A MODELING APPROACH TO UNDERSTAND PERFORMANCE OF LEAN PROJECT DELIVERY SYSTEM

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ABSTRACT

Many authors suggest that to overcome the problems of the construction industry such as adversarial relationships, low rates of productivity, lack of cooperation, ineffective communications, etc., it is necessary to move toward a better coordination of participants and more collaborative and integrated approaches (e.g. Lean Project Delivery (LPD)). Currently, there is not enough experience and information to understand (1) the adoption of LPD in the construction industry, and (2) the operation of LPD with respect to its organizational structure, operational system, and contractual relationships in a comprehensive manner. The purpose of this paper is to present a research initiative currently in progress that involves the development of models that can help to understand the factors that affect performance of LPD and their mechanisms to impact project results. The development of robust modeling capabilities for LPD can contribute to a better use and design of these systems. The paper provides a review of the literature on project delivery systems and explores the potential use of different modeling approaches to characterize the performance of LPD. A research methodology to develop and test the models is described for analysis and feedback from fellow researchers.

KEY WORDS

Project delivery, Relational, Lean Project Delivery, Modeling

INTRODUCTION

The Construction Industry has traditionally used different types of Project Delivery Systems (PDS), such as Design-Build (DB), Design-Bid-Build (DBB), Construction Management at Risk (CM@RISK), etc. Despite this range of options, many owners/customers remain dissatisfied: projects take more time, there are additional costs and the final product does not meet the quality expectations (Lichtig 2006). These problems are the product of lack of communication, coordination and integration among the stakeholders and many authors suggest that to overcome these problems, the construction industry needs to move towards a better coordination of participants and more collaborative and integrated approaches to provide more predictable results to owners/customers (Egan 1998; 2002; Mitropoulos and Tatum 2000; Fairclough 2002; CMAA 2009, cited by Kim and Dossick 2011).

Currently, there is not enough experience and information to understand: (1) the adoption of LPD in the construction industry, and (2) the operation of LPD with

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respect to its organizational structure, operational system, and contractual relationship in a comprehensive manner. Most studies about project delivery systems have been based upon statistical analysis of data from hundreds of projects developed with DBD, DB, and CM@RISK delivery systems. However, there are not enough cases of application of LPD to develop that type of studies, and an alternative way of understanding them is developing performance models that can be validated using experts and available data on performance of traditional systems.

The purpose of this paper is to present a research initiative currently in progress that involves the development of models designed to understand the factors that affect performance of LPD and their mechanisms to impact project result. The paper provides a review of the literature on project delivery systems and explores the potential use of different modelling approaches to characterize the performance of LPD.

CONTEXT

Presented below is a discussion of three critical factor of the construction industry according to several author's points of view. Some have suggested project delivery systems that create an environment of greater collaboration, trust, coordination and integrated work to respond to these shortcomings.

CRITICAL FACTORS OF THE CONSTRUCTION INDUSTRY

Fragmentation

The construction industry has suffered a fragmentation along the phases of the construction project life cycle for a long time period (Xue et al. 2010). Each area of specialization now tends to work in isolated silos, without a true collective knowledge integration (Lichtig 2006). In general, project stakeholders have no motivation to work together voluntarily, because each party seeks to maximize their own profits without considering project objectives and at the expense of others. This nature of the fragmentation in the construction industry has been seen as the critical factor that results in poor performance, low productivity, and uncompetitiveness (Xue et al. 2010).

According to Love et al. (1998), cited by Kim and Dossick (2011), the fragmented approach of the construction industry has affected project effectiveness, it does not stimulate integration, coordination and communication between the stakeholders.

There is a need for better coordination of participants and more collaborative and integrated approaches to provide more predictable results for owners/customers (Egan 1998 2002; Mitropoulos and Tatum 2000; Fairclough 2002; CMAA 2009 cited by Kim and Dossick 2011). The degree of achieved integration for delivering a construction project is subject to contractual, organizational, and technological mechanisms (Mitropoulos and Tatum 2000 cited by Kim and Dossick 2011).

Nature

Given the current nature of the construction industry: complex, high-risk, multiparty business, conflicts between the diverse participants, etc., it needs to be minimized through better relationships, cooperative teamwork, and under flexible contract conditions (Dissanayaka and Kumaraswamy 1999 cited by Rahman and Kumaraswamy 2004).

A construction project may range from slow, certain, and simple (stodgy) to quick, uncertain, and complex (dynamic). Managing a stodgy project is quite different from managing dynamic project. In addition, the relationship between the organizations involved in the project development can also change (Miles and Ballard 1997). These authors raised the hypothesis that complex and uncertain projects under time pressure require more development towards relational forms of cooperation compared with simple, certain and slow project.

Project delivery systems (PDS)

Many of the problems in the construction sector have their roots in the use of inappropriate project delivery methods (Toolanen and Olofsson 2006). Selecting an appropriate PDS is one of the most important strategic decisions towards a successful project (Mostafavi and Karamouz 2010), because the correct choice can decrease the project duration, provide flexibility for changes, reduce adversarial relationships, allow contractor participation in the design, provide cost savings, incentives to the contractor, and alternative financing methods (Gordon 1994). The success or failure of any delivery method depends upon the performance, trust, and cooperation among the parties (Kenig 2011).

PROJECT DELIVERY SYSTEMS

According to the presented context the authors suggest that an option to mitigate the above problems is through the use of systems that generate an atmosphere of integration, communication, collaboration, trust, etc. This could be achieved through the implementation of LPD. Before entering this point, the definition of PDS, the differences between traditional and integrated approaches are presented below.

Definition

In the literature there are different project delivery definitions, which somehow have generated confusion regarding its use and precision of meaning. For practical purposes of this research all project delivery systems have three basic domains within which they operate: the project organization, the project operating system, and the commercial terms binding the project participants (Thomsen et al. 2009).

Integrated approaches

- **Integrated Project Delivery (IPD):** The American Institute of Architects (AIA National and AIA California C 2007), define IPD as a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harness the talents and insights of all participants to optimize project results, increase value to the owner, reduces waste, and maximizes efficiency through all phases of design, fabrication, and construction.
- **Lean Project Delivery (LPD):** LPD emerged in 2000 from theoretical and practical investigations, and is in process of on-going development through experimentation in many parts of the world. It can be defined as a prescriptive system for managing projects, in which the project definition is represented as

a process of aligning ends, means and constraints (Ballard 2008). LPD uses an approach to project delivery that works to analyze the interaction of design and construction in order to remove waste at each component. LPD consist in 13 modules, 9 organized in 4 interconnecting triads or phases extending from project definition to design to supply and assembly, plus 2 production control modules and the work structuring module, both conceived to extend through all project phases. The post-occupancy evaluation module links the end of one project to the beginning of the next (Smith et al. 2011).

Main differences between traditional and integrated approaches

According to The American Institute of Architects (2007), integrated approaches differ from traditional systems mainly because of the following characteristics: (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, (6) jointly developed project goals.

METHODOLOGIES AND MODELS FOR THE STUDY AND SELECTION OF PROJECT DELIVERY

The main research efforts that have been developed in order to study project delivery systems and provide guidelines for its selection are presented below.

According to Miles and Ballard (1997), owners have the tendency to select a project delivery (DBB, DB, etc.) over another without systematic consideration of the nature of the project to be done. A project construction may range from slow, certain, and simple (stogy) to quick, uncertain, and complex (dynamic). In addition, the relationship between the organizations involved in the project development can also change. Therefore, there are three levels this needs to be examined: the nature of work to be done, the system for project delivery, and the organizational structure that determines the relationships between the parties.

Konchar and Sanvido (1998), developed a comparative study of project delivery performance: DBB, CM@RISK and DB, in terms of cost, time and quality parameters. This study used a database from 351 U.S building projects. In addition this study included the statistical development of multivariate linear regression models for predicting average project performance. An important outcomes of the study is that the design-build system can achieve significant improvements in project cost and schedule. In addition the design-build system produces equal and sometimes even better quality results than design-bid-build and construction management at risk.

Molenaar and Songer (1998), developed a decision support system to provide a formal selection model for public sector design-build projects. For this model five performance criteria that are directly related to overall project delivery performance were identified: overall satisfaction; administrative burden; conformance to expectations; schedule variance; and budget variance. The model supports public owner in determining which projects are appropriate for design-build delivery, thus increasing the chances of success. This model was based on the analysis of 122 case studies.

Alarcón and Ashley (1996), developed a methodology that consist of a conceptual, qualitative model structure and a mathematical model structure. The conceptual model is a simplified model of the variables and interaction that influence project performance. The mathematical model uses concepts of the cross impact analysis and probabilistic inference to capture the uncertainties and interactions among project variables. Based on this methodology, Alarcón and Ashley (2001), developed a model that was adopted by the Division of Foreign Building Operations (FBO) of the US Department of State, which is responsible for the construction and upgrading of the U.S embassies. FBO was frequently faced with the choice about project delivery strategies, contracting strategies, and project execution strategies, therefore this model was used to evaluate and forecast the effects that certain project execution strategies, would have on embassy projects developed in a systematic and structured way.

Thomas et al. (2002), conducted a study with the aim to measure the impact of design-build and design-bid-build delivery systems have on project outcomes, and provide the construction industry means by which it may measure and evaluate the economic value of these project delivery systems. For this study the Construction Industry Institute's Benchmarkingand Metrics (BMandM) database was used, which contains quantitative information of more than 1000 projects about cost, schedule, safety, changes, rework performance, and the use of essential practices in improving project performance.

Chen et al. (2011), propose a model for the selection of the project delivery system in Chinese construction projects, combining the use of artificial neural network and data envelopment analysis. The model is composed of three parts: (1) selecting similar projects, (2) examining indicator values, and (3) training and predicting. The indicators value are grouped in four categories: project objectives, project characteristics, owner characteristics, and contractor characteristics. Project delivery systems used in this research are: Design-Bid-Build (DBB), Design-Build (DB), Construction Management (CM), and Engineering Procurement and Construction (EPC).

Within the literature review several studies were found that have been oriented to analyze the impact of project delivery systems in project performance (cost, time, and quality), and development of methods for the project delivery selection. These research papers are mainly focused on the study of traditional project delivery systems, which are the most commonly used in the construction sector. As to integrated approaches there are no studies about their impact on project performance and its application in the construction industry.

DEVELOPMENT OF MODELS

In order to understand the factors that affect performance of LPD and their mechanisms to impact project results three models will be developed, which will be focused to model: (1) the general behavior of the system, (2) the internal dynamics of the process, that is to say, to understand that it happens within the system, and (3) the individual entities of the system (Figure 3). For the construction of models it is taken into account to use the following modeling alternatives, which are in a process of evaluation:

- **General Performance Model (GPM):** it is a methodology for modeling project performance that combines experience captured form experts and assessments from the project team. It consists of a conceptual, qualitative-model structure and a mathematical-model structure. The conceptual model is a simplified model of the variables and interaction that influence project performance. The mathematical model uses concepts of the cross impact analysis and probabilistic inference to capture the uncertainties and interactions among project variables. The GPM allows management to test different combinations of project execution options and predict expected cost, schedule, and other performance measures. Project options are management strategies that comprise an organized set of actions carried out to improve project performance (e.g., incentives plans, team-building, goal setting, and organizational structure (Figure 1) (Alarcón and Ashley 1996).

Agent – based Modeling (ABM): it is a technique that allows to model complex systems, for example in areas such as sociology, biology and organizational study. Through ABM a systems is modeled as a collection of autonomous entities called agents decision-makers. Each agent individually assesses his situation and takes decisions on the basis of a rules structure (Bonabeau 2002).

Social Network Analysis (SNA): it is a methodology used to identify the conditions of social structures by analyzing the interactions and interrelationships of a set of actors (Hu and Rachera 2008, de Nooy et al. 2005 cited by Park et al. 2011). This alternative proposes several indicators to assess a social network, such as cohesion, centralization, direct and indirect relationships, etc. (Park et al. 2011, Chinowsky et al. 2010, Durugbo et al. 2011).

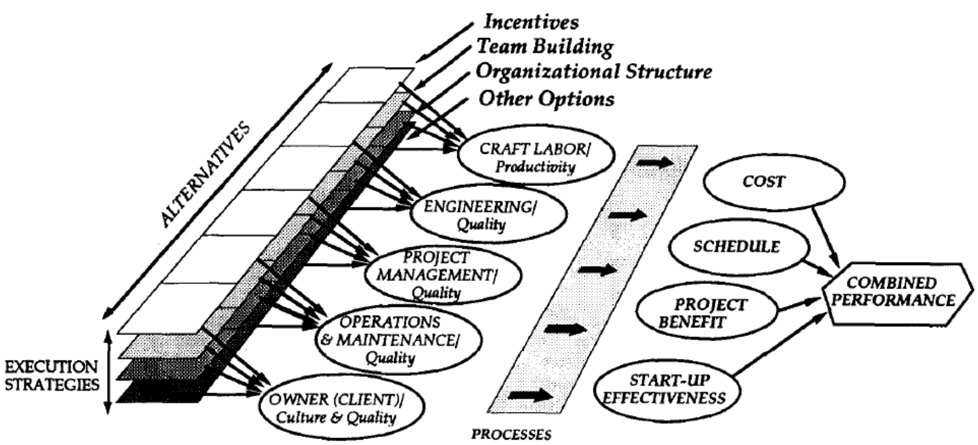

Figure 1: General Strategy Model (Figure 1 in Alarcón and Ashley 1996)

- **Virtual Design Team (VCT):** it is a computational discrete event simulation model that incorporates qualitative reasoning concepts derived from artificial intelligence research. Explicitly incorporates information communication and processing models from organization theory that allow qualitative predictions of Organizational performance (Jin et al. 1993; Jin and Levitt 1996; Levitt and Kunz 2002). In this view, an organization is an information processing and communications system, structured to achieve a specific set of tasks, and comprised of limited information processors (individuals or sub-teams). These information processors send and receive messages along specific lines of communication via communication tools with limited capacity. To capture these characteristics and constraints; VDT employs explicit descriptions of tasks, communications, actors, tools, and structures (Figure 2).

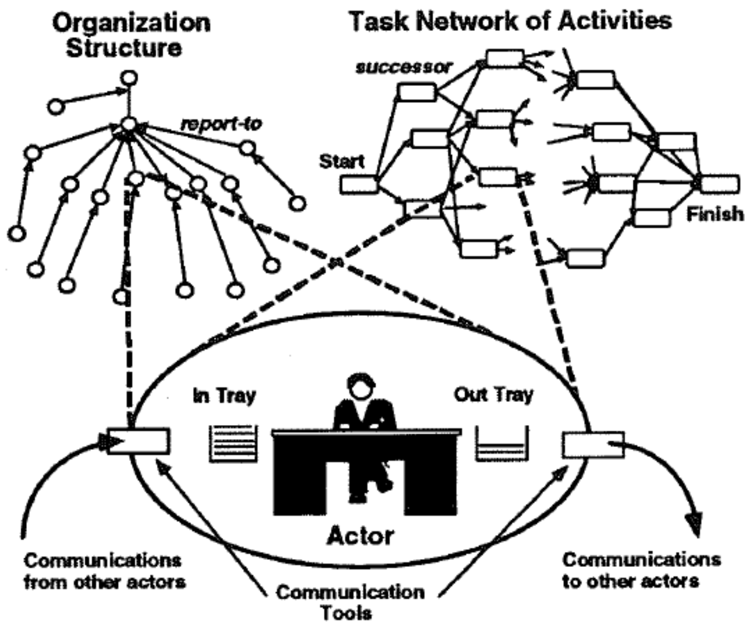

Figure 2: Overview of the Virtual Design Team (Figure 1 in Jin et al. 1996)

The simulation model can serve as a facility to formulate and test specific conjectures regarding the qualitative effect on project cost and duration of changes in the organization structure team, or in the communications tools available to participants (Jin et al. 1993).

- **Selecting Long-Term strategies for construction firms:** this methodology is developed based on the methodology developed by Alarcón and Ashley (1996), but as an additional analysis is incorporated into the external factors that impact the performance of internal model, which allows studying and analyzing internal and external scenarios of a construction company in the development of projects (Venegas and Alarcón 1997).

A modeling alternative will be selected according to each of the features to be modeled. With the GPM use the general behavior of the system will be modeled. Through VDT use the internal dynamics of the process will be modeled, and finally with an alternative 3 (e.g ABM), will model to the individual entities of the system. At the end a triangulation with these alternatives is planned in order to give greater support to the expected results (Figure 3).

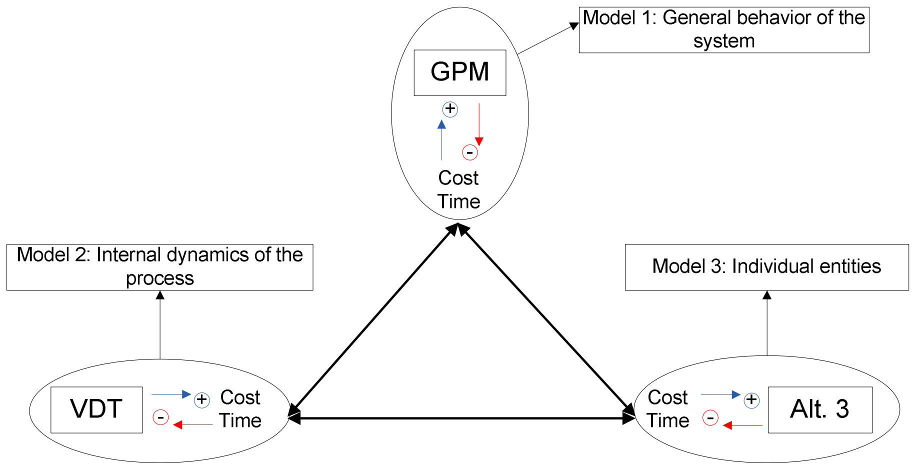

Figure 3: Models and triangulation

EXPECTED RESULTS

The research work and the development of the model should enable to: (1) understand the impact of Lean Project Delivery System on project performance, (2) understand the operation of LPD and the interrelationship between the internal and external factors that determine project success, (3) show what are the advantages of LPD with respect to traditional project delivery, (4) make decisions when selecting a project delivery systems. Furthermore, the work will be aimed to design a generic strategy for the progressive implementation of LPD in a Chilean company.

CONCLUSIONS

According to the context presented, the Construction Industry faces problems such as low productivity, poor performance, cost overruns, adversarial relationships, etc., which are the product of lack of communication, coordination and integration among project participants. All of this as a result of construction's nature, fragmentation, and selection and use of unsuitable project delivery systems. In addition, with the increasing complexity and uncertainty in construction projects, the need to be delivered faster, incorporate technological advances, etc., the use of integrated approaches (e.g., LPD) in response to these problems is increasing and in some countries such as United States and Australia begins to take force in the construction culture (Cohen 2010; Hauck et al. 2004).

In an effort to support an effective implementation of LPD, the paper presented a research currently undergoing that will allow a better understanding of LPD performance and provide valuable insights on the factors that affect the successful implementation of LPD. The modeling effort will tackle different aspects of performance: organization, contracts, people, and other relevant factors that are relevant for designing strategic aspects, providing valuable analysis and support for the implementation efforts and for a better understanding of LPD performance.

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