How can Lean, IPD and BIM Work Together?

A.H. Fakhimi[a], J. Majrouhi Sardroud[b] and S. Azhar[c]

[a]Department of Civil Engineering, Kashan Branch, Islamic Azad University, Kashan, Iran
[b]Department of Civil Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran
[c]McWhorter School of Building Science, College of Architecture, Design and Construction, Auburn University
E-mail: Ahfakhimi@iaukashan.ac.ir,J.Majrouhi@iauctb.ac.ir,Salman@auburn.edu

Abstract

As buildings have become more complex, the construction industry has become more specialized, but it is under greater pressure to become more efficient, productive and integrated. Thus, all recent and novel attempts including Lean Construction (LC) philosophy, Integrated Project Delivery (IPD) method and recently Building Information Modeling (BIM) technology are greatly aiding to improve productivity and efficiency via enhanced collaboration and integration. They have been very useful and resulted many benefits, but their drawbacks and challenges prevent them to take fully satisfying results from their individual implementation.

The objective of this paper is to investigate if LC, IPD and BIM can play all together complementary and synergistically, then to draw benefits and challenges of their collaboration. The research is archival in nature and an extensive literature review has been conducted on the implementation of LC, IPD and BIM in the complex project settings. No trilateral collaboration is found and so this study is focused on bilateral collaboration experiences to perceive the demarche of their combination. This paper presents a combination scheme for LC, IPD and BIM in an effort to provide pragmatic solutions to the complex project problems. Challenges, which need to be addressed, are also highlighted.

Keywords

BIM, Integrated Project Delivery, Lean Construction, collaboration, benefit and challenges

1 Introduction

The architecture, engineering and construction (AEC) industry does not have a reliable reputation as a protagonist in quality, efficiency, productivity, cost and time management due to recent more complex and multi-discipline projects. Many researchers believe project success is dependent on the complexity of a project and having a direct effect on the overall project performance [1].

It is a commonly held opinion that the reason for the poor performance is the design and construction processes being particularly complex. Therefore, an understanding of project complexity and its management is of significant importance. Gidado K. [2] suggests that there seem to be two perspectives of project complexity in the industry: The managerial perspective, which involves the planning of integration to form workflow and the operative and technological perspective, which involves the technical intricacies or difficulties of executing individual pieces of work. This may originate from the resources used and the environment in which the project was carried out [2].

Construction industry due to their higher complexity than many other industries needs new theories of production or construction to support a renewed drive for greater performance improvement. Therefore, it has been revived growing debate on flame ideas regarding construction complexity including, managerial perspective (process, LC) and operative and technological perspective (people, IPD and tools, BIM).

Many organizations and researchers pay attention to concept of these novelty ideas/approaches (LC, IPD, BIM) and direct their specific research to develop and implement these ideas individually or even bilaterally for overtopping the mentioned complexities as well as low efficiency and productivity. This paper strives to present a quick review on individual and bilateral collaboration concepts, benefits, barriers and challenges and suggests a trilateral collaboration idea for complex construction projects. The minority of bilateral collaboration researches and lack of trilateral collaboration of LC, IPD and BIM show us the necessity of this kind of research to make construction industry more integrated.

2 Methodology

The research data are comprised of journals, conference papers, thesis, dissertations, and internet articles collected through databases such as Science

Direct, Scopus, Emerald, universities libraries. Instead of comparing or evaluating the strength of reported studies, this paper seeks to reflect the interest of research community on LC, IPD and BIM collaboration topic, so conference papers, thesis, dissertation, and internet article are included in the pool.

The purpose of this Study is to discover the benefits, barrier and challenges of LC, IPD and BIM collaborations for complex construction. As trilateral collaboration did not find, analysis and synthesis of their individual concepts and bilateral collaborations are used to draw trilateral collaboration scheme through literatures and published case studies in AEC industry. The literature review includes the concept, definition and the use of individual and bilateral collaboration of LC, IPD, BIM and their benefits, barrier and challenges in three main aspects: process, people and tools. In addition, the study looks for direction of recent research studies on LC, IPD and BIM bilateral collaboration and their probable trilateral collaboration as an important gap found in this study especially in AEC industry.

3 Lean Construction(LC) project

Concept: Since the 1950s, Toyota Motor Company has implemented Toyota Production System (TPS) principles successfully. TPS had two pillar concepts: (1) Just In Time flow (JIT) and (2) Autonomation (smart automation) [3]. Lean construction is a philosophy based on the concepts of TPS. It is about managing and improving the construction process to deliver profitably what the customer needs. Koskela L. introduced the basic theoretical innovation idea of understanding construction as production, International Group for Lean Construction (IGLC) stated. Further, Koskela and Howell [4] showed the need for a broader foundation for project management in order to getting more efficiency and productivity via elimination of waste. Koskela [5] states that lean construction shares the goals of lean production: elimination of waste, cycle time reduction, and variability reduction. In fact, workflow reliability and labor flow are regarded as key determinants of construction performance [6].

Benefits: Shorter order fulfilment lead times, fewer projects down time, more innovation and true cost reduction are reported as benefits of the successful application of LC. This paper suffices to illustrate the result of McGraw Hill Construction finding in this regards (Figure 1).

Barriers and Challenges: Many studies focused on investigating barriers that prevent the diffusion and implementation of LC concept and identifying barriers that emerge during the execution of LC practices. These barriers could affect the application process of LC and hinder the project performance, if not properly managed. As mentioned, LC is a philosophy and focuses on process and people and it does not uses specific tools for its implementation. LC implements via a few well-known techniques like last planer system (LSP), Five S's, Huddle meetings, First-run studies (PDCA) and so on. This study assessed a number of structural (process) and cultural (people) barriers hindering the progress of the LC approach. Process barriers such as lack of adequate lean awareness and understanding, incorrect interpretation, lack of the use of process based PMSs, traditional management organization, contractual structure, financial issues and lack of exposure on the need for lean construction and people challenges such as lack of top management commitment, governmental aspects, culture and attitudinal issues, the fear and resistance to change, educational issues, lack of training and lack of human skills and experience are reported as main LC implementation's barriers and challenges [7,8].

Figure 1. Potential Benefits with a high influence on Non Practitioners for the adoption of lean practices (*McGraw Hill Construction*, 2013)

4 Integrated Project Delivery(IPD)

Concept: In 1990, BP in-house team formed an integrated group that combined engineering, subsurface and commercial interests. They called it Alliancing and were spectacularly successful. It continued to improve the concept and emerged with new face called IPD. Based on American Institute of Architects, AIA's most recent definition of IPD is defined 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" [9]. IPD brings all participants together early with collaborative incentives to maximize value for the project. Many researchers believe IPD has parallels with Koskela's lean construction movement, which has aimed to translate product manufacturing and production methods to construction. Mossman et al. do - not recognize a distinction between IPD and LC in their particular research [10]. IPD approach built around six characteristics that differentiate it from traditional project delivery; (1) a multi-party contract, (2) early involvement of key participants, (3)collaborative decision making and control, (4) shared risks and rewards, (5) liability waivers among key participants, and (6) jointly developed project goals [11].

Benefits: AIA explains that, achieving the benefit that IPD offers requires the participants of the project to follow some key important principles such as mutual trust, mutual reward, early involvement of key participants, early goal definition and leadership. AIA claims some benefits in this regards as bellow:

- Reduce or eliminate conflict on the project team.
- Optimize the efforts of the workforce.
- Improve communication and understanding among project stakeholders.
- Result in a clearer definition of project goals.
- Create incentives for exceptional results.
- Reduce waste by better planning and shared costs.
- Improve project delivery timelines.
- Reduce operational and maintenance costs of the finished project.
- Reduce requests for interpretation (RFI) from the contractor.
- Facilitate sharing of rewards and risks among stakeholders.
- Encourage the team to take a broader, more creative approach to addressing the client's needs.

Barriers and Challenges: Despite the emergence of IPD as a comparably advantageous project delivery approach, literature on this topic presents numerous obstacles. AIA with a group pioneer in IPD [12] defined the different level of collaboration achieved through contractual (process) and organizational (people) from IPD philosophy to IPD delivery method. The group stated, "Once an owner decides that change needs to occur and IPD is the desired direction, the bigger the organization, the bigger the challenge".

IPD same as LC does not introduces specific tools for its implementation. IPD introduces BIM as its powerful tool. Main IPD implementation barriers and challenges regarding process are legal (Liability , insurance and risk) issues, skill sets and communication protocols, technological barrier and financial issues, and regarding people are fear and resistance to the changes, willingness and knowledge of owner organization, overcoming decades of mistrust and training issues [11,13].

5 Building Information Modeling(BIM)

Concept: Professor Charles M. Eastman [14,15] has introduced BIM concept since 1970. As a solution to inefficiencies in the industry, BIM technology has been gradually developed and practically used in the AEC industry in projects starting from the mid-2000s [16].

The USA is the first country to implement BIM [17]. Nowadays, BIM is implemented in many countries [14]. A commonly accepted definition of BIM is: "Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" [17].

BIM technology creates a virtual model of a building's with quantitative and qualitative characteristics. Cooperation between the different parties involved in the project and supporting the project through its lifetime in the design, construction, fabrication, procurement and maintenance phases emphasized by LC and IPD, facilitate by this concept.

Benefits: BIM offers advantages to those businesses that embrace it. The most cited benefits expected BIM to grant AEC industry are: better production quality, faster and more effective processes and data transmission, reduction in project duration, better customer / client / stakeholder services and satisfaction, more productivity and efficiency, earlier and better coordination and collaboration between all partners, cost tracking possibilities, early design assessment to ensure project requirements are met, mitigating litigations, reduced number of RFI and change orders, elimination of rework via error free drawing production, achieve better logistics and procurement planning, and finally improved Commissioning and delivery of project [14-16,18-24].

Barriers and Challenges: By LC and IPD contrast, because BIM introduces powerful tools for its implementation individually or in collaboration with LC and IPD, BIM barriers and challenges divided into three categories: Process, People and Tools. Table 1 illustrated some recent references of main BIM implementation barriers and challenges regarding these three categories.

6 Collaboration and Integration

Collaboration is a data-centric activity while integration is a knowledge-centric activity. Integration occurs best when the participants view themselves as equal in the process and when the initial collaboration focuses on exploring and defining the problem, rather than commenting on another's proposed solution. The building process cannot be optimized without full collaboration and finally integration among all members.

Table 1 Main reported BIM barriers and challenges

	BIM Barriers and Challenges	Azhar, 2011	Azhar et al, 2012	Both and Kiviniemi, 2012	Erezi Utiome, 2010	Panaitescu, 2014	Stanley and Thurnell, 2014	Ning and Lowdon, 2010	Nurain, 2013	Elmualim and Gilder, 2014
Process	Legal Changes/Absence of Standard BIM Contract Documents	√	√	√		√				
	Implementation Issues/Need for a New Business Model	√		√		√		√		√
	Changes in Practice and Use of Information/Developing BIM modeling skills and redefining staff roles and responsibilities		√			√	√	√	√	
	Need to change information flow management / Integration of meaningful information/Data Organization/ data Validation	√	√			√	√	√	√	
	Required more time spent inputting and reviewing BIM data/cost of implementation	√	√			√	√		√	√
	Lack of collaborative work processes and modeling standards		√		√	√	√			
	complex nature of the AEC						√			
	lack of understanding of implementation processes									√
	Risk distribution (Liability and legal issues)					√			√	√
People	Collaboration and Teaming	√	√							
	Inertia/Resistance to change (Employee, Organization, Owner)			√	√	√	√			
	Absence of qualified BIM implementation team/users/operators		√						√	√
	Absence of owner's interest in using BIM technologies and further ownership of the model	√				√	√		√	
	Intellectual Property / Security /(IP and copyright issues)	√	√					√	√	
Tools	Need for standard data exchange languages/ Interoperatability	√	√	√	√	√	√	√	√	
	Training issue/ In adequate training/ Cost and time of training		√	√			√	√	√	√
	Taking responsibility for data exchange (Liability and legal issues)/Registry of communication and information exchange		√		√	√		√		
	growing propagation of non-standardised BIM applications				√		√			

However, with reviewing concept, benefits, barriers and challenges of the novel approach in the AEC industry (LC, IPD and BIM) and deep looking at their originations, their overlaps are clear. Nowadays, researcher and practitioner going to consider integration of them and introducing integrated framework via their reciprocal synergetic collaborations. Collaboration is the first step of integration and the AEC industry has to implement and experience synergetic collaboration of novel construction methods before integrating them.

7 Discussion, Finding and Areas for further research

LC, IPD and BIM are making fundamental changes in the AEC industry. While all of them conceptually independent, separate, all different from one another, address different aspects of professional practice and do not require together for running and implementation, but they are great complements, each can empowers the others and will have less effect on successful project collaboration if done in the absence of its complementary components. In the following, according to the previous description about benefits and challenges of LC, IPD and BIM, necessity of their collaboration for empowering them are stated.

LC focused its limit to attitudes, processes, techniques for continuous improvement, increasing value, eliminating waste inside a project [8], loose supply chains and interactions with third parties besides main barriers mentioned before. LC may be empowered by IPD, because IPD instead of introducing appropriate processes of how to reduce waste and optimize efficiency, concentrated on multi-party contract and collaboration between all parties [11]. IPD help the project team to apply the LC to maximize value and minimize waste in the production process. Some researchers (such as Mossman et al [10]), guidelines and standards (e.g. ConsensusDOCS 300, AIA) do not recognize a distinction between LC and IPD so that they introduce a combined name for their collaborations, Lean Integrated Delivery Project (LIPD).

One of the main drawbacks of LC and IPD is that, they focus on process and people via some techniques and they do not use specific tools for implementation. By contrast, BIM as a tool provides technological territory of information sharing between all parties and does not introduces any framework for cooperation between the different parties in the project. Looking at the overlaps of LC and BIM benefits show that the application of BIM produces almost the same benefits that LC is supposed to generate [15]. Sacks et al [25] uncovered 56 interactions of both approaches revealing significant synergy effects. They proposed a framework of BIM functionalities and associated Lean principles of such systems beyond construction. However, little has been published on its materialization in practical works. In this regards, The University of Salford has developed a maturity model for Lean and BIM. This model helps to assess the project's Lean and BIM implementation against the 10 identified main criteria [26].

AIA recommend that BIM should be used to achieve required collaboration for IPD. Through early collaboration and the use of BIM technology, a more integrated, interactive, virtual approach to building design, construction and operation is emerging [27,28]. The coupling of BIM with IPD enables a level of collaboration that not only improves efficiency and reduces errors, but also enables exploration of alternative approaches. Among other applications, IPD is materialized as a delivery method that could most effectively facilitate the use of BIM for construction projects [29].

Any collaboration is created to answer the concern, overcome the barrier, challenges and issues and pool the benefits. Based on this and considering the bilateral collaboration of LC, IPD and BIM, the main points should be taken into account for their collaboration and integration are [9]:

- Mutual trust and open communication among parties,
- Understanding each other's objectives and alignment of objectives
- Equitable and clear allocation of foreseeable and quantifiable risks
- Attitude of the Project Participants by develop a partnering culture and replacing individual responsibility by collective responsibility
- Readiness to compromise on unclear issues, awareness of risks and rewards
- Legal issues, What types of contracts should be used for optimum collaboration between all parties
- Develop a partnering culture

As a finding, this study clarified LC, IPD and BIM can work separately and appropriately, but achieving their full capacity is not possible without their collaborations. Until now, many researchers and practitioners define frameworks and methods for their reciprocal synergetic collaborations to issue their findings (Table 2, Table 3).

Table 2 Main reported bilateral collaboration barriers and challenges

	Bilateral Collaboration Barriers and Challenges	Bilateral			References
		BIM+LC	LC+IPD	IPD+BIM	
Process	•Need to qualified contractors			√	[38]
			√		[36]
	•Requires profound process changes of the involved parties			√	[29] [38] [39]
		√			[26]
	•Risk distribution between parties			√	[27]
	•Absence of standard collaborative contract documents			√	[29] [30] [38]
	•Responsibility, liability and model ownership(legal issues)			√	[29] [38] [39]
People	•Need to adequate training and education		√		[38]
	•Need to trusted and capable members		√		[36] [38]
	•team communication			√	[36] [38]
	•team's prior experience as a unit	√			[42]
	•cultural change			√	[38]
	• Fair of Changes		√		[29] [43]
	•commitment by management		√		[43]
		√			[44]
Tools	•Interoperability issues			√	[27]
		√			[42]
	•Lack of BIM product			√	[29]

Table 3- Main reported bilateral collaboration benefits

	Bilateral Collaboration Benefits	Bilateral			References
		BIM+LC	LC+IPD	IPD+BIM	
Process	• Better Planning and collaborative, integrated and transparent construction process			√	[9] [12] [30] [25] [7] [31] [32] [33]
	• Facilitate/catalyze the optimum project delivery process	√			[22]
	• Effectively facilitate the use of each other for construction projects		√		[34] [35] [35] [36]
	•Solve many of the issues (cost, constructability, schedules, quality, sustainability, waste, HSE, etc.) during project life cycle			√	[30] [31] [29] [32] [33]
		√			[37]
	•Increase productivity and efficiency and generates more added value to the client		√		[35]
	•Reduce amount of redundant data •Facilitate sharing of information			√	[30] [34] [38] [39]
	•Improve project relationships		√		[35]
	• Offer significant improvements in contractual and legal matters.			√	[35]
			√		
People	• Risk and reward could distributed amicably amongst project team			√	[39]
	•Facilitate closer collaboration from early stages of the Project •Suppliers will be integrated into the processes of the construction industry			√	[15] [27] [30] [36] [35] [40]
	• Help work teams to do the work with higher performance	√			[41]
Tools	• BIM acts as an excellent team building tools and accelerated the formation and strategies of IPD			√	[30]
		√			[42]
	• BIM provides data storage exchange service				[38]

However, their individual strength and weakness and bilateral collaborations for covering individual weakness to emerge their strength, direct us to suggest a trilateral collaborations for more empowerment by overruling some individual and bilateral barriers and challenges. It could be stated that IPD structures people's interactions and incentives, LC increases value and efficiency and BIM provides transparency and a single source of truth. Full benefits of this collaboration appear whenever collaboration tabernacles with integration. When BIM as a tool and LC as a process connect all people of project via IPD, the synergetic trilateral collaboration appears and all partners (owner, client, designer,..) get their benefit using synergies of them as a whole. Based on this study and inspiring existing experienced bilateral collaborations frameworks and models specially lean project delivery system (LPDS) [30], we propose a trilateral collaboration model (Figure 2) in which all parties could be collaborated and finally integrated in co-location, trilateral collaborative LC, IPD and BIM circumstance. It could be called the project delivery “hat trick”, a state-of-the-art approach to design and construction.

8 Conclusion

To date, to realise the full potential benefit of novel methods, it needs to be used collaboratively in a project. The necessary trilateral collaborative circumstance does not exist but, rather, is best created when all parties enter into a relationship based contractual arrangement(IPD) for delivering a lean project via a strong technological tools (BIM). In this regards, a trilateral collaboration scheme is proposed to emerge their synergetic use in a unique environment (Figure 2).

This trilateral collaboration enables a level of collaboration that not only improves efficiency and reduces errors but also enables exploration of alternative approaches and expansions of market opportunities. It is expected this scheme could help AEC to surmount challenges of bilateral collaboration such as team communication and synergise all benefits of bilateral collaboration.

The findings of this study could be used to help researchers, practitioners, general contractors and companies in the AEC industry to focus their attention and resources on the significant issues necessary to support the trilateral collaborative implementation of LC, IPD and BIM. Future research is recommended to investigate for overcoming barriers to implementing trilateral collaborations.

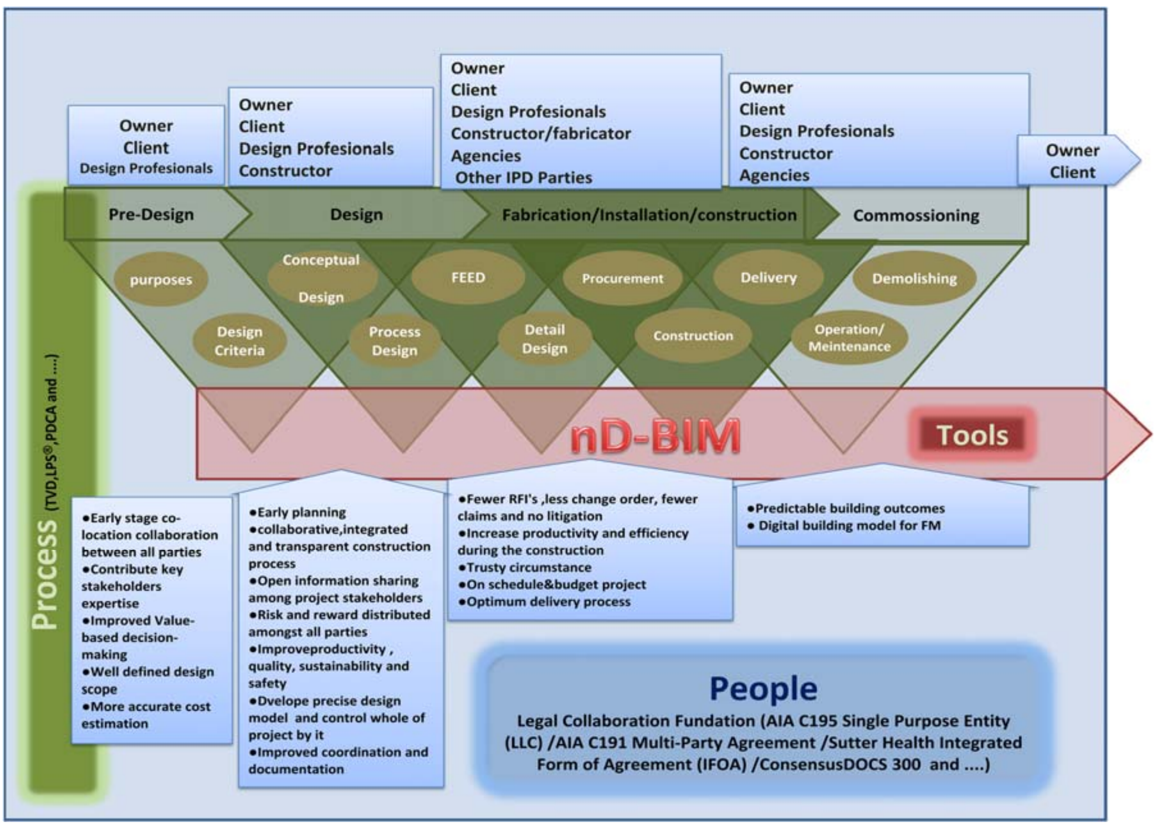

Figure 2- Proposed trilateral collaboration scheme

9 References

[1] Ochieng E. and Hughes L. Managing Project Complexity in Construction Projects: The way Forward. *Architectural Engineering Technology* 2(1): 1-2, 2013

[2] Gidado K. Project complexity: The focal point of construction production planning. *Construction Management and Economics*, 14:213-225, 1996.

[3] Aziz F.R. and Hafez SH.M. Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, 52:679-695, 2013.

[4] Koskela L. and Howell G. The theory of project management: Explanation to novel methods. *Proc. IGLC-10, 10th Conf. of Int. Group for Lean Construction.* pages 1-11,Porto Alegre, Brazil,2002.

[5] Koskela L. Management of production in construction: a theoretical view. *IGLC-7, 7th Conf. of Int. Group for Lean Construction*. pages 241-252, Berkeley, CA,1999.

[6] Thomas H., Horman M., Minchin R.JR. and Chen D. Improving labor flow reliability for better productivity as lean construction principle. *Journal of Construction Engineering and Management*,129(3): 251-261, 2003.

[7] Porwal V., Fernandez-Solis J., Lavy S. and Rybkowski Z.K. Last Planner System Implementation Challenges. *IGLC-18, 18th Conf. of Int. Group for Lean Construction*. pages 548-556. Haifa, Israiel,2010.

[8] Wandahl S. Lean Construction with or without Lean – Challenges of Implementing Lean Construction. *IGLC-22, 22th Conf. of Int. Group for Lean Construction*. pages97-108. Oslo, Norway, 2014.

[9] American Institute of Architects, California Concile. Integrated Project Delivery - An Updated Working Definition. AIA , 2014.

[10] Mossman A., Ballard G. and Pasquire C. The growing case for lean construction. *Construction Research and Innovation*, 2 (4):30-34,2011.

[11] Ghassemi R.and Becerik-Gerber B. Transitioning to Integrated Project Delivery: Potential barriers and lessons learned. *LCI Lean Construction Journal*, Lean and integrated project delivery special issue:32-52, 2011.

[12] NASFA, COAA, APPA, AGC AND AIA. Integrated Project Delivery For Public and Private Owners. pages 45, 2010.

[13] Rached F., Hraoui Y., Karam A. and Hamzeh F. Implementation of IPD in the Middle East and its Challenges. *IGLC-22, 22th Conf. of Int. Group for Lean Construction*, pages 293-304,Oslo, Norway, 2014.

[14] Aryani A.L. ,Suzila M. ,Narimah K. and Fathi M.S. Building InformationModeling (BIM) Application in Malaysian Construction Industry. *International Journal of Construction Engineering and Management*, 2(4A): 1-6,2013.

[15] Eastman C. et al. *BIM Handbook, A guide to building information modellin for owners, managers, designers, engineers and contractors.* Second edition. Wiley, 2011.

[16] Azhar S., Khalfan M. and Maqsood T. Building information modelling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building*, 12(4):15-28, 2012.

[17] National Institute of Building Sciences (NIBS), United States National Building Information Model Standard, Version1,NIBS,2013.

[18] Arayici Y. and Tah J. Towards building information modelling for existing structures. *Structural Survey*,26(3):210-222, 2008.

[19] Succar B. The five components of BIM performance measurement. *18th CIB World Building Congress*. Salford,UK, 2010.

[20] Joannides Maya M. et al. Implementation of Building Information Modeling into Accredited Programs in Architecture and Construction Education. *International Journal of Construction Education and Research*, 8:83-100, 2012.

[21] Azhar S. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership Manage. Engineering*, 11(3):241-252, 2011.

[22] Panaitescu R. *Building Information Modeling,Towards a structured implementation process in an engineering organization.* Delft University of Technology,Faculty of Civil Engineering. Delft, Netherland. 2014.

[23] Stanley R. and Thurnell D. The Benefits of, and Barriers to, Implementation of 5D BIM for Quantity Surveying in New Zealand. *Australasian Journal of Construction Economics and Building*, 14:105-117, 2014.

[24] Kalinichuk S. and Tomek A. Construction Industry Products Diversification by Implementation of BIM. *International Journal of Engineering and Technology Innovation*, 3(4):251-258, 2013.

[25] Sacks R., Koskela, L. Dave, B. and Owen R. Interaction of Lean and Building Information Modeling in Construction. *Journal of Construction Engineering and Management*, 136(9):968-980, 2010.

[26] Dave B., Koskela L., Kviniemi A., Owen R. and Tzortzopoulos P. *Implementing Lean in construction: Lean construction and BIM*. London: CIRIA, C725, 2013.

[27] Wright, J.A. The Integration of Building Information Modeling and Integrated Project Delivery into the Construction Management Curriculum. *ASEE Annual Conference*, 2012.

[28] Zallan Jay B et al. Restructuring The Achitechtural Practice: AEC Success in BIM, IPD and Beyond. *PRACTICAL BIM 2012:Building Information Modeling – Management,*

Implementation, Coordination and Evaluation. pages 257-262.California, USA: University of Southern California, 2012.

[29] Porwal A.A. and Hewage N.K. Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction,* 31:204-214, 2013.

[30] Ballard G. The Lean Project Delivery System: An Update. *Lean construction Journal*,pages 1-19, 2008.

[31] Elmualim A. and Gilder J. BIM: innovation in design management, influence and challenges of implementation. *Architectural Engineering and Design Management*,10(3-4):183-199, 2014.

[32] Dave B., Boddy S. and Koskela L. Challenges and Opportunities in Implementing Lean and BIM on an Infrastructure Project. *IGLC-21, 21th Conf. of Int. Group for Lean Construction*. pages 741-749, Fortaleza, Brazil,2013.

[33] Jones B. Integrated project delivery (IPD) for maximizing design and construction considerations regarding sustainability. *2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials*. pages 528-538. Yogyakarta, Indonesia, 2014.

[34] Volk R., Stengel J. and Schultmann F. Building Information Modeling (BIM) for existing buildings — Literature review and future needs. *Automation in Construction*,38:109-127, 2014.

[35] Halttulla H., Aapaojab A. and Haapasaloc H. The contemporaneous use of building information modeling and relational project delivery arrangements. *8th Nordic Conference on Construction Economics and Organization.* pages 532 – 539, Tampere, Finland, 2015.

[36] Ilozor B.D. and Kelly D.J. Building Information Modeling and Integrated Project Delivery in the Commercial Construction Industry: A Conceptual Study. *Journal of Engineering, Project, and Production Management*,2(1): 23-36, 2012.

[37] Rokooei, S. Building Information Modeling in Project Management: pages 87-95, 2015. *Procedia - Social and Behavioral Sciences, Elsevier*,210(2):87–95, 2015.

[38] Sarkar D. A framework for development of Lean Integrated Project Delivery Model for infrastructure road projects. *International Journal of civil and structural Engineering,* 5(3):267-271, 2015.

[39] Hall D., Algiers A.,Lehtinen T. et al. The role of Integrated Project Delivery Elements in Adoption of Integral Innovation. *Engineering Project Organization Conference.* Devil's Thumb Ranch, Colorado, 2014.

[40] Suttie J.B. The Impacts and Effects of Integrated Project Delivery on Participating Organisations With a Focus on Organisational Culture. *IGLC-21, 21th Conf. of Int. Group for Lean Construction*. pages 267-276, Fortaleza, Brazil,2013.

[41] Rodewohl, C.F. *The presence of Lean Construction principles in Norway's transport infrastructure projects.* Norwegian University of Science and Technology,Department of Civil and Transport Engineering. Trondheim, Norway. 2014.

[42] Oskouie P., Gerber D.J. , Alves T. and Gerber B.B. Extending the interaction of building information modeling and lean construction. *IGLC-20, 20th Conf. of Int. Group for Lean Construction*, San Diego, California, 2012.

[43] Ma C., Li X. and Meng Y. Study on the Application of BIM Technology in Construction Projects under IPD Mode. *ICCREM 2014: Smart Construction and Management in the Context of New Technology*, pages 229-236.Kunming, China, 2014.

[44] Miettinen R. and Paavola S. Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. *Automation in Construction*, 43: 84-91, 2014.

[45] Clemente J. and Cachadinha N. BIM-Lean Synergies in the Management on MEP Works in Public Facilities of Intensive Use - a Case Study. *IGLC-21, 21th Conf. of Int. Group for Lean Construction*. pages 751-760, Fortaleza, Brazil,2013.

[46] Hamd O. and Leite F. BIM and Lean Interactions from the BIM Capability Maturity Model Perspective: A Case Study. *IGLC-20, 20th Conf. of Int. Group for Lean Construction*, San Diego, California, 2012.

[47] Both P. and Kindsvater A. Potentials and barriers for implementing BIM in the German AEC market- Results of a current market analysis. *14th International Conference on Computing in Civil and Building Engineering.* Moscov, Rusia, 2012.

[48] Ning G. and London K. Understanding and facilitating BIM adoption in the AEC industry. *Automation in construction*, 19(8): 988-999, 2010.

[49] Nurian H.I. Reviewing the evidence: use of digital collaboration technologies in major building and infrastructure projects, *Journal of Information Technology in Construction,* 18: 40-63, 2013.