A Technology Platform for a Successful Implementation of Integrated Project Delivery for Medium Size Projects

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Abstract –

Traditional project delivery methods are inflexible for projects that require a high level of collaboration among project teams as well as present challenges to innovative design and construction approaches. In today's era, projects are executed at a faster pace at the early stages of scope definition. This causes a high cycle of requests for information (RFI), change orders, and disputes. To address this issue, a framework for implementing IPD to a medium-size energy project from the engineering phase to the commissioning phase was developed. The framework consists of 1) project stakeholders classification; 2) disciplines identification; 3) relationships, responsibilities; and objectives matrix, and 4) monitoring, control, and feedback. The framework was implemented using Building Information Modelling (BIM) platform and project Document Management System. Synchronizing everyone's objectives in the framework and ensuring these objectives are achieved is a strategy for the success of the project's delivery. The framework was implemented using actual project and was able to enhance design and construction coordination and reduce project cost by 20% and cut project duration by 25%. However, stakeholder coordination and availability of technologies pose a challenge for the successful implementation of the framework.

Keywords –

Integrated Project Delivery; Building Information Modeling; Construction Information System; Construction

1 Introduction

Increased collaboration in the architecture, engineering, and construction (AEC) industry is integral in responding to construction deficiencies within complex projects. These deficiencies are common among nearly all projects and, within traditional delivery methods, responses to them include late, disconnected decision making that results in more rework, schedule overrun, and a high number of requests for information (RFI). The American Institute of Architects defines integrated project delivery as "a project delivery method by a contractual agreement between a minimum of the owner, design professional, and builder, where risk and reward are shared and project team's success is dependent on project success" [1]. Since its introduction to the industry about 15 years ago, professionals have had a high level of optimism for Integrated Project Delivery (IPD) becoming a reliable and accepted delivery method [2].

Construction projects are complex, dynamic in nature and subjected to cost, time, and scope deviations. When these deviations inevitably occur, workers investigate and often submit an RFI to the architect. IPD has provided an approach to communication problems that results in ongoing collaboration and quick responses to deviations. In general, the latest uses of IPD on projects have mainly produced fewer change orders, decreased project timeline, fewer costs, and incidentally fewer requests for information [2]. However, the limitations of IPD still exist. The current research on IPD has dealt with its performance, potential collaboration techniques, pairing with BIM, contractual implications, and adoption into the industry. There is a knowledge gap on the structure of implementation, the mechanism of interactions among the project players (design and construction), and required supporting technology. We claim these are three elements responsible for the failure associated with IPD implementation.

Building Information Modeling (BIM) is a powerful technological tool that provides a rich 3D model with digital information of the project to stakeholders. Furthermore, and more importantly, BIM acts as a "shared knowledge resource for information about a facility (physical and functional) forming a reliable basis for decisions during its lifecycle from inception onward" [3]. BIM has closed many gaps on the issue of interoperability and is most efficiently used in conjunction with a document management system and a common information exchange software, such as

Industry Foundation Classes (IFC) or BIM Cloud, that tackles the difficulty of diversity between software [4]. Future research efforts need to focus on a sophisticated and diverse implementation of BIM and the associated technologies to support the smooth adoption and implantation of the IPD [5], additionally the socio technical implications in the flow of production within a given project [6].

IPD is an emerging method of delivering complex projects and projects that require a higher overlap between design and construction. This method is an efficient tool to apply when integrated collaboration, cost, and schedule are major constraints for the successful delivery of the projects. However, implementing this method successfully in the AEC industry continues to be a challenge, especially for medium size projects or inexperienced project stakeholders with IPD. Other challenges are also observed in selecting the right technology for implementation (BIM, cloud based-data management system for design and as-build data, and the implementation infrastructure).

This paper proposes a framework to assist owners to implement IPD to medium-sized projects and allow them to measure project performance based on several metrics. These metrics include customer satisfaction, safety, quality, cost, and schedule. The framework is made possible by IPD and BIM implementation and describes the relationships and responsibilities of stakeholders within each phase of the project lifecycle.

2 Literature Review

2.1 Why IPD Should Be Implemented

The AEC industry has struggled for a long time with low productivity, cost overrun, schedule delay, and a high number of change orders and rework. One of the main reasons for these issues is impeded in the rigid mechanism of delivering projects. In comparing IPD with other delivery methods, IPD produces fewer change orders, cost savings, and a shorter schedule [2]. Additionally, traditional project delivery methods contain ten RFI per one million dollars and a 2-week processing time, compared to an IPD project, which contains two RFI per one million dollars and 1-week processing time [7]. IPD represents a hope to overcome many of the problems that the AEC industry faced for decades without a rigorous solution. Many studies have shown that the AEC industry is the only industry that did not show signs of productivity improvement for a long time and still this issue continues to be the main cause for high waste in the construction industry. IPD has proven its ability to increase efficiency and save resources in construction projects. However, successful implementation of the method represents the main hurdle in current practices.

2.2 Basic Strategies for Implementing IPD

There are 2 basic strategies for implementing IPD in the AEC industry: heavy collaboration among project stakeholders and adopting an advanced design and data management system.

To achieve collaboration, it is helpful to use a platform that allows for shared knowledge between major parties. The "big room" in design refers to the physical shared space for early design development that includes all necessary parties. For medium-sized projects, the big room can be tricky to maintain because many of the employees might have several projects at once and may not be in the same geographic area [8]. This obstacle was carefully weighed in our implementation of a virtual big room with many participants, similar in principle to past research [8][9].

Along with collaboration, the right technology must be used. BIM provides an integrated platform for live feedback and collaboration. BIM gives foresight to the different proposed possibilities of the project beforehand and visualizes necessary changes during for clarity of the project managers [10]. In the Autodesk HQ construction case study, a BIM execution plan was established and moved forward with at-risk subcontractors having been BIM-enabled [11]. This allowed for constant feedback during the design phase from the builders who knew construction processes well.

IPD allowed for scope changes totaling 30% in this project [11]. Furthermore, when a hefty design change was requested from the owner, the design firm acted quickly to provide a virtual walkthrough using BIM of the proposed change within a week of the request, allowing the owner to make an informed decision on the change [11]. The integration capabilities of BIM make it appealing to any construction project because of its time and cost estimation capabilities [12]. BIM is most useful in an IPD project because of its allowance for multi-user access and contributions to the model [4]. The following is an excellent descriptor of how BIM can aid in IPD:

"The project team can deal and interact with a unified model when a composite model is built from an amalgam of various disciplines' models. Having this capability, and through the different phases of a construction project, BIM can coordinate the design, analysis, and construction activities on a project and, therefore, results in integrity of projects." [13]

2.3 Gaps in prior research

It is crucial that we identify the basic components of IPD which include a multi-stakeholder contract, rigorous collaboration and coordination, and technology usage.

However, we also identified a knowledge gap with a few implementation factors. We are defining this necessary knowledge gap as:

The methods of collaboration between stakeholders and their subsequent responsibilities during each phase of construction in IPD.

This gap demands a system to define the methods of collaboration, which includes classifying the stakeholders, defining the relationships, responsibilities, and objectives between stakeholders, and monitoring the construction through constant feedback. If chosen to perform, stakeholder analysis and classification are usually done by the project manager [14], but in our IPD framework, the responsibilities will be distributed among the major stakeholders based on the accepted framework. This is supported by the conclusion that an iterative process that includes cooperation between major stakeholders on their classification is more effective than considering it a desk task by one individual [14]. A simple classification of stakeholders includes key members, key supporting participants, tertiary stakeholders, and extended stakeholders [15]. An IPD framework has been defined in the past with macro and micro aspects, but we are more interested in one of the micro aspects: information design [16]. In IPD, information must be the common basis of understanding for all stakeholders, and information must be accessible, available, and reliable [16]. Due to the lack of research linking information design to collaboration, we are interested in the relationships shared between stakeholders as they utilize our information framework.

3 Integrated Project Framework

IPD is set apart from other delivery methods in the unique early stages of project planning and communication, wherein every player in the project, regardless of their role, must be incorporated into planning and development before the design is finalized to optimize the usage of IPD. This enhanced collaboration is hard to achieve and requires shared project planning goals and a rigid strategy for communication. For us, this meant putting a system in place so that the implementation of the technology is smooth. The following system is a step by step procedure through the entirety of the project that can be agreed upon by the major stakeholders. The system has been divided into 5 stages: qualification, bidding, pre-construction,

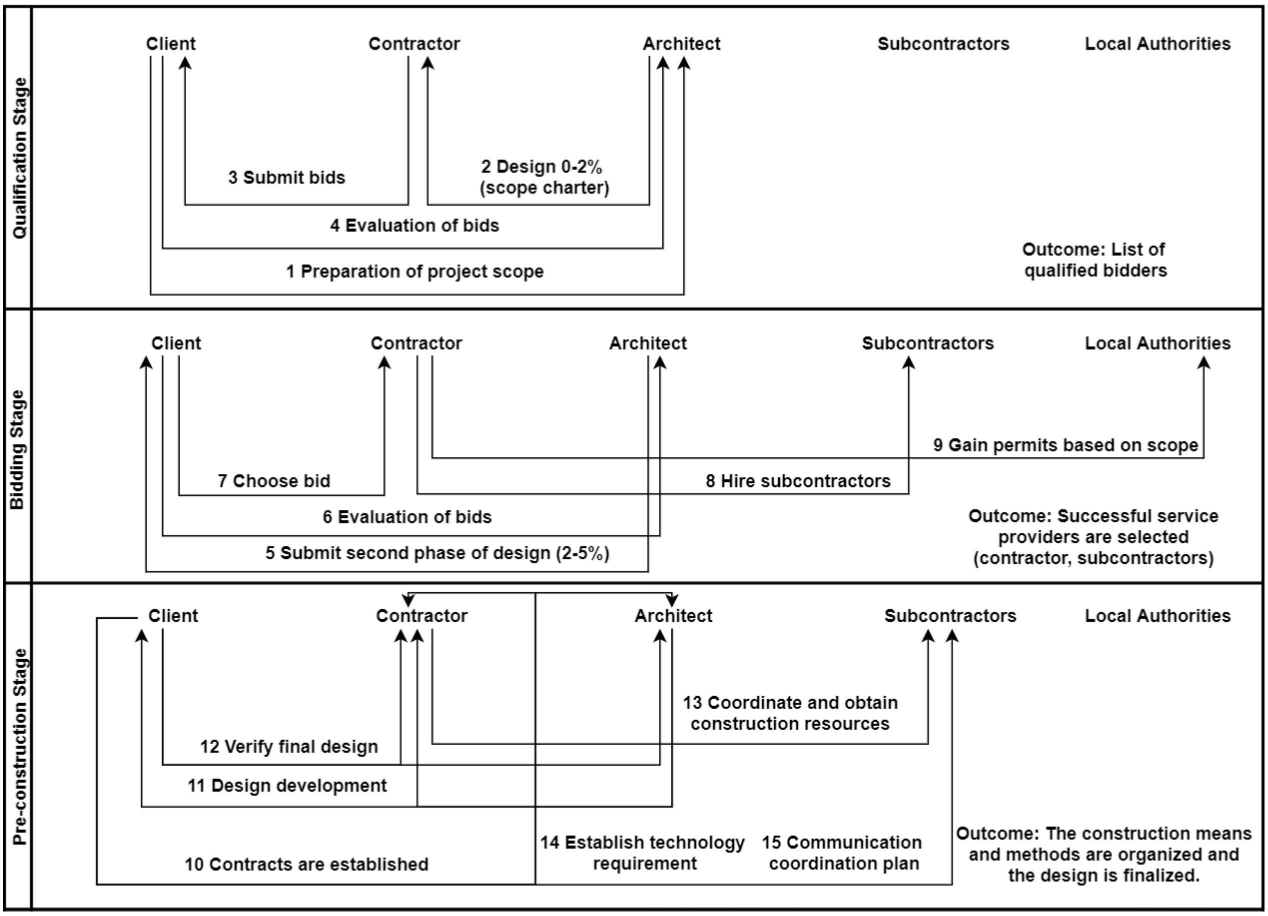

Figure 1. First 3 Stages of the IPD Implementation Framework

construction, and closeout as illustrated in Figure 1 and Figure 2. Each step is organized chronologically, and the final step of each stage is followed closely by the first step of the next stage. The most important phase in our research, the construction stage, contains many moving parts and will be organized in a different way than the other stages.

3.1 Qualification Stage

The first stage is named the qualification stage because the main outcome of this stage is the client having a list of qualified bidders, as shown in Figure 1. This stage is an early stage in the project and should involve the client and the architect only. This is because there is a need to create the project framework and the scope charter. The project's goals and expectations come from the client and are communicated to the architect for better refinement. This stage begins with the client preparing the project scope and delivering it to the architect, who reviews the scope and develops a high-level schematic design. The high abstract of the project's scope lays out the project's goals and necessary design and construction work, and a clearly defined scope main framework necessary in avoiding design delays and cost overruns [17]. Then, the architect will begin the design based on the initial scope of work and the schematic designs. Up to 2% of the Front End Engineering Design (FEED) put together by the architect along with Request for Qualification (RFQ) is shared with the client so the client in collaboration with the architect solicits interested prime contractors in executing the project within the IPD environment. The interested contractors will then submit the qualification to the client for evaluation. In IPD, this step includes the architect evaluating the bids with the client because of the architect's knowledge of the design. The qualification stage results in the client having a list of qualified service providers, which allows the team to move into the bidding stage.

3.2 Bidding Stage

In the bidding stage, there are a variety of steps required which involves every party, as shown in Figure 1. The outcome of this stage is that the service providers are selected, which includes the contractor and subcontractors. This stage begins with the architect submitting the second phase of design (2-5%) to the client, followed by the bidding for the project by the selected list in the first stage, then the successful bidder will be selected. All submitted bids must include the major subcontractors and their qualifications for the successful implementation of the IPD. This step is very essential to ensure every stakeholder is going to function in an integrative type of design and construction environment. Contractual obligations and terms are stated in this stage among all parties. Clear expectations of schedule, tasks, deliverables, coordination, cost, frequency of data update, and meetings are stated at this stage. From the authors' experience, the mechanism of implementation can be overwhelming to many subcontractors due to the unfamiliarity with the IPD. Equality important, the implementation technology platform for all parties involved should be created at this stage through the Technology Execution Plan (TEP). Subcontractors should be involved in creating the TEP and should have access and be familiar with the implementation infrastructure.

3.3 IPD Technology Requirement

Technology infrastructure is the most important aspect of IPD implementation. There is no doubt that IPD became a choice for many owners due to the development of design approaches such as BIM and project data management. Incorporating BIM approach into the IPD process allows project team to utilize the information in an integrative environment. For example, information from design, procurement, construction, quality, and other areas is being received and processed in a way it allows everyone to be informed. This high level of information management is essential for the fast pace of the IPD. To achieve this, however, a technology infrastructure must be accessible to those who are involved. BIM is the main platform to use for design, construction, and commission for the proposed method. The issue that can create problems in using BIM in IPD environment is the interoperability of the project 3D files.

The next part of the technology infrastructure for the IPD is having a system that handles the information receiving, using, and transferring. Many cloud-based tools available such as Procure and Aconex that can be utilized for managing the project information. The strength of the cloud-based tool in the multi-organizations project collaboration, where data can be stored and accessed efficiently. Tasks that include document and correspondence management, workflow automation, request for information, change orders, BIM file management, and more can be reviewed and addressed.

3.4 Pre-Construction Stage

The pre-construction stage contains many vital responsibilities that must be performed effectively for construction to even be possible, as shown in Figure 1. In this stage, the implementation of the technology infrastructure is tested. Flaws in the IPD technology system should be captured in this stage to modify the TEP. Flaws represented through subcontractors include not having the proper technology or the lack of required subcontractors' crew training. For instance, a mechanical subcontractor might be using an IFC complying tool to model the mechanical design part, but files generated from this tool are not properly interoperable with another parametric model generated by the electrical subcontractor. The outcome of this stage is to define the major construction means and methods. After ensuring all project parties are familiar with the project scope and technology, contracts between the contractor and the major stakeholders are established. This includes defining many details, such as the level to which risk and reward are shared, the possible incentives for quality construction, and more. The level of integration of the project, or level to which IPD is implemented, must be defined in the contract and must be agreed upon by all major stakeholders. Following this, an intensive collaboration between the client, architect, and contractor ensues with the goal of developing the design further. IPD is unique in that it brings these 3 major stakeholders into the "big room" before construction is initiated so that any inconsistencies between the design and construction can be worked out. Developing the design among these stakeholders carries through the construction stage but is initiated in the pre-construction stage. The client will verify or request changes to the in-progress design with the architect and the contractor. After verification, the contractor will organize the obtaining of construction resources alongside the subcontractors. Finally, the client will clarify to the architect, contractor, and subcontractors the plan of communication between the stakeholders, which includes the updating of BIM, a communication software, and regular "big room" meetings, and the client will distribute access to the agreed upon technology which will be utilized throughout the project.

3.5 Construction Stage

The construction stage must be closely monitored throughout because there are many actions and cycles working all at once. The outcome of this stage is that the design and construction of the project are finished. The technology platform holds IPD together, as displayed in Figure 2. BIM is the technology that collects and analyses data from every important member during construction. This stage works in a cyclic process and casual feedbacks fashion. For example, if a major stakeholder (architect, contractor, client, or subcontractor) encounters a design or construction issue, they report the issue using the proper technology tools so all other stakeholders can receive the information about the issue. The responsible stakeholder will then update the project data management system (BIM tool) with the necessary answer and information to move forward, whether that be a slight change in design or major change order. Since the subcontractor has continual access to BIM, this process takes the least amount of time in an IPD setting. Processes like these can start on the construction site or from the desk of the client and flow through BIM quickly and efficiently. Useful information that can be accessed in BIM in the construction stage includes equipment, construction processes, materials, quality, subcontractors' contributions, RFIs, change orders, safety guidelines, and environmental compliances. This information is inputted into BIM and used by stakeholders to perform project status tracking, information management, and activity scheduling. These three functions of BIM are optimized by stakeholders through heavy collaboration and on-site monitoring. Project status tracking demands accurate reporting and documentation on design changes which limits contractual issues and cost overruns. Information management of BIM data helps to limit the number of inconsistencies between design and construction. Activity scheduling requires ongoing communication on-site so that stakeholders can plan accordingly to minimize the project's timeline. Through the construction stage, the design is constantly being changed and approved in BIM. The construction project is finished in this stage.

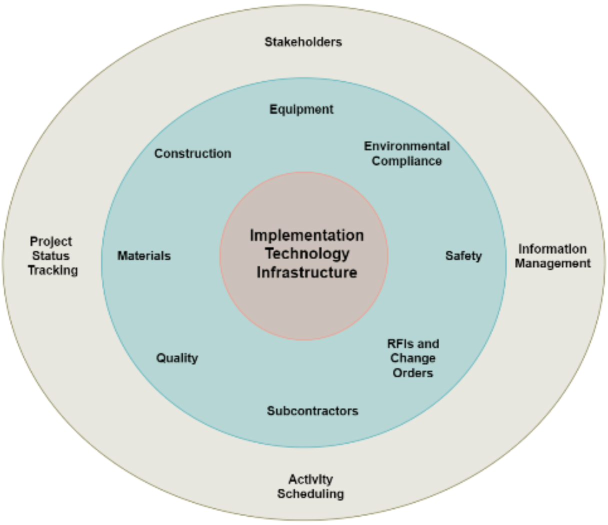

Figure 2. Construction Stage

3.6 Closeout Stage

The closeout stage is an often-overlooked part of the project but must be carried out to ensure success. The client will start by making sure that the design changes inputted into BIM were fulfilled in construction. Then, the client and contractor will evaluate the success of the project based on 5 metrics in Figure 4: customer satisfaction, safety, quality, cost, and schedule. Finally, the client will fulfill the obligations laid out by the contract to the contractor, architect, and subcontractors. Risk and reward sharing are important parts of the contract and are based on the accurate success evaluation of the project. The outcome of this stage is that the final project is evaluated based on 5 metrics and the contractual obligations are fulfilled.

4 Project Success Metrics

There are a variety of factors to consider when determining the success of a project delivery. Some of the main performance metrics considered are execution schedule, project cost, client satisfaction, changes, quality, and safety. Similarly, the success of the project delivery can be measured by interactive processes, contractual arrangements, and project characteristics and participants [18]. Table 1 contains the project success criteria that the authors used to measure the satisfaction of the project stakeholder of using IPD.

4.1 Customer Satisfaction

We measure customer satisfaction by the number of legal claims made by the client and the potential for future business with the other stakeholders. The claims refer to if a mistake in construction is large enough the client will submit a legal claim against the contractor, which adds more time to the closeout stage. The potential for future business refers to the level of project satisfaction of the client based on the specific work of each stakeholder and if the client would do business with them again. A low number of legal claims and a high level of potential for future business results in good customer satisfaction.

4.2 Safety

We measure safety by the number of incidents in construction that occurred and the lost-time due to injuries. The number of incidents is the number of construction accidents by the workers; a high number of incidents reflect poorly on the project's safety. The lost-time due to injuries refers to the time delays after an incident has occurred. A low number of incidents and a small amount of lost time due to injuries results in good project safety.

4.3 Quality

We measure quality by the number of non-conformance reports, the punch list, the number of RFIs, and construction rework. Non-conformance reports refer to those reports that list the failures of adherence to construction and environmental regulations of the final project. The punch list is the report made by the contractor that contains the deviations between the contractual specifications and the final construction product. RFIs, or requests for information, refer to the requests made by the contractor or subcontractors for more information if there is a gap in knowledge of a part of the design. Construction rework is the amount of rework done on the project because of structural or design failures. A low number of non-conformance reports, a small amount of deviations on the punch list, a low number of RFIs, and a low amount of construction rework results in good project quality.

4.4 Cost

We measure cost by cost overrun, change order cost percent, RFIs per unit price, and markups percent. Cost overrun refers to the extra cost to finalize the project based on the original cost laid out by stakeholders. Cost overrun percent is the difference between the actual project cost and the award price over the award price (1).

$$Cost\ Overrun\ \% = \frac{Actual\ Cost - Baseline\ Budget}{Baseline\ Budget}\ x\ 100 \quad (1)$$

Change orders are the requests to add or delete certain parts of the design when in construction. The change order cost percent is the total cost of all the change orders submitted over the actual total project cost (2).

$$Change\ Order\ Cost\ \% = \frac{\sum Change\ Orders\ \ Cost}{Baseline\ Budgte}\ x\ 100 \quad (2)$$

The percentage of the cost impact of the RFIs is the total cost of the add work due to the RFI answers over the project budges cost (3).

Table 1. Project Success Metrics

Customer Satisfaction	**Safety**	**Quality**	**Cost**	**Schedule**
Claims	# of Incidents	Non-Conformance Reports	Cost Overrun	Schedule Overrun
Future Business	Lost-Time-Injuries	Punch List	Change Order Cost %	Constructability
		# of RFIs	Markups %	
		Rework		

$$RFIs\ Cost\ \% = \frac{cost\ of\ added\ scope\ due\ to\ RFIs}{Baseline\ Budget} \text{x}100 \quad (3)$$

The markup percent is the profits for each stakeholder based on the final product. A low cost overrun, a low change order cost percent, a low RFIs per unit price, and a high markup percent result in good project cost.

4.5 Schedule

We measure schedule by schedule overrun and constructability. Schedule overrun is how much construction deviated from the project timeline and is most easily measured by schedule delays, which are defined as the difference between the actual duration and the baseline duration over the baseline duration of the project (4). The actual duration is how long the project took and the baseline duration is the construction time reported by the planned timeline.

$$Schedule\ delays\ \% = \frac{Actual\ Duration - Baseline\ Duration}{Baseline\ Duration} \text{ x } 100 \quad (4)$$

To evaluate the added time to execute the scope described in the RFIs, the RFIs Time % is calculated by finding the total extra time needed to execute the RFIs scope over the baseline duration (5).

$$RFIs\ Time\ \% = \frac{Total\ time\ added\ due\ to\ RFIs}{Baseline\ Duration} \text{ x } 100 \quad (5)$$

The constructability is how easily the project was constructed and kept close to the timeline. A low number of schedule delays and a high level of constructability results in a good project schedule.

5 Preliminary Results and Analysis

The presented framework was developed and implemented for a medium-size gas plant of 120-million-cubic-foot-per-day capacity. The project owner's objective was to complete the design, construction, and commissioning of the project in less than 2 years. The project contract was a Guaranteed Maximum Price (GMP) of 263 million dollars. The IPD implemented was described in the previous sections. The project was completed in 20 months with an actual budget of $220 million dollars. The framework reduced the project cost by 20% and cut project duration by 25%. There was zero Lost Time Injury (LTI). The changes in the project scope were minimal and were easily accommodated. The execution design and construction team established design and construction gates (milestones), which meant if a milestone stage in the design was completed, reviewed, and approved, then there was no need to go back for changes. This was because the next stage involved major equipment sizing and manufacturing. The required equipment usually is of long-lead items and needed to be procured early enough to get manufactured by vendors. Similarly, other critical design gates involved major pipes sizing and power load determination. However, the implementation of the proposed framework involved tedious coordination and high caliber management and engineering skills. The team selected to work on this project was very experienced and of different years of experience. Another major challenge was ensuring the functionality and interoperability of infrastructure technology. Furthermore, some of the vendors on the project were from overseas and ensuring their attendance in the coordination meetings was a difficult task to achieve all the time. The next phase of this IPD framework is to track and analyze the project's performance indicators and then refine the framework for a wide-scale implementation.

6 Conclusions

Integrated project delivery is groundbreaking for the construction industry, but still new and challenging to implement. Forming the right project team that is committed to the main aspects of IPD is essential to the project’s success. Consistent collaboration and usage of the right technology must be considered when delivering an IPD project.

The framework we have laid out focuses on the relationships between stakeholders and their responsibilities during each stage of an IPD project. By adhering to this system, the client can keep the project delivery organized and maintain the efficiency of the contributions from each team member. Our project success criteria are based on the framework and on the researched effects of IPD projects.

We acknowledge the many moving parts of a construction project and advise any clients who want to use our system to plan accordingly because IPD takes a large amount of work to efficiently implement. There are still gaps of knowledge, mainly in the construction stage, due to the increasing capabilities and benefits of construction monitoring in IPD. Similarly, the technology used in the construction stage demands much organization and coordination between stakeholders. IPD linked with BIM has the potential to change the construction industry through increased planning and further research into the relationships between the two.

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