Intersection of Prevention through Design (PtD) and Integrated Project Delivery (IPD)

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The paper presents an in-depth literature review and analysis on the subject of Integrated Project Delivery (IPD) to determine if and how IPD facilitates implementation of Prevention through Design (PtD) and improves safety. Based on the responses of a survey conducted among the top contractors listed by Engineering News Record, the paper investigates how PtD implementation can be facilitated through IPD. Early involvement of key stakeholders and vendors in IPD provide the opportunity for designers and contractors to collaborate on safety, implement PtD, and identify opportunities for prefabrication. In addition, the IPD multi-party contracting with shared risks and rewards results into a better alignment of designers and contractors towards a common goal of safety while enhancing project's value.

Key Words: Integrated Project Delivery (IPD), Prevention through Design (PtD), Safety, Building Information Modeling (BIM), Construction Project Delivery

Introduction

Improving safety in construction remains a priority in almost every country around the world, because the construction industry stands out among all other industries as the main contributor to severe and fatal accidents. With a high fatal work injury rate of 9.1 per 100,000 full-time equivalent workers (only next to Agriculture, Mining, and Transportation sectors), the construction industry is also responsible for in excess of 200,000 cases of injuries and illnesses annually (BLS, 2012). These figures are disproportionately high compared to other industry sectors, given that construction workers only constitute approximately 7% of the total workforce (CPWR, 2008).

The burden of the human cost of occupational accidents coupled with the economic effect can have a sizeable impact on business performance. Accidents have an adverse effect on any business, due to escalating workers' compensation insurance costs, high cost of medical treatment and rehabilitation programs. The economic losses also include indirect costs, such as administrative costs, productivity losses and low morale. On an average, it is estimated that the death of a construction worker results in losses valued at $4 million, while a nonfatal injury involving days away from work costs approximately $42,000 (CPWR, 2008).

The figures mentioned above highlight the importance of occupational safety and health in the construction industry. The implementation of the Occupational Safety and Health (OSH) Act in 1970, and the subsequent emphasis on the compliance with the regulations listed in Title 29 of Code of Federal Regulation have been instrumental for the improvement in safety performance of the construction industry. Though based on statistics alone, safety appears to be improving somewhat in the construction industry; yet the numbers reveal that in the period from 2001 to 2011 more than 1,000 workers lost their lives per year working in the construction industry. Researchers have stated that current status of safety in construction industry may be rooted in the way the industry views the responsibility for safety. Traditionally, the responsibility for safety of the construction workers rests entirely with the contractors. The OSHAct specifically mentions that the employers (contractors) are responsible to provide a safe and healthy workplace for the employees (construction workers in this case). However, the present arrangement limits the roles of designers or architects to improve safety in construction projects. Recently the National Institute of Occupational Safety and Health has started the initiative of 'prevention through design' (PtD). PtD addresses occupational safety and health needs in the design process to prevent or minimize the hazards down the stream (Howard, 2008).

The current paper presents the results of a survey conducted among the contractors to gauge their perceptions about the concept of PtD. Majority of the responding contractors agreed that addressing safety during the design phase would be beneficial. Further, they also rank ordered the facilitators to adoption of PtD. Alternate project delivery method such as Integrated Project Delivery (IPD) was identified as one of the critical facilitators for the adoption of PtD. With the responses of the contractors as the baseline, this paper explores the intersection of PtD and IPD looking into how these two concepts can complement each other. In the following sections, the paper presents a brief description of the survey along with the summary of the responses, discussions on the intersection of PtD and IPD based on content analyses of existing literature, and finally the conclusions.

Introduction to the Concept of PtD

A systematic review of the literature primarily from journal articles and conference proceedings identified several prevailing safety improvement approaches in the construction industry, such as personnel selection, technological intervention, behavior modification, poster campaign, quality circle, zero injury technique, and similar. A fundamental problem of the prevailing safety improvement approaches is the failure to recognize that safety of any operation is determined long before the people, procedures, and equipment come together at the work site. Construction operations are not different in this respect from any other operation. Until recently, most of the efforts expended to improve safety performance have been targeted towards implementing rules, regulations, and devising advanced equipment – in brief transferring the burden on the contractors. Construction contracts and regulatory requirements from OSHA place the burdens for worker safety solely on the contractors. On the other hand, the role of the architects and engineers to impact safety in construction projects has not been fully utilized.

From a strategic point of view, the architects and designers are the entities who have the most prolonged involvement in any construction project, other than the owners. As a natural corollary they have the opportunity to influence the outcome of the projects from the phase of inception. NIOSH is leading a national initiative on Prevention through Design (PtD) in the United States to utilize the role of designers in safety improvement. American Society of Safety Engineers defined the concept of PtD as “addressing occupational safety and health needs in the design process to prevent or minimize hazards and risks associated with the construction, manufacture, use, maintenance, and demolition of a facility”. Historically PtD was first conceptualized in 1985 by the International Labor Office (ILO). It recognized that the architects and engineers could actually play a significant role in the safety of construction projects. ILO emphasized that architects and engineers should consider the safety of the construction workers who will be actually working in the construction site, during the design phase. Recommendations of ILO were supported by The European Foundation for the Improvement of Living and Working Conditions. Upon review of safety performance of the United Kingdom’s construction industry, Jeffrey and Douglas (1994) concluded that safety considerations should be incorporated in the design process from the very beginning to increase the efficacy. According to Szymberski (1997), the ideal time to consider construction safety is during conceptual and preliminary design phases to be more effective. In contrary to the prevailing safety approaches, which are implemented during the actual construction phase, PtD is more effective as it is introduced earlier in the design phase.

A growing number of industry leaders throughout the world have started recognizing PtD as a cost-effective means to enhance occupational safety and health. The United Kingdom has made it mandatory for construction companies, project owners, and architects to address safety and health during the design phase of projects in 1994 and companies there have responded with positive changes in management practices to embrace the move. Australia developed their Australian National OHS Strategy 2002–2012, which set “eliminating hazards at the design stages” as one of the priorities (Howard, 2008). In addition, France passed regulations, which mandate a holistic view of construction safety including the design and other European countries have since followed with similar regulations (Behm, 2005).

Survey and Summary of Responses

Conducting the survey involved the following major steps: (1) selecting sample contractors to participate in the survey; (2) developing and distributing the survey questionnaires to the sample; (3) collecting and analyzing the collected data.

It was the intent of the survey to gather information related to PtD from a diverse sample of contractors located over a broad geographic area within the United States. For this purpose it was determined that the list of top contractors published by Engineering News Record (ENR – September 2011 issue) would be used as the sample population. The reasoning behind targeting the particular sector was their receptiveness to innovative techniques and methods such as PtD. As adopting innovative techniques and methods always comes with an upfront investment of resources, the smaller companies cannot always afford the burden of experimentation. All 400 contractors listed by ENR were contacted through general e-mails and phone calls for the purpose of acquiring the contact information of the safety directors/supervisors. 112 email addresses and phone numbers of safety directors/supervisors from different companies were collected (28% of the population of 400), and the survey questionnaire was sent to them.

The instrument was prepared based on the study's key constructs of interest identified through review of previous studies by CII (2007), Gambatese (2010), Hecker, Gambatese & Weinstein (2005), and Behm (2005). The survey questionnaire was made into printed copies, and also encoded using a web survey tool to facilitate the distribution and collection of data via internet. 78 out of 112 safety directors/supervisors responded to the survey, reflecting a response rate of 69.6%. However, there were in total 17 incomplete responses, which were not included in the analysis.

Survey data where responses were measured in a five point Likert scale were analyzed using Simple Relative Index (RI). Each respondent was asked to assign a level of importance (from 1 to 5, 1 being minimum) to facilitators to the adoption of PtD. From this, the magnitude of the RI for each item was calculated. Thus, the numerical scores of each of the items on the questionnaire were transformed to relative indices to decide the rank orders. The RI was calculated using the following formula:

$$\frac{\sum w}{Wn}, \ (0 \leq \text{RI} \leq 1)$$

Where,

w = weight given to each item by the respondents ranging from minimum of 1 (denoting least important item) to a maximum of 5 (denoting most important item);

W = the maximum weight (which was 5 in the study);

n = total number of respondents.

This was followed by rank ordering of the items based on the RI, where the highest RI = highest rank and vice versa. The ranked variables gave insight as to the perception of the contractors on various aspect of PtD.

Summary of Responses

To realize the diversity of the responding contractors, the questionnaire asked about the company size and annual revenue of responding contractors. Majority of the contractors (78.2%) participating in this survey was in the category of having 251 to 1000 employees that classified them as large contractors. The majority of the contractors (96.2%) did business more than worth 50 million USD annually. Though the distribution was a little bit skewed, but appeared tailor made for this survey as the goal of the study was to understand the attitude of contractors toward PtD who are best suited to embrace the concept.

To develop a baseline understanding about the facilitators to adopt PtD as perceived by the contractors, the respondents were asked to indicate their perception about the importance of each of the six items identified from literature (Ahn & Pearce, 2007; Souder & Gier, 2006; Taiebat & Ku, 2010). To test the internal consistency reliability of the survey instrument, the Cronbach's alpha (α) was calculated. It was found that $\alpha = 0.81$ for the contractors' responses. Considering the threshold value of $\alpha = 0.70$ for acceptable reliability (Nunnally, 1978), the instrument was considered reliable for measuring the perception of the contractors.

A strong underlying culture of safety in the organization was identified as the biggest motivation for the adoption of PtD (Table 4). In most cases a strong culture of safety is engrained in an organization from practice of effective risk management. As a consequence, ‘effective risk management practices’ has been ranked as the second best motivation for the adoption of PtD by the respondents. According to the respondents alternate project delivery methods such as Integrated Project Delivery (IPD) and Design-build approaches had positive impact on the adoption of PtD. Both the approaches adopt a collaborative approach to design and construction bringing the designer and the contractors aboard from an early stage of the project. In addition the shared approach of risk and reward in the IPD method may be more conducive to addressing occupational safety and health needs earlier in the lifecycle of the project. However, “willingness of architects/engineers to adopt PtD” being identified as the least important facilitator indicates that the designers were not willing to adopt PtD. The contractors perceived the willingness of the owners to be a less critical factor toward the adoption of PtD.

Table 4

Facilitators to adoption of PtD

Items	Relative Index	Rank
Strong project safety culture	0.94	1
Effective risk management practices	0.93	2
Project delivery methods: Integrated Project Delivery	0.89	3
Project delivery methods: Design-build	0.81	4
Willingness of Owners to adopt PtD	0.74	5
Willingness of Architects/Engineers to adopt PtD	0.69	6

Integrated Project Delivery (IPD) and Safety

Integrated Project Delivery (IPD) is a project delivery method and a contracting strategy distinguished by a single multi-party contracting among key IPD stakeholders, including owner, designer, and contractor. In IPD, risks and rewards are shared and individual success is tied to project success. Originally, IPD is established upon lean philosophy focused on “increased project value”. Similar to lean, IPD views a project as a collective enterprise as opposed to fragmented pieces, and it aims to optimize the entire project through reducing waste and maximizing efficiency. Even though lean and IPD share the same philosophy and goal, each offers different approach towards promoting integration. While lean offers production management techniques to promote relatedness of project systems, IPD provides a unique organizational structure and a contract type to facilitate alignment of project participants towards project goals.

Integrated Project Delivery (IPD) seems to be a superior approach to other project delivery methods in promoting safety due to various reasons as listed follow. IPD necessitates early involvement of key stakeholders and includes shared risks and rewards provisions which are critical in establishing a community of practice around safety.

According to (Thomsen, Darrington, Dunne, & Lichtig, 2010), a community of practice refers to a multi-disciplinary team whose members share the same goals and interests and are aligned to share knowledge and discuss solutions to achieve their common goal. Lean practice suggests developing different communities of practice focusing on different areas, such as quality, safety, etc. Forming a community of practice around safety is value-adding as it gives its members a sense of joint enterprise and it leverages existing multi-disciplinary practices on safety.

In IPD, key project participants including owner, key designers and contractor are on board at the beginning of the project and have the opportunity to discuss safety considerations early in the design phase. This will be far more effective than the current industry’s re-active approach to safety, which involves hazards prevention considerations during construction phase only. In addition, IPD can further align business interest of project designers and contractors towards achieving safety goal through setting up a shared risks and rewards structure tied to safety performance of the team.

Establishment of a community of practice on safety can be facilitated through an IPD contract which share risk of safety among the team. Even though the liability for safety accidents is assigned to the party at fault, there exist mechanisms in IPD to share cost associated with safety accidents to some extent. As described by (Duke, Higgs, & McMahon, 2010), when a project specific insurance, such as CIP (controlled insurance program) is in place, a cost premium must be carried in the total project budget to cover cost of potential insurance claims, with potential rewards of savings to incentivize the team. Setting up a shared insurance contingency, force the design and construction teams to be further aligned to proactively and collaboratively plan for safety throughout design and construction. Thus, implementing PtD is much easier in IPD than other delivery methods due to early involvement of key stakeholders and shared mutual goals.

In addition, IPD helps reducing waste associated with over-design. In traditional delivery method, engineers typically overdesign to ensure safety; as they are uncertain about the quality of construction performed by a low-bidder subcontractor who gets selected once design is complete (Thomsen, et al., 2010). In contrast, in IPD key trades are selected based on qualification and are on board early in design phase. The designers and contractors share risks and rewards associated with completing the project within target Cost. As a result, they are both incentivized to find cost effective solutions which also meet safety, quality and performance goals.

Intersection of PtD and IPD

IPD and PtD implementation process is compared side by side in Fig 1 on the following page to identify how IPD supports and facilitates PtD. According to (AIA California Council, 2007), traditional design construction phases create workflow boundaries, IPD however requires a more integrated workflow. Following sections describe different phases of IPD process corresponding with safety.

Conceptualization phase - During this phase, all key stakeholders participate in developing and capturing key goals and parameters, such as cost, time, safety, and technologies. Metrics are developed for assessing performance and successful outcomes are agreed upon. Early involvement of contractor at this early phase allows for identification of pre-fabrication opportunities, which in turn improves safety.

Criteria Design - Throughout this phase, the architect finalizes the fire/life safety plans. The structural engineer determines structural gravity and lateral framings, the MEP engineers design building systems; and the contractors analyze the model to ensure safety during construction. BIM-based safety tools can be utilized to assess different design alternatives from the standpoint of safety. PtD is enabled and facilitated by the involvement of contractors early in the design phase. In addition, design is adjusted through the input of contractors to facilitate pre-fabrication and installation.

Detailed Design - During this phase, the key design decisions are finalized and defined. Contractors, subcontractors and vendors help identify and resolve any potential conflicts and inconsistencies. Involvement and close collaboration of trades at this stage allow for working out tolerances between trades which in turn enable pre-fabrication. IPD provides the opportunity of designing for fabrication.

Implementation Document - The traditional shop drawing is integrated to design as subcontractors and vendors indicate how systems and structures will be built. This phase is only aimed for presenting how the building will be built and not to change or add design. Using Architect's BIM model, the subcontractors and vendors could further develop the model to produce shop drawings. In addition, the subcontractors could use BIM safety rule checking capability to analyze final design from safety standpoint. At this stage, subcontractors could develop their detailed safety plan.

Prevention through Design (PtD)	Pre-construction Phase of a Project	Integrated Project Delivery (IPD)
	CONTRACT PROCUREMENT	
▪ Establish PtD process ▪ Identify tools of PtD ▪ Identify opportunities for prefabrication	**Conceptualization** Owner Architect/Engineer CM/GC	▪ Early involvement of CM/GC, key subs and vendors in the process ▪ Establishing safety goals & metrics ▪ Identifying opportunities for pre-fabrication
▪ Perform preliminary hazard analyses ▪ Apply multi-attribute decision tools	**Criteria Design** Owner Architect/Engineer CM/GC	▪ Subs provide input regarding design adjustment to facilitate pre-fabrication & installation ▪ CM/GC and key subs provide analysis of design alternatives from safety standpoint
▪ Communicate critical hazards - plans and spec ▪ Incorporate site safety knowledge	**Detailed Design** Owner Architect/Engineer CM/GC	▪ Working out tolerances between trades and enabling pre-fabrication
▪ Consider safety constructability ▪ Identify safety expectations from participants	**Implementation Document** Owner Architect/Engineer CM/GC	▪ Finalizing safety implementation plan

Figure 1: Comparison of PtD and IPD processes

Conclusion

Implementation of PtD is significantly facilitated and enabled through IPD approach due to the following mechanisms: (1) early involvement of CM/GC, key subcontractors and vendors allow for identifying pre-fabrication opportunities and thus construction in a more controlled environment ; (2) design assist services provide opportunities for subcontractors and CM/GC to analyze the design alternatives from safety standpoint and to provide design input to facilitate fabrication and installations; (3) lastly, but most importantly, IPD multi-party contact facilitates shared risks/rewards structure, align designers and contractors towards a common goal. Through sharing IPD contingency, at-risk fees, and insurance contingency, both the designers and the contractors are incentivized to collaborate and mitigate safety related risks through PtD and safety planning.

As also stated by (AIA California Council, 2007), construction phase at IPD involves less injuries since IPD offers a greater opportunity to pre-fabricate the work in a controlled environment, and design is developed and assessed to enhance safety.

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