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Investigation into the effects of project delivery methods on LEED targets

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INVESTIGATION INTO THE EFFECTS OF PROJECT DELIVERY METHODS ON LEED TARGETS

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EXECUTIVE SUMMARY

Due to the environmental impacts of buildings and the increased demand for sustainable construction, it is essential that the construction industry can effectively deliver green buildings. The U.S. Green Building Council (USGBC) created the Leadership in Energy and Environmental Design (LEED) rating system to aid in the construction and evaluation of green buildings. The project delivery method, chosen by the owner, can affect the achievement of project targets (e.g., budget, schedule, LEED certification). The most utilized project delivery method is the traditional Design-Bid-Build (DBB). Integrated Project Delivery (IPD) is an emerging project delivery method that has gained attention for the potential to deliver buildings more effectively (i.e. reaching or exceeding project targets) than previous methods. Currently, there is a lack of IPD research regarding green building.

This research compared the most widely used DBB method to the IPD to identify the superior project delivery method for constructing a LEED certified building. Sixteen case studies of both DBB and IPD commercial construction projects in the U.S were studied. The research found that the important contributors to the achievement of LEED certification goals include early involvement of key project participants, collaboration, and use of technology. Although these factors can be utilized with both DBB and IPD project delivery methods, IPD facilitates the use of technology and incentivizes early participant involvement and collaboration. Thus, IPD provides more assurance that project performance targets (e.g., LEED certification) will be met or exceeded. This research recommends the adoption and utilization of IPD as the method of delivery for LEED projects in order to minimize the impact of buildings on the environment.

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ACRONYMS AND ABBREVIATIONS

BD+C – Building Design and Construction

BIM – Building Information Modeling

C&D – Construction and Demolition

DBB – Design – Bid – Build

DOE – U.S. Department of Energy

EPA – U.S. Environmental Protection Agency

HVAC – Heating, ventilation, and air conditioning

ID+C – Interior Design and Construction

IFOA – Integrated Form of Agreement

IPD – Integrated Project Delivery

LEED – Leadership in Energy and Environmental Design

ND – Neighborhood Development

O+M – Building Operations and Maintenance

TVD – Target Value Design

USGBC – U.S. Green Building Council

1 INTRODUCTION

The impacts of buildings are detrimental to the environment. In order to mitigate the impacts, the construction industry has introduced green building strategies. The U.S. Green Building Council (USGBC) created the Leadership in Energy and Environmental Design (LEED) rating system to help building professionals construct and evaluate green buildings (USGBC, 2009). The demand for green buildings in the U.S. has increased over the past ten years due to market demand, client demand, and the establishment of the LEED rating system (McGraw-Hill, 2013). Typically, green buildings are more difficult to construct than standard buildings due to complex systems and higher standards that must be met (Robichaud et al., 2011). With the demand for green buildings increasing, it is critical that the construction industry can effectively deliver buildings with sustainable specifications to meet project goals and to reduce environmental impacts.

Project delivery methods can affect the achievement of project goals (e.g., budget, schedule, quality, and sustainability) (Korkmaz et al., 2011; Alarcón and Mesa, 2015). The most commonly utilized project delivery methods include the traditional Design-Bid-Build (DBB), Construction Management at-risk (CMR), and Design – Build (DB) (Alarcón and Mesa, 2014). Integrated Project Delivery (IPD) is an emerging project delivery method that has gained attention for the potential to deliver buildings more effectively (i.e. reaching or exceeding project goals) than the previously mentioned methods (Alarcón and Mesa, 2014; Asmar et al., 2013). Currently, there is a lack of peer-reviewed references comparing IPD to other project delivery systems regarding achieving green building targets. Thus, this research will be comparing the IPD method to the traditional DBB project delivery method for achieving LEED certification. In order to evaluate the benefits and limitations of IPD and DBB, case study research of 16 construction projects across the U.S. will be utilized.

1.1 BACKGROUND

This section provides foundational information related to the research. The current environmental problems related to construction are described followed by mitigation measures using green building. Then, the LEED certification process is explained in detail. Finally, the project delivery methods used in this research are defined.

1.1.1 ENVIRONMENTAL IMPACTS OF BUILDINGS AND CONSTRUCTION

The operation and construction of the built environment dominates resource use, and contributes to greenhouse gas emissions and landfills. In the U.S., commercial and residential buildings use more energy than any other sector, leading to greenhouse gas emissions (DOE, 2012). U.S. buildings consume 12% of the total water usage primarily for plumbing and irrigation (Kibert, 2008; NIBS, 2008). The construction and demolition of buildings use finite raw materials and add millions of tons of waste to landfills every year. Thus, buildings negatively impact the environment.

In 2010, residential and commercial buildings accounted for 41% of the primary energy consumption in the United States, more than both the industry and transportation sectors (Figure 1) (DOE, 2012). U.S. buildings account for 7% of global primary energy consumption. The high energy demand of buildings is largely due to the need for electricity to operate heating, ventilating, and air conditioning (HVAC) units, to heat water, to run appliances, and for lighting (DOE, 2012; EPA, 2014). In 2010, residential and commercial buildings accounted for 74% of U.S. electricity consumption (DOE, 2012). Due to their reliance on electricity, buildings are a top contributor of greenhouse gases.

Since buildings heavily depend on electricity, the primary energy sources buildings rely on are fossil fuels. Approximately 67% of the electricity produced in the U.S. comes from natural gas and coal (DOE, 2012). Thus, the consumption of electricity is a major contributing factor to U.S. buildings producing 40% of the country's carbon dioxide emissions and 7.4% of global carbon dioxide emissions. Overall, the commercial and residential sectors produce approximately 33% of the U.S. greenhouse gas emissions (Figure 1). Greenhouse gas emissions are the primary cause of climate change (IPCC, 2014). If anthropogenic greenhouse gas emissions are not reduced, then negative impacts to humans and the environment will persist and become more severe.

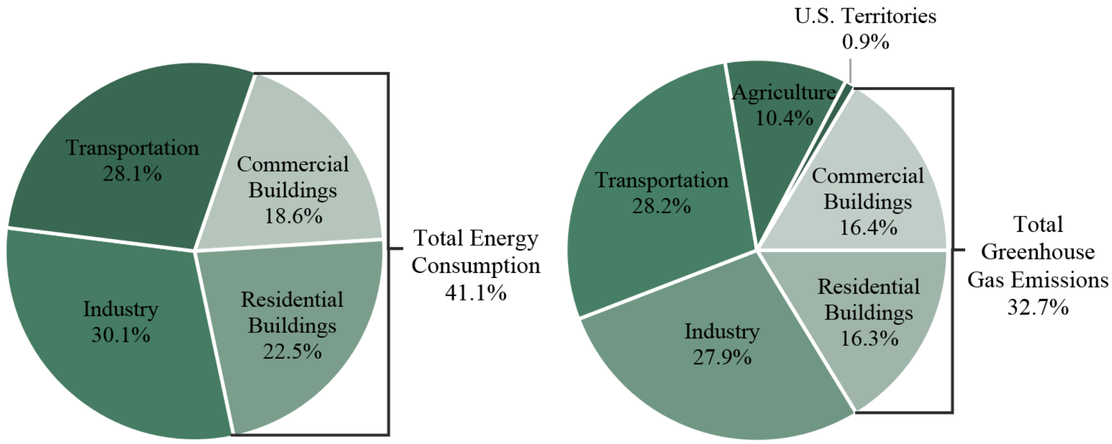

Figure 1. U.S. energy consumption and greenhouse gas emissions by sector (DOE, 2012; EPA, 2014)

In addition to energy, the built environment also consumes a substantial amount of water. Approximately 2.5% of the water on Earth is fresh water, but 68.7% of that fresh water is in the form of glaciers and permanent snow cover (Shiklomanov, 2000). Thus, fresh water that is accessible to humans is a limited resource, especially in arid regions (e.g., the western U.S.) (Shiklomanov, 2000; Kats et al., 2003). Buildings account for approximately 12% of U.S. water usage (Kibert, 2008; NIBS, 2008). Though the uses of water vary depending on the commercial building or residential home, landscaping and bathrooms were consistently the largest water consumers (DOE, 2010; EPA, 2012). Using between 1.6- 6 gallons of potable water per toilet flush is a substantial use of a valuable resource (Kibert, 2008; EPA 2013a). The water usage in buildings and for landscaping is detrimental for humans and the environment.

Furthermore, the construction and demolition of buildings expend natural resources and contribute to landfills. Globally, buildings utilize 24% of raw material extractions (Bribián et al., 2010). The construction industry uses more materials by weight than any other industry (Horvath, 2004; Matos and Wagner, 1998). Additionally, the Environmental Protection Agency (EPA) (2003) estimates that in 2003 approximately 170 million tons of debris was produced from construction, renovation, and demolition of residential and nonresidential buildings in the U.S. Using a materials flow analysis approach, Cochran and Townsend (2010) estimate that the U.S. could have generated between 209 and 242 million tons of construction and demolition (C&D) debris in 2002 if the materials had a typical or a short lifespan, respectively. Approximately 60% of the C&D materials generated are then added to landfills (EPA, 2008). Thus, construction and demolition of buildings extract natural resources and supply landfills which is damaging to the environment.

Due to the large consumption of energy, water, and natural resources and the contribution of greenhouse gas emissions and debris, typical buildings are destructive to the natural environment. However, the built environment is critical to the progress and survival of human civilization; therefore, it is important that buildings are designed and built to reduce their impact. Building professionals are becoming aware of these environmental problems. In order to help solve these issues, green building strategies have emerged in the construction industry.

1.1.2 GREEN BUILDING

In order to mitigate the environmental impacts of buildings, green building strategies are employed. Green buildings are designed and constructed with the intention of reducing resource use (e.g., energy, water, and raw materials), greenhouse gas emissions, and debris with regard to the entire lifecycle of the building. Occupant comfort and health is also a concern in green buildings (Kibert, 2008). There are many different green building methods and this section introduces some examples that can be implemented.

One important green building strategy is decreasing energy consumption. Lighting, space heating, cooling, and ventilation account for 55% of a typical building's energy use and of its carbon dioxide emissions (DOE, 2012). Thus, accurately sizing HVAC components and specifying an energy efficient HVAC system (i.e., utilizing heat exchangers, or demand-controlled ventilation based on occupancy) can reduce the energy use of a building 30-75% thereby lowering carbon dioxide emissions (Harvey, 2009). By utilizing solar energy through passive solar design, the energy to run mechanical systems can be reduced even more (Harvey, 2009). When applying passive solar strategies, the design of a building is site specific and is influenced by the sun and climate. Thus, decisions regarding building orientation, shading, daylighting, passive ventilation, and thermal mass drive the design (Harvey, 2009). As a result, the building does not need to run mechanical systems (e.g., HVAC units and lighting) as heavily. The use of renewable energy sources, like photovoltaics or wind turbines, on a building reduces or eliminates the need for electricity generated from fossil fuels (Kibert, 2008). The green building strategies described are just a few examples that can reduce energy consumption and greenhouse gas emissions.

Additional green building methods include implementing water reduction strategies. Water-efficient and low flow appliances (i.e., showerheads, toilets, and washing machines) use

38-58% less water than standard models (Lee and Tansel, 2002). Replacing older model toilets in U.S. homes with EPA WaterSense toilets would save approximately 520 billion gallons of water every year (EPA, 2013a). Minimizing the need for irrigation, through use of native and drought tolerant plants, can reduce residential water use by 30% in the U.S. (Kibert, 2008; EPA, 2013b). Installing a rain water collection or grey water system can also reduce the use of potable water for landscaping. These examples reveal how conscientious modifications in buildings can have major impacts on water consumption.

Increasing material recovery at the end of a building's life is another way of reducing the negative effects of the built environment. Currently, a building's end of life is typically not considered in the design plan (EPA, 2008). Therefore, recovering materials is labor intensive, expensive, and in some cases impossible if contaminated with hazardous material, like lead based paint (EPA, 2004). Buildings are then demolished and disposed of instead of deconstructed. By designing for deconstruction, a building could be disassembled and the raw materials recovered for reuse in another building (EPA, 2008). Thus, the entire lifecycle of a building is considered. Designing buildings to be deconstructed can save raw material usage and decrease the amount material added to landfills.

Green building in the current construction industry has increased globally. McGraw-Hill (2013) conducted an international survey of building professionals (i.e., architects, engineers, owners, and contractors) to find out how global green building, projects certified or built for certification under a recognized green building rating system, has changed since the last survey conducted in 2009. McGraw-Hill (2013) revealed that firms that conduct 60% or more green projects increased from 13% in 2009 to 28% in 2012. Green construction in the U.S. increased from 2% in 2005 to 48% in 2012. The increase has been due to higher client demand and also because of the established U.S. Green Building Council (USGBC) (McGraw-Hill, 2013).

The USGBC is a non-profit organization formed in 1993. The members of the USGBC formed a committee of diverse building professional perspectives to develop a green building rating system (USGBC, 2009). Five years after the formation of the USGBC, the Leadership in Energy and Environmental Design (LEED) rating system pilot version was launched.

1.1.2.1 *Leadership in Energy and Environmental Design*

In order to provide designers, builders, owners, and operators with a guide to implement, define, and evaluate green buildings, the USGBC developed the LEED green building rating system. Through the creation of LEED, the USGBC's mission is, "to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life" (USGBC, 2009). The pilot version of LEED was released in 1998. Since then, there have been five versions of LEED released with the most recent, LEED v4, in 2013 (USGBC, 2014a). When a new version is released, the previous version is transitioned out to allow the industry time to adapt to the updates (GBCI, 2012). Currently, LEED is in transition from LEED 2009 to LEED v4. After October 2016, projects will only be able to register for LEEDv4 (USGBC, 2014b). The different versions are necessary because LEED is continually evolving to improve, stay current, and expand initiatives.

The five current rating systems are tailored to different project scopes. They include: Building Design and Construction (BD+C), Interior Design and Construction (ID+C), Building Operations and Maintenance (O+M), Neighborhood Development (ND), and Homes (USGBC, 2014a). Within these five rating systems, there are different variations (e.g., new construction, schools, healthcare) depending on the project type, and it is up to the project team to determine the appropriate system (Figure 2). For example, BD+C is for projects that are being newly constructed or undergoing major renovation. Therefore, a project team would select BD+C: Schools for the construction of a new high school (USGBC, 2014c).

Since rating systems are customized by project type, each system has a unique combination of credit categories and credits (USGBC, 2009; USGBC, 2014a). Under each credit category, there are credits that a project can work to achieve. There are points associated with each credit, so the more credits met the higher the point value the project accrues. Depending on the amount of points earned, a project achieves a certification level (Certified, Silver, Gold, or Platinum) (Figure 2) (USGBC, 2014a). One major update with the release of LEED 2009 was credits became weighted based on their life cycle assessment (USGBC, 2012). Previously, the Technical Advisory Committees allocated points for each of the main credit categories, and every rating system had a different number of total points and certification thresholds (USGBC, 2012). Since points are now weighted, each rating system in LEED 2009 and LEED v4 have a consistent total of 110 points and the same certification thresholds (USGBC, 2009; USGBC, 2012). Therefore, any project that completes the prerequisites and earns between 40 to 49 points becomes LEED certified (USGBC, 2014b). The higher levels of certification are: Silver (50-59 pts), Gold (60-79 pts), and Platinum (80+ pts) (USGBC, 2009; USGBC, 2014a).

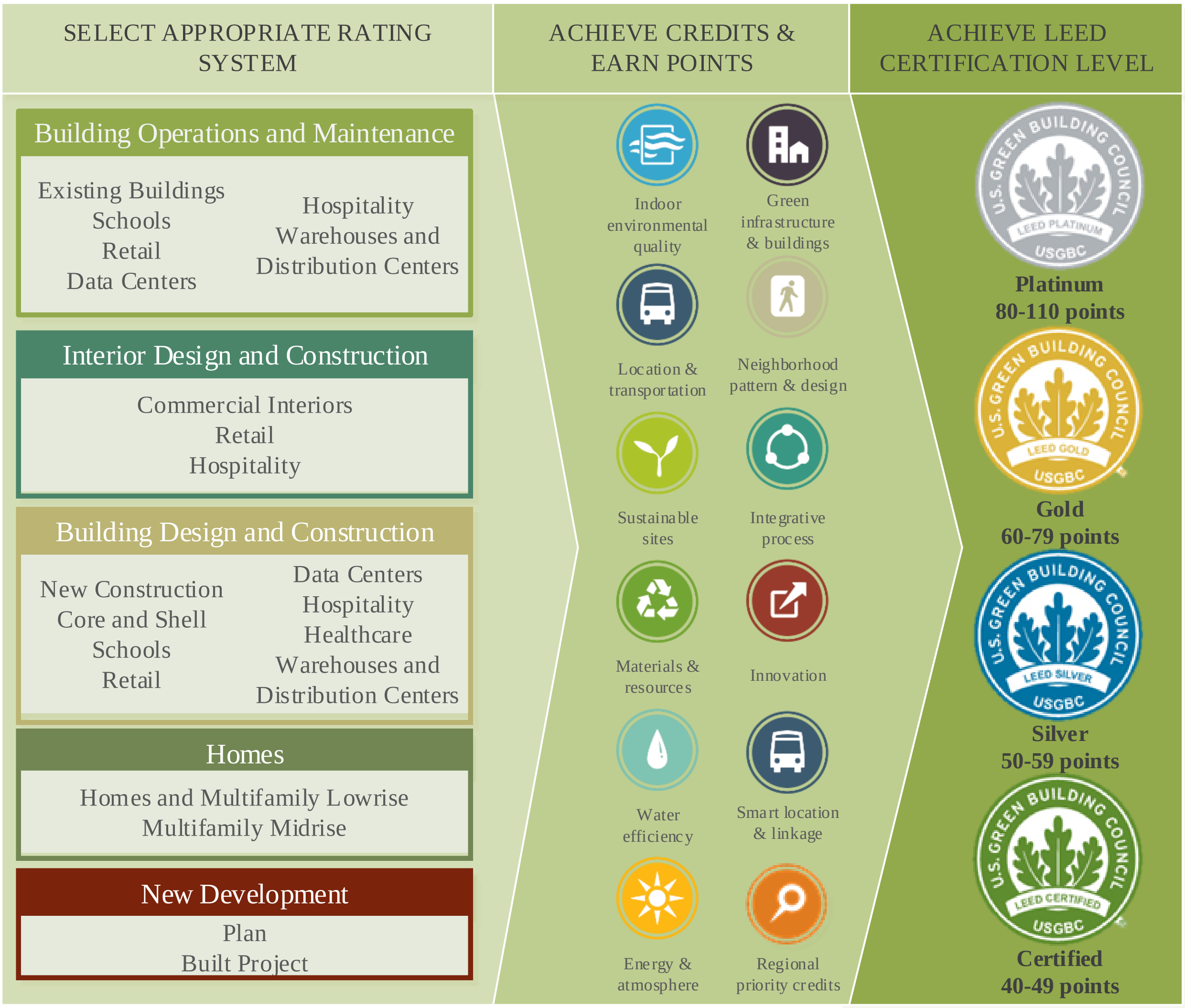

Figure 2. LEED process depicting rating systems, credit categories, and certification levels.

The LEED rating system helps building professionals deliver green buildings. In a survey by McGraw-Hill (2013), approximately 91% of U.S. building professionals had experience using LEED. Globally, respondents believe the top benefit of using a green building rating system is because they help building professionals create a better performing building (McGraw-Hill, 2013). A study by the U.S. General Services Administration (GSA) (2011) found that the LEED Gold GSA buildings used 27% less energy compared to the average U.S. building. Another study found that LEED buildings used an average of 24% less energy than the national average (NBI, 2008). Currently, there are approximately 21,639 LEED certified buildings and 30,563 LEED registered buildings in the U.S. and the number grows every day (Figure 3).

Figure 3. Growth of LEED certified buildings in the U.S. (USGBC, 2015a).

1.1.3 PROJECT DELIVERY METHODS

The design and construction of a building involves several parties, including the project owner, architect, engineers, contractors, and sub-contractors (Jackson, 2010; Lichtig, 2005). The timing and extent of interaction between the parties is determined by the project delivery method chosen by the project owner (Jackson, 2010; Lichtig, 2005; Alarcón and Mesa, 2014). The project delivery method designates responsibility to an organization or individual for providing the design and/or construction services and determines the contractual relationships between the owner and other parties involved in the design, documentation, and construction of the building (Jackson, 2010; AIA, 2011; Alarcón and Mesa, 2014). Currently, the three prominent project delivery methods include, Design-Bid-Build (DBB), Construction Management at-Risk (CMR), and Design-Build (DB) (Alarcón and Mesa, 2014). Integrated Project Delivery (IPD) is a newly emerging project delivery method (Alarcón and Mesa, 2014; Asmar et al., 2013). The focus of this research paper will be on the Design-Bid-Build (DBB) and Integrated Project Delivery (IPD) methods.

1.1.3.1 *DESIGN – BID – BUILD*

The DBB system is the traditional approach to completing a construction project (Ibbs et al., 2003). During the 20th century, DBB was the most commonly used project delivery method in the U.S. (Knochar and Sanvido, 1998; Kent and Becerik-Gerber, 2010) In a DBB project delivery method, the owner has separate contracts with the contractor and with the design team (architects and engineers) (Figure 4). DBB works in a linear structure; the design team completes contract documents (e.g., drawings and specifications) which the owner then uses to get competitive bids from contractors (Ibbs et al., 2003; AIA, 2011). Typically, the owner awards the construction firm with the lowest bid with the contract. Thus, contractors are not involved in the design process of the project and communication goes through the owner (Jackson, 2010). The contractor takes on a majority of the risk in this project delivery system due to the contract structure (Ibbs et al., 2003).

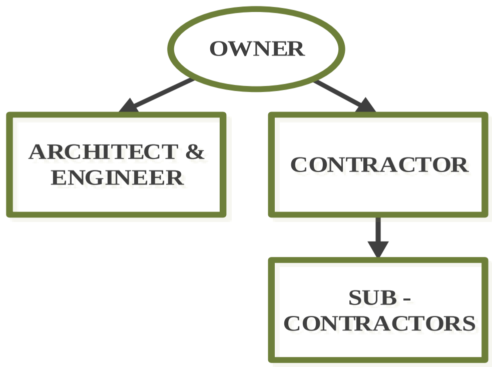

Figure 4. Diagram of Design-Bid-Build contract structure (Jackson, 2010).

1.1.3.2 *Construction Management At Risk and Design – Build*

The Construction Management at-Risk (CMR) project delivery method was introduced in the 1960's as an alternative to DBB (Kent and Becerik-Gerber, 2010). CMR includes a construction manager who not only consults during the design phase but also acts as the general contractor during the construction process (Konchar and Sanvido, 1998; AIA, 2011). The owner still has two separate contracts between the design team and general contractor but the contractor becomes involved in the project earlier compared to DBB (Figure 5). The general contractor can provide the design team with advice about cost and scheduling, and get tasks done in advance like ordering materials and coordinating sub-contractors (Jackson, 2010; AIA, 2011).

The Design – Build (DB) method started to gain popularity in the U.S. in the 1990's (Molenaar et al., 1999; Kent and Becerik-Gerber, 2010). During a DB project, there is only one contract between the owner and a design-build entity (Figure 5). The design – build entity then completes both the design and construction of the project (Jackson, 2010; AIA, 2011). The design – build entity can either be a partnership of an architectural firm and a construction firm, or a joint venture (legal entity for duration of the project), or can be one firm that does both design and construction work (Jackson, 2010). This allows for more collaboration during the entire design and construction process.

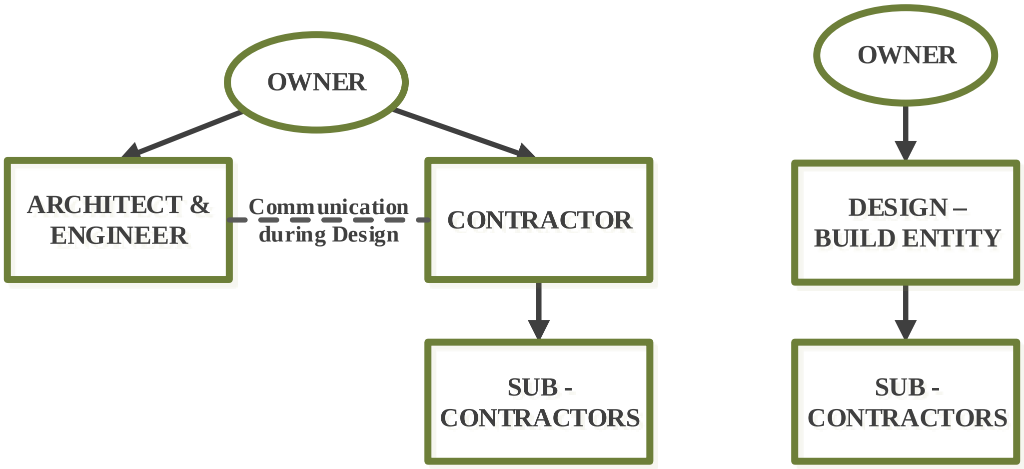

Figure 5. Diagrams of Construction Management at-Risk and Design-Build contract structures (Jackson, 2010).

1.1.3.3 *Integrated Project Delivery*

Unlike the other project delivery methods, the Integrated Project Delivery (IPD) method has one multi-party contract between at least the owner, design team, and contractor but can include trade contractors and key participants as well (Figure 6). The American Institute of Architects (2014) describes IPD as "a project delivery method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction". The IPD approach allows the owner, contractor, architect, engineer, trade contractors, and consultants to collaborate during the entire duration of the project from the pre-design phase through the construction phase (Kent and Becerik-Gerber, 2010; Asmar et al., 2013). In order to incentivize collaboration, the IPD method spreads the financial risks and rewards of the project across all parties (Kent and Becerik-Gerber, 2010; AIA, 2014). Thus, the participants work in the interest of the project in its entirety instead of just their own scope (as is the case in a DBB contract) (Kent and Becerik-Gerber, 2010).

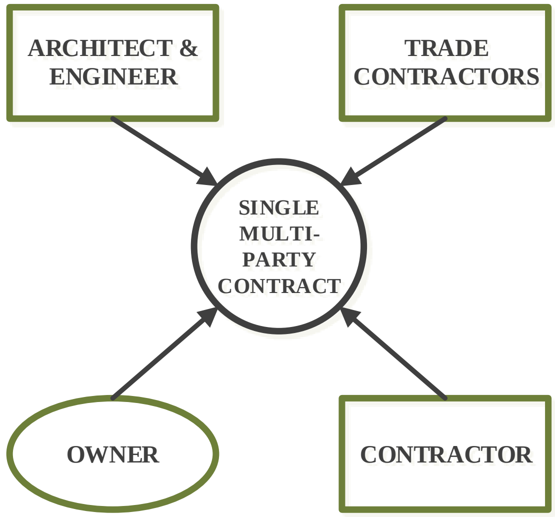

Figure 6. Diagram of Integrated Project Delivery contract structure (AIA, 2011; AIA, 2014).

The defining principles of IPD for this research are emphasized below.

- **Early involvement of stakeholders and Collaboration** – The key participants (e.g., architects, engineers, contractors, trade contractors, consultants) become involved in the project at the earliest possible moment. All the participants collaborate to create design plans and ensure the building will meet the determined targets. Collaboration and communication is continued throughout the entire construction process (Kent and Becerik-Gerber, 2010; AIA, 2014).
- **Multi-party contract** – A single contract including at minimum the architect, owner, and contractor but can include trade contractors and other key stakeholders (Kent and Becerik-Gerber, 2010; AIA, 2014). An integrated form of agreement is an example of a multi-party contract.
    - **Integrated Form of Agreement (IFOA)** – A type of relational contract used in the delivery of capital project developed by Lichtig (2006), that spells out commercial terms for project delivery, promotes the used of lean principles and methods, and is signed by multiple parties agreeing to collaborate on project delivery (Tommelein and Ballard, 2015).
- **Shared risk & reward** – If the project is delivered to meet or exceed its established targets, then profit is shared among the participants and bonuses may be rewarded to the team. If the project does not meet an established target, then part of the profit is deducted. Utilizing

shared risk & reward, aligns all the participants' goals to the success of the project as a whole and incentivizes collaboration (Kent and Becerik-Gerber, 2010; AIA, 2014).

Principles and strategies that are strongly associated with IPD but not mandatory. All definitions come from the lean construction glossary unless otherwise noted (Tommelein and Ballard, 2015).

- **Building Information Modeling (BIM)** – The process of generating and managing building data during the life cycle of a building. The systems comprising an integrated database, one output of which is a 3-dimentional model (Figure 7). 3D BIM refers to the 3-dimensional geometrical model, including spatial relationships, geographic information, and non-spatial properties of building components and systems. 4D also includes time so it may allow for simulation of the building assembly process. 5D further includes cost data so it may allow for cost modeling. 6D BIM refers to a DIM annotated with data so it may support facility life-cycle management.
- **Pre-fabrication** – To use technology (e.g., BIM) and fabricate components off-site at a warehouse and install them on-site (EPA, 2008).
- **Co-location/Big Room** – A designated place for a team to co-locate and maintain a visual workplace.
- **Target Value Design (TVD)** – The practice of defining scope, performance goals, and target cost in advance of starting design, and then steering the design and construction process so as to meet all.

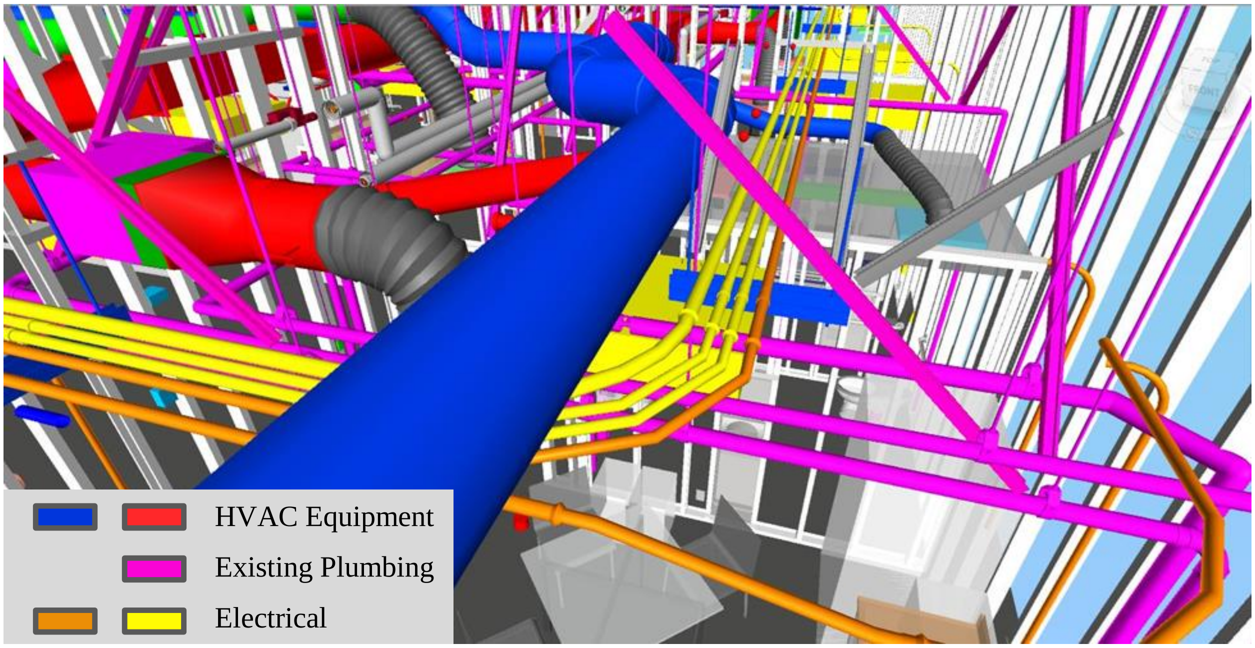

Figure 7. Image of BIM model showing the intricate mechanical, electrical, and plumbing systems (Frandson, 2013).

IPD is a new approach to project delivery. AIA (2014) estimates that there are approximately 200 projects delivered using IPD with a multi-party contract. A 2010 survey of building professionals found that approximately 25% of respondents have not worked on an IPD project and were not familiar with IPD (Kent and Becerik-Gerber, 2010). Approximately 45% of respondents had experience on an IPD project but upon further inquiry only 51% of these respondents used an IPD contract while the others utilized a traditional contract (Kent and Becerik-Gerber, 2010). This study reveals that the construction industry is unaware about IPD and are unclear what constitutes an IPD project. In 2014, McGraw-Hill completed a survey of architects, engineers, and owners to find out their awareness and use of different project delivery systems. It was noted that some of the respondents reporting about IPD may have only had experience with IPD principles and not a contractual IPD project. Approximately 23% of architects and 28% of contractors were familiar with IPD but only 2% of both architects and contractors had experience on an IPD project within the past three years of the survey (McGraw-Hill, 2014). Over 75% of owners had never been involved in an IPD project. The most frequently used project delivery system was DBB (McGraw-Hill, 2014). The most influential reasons owners choose DBB is to reduce costs and maximize the budget. Since IPD is a new project delivery system, IPD is not used frequently and there is confusion surrounding the definition of IPD.

1.2 RESEARCH OBJECTIVES

Green building is critical for environment management and demand is growing rapidly. Project delivery methods greatly affect project performance, thus it is important owners select the appropriate method for their sustainable project (Korkmaz et al., 2011; Alarcon and Mesa, 2015). IPD is a new project delivery method that is gaining interest due to its potential to reach and exceed project goals (Asmar et al., 2013). Currently, there is a lack of IPD research especially related to the delivery of green buildings. This research will compare the traditional and most widely used DBB method to IPD to observe if there is a superior project delivery method for constructing a LEED certified building. Case studies of DBB and IPD commercial construction projects in the U.S. will be utilized. The purpose of this paper is to contribute to green construction and IPD research. The research questions are:

1. Do IPD commercial construction projects in the U.S. meet or exceed their LEED rating target more frequently than DBB projects?
2. Why were the LEED targets missed, achieved, or exceeded?
3. How were the budget and schedule of the IPD projects affected?

2 METHODOLOGY

2.1 INTRODUCTION

This section describes how data was collected for the literature review and case study research. According to Yin (2014), case study work should be conducted when the researcher is trying to answer "how" and "why" questions, the research is contemporary, and the researcher does not have control over the behavioral events. Thus, case study research is utilized to provide insight into whether IPD is the preferable method for delivering LEED buildings.

2.2 LITERATURE REVIEW

The literature review is a collection of current peer-reviewed research regarding project delivery systems and principles of IPD affecting budget, schedule, and sustainability. The primary research databases used were Web of Science, Scopus, and Google Scholar. The main search terms used were integrated project delivery, lean construction, collaboration, green building, and LEED.

2.3 CASE STUDY RESEARCH

In order to compare DBB and IPD projects, it was essential to first define the factors that would be assessed. The DBB projects used in this research are projects delivered using a traditional design-bid-build project delivery method. Some of the DBB projects utilized collaborative approaches (e.g., early involvement of key project participants) and technology which was observed. An IPD project for this research was defined as a project that utilized a multi-party contract. "IPD-ish" has become a term to describe projects that utilize IPD principles (e.g., early collaboration with contractors) but do not use a multi-party contract (AIA, 2014). It was determined that "IPD-ish" projects would not be used because, though they utilized IPD principles, contractually they were not a complete representation of IPD.

It was crucial to objectively determine if a project had achieved its sustainability goal. This was accomplished through the use of the LEED green building rating system since there are specific levels of certification. In order to construct a green building, one of the first steps is a meeting between the initial project participants to determine the project targets including desired certification level (Said et al., 2013). Thus, comparing a project's LEED level target to the actual LEED level achieved would determine if a project missed, attained, or exceeded sustainability goals. This meant that the construction of a project and the LEED certification process had to be complete. Only two projects with a LEED Platinum target were used for each project delivery method since a project cannot exceed the platinum level.

Since meeting budget and schedule targets are typically used to define a project's success, budget and scheduling information was evaluated for IPD projects (Konchar and Sanvido, 1998; Molenaar et al., 1999; Ibbs et al., 2003; Mollaoglu-Korkmaz et al., 2013). Owners reported the primary reason for choosing DBB to deliver their projects was due costs and maximizing the budget (McGraw-Hill, 2014). Thus, an effective project delivery system must meet budget and scheduling goals as well as sustainability goals.

There was no information available regarding budget and schedule targets for the DBB projects so, only the LEED targets were compared. The information available also drove the number of case studies examined. As stated earlier, IPD is a new approach to project delivery and the number of IPD projects with LEED certification is limited. Nevertheless, eight case studies throughout the U.S. were examined for each project delivery method. Information on these projects were collected through web-based research, primarily databases.

The primary resource used to find the DBB projects was the U.S. Department of Energy's (DOE) High Performance Building database (2015). The database is a collection of 119 high performance buildings throughout the U.S. created by the DOE and National Renewable Energy Laboratory (NREL) as a reference for the building industry. The database has basic information about each project including the square footage, companies involved in construction, completion date, etc. Some projects have more detailed information including project delivery method used, goals that were established, and lessons learned. Each description also includes the environmental aspects of the project, including if LEED certification was achieved. The DOE database was searched for projects that used a DBB procurement process and had also achieved LEED certification. The projects that had the LEED target information were used for this research which produced eight case studies.

The IPD case studies by the American Institute of Architects (AIA, 2010a; AIA, 2012) and previous case study work served as the main resources for the IPD projects. The AIA (2012) completed project profiles on twelve IPD projects in the U.S. which contained information such as the contract used, initial and actual budget, initial and achieved schedule, and the sustainability goal. The AIA case studies were a combination of true IPD and "IPD-ish" projects thus, only two case studies could be utilized for this research paper. Other major resources used for the IPD projects include project participant case studies and other researchers' case studies. The research resulted in eight IPD case studies that could be utilized for this paper.

The USGBC database was used to confirm the projects LEED certification. The USGBC (2015b) database, Green Building Information Gateway, includes of all the projects that have registered for or received LEED certification around the world. The project profiles include the number of LEED points achieved, certification level, and the version and type of LEED rating system utilized. DBB and IPD projects were only used if the LEED certification level could be verified through the USGBC (2015b) database and the certification process was complete. Since none of the IPD projects used the pilot version of LEED, there were no DBB projects used that had been certified under the pilot version in order to keep some consistency between the LEED rating systems. The LEED rating systems used by the DBB case studies include BD+C: New Construction, Schools, and Core and Shell and the versions were v2.0 or higher. The LEED rating systems used by the IPD case studies include BD+C: New Construction, Healthcare, and Core and Shell and ID+C: Commercial Interiors. The LEED versions used by the IPD projects were v2.0 or higher.

In summation, sixteen case studies were assessed for achievement of sustainability goals (i.e. LEED certification targets). Eight of the projects were delivered using DBB and the other eight using IPD. The IPD projects were further assessed for achievement of budget and schedule targets. The case studies will be compared to provide insight into the superior project delivery system to construct LEED buildings.

3 LITERATURE REVIEW

Strategies to reduce inefficiencies within the construction industry and improve project performance have been researched for decades (Paulson, 1976; Konchar and Sanvido, 1998; Ibbs et al., 2003). Construction projects frequently have problems with low productivity, exceeding the budget and schedule, and not meeting quality expectations (Kent and Becerik-Gerber, 2010; Alarcón and Mesa, 2014). Approximately 50% of construction time is spent on non-productive work and wasteful activities (Thomas, 1990; Horman and Kenley, 2005). Adding to the complexity of construction, green buildings are more involved than traditional buildings because they require more planning, documentation, and specific construction practices, materials, and mechanical systems (Robichaud and Anantatmula, 2011; Said et al., 2013; Mollaoglu-Korkmaz, 2013). In response to the challenges faced by the construction industry, different project delivery methods and strategies have emerged. Although, the traditional Design-Bid-Build remains to be the most widely used project delivery method (McGraw-Hill, 2014).

3.1 PROJECT DELIVERY METHODS AND PROJECT PERFORMANCE

As different project delivery methods are utilized, research is done comparing the effectiveness of achieving project performance (e.g., cost, time, and sustainability). Paulson (1976) found that early involvement of contractors can lower project costs. The project participants have the greatest control of the costs the earlier in the project thus, making more informed choices in the design phase can reduce the final costs (Figure 8). Contractual agreements that increase the exchange of construction and operations knowledge during the design phase should be utilized. Furthermore, owners that keep project costs low with competitive bidding (e.g., Design-Bid-Build) compromise design quality and craftsmanship and as a result, will pay more long term costs due to greater operations and maintenance expenses (Paulson, 1976). Although Paulson published these ideas in 1976, the concepts are still relevant and reflected in current project delivery assessments.

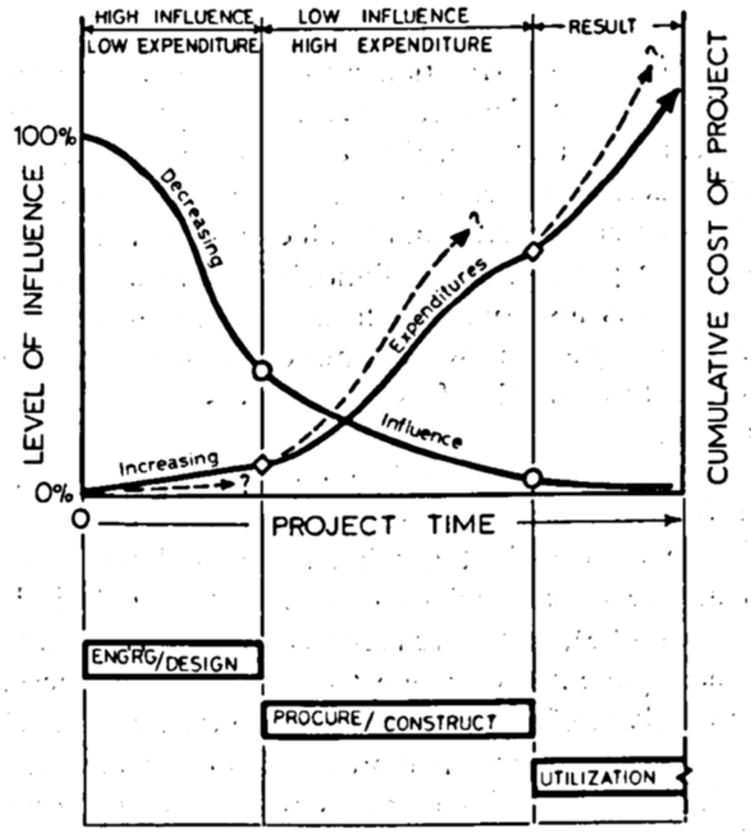

Figure 8. Level of influence on final project costs (Paulson, 1976)

Since 1976, there has been quantitative research studying how Design-Bid-Build (DBB), Construction Management at-risk (CMR), and Design-Build (DB) affect budget and schedule. Konchar and Sanvido (1998) used multivariate regression models for unit cost (R^2=99%), construction speed (R^2=89%), and delivery speed (R^2=87%) to compare the project delivery methods. DB projects were delivered for 4.5% less than CMR and 6% less than DBB in unit cost. The construction speed of the DB projects was 7% faster than CMR and 12% faster than DBB (Konchar and Sanvido, 1998). The project delivery speed (design and construction) was 23% faster than CMR and 33% faster than DBB. The quality of the DB projects were equal to CMR projects but significantly better when compared to DBB projects (Konchar and Sanvido, 1998). For example, the DB projects surpassed DBB projects in quality of operations and maintenance (p=0.024), and building structure (p=0.008). Thus, DB resulted in superior project outcomes over CMR and DBB project delivery methods. Molenaar et al. (1999) studied public-sector projects delivered using DB. The findings reflect the cost and time savings of DB projects reported by Konchar and Sanvido (1998). Of the projects studied, 59% had 2% or less budget growth and 77%

of projects had 2% or less schedule growth. Ibbs et al. (2003) compared performance of DB and DBB projects and found that the DB projects had time saving benefits but the cost benefits were questionable. Ibbs et al. (2003) emphasized that the proficiency of the project team greatly influences the project performance not simply the project delivery system used. If implemented properly, the DB project delivery method can result in projects that are designed and constructed more quickly, at a lower cost, and without compromising quality compared to CMR and DBB projects.

Mollaoglu-Korkmaz (2013) observed similar results when comparing 12 in-depth case studies of LEED certified projects that utilized DBB, CMR, or DB project delivery methods. High levels of team integration (e.g., early contractor involvement, multiple forms of communication) resulted in superior project performance (e.g., achievement of LEED certification, cost, and schedule targets). Projects with more team collaboration had a greater probability of exceeding the LEED certification goal (Mollaoglu-Korkmaz, 2013). Although team integration was possible with DBB, the DB and CMR project delivery methods facilitated greater team integration. Overall, DB and CMR projects resulted in higher performance outcomes compared to DBB projects.

The figure presented by Paulson in 1976 was expanded to represent the benefits of Integrated Project Delivery on project costs. Introduced in 2004, the MacLeamy Curve represents when the majority of the design work is completed in an IPD method compared to traditional DBB method (Figure 9). When major decisions are made far along into the project, they cost more to implement. Thus, IPD is theoretically a more cost effective approach to designing and constructing buildings. In a comparison of a two similar hospital projects, one delivered with CMR and the other IPD, the cost savings of IPD were apparent (Bilbo et al., 2014). Although, CMR was more effective at controlling schedule. Bilbo et al. (2014) concluded that CMR and IPD are both effective project delivery methods due to the early involvement of project participants.

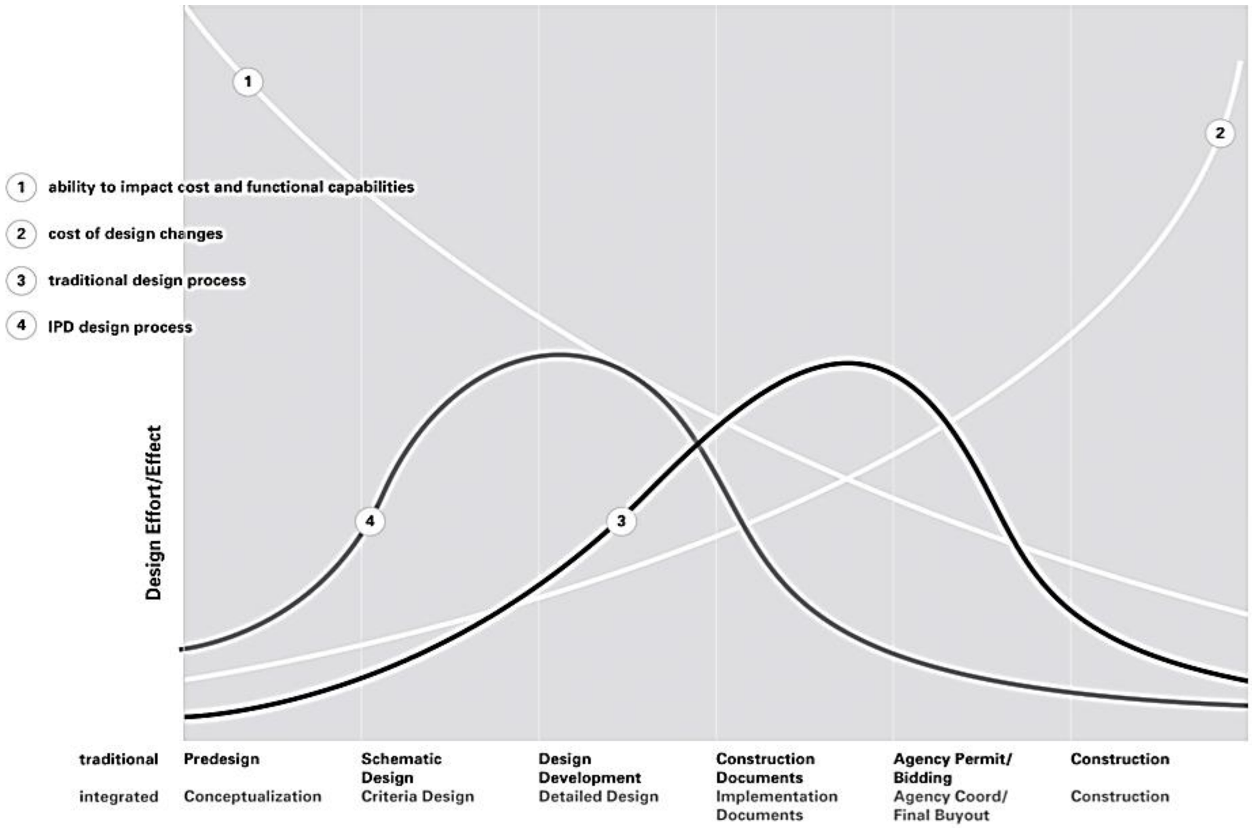

Figure 9. The MacLeamy Curve - IPD and DBB design effort in relation to level of influence on project costs (AIA, 2007; Mossman et al., 2010)

In a statistical analysis of IPD projects compared to non-IPD projects, IPD produced significantly better outcomes (Asmar et al., 2013). The non-IPD projects were defined as DBB, CMR, and DB projects. The IPD projects outperformed the non-IPD in quality, specifically deficiency issues (p=0.001) and systems quality (p=0.032). The delivery speed (p=0.046), which includes design and construction, and change order processing time (p=0.000) for IPD projects was significantly faster (Asmar et al., 2013). IPD projects also produced fewer tons of material waste (p=0.022) than non-IPD projects. There was no significant difference in cost comparisons. Asmar et al. (2013) concluded that IPD produces better quality projects faster and without higher costs compared to DBB, CMR, and DB project delivery methods.

Overall, utilizing IPD results in better project outcomes compared to DBB. Paulson (1976) identified the benefits of early contractor involvement for project costs and quality. These ideas were then reflected in both qualitative and quantitative research comparing DBB, CMR, and DB (Konchar and Sanvido, 1998; Molenaar et al., 1999; Ibbs et al., 2003; Mollaoglu-Korkmaz et al., 2013). DB enables early involvement of contractors and DBB typically does not. Thus, DB projects had higher performance outcomes than DBB projects for costs, delivery time, quality, and LEED certification (Konchar and Sanvido, 1998; Molenaar et al., 1999; Ibbs et al., 2003; Mollaoglu-Korkmaz et al., 2013). Due to the multiparty contract and shared risks and rewards, IPD facilitates collaboration and early involvement of project participants (e.g., contractors and trade contractors). Thus, IPD resulted in higher project outcomes for quality, delivery time, and construction waste production compared to non-IPD projects (Asmar et al., 2013). While Asmar et al. (2013) did not find any significant cost differences between IPD and non-IPD projects, Bilbo et al. (2014) found IPD to have cost savings over CMR. Since DB had better cost performance over DBB, one can conclude that IPD would have similar results compared to DBB projects though more research is needed. The previous research reveals that IPD projects have better project performance compared to DBB projects.

4 CASE STUDY RESEARCH

The case study research resulted in sixteen construction project case studies across the U.S (Figure 10). The majority of the projects were hospitals and schools (Figure 11). There were a mix of LEED certification levels achieved by the projects for each project delivery system.

Figure 10. Map of case studies

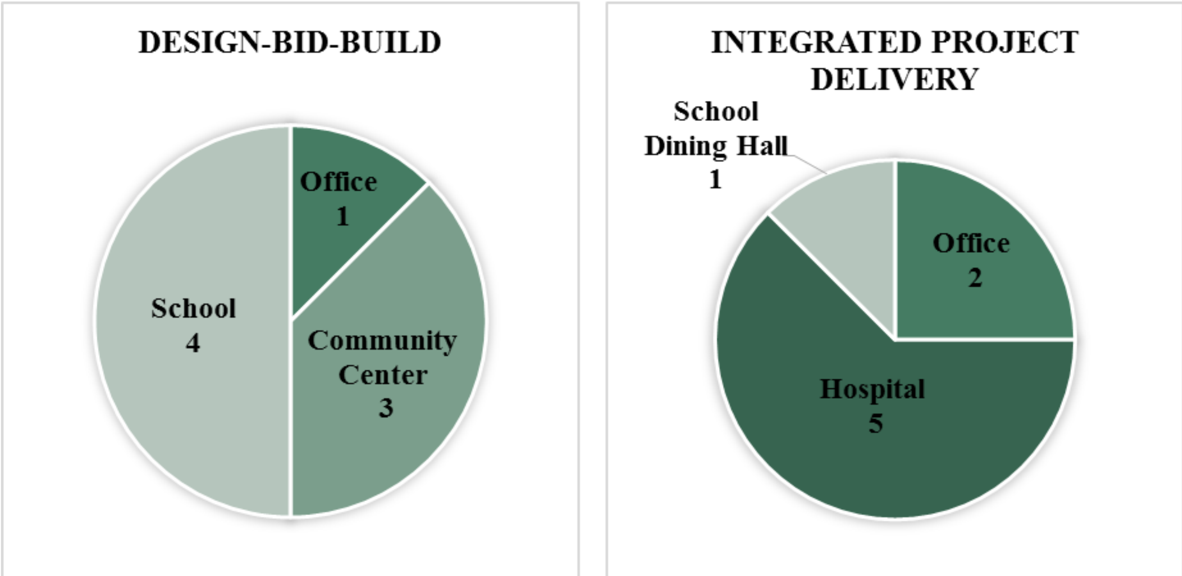

Figure 11. Types of buildings represented in the case studies

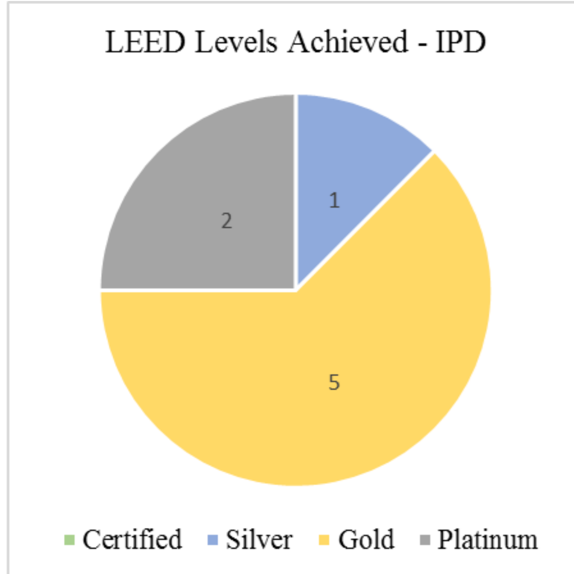

Figure 12. LEED certification levels achieved

The comparison of the case studies revealed that LEED certification goals can be met with both DBB and IPD project delivery methods. Six of the DBB projects achieved their LEED target and one exceeded their target (Figure 13). Three of the IPD projects achieved their LEED target and five of the case studies exceeding their target (Figure 13). The IPD method resulted in more projects that exceeded their goal and none of the IPD projects missed their LEED target.

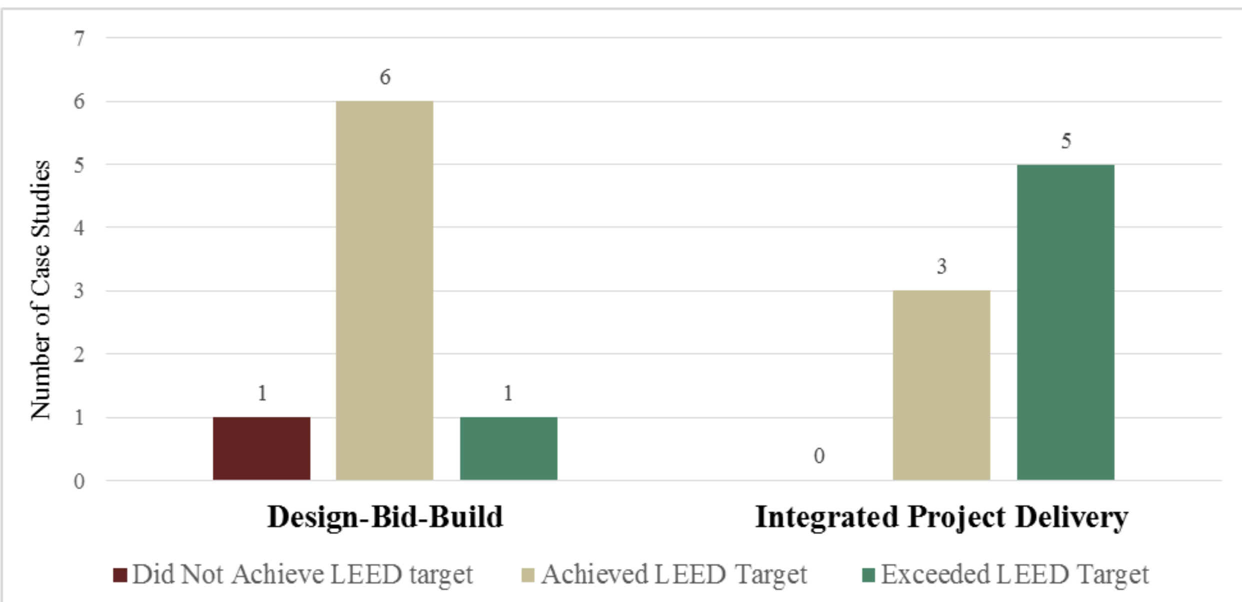

Figure 13. Comparison of LEED targets achieved with DBB and IPD.

The schedule and budget targets were also evaluated for the IPD case studies. There was one project that did not achieve the schedule and budget targets (Figure 14). The budget was 1.9% over the budget goal and one month over schedule (Case Study 4.2.2). Though the project team missed these targets, they were still very close to accomplishing them. The project was able to exceed the LEED Silver target and achieved LEED Gold.

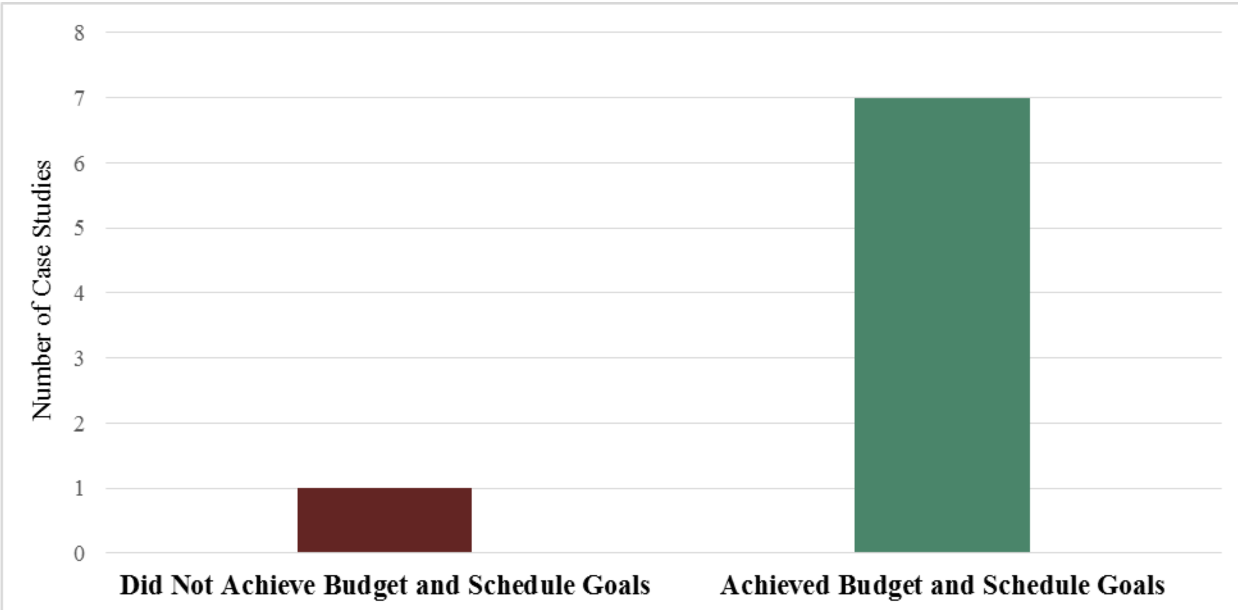

Figure 14. IPD schedule and budget performance

While a majority of the case studies met their LEED targets, it is important to explore further into the case studies to find out how the sustainability goals were achieved. It is also important to answer how a majority of IPD projects were able to exceed their LEED targets while also achieving budget and schedule targets. Thus, a deeper investigation of the case studies was completed.

4.1 Design – Bid – Build Case Studies

Despite the traditional contract method, many of the DBB projects utilized technology and early involvement of key project participants. There were four DBB projects that used computer modeling to aid in LEED certification and three projects had early involvement of key project participants (e.g., energy engineer, or contractor). Two DBB case studies mentioned that there may have been missed opportunities by not having environmental consultants or contractor knowledge during the design phase. The use of technology and collaboration contributed to the DBB projects achieving their LEED targets.

The Nueva School, located in Hillsborough, CA, and the Clearview Elementary School, located in Hanover, PA, project teams both utilized modeling software to achieve their LEED goals (DOE, 2015; DOE, 2002). The project teams for both schools used computer energy modeling to ensure the energy performance goals would be met. The schools both achieved their LEED Gold targets (DOE, 2015; USGBC, 2015b).

The project team for the Fossil Ridge High School, located in Fort Collins, CO, was able to achieve the LEED Silver goal due to early involvement of the Fort Collins Utilities and the Fossil Ridge operations and maintenance staff (DOE, 2015; USGBC, 2006; USGBC, 2015b). The project team described the design phase as collaborative involving the designers as well as, energy engineers from the local utility company and the operations and maintenance staff, who would be managing the building once complete (DOE, 2015; USGBC, 2006). The energy engineers utilized energy modeling software to ensure the energy use would be reduced. The operations and maintenance staff were able to give input during the design phase and smoothly took over operations of the building once complete (DOE, 2015).

The Redding School of the Arts, located in Redding, CA, was able to achieve the rigorous LEED Platinum goal by involving contractors early (DOE, 2015; Gifford Construction, 2015; Theimer, 2013; USGBC; 2015b). Due to the tight delivery schedule, the general contractor was involved in the design phase and construction even started before the design was finalized. This is uncommon for a DBB project. 3D modeling was utilized for the structural foundations and daylighting assessment (Figure 15). The early contractor involvement helped the project realize the LEED target.

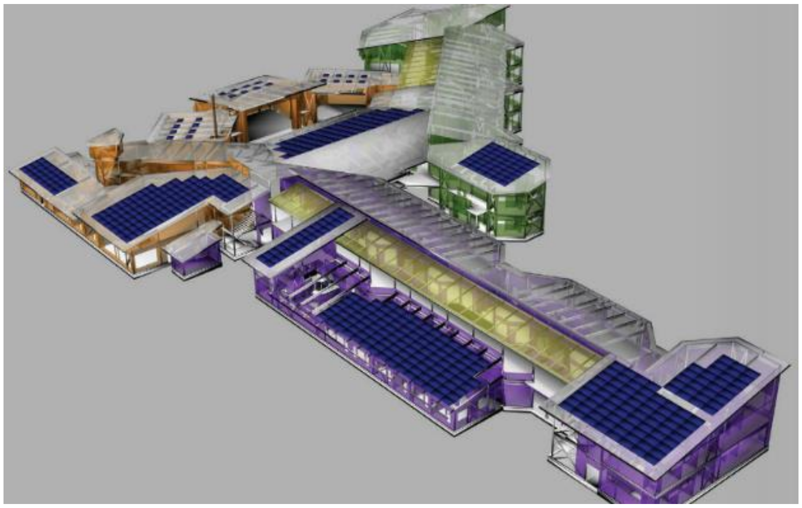

Figure 15. 3D Model of Redding School of the Arts (Theimer, 2013)

The project team for the Lanford Brothers Company Office Building, located in Roanoke, VA, involved faculty members from the School of Construction at Virginia Tech to help with the sustainable design and construction (DOE, 2015). The university faculty utilized this as an opportunity to learn about and apply sustainable construction strategies for sustainability course material. The project team was able to exceed the project goal of LEED certified and achieved LEED Silver in January 2010 (DOE, 2015; USGBC, 2015b). Even though DBB was used, the project team was able to have informal involvement of construction experts during the design and construction phase which helped the project exceed the LEED goal.

The project participants for the Aperture Center at Mesa del Sol project, located in Albuquerque, NM, noted that the environmental consultant was not involved in the early design phase so, energy reducing strategies may have been missed (DOE, 2015). The project team was still able to meet the LEED Silver goal in December 2009 (DOE, 2015; USGBC, 2015b). The project team for the Hawaii Gateway Energy Center project in Kailua-Kona, HI made a similar observation. A lesson learned was that having contractor input earlier would have helped the project avoid or resolve problems that occurred during delivery more quickly (e.g., constructability and waste management issues) (DOE, 2015). When the general contractor did become involved in the construction phase, they assisted with the LEED process. Despite the lack of contractor involvement during the design phase, the project was able to achieve the LEED Platinum target in December 2005. The project teams for two of the DBB projects noted that consultant and contractor expertise early on in the design phase would have been beneficial.

The Fischer Pavilion project, located in Seattle, WA, held a collaborative meeting with the engineers and architects. The LEED Silver goal was not achieved and the project achieved the LEED Certified level in April 2004 (DOE, 2015; USGBC, 2015b). While collaboration is beneficial, if there are missing project participants (e.g., contractors) then there is a lack of expertise to help achieve projects goals.

The DBB case studies reveal that use of technology and early involvement of key participants is possible with a DBB contract structure and greatly benefits achieving LEED targets. The computer modeling, especially for energy, was a key tool for four of the projects to ensure energy and LEED goals were accurately met. Though early involvement was not a contractual obligation, energy engineers, operations and maintenance staff, and contractors were able to give input during the design phase which allowed the project to achieve or exceed their LEED targets.

4.2 INTEGRATED PROJECT DELIVERY CASE STUDIES

4.2.1 SEATTLE CHILDREN'S BELLEVUE CLINIC

The Seattle Children's Bellevue Clinic is located in Bellevue, WA and was completed in 2010 (AIA, 2010b). It is a two story hospital with a total of 80,000 gross square feet that cost approximately $75 million dollars to construct (AIA, 2010b; Zemtseff, 2009). The project utilized an Integrated Form of Agreement (IFOA) contract thus, the owner, design team, and general contractor all entered into a single contract (Kim and Dossick, 2011). The mechanical and electrical sub-contractors were involved early and contributed during the design phase. Though many of the project participants had not previously worked on an IPD project, they were able adapt to the IPD methods. Due to the shared risks and rewards of the IFOA, the project participants changed their typical approach by making the project's overall success the primary goal (Kim and Dossick, 2011). The project was delivered three months ahead of schedule, $30 million was saved from initial estimates, the square footage was reduced 27%, and the green building goal was exceeded due to the IPD method (AIA, 2010b; Olson, 2011; Pearson, 2012).

Through utilization of target value design (TVD), building information modeling (BIM), and a high degree of collaboration the project team was able surpass the project's budget and schedule goals (Kim and Dossick, 2011). The use of TVD between the design and build teams ensured that the design stayed within budget. Thus, design re-work and change orders during construction were reduced which saved time and money (Kim and Dossick, 2011). The team also used BIM which allowed the stakeholders to visualize the different scope models (e.g., concrete model, mechanical model) for effective meetings and to ensure the designs merged accurately. The use of BIM promoted a better understanding of the overall design. As a result, materials were ordered more precisely and construction moved efficiently (Kim and Dossick, 2011). The collaborative effort between not only the project team but the hospital staff and patients allowed a 27% reduction in square footage (Olson, 2011; AIA, 2010b). The project team involved doctors, staff, and patients to gain insight into the needs of the occupants (Olson, 2011; AIA, 2010b). The floorplan designs were then modified to maximize space and improve the flow of traffic. The new layout reduces congestion and travel time so, doctors can get to patients more quickly and patients can find their rooms easily (Pearson, 2012; AIA, 2010b). The IPD method resulted in a more efficiently designed hospital with reduced use of natural resources, $30 million under budget, and three months ahead of schedule.

The IPD process also allowed the project team to exceed their sustainability goals. The architects collaborated with the local energy company to reduce energy demands and identify incentives to further reduce costs. A portion of the money saved due to the IPD process was reinvested back into the building through added sustainability measures (Zemtseff, 2009). Originally, LEED certification was not a project goal but due to the additional money the project team decided to pursue LEED (Zemtseff, 2009; Pearson, 2012). The project achieved LEED Gold in 2011 (Zemtseff, 2009; USGBC, 2015b). Thus, the project team was able to deliver a hospital that exceeded the budget, schedule, and LEED goals.

4.2.2 ENCIRCLE HEALTH AMBULATORY CARE CENTER

The Encircle Health hospital is approximately 156,000 square feet, three stories tall, and located in Appleton, Wisconsin (AIA, 2010). The contract used was an IFOA including the owner (ThedaCare), architect, and contractor, and four trade contractors (AIA, 2010). There were shared risks and rewards between contract parties with a performance contingency if goals were met. The budget and schedule targets were not achieved but the LEED target was exceeded.

Collaboration lead to the success of the Encircle Health hospital project. During the design process, the designers, contractor, and trade contractors all worked together and focused on the goals of the entire project (AIA, 2010). Since four trades participated in the design and scheduling process, they had more confidence and involvement in the project therefore, took more ownership over their work (AIA, 2010). The project participants utilized BIM to ensure that their designs for each scope would integrate properly before construction started. Using BIM saved time and money since re-design was not necessary for the project (AIA, 2010). If problems did arise, weekly meetings were held between at minimum the owner, architect, and general contractor representatives to resolve any difficulties. The project went 1.9% over the original contract cost of approximately $38 million (AIA, 2010). The project was also one month over schedule due to five months of severe Wisconsin winter weather. Even though the project went slightly over budget and schedule, the project team exceeded their original goal of LEED Silver and achieved LEED Gold in August 2010 (AIA, 2010; USGBC, 2015b).

4.2.3 SUTTER HEALTH EDEN MEDICAL CENTER

The Eden Medical Center is a 230,000 square feet and seven story tall Sutter Health hospital located in Castro Valley, CA (Post, 2011; Aliaari and Najarian, 2013). The contract utilized to design and construct the hospital was an 11- party IFOA contract which included the owner, architect, contractor, three design consultants, four trade contractors, and a process consultant (Post, 2011; Aliaari and Najarian, 2013). The Eden Medical Center was the first project in the U.S. to use an 11- party contract. The owner chose an IPD contract because the project had to meet rigorous schedule and budget goals so, a multiparty contract was believed to be the best option (Khemlani, 2009). The shared risks and rewards between the contract parties incentivized teamwork to achieve the project goals. The project met all the targets set including schedule, budget, and LEED certification.

The project was successful due to collaboration between disciplines and use of technology. The project team co-located and held bi-weekly meetings with participants to ensure the project was on track to meeting the goals and to resolve issues. (Post, 2011; Khemlani, 2009). Target value design was used and the initial design estimations were $36 million over the budget (Post, 2011). In order to bring costs down, materials were ordered in advance and laser scanning and BIM were used to ensure design accuracy. During the bi-weekly meetings, the team would project the BIM models which allowed for the detection of problems in the model instead of on-site during construction, saving money and preventing delays (Figure 16) (Post, 2011; Aliaari and Najarian, 2013). The project also had to meet a demanding schedule that was 30% faster than a typical comparable project (Aliaari and Najarian, 2013; Khemlani, 2009). Due to the IPD contract, the project was able to start construction while design work was still being completed (Aliaari and Najarian, 2013). The IPD process allowed the project team to meet the $320 million target, schedule target, and achieve the target of LEED Silver in December 2012 (Aliaari and Najarian, 2013; ESA, 2008; USGBC, 2015b)

Figure 16. Project participants studying BIM models (Khemlani, 2009)

4.2.4 SAN FRANCISCO AUTODESK OFFICE

Autodesk renovated a 46,000 square foot existing historic building located in San Francisco into an office and gallery (Becerik-Gerber and Kent, 2010). In order to complete the project, Autodesk used a 4-party contract including the owner (Autodesk), general contractor, and two architects with shared risks and rewards (Becerik-Gerber and Kent, 2010; AIA, 2009). During the design phase, the contract parties were involved, as well as design consultants and sub-contractors, to ensure that a high level of collaboration and expertise was injected into the design. The project met the established schedule, budget, and LEED project targets.

Since Autodesk creates BIM software, utilizing BIM was imperative for the project and was included in the IPD contract. The models were utilized to ensure the scope designs integrated properly and for sustainability strategies like energy modeling and daylighting analysis (Figure 17). The models were also used for pre-fabricated work which reduced time and material use (Becerik-Gerber and Kent, 2010; AIA, 2009). The project team installed a smart board on-site so, the BIM models could be easily viewed and manipulated for effective and collaborative meetings (AIA, 2009). Technology and collaboration allowed this project to be delivered in the tight 22 week schedule on-budget. The project team had the challenge of achieving the rigorous LEED Platinum level which was met in March 2009 (Becerik-Gerber and Kent, 2010; AIA, 2009; USGBC, 2015b)

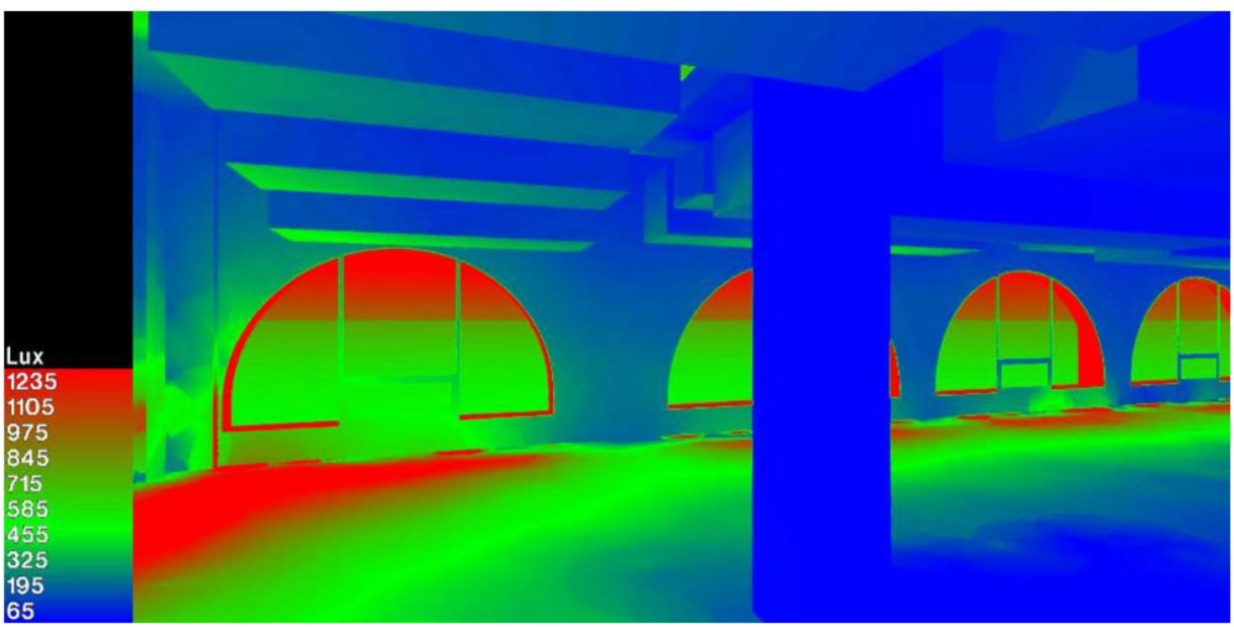

Figure 17. Daylighting analysis of Autodesk office interior using BIM (AIA, 2009)

4.2.5 MICHIGAN STATE UNIVERSITY SHAW HALL

The Vista at Shaw Hall is a dining facility on the Michigan State University campus (Neumann & Smith Architecture, 2014). When the school decided the dining facility needed to be renovated, MSU chose to utilize an IPD contract. Thus, the Vista became the first IPD project on a U.S. public university campus (Krempoksy, 2014). The contract included the owner, architect, general contractor, and four trade contractors thus, all shared the risks and rewards of the project. The project was delivered three weeks ahead of schedule, was under budget, and exceeded the LEED target.

The team spent 18 months learning about the IPD process and collaborating on the design which caused the construction phase to move quickly. Since the contractors were a part of the design process, they knew the design thoroughly at the start of construction (Krempoksy, 2014). The contractors understood their project scope and had their construction strategies established by the first day of construction. Thus, construction moved efficiently and the project was delivered three weeks ahead of schedule (Krempoksy, 2014). The additional few weeks allowed the MSU staff more time to get settled into their new work environment and prepare for student diners.

The project team utilized TVD during the design process so, costs influenced design decisions to ensure the budget was not exceeded. Although the trade contractors had to adjust to the IPD process, they eventually became comfortable providing design feedback to confirm the budget was met (Krempoksy, 2014). Ultimately, all the project participants adopted the IPD method and worked as a team for the overall success of the project. For example, two trade contractors assisted another trade contractor who was slightly over budget (Krempoksy, 2014). Together they collaborated and came up with a solution to reduce costs. The project came under budget so, the extra money was invested back into the building for added value. The project was able to exceed the LEED target by achieving LEED Gold in 2014 instead of the original goal of LEED Silver (Krempoksy, 2014; USGBC, 2015b).

4.2.6 AUTODESK AEC SOLUTION DIVISION HEADQUARTERS

The Autodesk office is located in Waltham, Massachusetts and was completed in 2009 (AIA, 2010). The 55,000 square foot project was a tenant improvement project to an existing three-story building. The owner chose to utilize a multi-party IPD contract after previous success with the office renovation in San Francisco (AIA, 2010). The contract included the owner, architect, contractor, and three trade contractors (AIA, 2010; Autodesk, 2009). Even though only the owner had worked on an IPD project previously, the team was able to meet all of the project targets.

The owner set targets for budget, quality, craftsmanship, schedule, and sustainability which had to be achieved in order for the team to receive the incentives (AIA, 2010; Autodesk, 2009). Thus, the shared risks and rewards between the participants involved in the contract incentivized collaboration to meet the project's overall targets (AIA, 2010; Autodesk, 2009). For example, contractors are typically not proponents for allocating money for high-end materials. However, due to the IPD contract, the head of the construction company worked hard to ensure that an adequate portion of the budget was allocated for quality materials and craftsmanship (AIA, 2010). The persistence paid off because the team surpassed the quality and craftsmanship goals.

The IPD method allowed the team to deliver the project on time, on budget, and meet sustainability expectations. In order to facilitate collaboration between disciplines and stay on schedule, TVD and BIM were utilized. The architects and engineers worked closely with the contractors to ensure the design could meet all of the required targets (Autodesk, 2009). The BIM technology helped the project participants visualize the design to make better decisions. BIM was especially valuable on this project when the owner decided that an atrium was needed to make an impact and bring in natural light even though the design was complete (AIA, 2010). The designers and contractors came together and created a new design, using BIM, which featured an atrium and could still be delivered on time and on budget. The team was able to visualize the atrium three dimensionally using the model and decided to move forward with the improved design (AIA, 2010; Autodesk, 2009). The design and construction of the project was delivered on budget and in eight and a half months, which the project team believes would not have been possible with any other delivery method (AIA, 2010). In October 2009, the project earned LEED Platinum certification, the highest LEED level (USGBC, 2015b).

4.2.7 SUTTER HEALTH CENTER OF SANTA ROSA

The Sutter Health hospital is two stories tall, 182,300 square feet, and located in Santa Rosa, CA (Sutter Health, 2012). The project utilized a 12 - party IFOA contract between the owner, architect, general contractor, trade contractors, and engineers (Eaton, 2012). The shared risks and rewards between the contract parties incentivized collaboration to meet the project targets. The project team co-located on-site so, communication between disciplines was open and efficient

(Eaton, 2012). Overall, the hospital was delivered on time, under budget, and exceeded the LEED target.

The strategies employed to meet the targets include TVD, BIM, pre-fabrication, and effective teamwork. TVD was applied to ensure the design would fit within the given budget. The project team worked together to continuously improve the design and find cost savings (Eaton, 2012). BIM technology also helped the project meet expectations. The team utilized a 4D BIM model so, it included scheduling information. The 4D model ensured the design was accurate and that the construction timeline was met each week (Eaton, 2012). The BIM model was used by trades for pre-fabrication of the plumbing and mechanical systems which saved money and time. Using technology and collaborative strategies, the hospital opened on time, was $3 million under the $284 million budget, and exceeded the LEED Silver target by achieving LEED Gold in March 2015 (Sutter Health, 2012; Unger Construction, 2014; USGBC, 2015b).

4.2.8 MaineGeneral Medical Center

MaineGeneral Medical Center is a 640,000 square foot, $224 million hospital located in Augusta, Maine (Robins & Morton, 2013). The project utilized a tri-party IPD contract which included the owner, architectural firms, and contractors. In order to facilitate collaboration, the entire project team co-located in a single office throughout the design and construction of the project (Robins & Morton, 2013). Thus, the owner, architects, engineers, contractors, sub-contractors, and consultants all worked side by side. The project was delivered ahead of schedule, came under budget, and exceeded the LEED target.

The IPD method enabled the project to exceed the project team's initial goals. The team utilized TVD, BIM, and pre-fabrication which helped the project move efficiently and stay within budget (Robins & Morton, 2013). A local company pre-fabricated the exterior walls which were transported then installed on-site. The project team saved time, money, materials, and ensured quality by having the exterior walls pre-fabricated in a warehouse rather than built on-site (Robins & Morton, 2013). The IPD contract shortened the schedule since the design phase and construction phase could overlap. The construction phase was completed in 24 months instead of the original target of 34 months. By making cost effective design decisions and reducing the construction schedule ten months, the project team saved approximately $20 million dollars (Robins & Morton, 2013).

The money that was saved was reinvested back into the hospital. One of the investments was in green building strategies, like a heat recovery system (Robins & Morton, 2013). The added sustainability approaches enabled the project to achieve LEED Gold in May 2014 thereby exceeding the original target of LEED Silver (Robins & Morton, 2013; MaineGeneral, 2012; USGBC, 2015b). The hospital was delivered ahead of schedule with $20 million dollars of added value including achieving LEED Gold due to the use of an IPD contract and collaboration among project participants.

4.2.9 DISCUSSION

All of the case studies either achieved or exceeded their LEED target and seven achieved their schedule and budget goals due to the IPD process. There were five projects that were able to exceed the LEED target. Out of the three projects that achieved the LEED target, two attained the goal of LEED Platinum, the highest level, and cannot be exceeded. The major contributing factor to the success of the projects was the collaboration and early involvement of key project participants, primarily general contractors and trade contractors. The early involvement was possible due to the multiparty contracts, a defining IPD principle. The shared risks and rewards shifted the priorities of project participants from a narrow, individual work scope to the overall success of the project. All of the projects emphasized a high level of communication and four projects utilized co-location. Six of the project teams utilized TVD thus, they designed to the project goals. This provided assurance that project goals would be met and design re-work was not necessary, which contributed to the success of the projects. There were three projects that saved money that was then reinvested back into the building to add value thereby creating a better quality building and exceeding LEED targets.

BIM was utilized by seven of the IPD projects proving to be a powerful tool to attain project goals. The BIM models were advantageous in several ways. The BIM models helped enable collaboration between different disciplines by allowing them to visualize the project. There were four projects that applied BIM towards the pre-fabrication of building components. Off-site pre-fabrication saved the projects time and material waste. The BIM models also ensured accuracy of design by detecting design problems before construction occurred, which saved time and money. The Sutter Health Santa Rosa Hospital utilized a 4D BIM model to ensure the project stayed on schedule. The Autodesk Office in San Francisco used BIM for sustainability purposes (e.g., energy modeling and daylighting assessment) which aided in the achievement of LEED Platinum. Overall, the IPD projects studied had exceptional project performance outcomes.

5 CONCLUSION

The early involvement of key project participants, collaboration, and technology are important contributors to the achievement of LEED certification goals. Although these factors were achieved with both DBB and IPD project delivery methods, IPD provides more assurance that project performance targets will be met or exceeded. There were eight total DBB projects studied, six projects achieved the LEED target, one project exceeded, and one did not meet the LEED target. The two project teams both identified that early involvement of contractors or consultants would have improved the project delivery and potentially project performance. Five of the DBB projects discussed the use of technology (e.g., energy modeling) and/or early involvement of key project participants (e.g., contractors) which contributed to the projects either achieving or exceeding the LEED target.

Although the majority of the DBB case studies researched had success achieving LEED certification, previous research identifies DBB as an inferior project delivery system. More collaborative approaches to project delivery (e.g., Design-Build) were significantly better compared to DBB in cost, quality, and schedule (Konchar and Sanvido, 1998; Molenaar et al., 1999; Ibbs et al., 2003; Mollaoglu-Korkmaz et al., 2013). The contractual structure of DBB does not promote collaboration between the design team and contractor, which hinders project performance. Though early involvement of contractors is possible with DBB, it is typically not to the extent of a more integrated project delivery system (Mollaoglu-Korkmaz et al., 2013). An initial study revealed that IPD has significantly improved performance outcomes compared to non-IPD projects (Asmar et al., 2013)

The IPD case studies had notable project performance outcomes. All of the IPD projects met or exceeded the LEED target. Seven of the IPD projects met the budget and schedule targets. There were two exceptional IPD projects that were delivered months ahead of schedule and millions under budget, which allowed the owner to invest into more sustainability features. Thus, the LEED targets were exceeded. The project performance outcomes of the case studies were accomplished due to the IPD method. There is a contractual obligation for early involvement of key project participants and collaboration is incentivized with shared risks and rewards. In addition, strategies to keep project costs and schedules on target (e.g., BIM, TVD, Pre-fabrication) and facilitate collaboration (e.g., co-location) are commonly used on IPD projects, which was apparent from the case study research. All of the IPD projects utilized at least one of these strategies and five projects utilized three or more strategies.

Though LEED certification can be achieved with the traditional Design – Bid – Build method, there is more assurance the target will be met using an Integrated Project Delivery method. The main factors that attributed to the achievement of LEED certification include early involvement of key project participants, collaboration, and technology. The IPD multiparty contract allows early involvement of key project participants and facilitates collaboration, unlike the fragmented DBB contract structure. Furthermore, BIM technology is frequently used during IPD projects. Thus, IPD is the recommended project delivery method for LEED buildings.

5.1 LIMITATIONS AND FUTURE RESEARCH

There were several limitations during this research thus, there is a need for future research. The information that was used is not original data so, the research was limited to available data, mainly from databases. In the future, a survey or interviews should be conducted with the stakeholders involved in the projects, especially the owner, contractor, and design team. They can provide more detailed information and answer specific questions about the case studies.

A major limiting factor was the lack of case studies utilizing a multi-party IPD contract. Though IPD is gaining recognition in the building industry, it is not commonly used yet. In the AIA (2012) case studies, it was noted that the some projects could not use a multi-party contract due to a requirement by the federal government or city government. There were also IPD projects that did not pursue LEED certification or were currently under construction which further reduced an already small sample size of IPD projects. In the future, more IPD projects will be completed which will increase the number of case studies that can be researched. With additional case studies, statistical analysis could be completed to provide more clarity to the potential benefits of IPD for delivery of green buildings.

There were also variations in the LEED versions and rating systems used by the case studies. It is difficult to reduce this variable because LEED is continually being updated and different types of projects require different rating systems. As more IPD projects are completed, the versions and types of LEED rating systems can become more consistent. Reducing this variable would strengthen the results and further define the comparison of DBB and IPD project delivery methods.

5.2 RECOMMENDATIONS

There is a need for a more clear IPD definition and increased IPD education in the construction industry, especially owners who ultimately choose the project delivery system. Surveys confirm that there is confusion regarding IPD(Kent and Bercerik-Gerber, 2010; McGraw-Hill, 2014). Many building professionals are unclear what constitutes an IPD project. In some literature, the term “IPD-ish” was used to describe projects that utilized IPD principles but did not utilize a multi-party contract. Ambiguous language like “IPD-ish” needs to be eliminated from use because it creates confusion. The construction industry needs more awareness of emerging project delivery methods, because they might provide better project outcomes, like sustainability measures. Without common and well-defined language, promotion of IPD will be confusing and challenging.

While the DBB projects were able to meet LEED targets, the IPD case studies provided and the initial research of IPD reveal that project performance targets can be achieved and exceeded successfully using IPD. Thus, this research recommends the adoption and utilization of IPD as the method of delivery for LEED projects in order to minimize the impact of buildings on the environment.

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