Company A. Case Study 1 effectively became a project using a mixed IPD and traditional procurement approach; this led to a miscommunication between the designer and contractor resulting in an on-site delay. Case Study 2 demonstrates a clear progression from Case study 1 in terms of communication between parties and the successful execution of the design and build of the project. The purpose of this paper is to highlight the advantages of IPD and to establish its ability to work effectively in the Irish construction industry.

Changing the Construction Process

Company A are a small construction company with their own pre-fabrication factory. The adoption of Integrated Project Delivery (IPD) was deemed necessary as a way of introducing BIM technology to streamline both the construction and manufacturing facets of the company and to improve upon the segregated traditional project delivery approach. Company A typically use a traditional procurement option of contractor-led design and build. In this format, the client outlines what is required in terms of the build and the contractor designs and constructs the project in accordance. An in-house or an externally sourced design consultant may be used to develop the overall project design (Cooke and Williams 1997).

IPD is the collaboration between all parties involved in a construction process. It is based on the open and collaborative relationships between the three main parties of a construction project: the client (owner), the designer and the constructor. In an IPD project, the early communication flow between the main parties is the key to the overall project success (AIA 2007). The open and honest transfer of information amongst the group is maintained for the entire project as this removes the segregated roles of traditional construction processes. If implemented to its full effect, IPD can result in increased value to the client and a reduction in the overall project waste (Lévy 2011). Early establishment of the project parameters is an important step, particularly if there is any off-site manufacturing involved. This is important for both the designer and building contractor to keep in mind when collaborating on the design/manufacture element. The contrast between a traditional approach and IPD led design is outlined in Figure 14- *Schematic illustration showing traditional & integrated design processes* below;

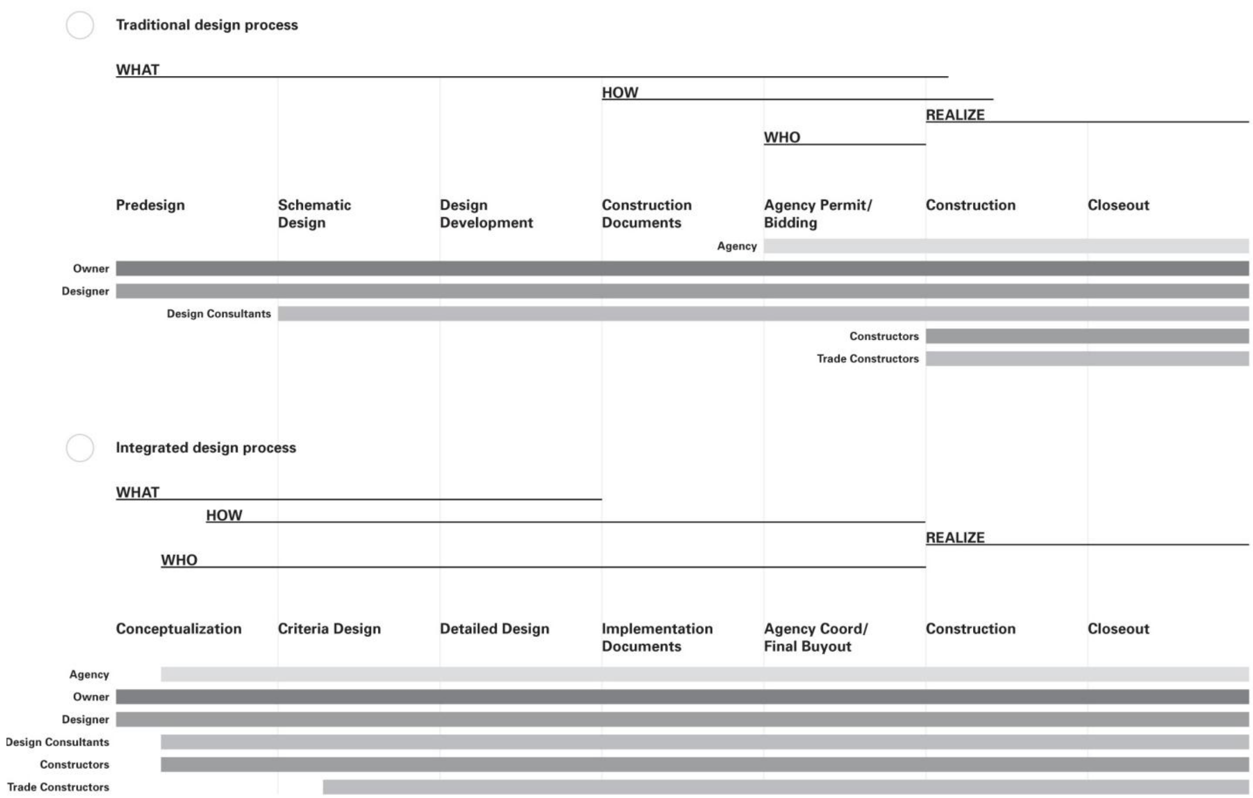

Figure 14- Schematic illustration showing traditional & integrated design processes

Working as part of an IPD system allows better management and control of arising problems at any stage of the project. Instead of assigning blame, which is synonymous with traditional practices, IPD teams work together to find a solution to the problem (Greenhalgh and Squires 2011). This change of focus offers a large advantage in time and cost saving as the reduction or removal of possible problems promotes an easier transition from design to construction. However as mentioned previously, this assessment of IPD aims solely to highlight its advantages and ability to work effectively in the Irish construction industry.

A key factor of the application of IPD to a construction project is the use of Building Information Modelling or BIM (Lévy 2011). The use of BIM as a tool of organisation, costing and planning is maximised in an IPD setting as it allows the client, contractor and designer to visualise the project in its entirety before project work has begun (Lévy 2011). For the purpose of this paper, a further benefit to IPD is utilised, effective management is made easier and this in particular applies to projects which use off-site construction. Both the structure of Case Study 1 and 2 were constructed entirely off site and so both the design and construction management of each project largely hinged on the correct application of BIM and the effective management of the production process.

BIM

Building Information Modelling (BIM) is an intelligent model-based process that provides insight for creating and managing building and infrastructure projects faster, more economically, and with less environmental impact (Autodesk 2012). BIM is a 'modelling technology and associated set of processes to produce, communicate, and analyze building models.'(Eastman 2011). It allows construction types, materials and 3D views to be accurately drawn with the information being utilised by Company A to extract quantities, costs and areas from initial concept stage.

BIM can enhance collaborative coordination and knowledge sharing in an IPD process through a robust collective 3D environment (Eastman 2011). In recent times the design and detailing of construction projects has been significantly aided by the use of BIM in a project. The distinct bonus of BIM is its ability to create a single common model of a project that can both be used and updated in light of requested changes or the detection of design mistakes (Halpin 2011). In a typical IPD process, the BIM model of the project is used to organise the building design and construction methods . The integration of various sub-contracted elements such as structural steel or mechanical ventilation can be added to the designed model (Eastman 2011). The finalised structural drawings can be sent to fabrication with the knowledge that the correct sizes and dimensions have been established. From these drawings, the various elements should fit accordingly during the construction process. The use of BIM also provides a source for the generation of bills of quantities for more accurate costing and estimating earlier in the project (Forbes and Ahmed 2011).

The unique ability of BIM to allow Company A to extract quantities, easily change project design, and illustrate a more realistic view of the final product gives a certainty to the client about what they want and what can be achieved. Using BIM software makes the facts of a project clearer and using BIM data promotes easier decision making (AIA 2007)

However, as comprehensive as BIM may be when designing a project, construction details can be overlooked in the initial design illustrations. Initial design illustrations are simply 3D BIM models drawn to a stage whereby images of the building design meet the client's approval. Following approval, the project can move forward to detail stage. At this stage, the anomalies of unforeseen detailing can surface which is due to focus on client approval at the initial design stage, as was experienced by Company A, previous to Case Study 2. Thus, the design drawings evolved into the manufacture drawings for panel production systematically ensuring the project design dimensions remained unchanged.

The concept design is initially drafted using Autodesk Revit Architecture, one common form of BIM software, which informs both the client and the contractor of the layout, options available, quantities and costs involved. This 'design file' although attractive and necessary, lacks the totality of a production drawing. For panel production, the 'design file' is then linked to a new 'structural file' which strips the rendering materials and graphics replacing them with timber studding and panels locked to the dimensions of the 'design file'.

Context

Closed panel timber frame construction

Within this paper, both case studies presented were manufactured using closed panel timber frame construction. Closed panels are essentially a more streamlined alternative to open panel timber frame construction. It allows much more of the overall fabrication of the building to be carried out in a factory setting. This applies to elements such as insulation and windows which can all be installed before the structure is brought to site (Department Of Environment 2002). Similar to the open panels system, the closed panels are brought to site and fitted together to form a building structure. However, due to the increased materials contained within the walls, each closed panel is heavier than an open panel equivalent and generally requires the use of a crane for positioning (Ruske 2004). Closed panel timber frame construction is classified as a modern method of construction (MMC). As most of the construction work is carried out off-site, a more advanced system of construction management is required to control the pre-fabrication and assembly process (Hairstans 2010).

Case Study 1

Implementation of IPD into the process of construction for Company A began with Case Study 1. The project comprised of the prefabrication and erection of a 40m^2 (430.5sq.ft) single storey house extension. In line with a typical IPD process, this project involved the collaboration of Client, Contractor and the designer however, the initial stages of the project proceeded with a client – contractor liaison leading to a final concept design. Once a design had been finalised, the designer was then introduced to the project. This was systematic of a traditional project delivery approach as individual team members remained segregated, the transfer of information was not open and existed on a 'just-as-needed' basis (AIA 2007).

The designer's involvement led to the application of BIM as a project design tool for case study 1. This addition of the designer to the project enabled a 2-way communication process between contractor and designer. Following this, the structural design was sectioned and panelised by the designer using BIM. The finalised design dimensions were then passed onto the contractor for factory production. This is illustrated in Figure 16 – 3D Design File and Figure 15 as the concept design is evolved into the structural/manufacture file.

At this point in the process, communication between contractor and designer ceased. It was assumed that the design dimensions and production drawings would provide accurate and synchronised construction on site.

Figure 16 – 3D Design File

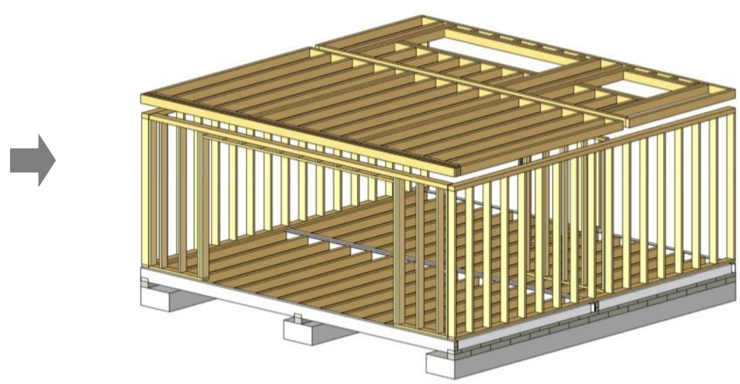

Figure 15 - 3D Structural File

The construction management process entailed overseeing the panel manufacturing process from initial design drawings to completed factory panels. Foundations were built on-site before panel production from the design drawings commenced. After foundation construction, all timber panels were manufactured from the same drawings which were not updated to reflect any tolerances in the 'as built' foundation measurements. This required on-site modifications adding 5 hours to the expectant assembly time.

Figure 17- IPD Working Definition sequence (AIA 2007)

By reviewing the working definition of IPD according to AIA, it was noted that a fundamental step within the IPD working definition sequence (Figure 17) was missed resulting in the aforementioned time delay with the on-site assembly. Within the Implementation Documents stage a failure to relay the as-built dimensions of the on-site foundations resulted in the procurement of an incomplete on-site assembly and layout plan. This lack of project coordination and open communication coupled with the late addition of the designer to the project team highlights Company A's initial lack of understanding of the criteria required for the implementation of IPD.

Review of the IPD Process

Following the completion of Case Study 1, a systematic review of the IPD process was necessary in order to avoid a repeat of the miscommunication which hampered on-site assembly of the project and to establish a clearer understanding of the IPD process. Before the commencement of the next project; Case Study 2, an internal focus group was held by Company A. The purpose of the focus group was to establish amongst the project team what went wrong and why. As mentioned previously, the misinterpretation of the IPD Working Definition was prevalent throughout Case Study1. As a function of the focus group, a production management system was implemented to ensure efficient design, production and site assembly by following the prescribed IPD stages. A number of key points were outlined for attention during the design/manufacturing process; these points were compiled as a continually developing checklist and added to the Criteria Design Stage as follows;

+ Allocation of particular attention to ope sizes, doors, windows & rooflights
+ Establishment of final ceiling heights
+ Identification of panel connection points
+ Establishment of roof levels and falls
+ Consciousness of external wall build-up and impact on internal wall panel connection
+ Implementation of as-built foundation measurements
+ Implementation of final panel production cross-check with production drawings

This checklist, as part of a management process, was put in place at a very early stage for Case Study 2 when initial consultation with the clients began. The involvement of the client, designer and contractor at this stage was typical of an effective IPD process (Greenhalgh and Squires 2011). The client in Case Study 2 had a much greater involvement than that of Case Study 1 and as a result, an excellent and open working relationship between all parties developed. The checklist assisted in the early elimination of potential design faults which otherwise may manifest further along in the IPD process. The relay of information was made easier between the project team without compromising any design/construction aspects. It is also important to note that the designer had been introduced in Case Study 2 far earlier than in Case Study 1 allowing for greater control and consultation during the design process.

Once the Conceptualisation and Criteria Design had been finalised, the transition from design to production ensued. Following the experience of Case Study 1, stricter adherence to the IPD process was maintained at Detail Design Stage through to Document Implementation Stage. The exchange and management of information between the designer and factory-floor workers was a key component of the improved IPD process applied in Case Study 2.

The management of the production process incorporated rigorous cross-checking of each panel. Every factory-produced internal or external wall panel was cross checked in accordance with the drawings including ope sizes, stud positions, bracing positions, insulation placement and internal reinforcement within particular panels. Each panel was photographed and approved once it had been cross-checked. Following this protocol ensured that document implementation stage was carried out with the same degree of rigour as the previous stages. This diffused any fears that the contractor, designer and client had about the layout and precision of the building. As already alluded to, an off-site method of construction works extremely well with an IPD system. Case Study 2 increased the level of integration between the designer and construction manager by adding more control and clearer channels of communication across the entire project.

Case Study 2

Case Study 2 comprised of the prefabrication and erection of a 300m^2 (3229sq.ft) two storey detached house. For this, the 'structural file' established at detail design stage was used as a template for other work packages associated with Case Study 2. This included drainage and foundation layout. As-built foundation dimensions were taken on-site which replaced the initial design dimensions within the 'structural file' to ensure complete accuracy of wall, floor and roof panels. All window & door dimensions were double checked to ensure accurate fitting within a 10mm tolerance. The first floor truss joist I-beam (TJI/TGI) system design was another element based on the revised 'structural file'. This ensured that the ground floor, first floor and roof parameters lined up exactly as illustrated in *Figure 18* and *Figure 19*

Figure 18- 3D Design File

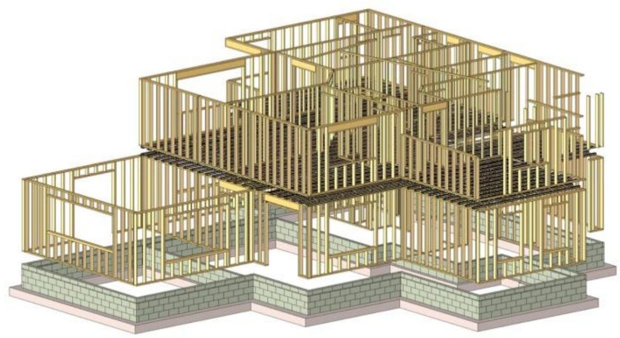

Figure 19– 3D Structural File

Construction of case study 2 was made exceptionally simple by the attention to detail of every panel produced in the factory. A total of 65 wall panels were manufactured and assembled on site with 100% accuracy and precision. The erection of the ground floor walls, intermediate floor TJI beams and first floor wall panels took four days with no delays caused by dimensional inaccuracies. Further to this, the entire roof component of the project was pre-assembled at the factory location before being dis-assembled in panel format and taken to the site location. The roof was then erected in one day and rested within a 10mm tolerance on the first floor wall plate.

This systematic approach to Case Study 2 is representative of the developed understanding and appreciation of the IPD process by Company A. Throughout this project, clear communication between contractor, designer and client was maintained and information was frequently circulated between all parties. This ensured that all panels were prefabricated in the correct sequence and more importantly to the correct dimensions preventing any issues with on-site assembly later in the project. Although this consumed more time at detail design stage than expected, time was saved at construction stage through the elimination of possible delays on-site.

Conclusions and reflection

The adoption of IPD by Company A led to the eventual standardisation of the company's overall construction process. Case Study 1 provided an opportunity to adopt IPD however, the transition from the traditional method of project delivery did not run smoothly as the open, free-flowing communication between client, contractor and designer did not materialise. Although there was miscommunication leading to on-site delays, the potential of IPD to work within the company's structure was apparent and more importantly, the company were still keen to draw on the benefits of IPD. Assessing the mistakes of Case Study 1 and implementing an effective IPD system had been paramount to the company's improvement in terms of design, manufacturing and on-site assembly of Case Study 2. Both the design and management faculties of the company developed a stronger working relationship through the course of Case Study 2. Issues or queries relating to design or assembly were dealt with in an effective and collaborative manner. This is typical of the implication of IPD and demonstrated the company's commitment to using this method of project delivery.

The level of off-site construction in Case Study 2 required particular attention and focus in the organisation of the walls, floors and roof elements. Co-ordinating these particular aspects of the build was made easier by the use BIM software. BIM controlled the dimensions and layout of the entire project allowing for precision in the manufacture and positioning of all the elements. This reduced the complexity of the building by stripping each element down to its individual structural unit and streamlining the manufacturing process. The production and assembly process was simplified by the earlier involvement of all parties to the project. This provided further focus on cross-checking and improving standards throughout the entire project.

The ease of on-site construction is testament to the influence of the IPD process on company A, when contrasting both project 1 and project 2; the difference in approach and willingness to adapt to the IPD system is evident. As previously stated, it is not feasible to compare both projects in terms of costing however, in terms of project efficiency and the effective delivery of a prefabricated, off-site building the cohesion and co-operation demonstrated during the course of project 2 suggests that IPD is very beneficial in relation to a project controlling process. Undoubtedly this translates to a more cost effective approach as the number of production errors, on-site modifications and assembly delays are reduced if not eliminated completely. The success of an IPD system hinged largely on the total immersion of Company A into the process. Without the support of all parties to the project the full benefits of IPD system would not be realised. The IPD process will be utilised and developed further by Company A to ensure quality and standards are continually developed for all future projects.

As outlined in Case Study 2, an efficient and dynamic IPD team structure can be the difference between a successful project or a commercial failure.

References

AIA. 2007. *Integrated Project Delivery: A Guide*. California USA.

Autodesk. 2012. Autodesk - Building Information Modeling - About BIM.

Cooke, B. & P. Williams. 1997. *Construction planning programming and control*. Basingstoke: Macmillan.

Eastman, C. M. 2011. *BIM handbooka guide to building information modeling for owners, managers, designers, engineers and contractors*. Wiley. http://0-lib.myilibrary.com.ditlib.dit.ie/?id=307247 (last accessed.

Forbes, L. H. & S. M. Ahmed. 2011. *Modern construction : lean project delivery and integrated practices*. Boca Raton, FL: CRC Press.

Greenhalgh, B. & G. Squires. 2011. *Introduction to building procurement*. London ; New York: Spon Press.

Hairstans, R. 2010. *Off-site and modern methods of timber construction : a sustainable approach*. Buckinghamshire: TRADA Technology.

Halpin, D. W. 2011. *Construction management*. Hoboken, N.J.: Wiley.

Lévy, F. 2011. *BIM in small-scale sustainable design*. Hoboken, N.J.: Wiley.

Ruske, W. 2004. *Timber construction for trade, industry, administration : basics and projects*. Basel, Switzerland: Birkhäuser.