Research on Factors Influencing Project Delivery System selection for Construction Projects

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ABSTRACT

The selection of a proper PDS is a complex decision that involves many factors. With considerable studies, the factors influencing PDS selection have already been identified. However, the clients still have difficulties in selecting PDSs, because so many indicators still puzzle clients. To address this issue, this study employs collective intelligence of experts and practitioners to quantitatively analyze relative importance of factors influencing PDS selection. This paper begins with a literature review to identify the factors already known to be associated with PDS selection. Then we survey a large panel of experts and practitioners about the importance of each factor, and aggregate these opinions to reliably weigh different factors. The results presented in the paper suggest that client's characteristics and requirements play more roles in PDSs selection than project characteristics and external environment. Also, those quantitative results illustrate that clients need focus more on project type, client's capability, client's requirement for schedule, risk distribution, client's requirement for cost, project scale and responsibility when choosing PDSs. Such results could deepen understanding of PDS selection and offer references for clients' decision-making on PDS.

INTRODUCTION

Project Delivery System (PDS) determines the roles and responsibilities of stakeholders involved in projects, and distribute the risk of stakeholders and build frames for the execution of projects (Oyetunji & Anderson 2006). For a project, PDS affects the realization of its goals in terms of cost, schedule, and quality (Shane et al. 2013). Therefore, a key factor for project success is the employment of proper PDSs. The selection of a proper PDS is a complex decision that involves many factors. Many scholars have researched the potential factors influencing PDS selection (e.g. Cheung et al. 2001; Liu et al. 2016; Liu et al. 2015a; Liu et al. 2014; Love et al. 1998; Luu et al. 2005; Ng et al. 2002). As a result, the factors influencing PDS selection have already been identified. However, the clients still have difficulties in determining which factor should be considered more important, as there are so many factors that cannot be valued equally. Consequently, an effective analysis of the importance of factors influencing PDS selection to help clients choose PDS becomes an urgent need.

Although PDS is chose by clients, it involves different stakeholders in projects. Acceptation of stakeholders can smooth PDS implementation. Therefore, the opinions of large groups of experts and different stakeholders involved in projects (e.g., clients, contractors, engineers) on the selection of PDSs can be comprehensive, objective, and reliable in PDS decision-making for most projects. Based on this, this study surveys a team of experts and practitioners about their understanding of the importance of each factor for PDS selection and aggregates those opinions to weigh these factors. The results are beneficial to deepen understanding of PDS selection (include the relative importance of each factor in PDS selection and how to use those factors to choose a proper PDS) and offers reference for clients' decision-making on PDS.

The remainder of this paper is organized as follows. Part one is the literature review. In this part, the PDS selection approaches and decision factors are reviewed and summarized. And a PDS decision-making index system is built. The part two includes an introduction to the questionnaires, and a description and statistical analysis of the survey data. And the mathematical model used in this paper is also introduced here. Part three makes a quantitative analysis of the importance of factors influencing PDS by aggregating opinions of respondents, and factor weights is achieved. Finally, we conclude this paper.

THE INDEXES OF PDS SELECTION

The analysis of factors influencing PDS selection is not only the basis of scientific PDS decision-making but also a hot spot in PDS theory (Chan 2007). There are numerous studies on the factors influencing PDS selection either through theoretical analysis or case studies (e.g. Chen et al. 2011; Love et al. 1998; Luu et al. 2003, 2005; Oyetunji and Anderson 2006). From the review of past works, 19 factors

are identified and classified into three categories: characteristics and requirements of clients, characteristics of projects and the external environment. Furthermore, the indexes are summarized in detail (see Table 1).

METHODOLOGY

To analyze the importance of factors influencing PDS selection, a questionnaire was built to collect data. First, the questionnaire was designed to cover the factors summarized in literature review. And initial questionnaire was modified with help of expert interview and pilot test to insure the clearness and the exact meaning of questionnaires. Second, revised questionnaires were sent out to experts in

Table 1.Index System of Influencing Factors in PDSSelection.

Index	Meaning of Index	Literature Source
Client Characteristics and Requirements	Client's experience	Client's experience with similar projects 8,10,12
	Client's capability	Client's ability, e.g., ability in controlling, organizing and managing a project 1,10,11,12
	Responsibility	The expectation of the client in the smallest number of stakeholders who take responsibility 1,3,4,5,8,10.13
	Client's involvement	Client's willingness to be involved in the project after award of contract 2,3,10,11,13
	Risk distribution	The expectation of the client in undertaking risk and loss (equally divided between the client and contractor; the client or the contractor undertakes the most risk) 1,3,4,8,10,11,13,
	Design control	The intention and degree of the client's control of the design 1,3,11
	Client's requirement for quality	Client's requirements that the project be of the best quality 3,4,5,6,9
	Client's requirement for schedule	Client's wishes for project to be completed on schedule 1,4,6,9,13,14
	Client's requirement for cost	Client's wishes for project to be completed within budget 4,6,9,13
Project Characteristics	Project scale	Compared with the average scale of projects in the same industry 2,3,4,9,11,14
	Complexity	Whether the project requires a breakthrough in the construction method and management; complexity of the technology 2,3,4,7,9,11,14
	Project type	To which type the project belongs (e.g., building construction project, infrastructure project, industrial project) 3,4,7,8,10
	Scope clarity	Degree of clarity of the project scope defined by the client 1,2,4,7
	Flexibility	Degree of potential design changes during both design and construction periods 4,5,7,9,11
	Dispute	Severity of the potential dispute during construction of the project 4,6,11,14

Table 1.(Continued).

Index	Meaning of Index	Literature Source
External environment	Competition in the market	Degree of competition of the contractors and project management companies in the construction market	1,2,4,5,7,8,10,14
	Availability of materials	Level of difficulty in the acquisition of necessary materials for the project	1,4,10,13
	Availability of technology	Level of difficulty in the acquisition of necessary technology for the project	1,6,7,8,10,14
	Influence of laws and regulations	Limitations and supports of laws and regulations in PDS selection	2,4,8,10,11,14

. Khalil 2002; 2. Azhar et al. 2014; 3. Chan et al. 2001; 4.Chen et al. 2011; 5. Cheung et al. 2001; . Kumaraswamy and Dissanayaka 2001; 7. Ling et al. 2004; 8. Luu et al. 2003; 9. Luu et al. 2005; 10. Luu et al. 2006; 11. Mahdi and Alreshaid 2005; 12. Mafakheri et al. 2007; 13. Oyetunji and Anderson 20; 14. Touran et al. 2010.

the engineering community and stakeholders of projects, who were asked to grade the importance of factors influencing PDS selection. Third, data were acquired by retrieving questionnaires, and then data processing and statistical analysis were conducted. Finally, data was processed to make quantitative analysis of the importance of factors influencing PDS selection using a mathematical model.

Data Collection. Data collection for this study is performed using questionnaires that contain two parts. Part one is the collection of the basic information of the investigation objects, including the types of the respondents' work units, jobs and length of employment of the respondents. Part two requires the respondents to estimate the importance of each index in Table 1 for PDSs selection. Sample items are "How important is 'Client's requirement for schedule' in the selection of PDSs for general projects?" The index estimation uses a Likert scale with 1 to 5 points for each index. In order, 5 to 1 represent very important, important, modest, not important and useless. The questionnaires were mainly released by e-mails or in paper form to respondents. The potential respondents were selected from the membership lists of the China Water Engineering Association, the China Architectural Engineering Association, some energy and chemical enterprises, and metallurgical engineering companies. Of 250 released questionnaires, 150 were retrieved. To ensure data quality, 26 questionnaires were eliminated for no or incomplete basic information. Furthermore, 71 questionnaires are abandoned, because respondents have less than 5 years' work experience in construction industry. As a result, 53

valid questionnaires were obtained, for an effective return rate of 21.2%.

According to the effective questionnaires, respondents are mainly clients, contractors, project consultants and employees at scientific research institutions at rates of 22.64%, 41.51%, 13.21%, and 11.32%, respectively, which means the sources of the respondents are well-distributed. The jobs of the respondents include senior manager, professor, project manager, chief engineer, supervision engineer and consultant, and more than 60% of respondents who are at superior levels in companies or institutions have a macro view on the operation of a company or a project. The time employed in engineering field revealed that 73.58% have 6-10 years' experience, 13.21% have 11-15 years' experience and 13.21% have involved in engineering field for more than 15 years. Besides, Cronbach's α coefficient of the data calculated by IBM SPSS 20 is 0.854>0.7, which means questionnaire are reasonable and the data are acceptable (Mallery 1999).

Information aggregate method. A large number of experts with different knowledge backgrounds and experience always have differences in choice preferences, which increase the inconformity and difficulty in the process of aggregating their opinions. Large group decision-making model, which is aimed at reasonably and effectively aggregating decision preferences from large groups of decision makers, can be a valid approach and has been well applicable in fields, such as data mining, risk management and electronic democracy (Liu et al. 2015b; Xu et al. 2015). Therefore, this paper uses a large group decision-making model to aggregate experts' opinions and determines the weights of factors influencing PDS selection. The detailed mathematical model can be found in Xu et al. (2009) and Xu and Chen (2005), and its steps could be summarized briefly as follow:

Step 1, Organize questionnaire data into an initial decision table.

Step 2, remove the members who offers insufficient information. Calculate the entropy weight of decision-making member and remove those members whose entropy weight is lower than threshold value. The remainder data is organized as a revised decision table.

Step 3, divide remaining members into groups. The revised decision table is processed to cluster remaining members into groups by group aggregation method based on vector space (Xu and Chen 2005).

Step 4, determine the weight of each member. Based on the grouping result in step 3, the weights of members are achieved by the majority principle.

Step 5, determine the attribute-weights. The attribute-weights are calculated based on the revised decision table and member weight.

RESULTS AND DISCUSSION

The method above aggregates the opinions about PDSs selection criteria from 53 experts effectively and presents the weights of each factor category and its corresponding factors. These weights reflect the influence of each factor and category

in confirming the matching between PDSs and projects to improve the likelihood of project success. The results are displayed in Figure 2~Figure 5. The achieved weights do not directly indicate preference in terms of the absolute importance of each factor. Instead, they indicate the relative importance that experts impose when choosing PDSs for construction projects. In other words, having a factor with high weight value reflects its relative importance in determining which PDS is fit for a construction project. On the other hand, having a factor with a low weight value indicates that it plays a relatively small role in decision-making of PDSs.

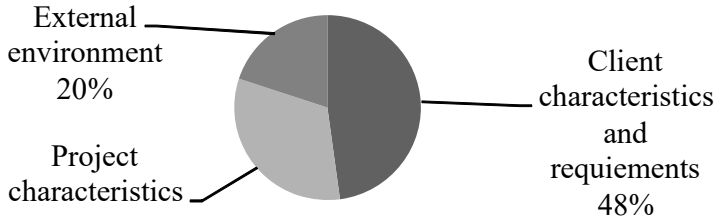

Figure 2.Weights of three factor categories.

The results shown in Figure 2 indicate the relative importance of each factor category and illustrate that client characteristics and requirements should be valued most during the selection of PDSs, followed by Project characteristics and External environment. Undoubttedly, the client has most important influence on the PDS decision-making of a project (the weight value of client's characteristics and requirement reaches 48%). The client initiates a project and owns the final engineering product. Therefore, the client plays an irreplaceable role in terms of participating in and influencing a project. Regarding to client's characteristic, the experience, ability, risk preference and desired involvement of the client should be considered to choose a proper PDS (Alhazmi and Mccaffer 2000; Luu et al. 2005). For example, DBB considers more responsibility and risk sharing along with high requirements for technology, management ability and communication ability of the client (Azhar et al. 2014). However, the client has good control over the project owing to a high degree of participation (Touran et al. 2010). The client only signs a lump sum contract with the general contractor under the general contracting model (e.g., DB) (Ibbs et al. 2003). Under this PDS, the risk and responsibility of the client decrease, whereas the client's control over the project, such as the control over design, also decreases (Xia et al. 2014). Therefore, this PDS suits clients with low

technology and project management ability. Moreover, regarding to client's requirement, the client's requirements for project construction period, cost and quality affects the result of the PDS decision-making directly. Clients may require the shortest construction period, the lowest cost or special standards for quality, and a PDS matching the client' requirements will help better realize the goals. Moreover, even with similar projects, a client may choose different PDSs according to different requirements for schedule, cost and quality (Khalil 2002).

Specially, regarding client's characteristics and requirements, Figure 3 indicates weight of each factor and illustrates that client's capability, client's requirement for schedule, risk distribution and client's requirement for cost are attached more importance in choosing PDSs for construction projects, followed by responsibility and client's requirement for quality. Design control, client's experience and client's involvement are also important, but play fewer roles in PDSs selection. The results shown in Figure 3 also indicate that though cost, time and quality are three main goals in construction projects, they are discriminative in selecting PDSs.

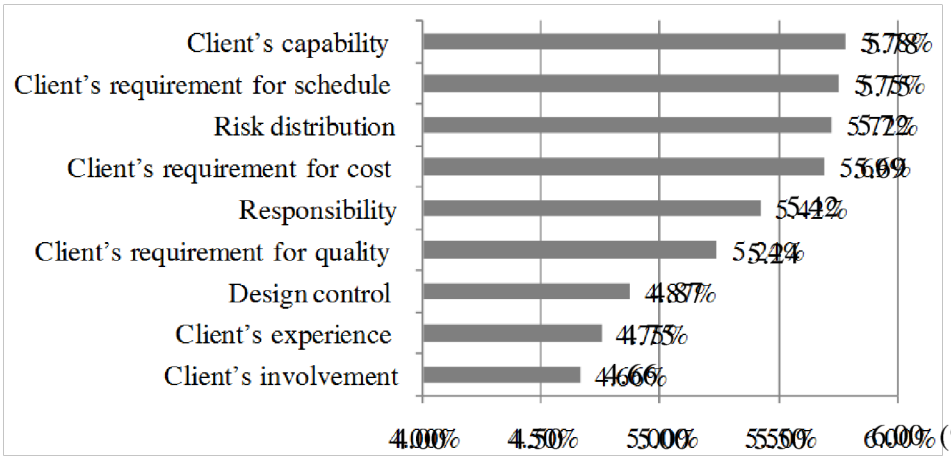

Figure 3.Results regarding client's characteristics and requirements.

Regarding project characteristics, Figure 4 illustrates that project type and project scale are most important factors when clients choose PDSs for construction projects, which also indicates that the preference about some PDS exists among different industries and fields, such as EPC in petrochemical industry. Furthermore, complexity, flexibility, scope clarity of project and dispute contribute less in PDSs selection, but this is not meant to discourage clients from valuing them. Those factors are also valued. For example, the DB approach is especially successful in cases where the scope is clearly defined, the design is a standard, repetitive design, and the schedule is tight (Mulvey 1997). Figure 5 indicates the weights for factors regarding external environment. As the long-term, interactive systems intertwined with construction project implementation, PDSs are hypersensitive to the project delivery environment. Figure 5 indicates that influence of laws and regulations are most

critical environmental factor to PDSs selection, followed by competition in market, availability of materials and availability of technology.

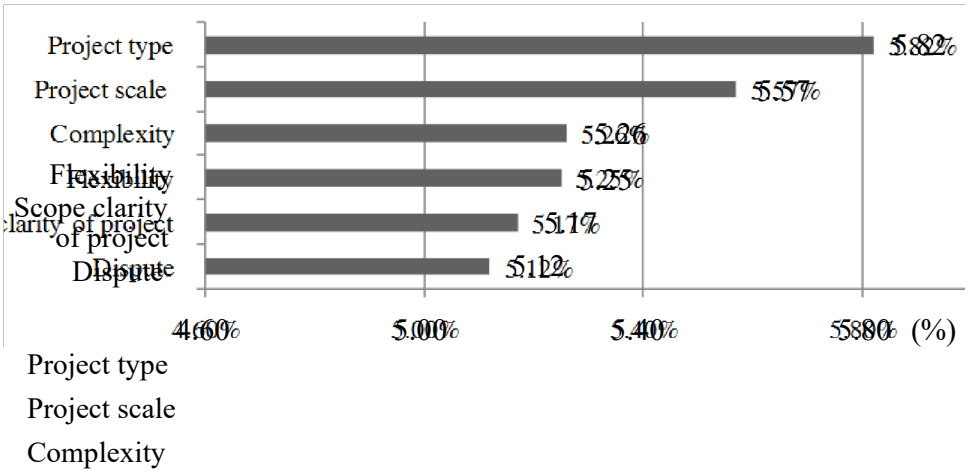

Figure 4.Results regarding project characteristics.

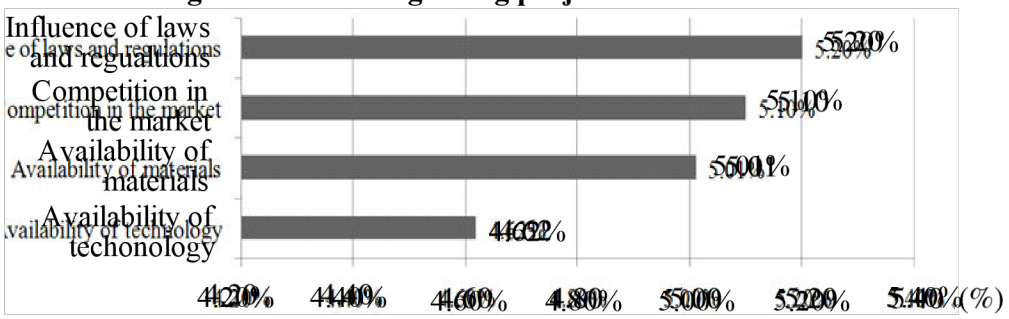

Figure 5.Results regarding external environment.

Finally, the results of applying the mathematical framework to the research data can be interpreted as weights of each factor, as shown in Figure 6. With respect to all factors affecting PDSs selection, Figure 6 illustrates that project type, client's capability, client's requirement for schedule, risk distribution, client's requirement for cost, project scale and responsibility are the most important factors in choosing PDSs, as their weights are higher than the average. On the contrary, availability of technology, client's involvement, client's experience and Design control play fewer roles in determining PDSs.

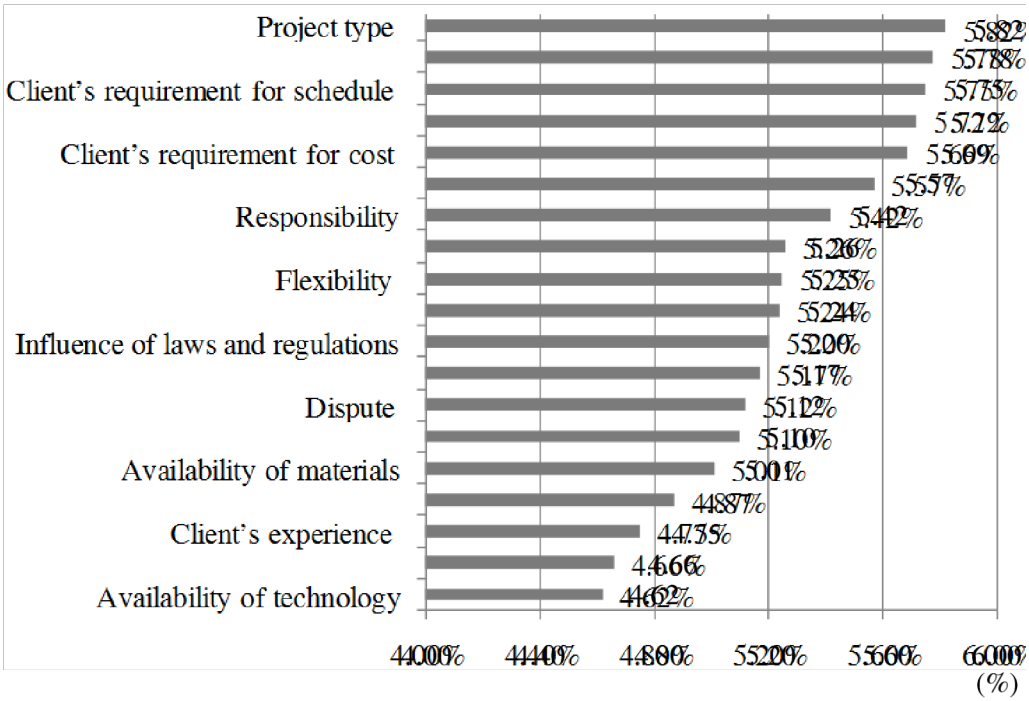

Figure 6.Results regarding all of factors affecting PDSs selection.

CONCLUSIONS

PDSs play a key role in determining the success or failure of a project; hence the effective decision-making process is crucial. Though indicators for PDS decision-making are identified by plentiful studies, the clients still have trouble in which factor should be considered more important. After summarizing widely used factors influencing PDS selection, this study aggregates massive experts and practitioners' opinions to weigh factors affecting PDS decision-making. The weights derived from applying a information aggregate model to actual data suggests that clients' characteristics and requirements are most critical when clients choose PDSs for their construction projects, rather than project characteristic and external environment. Specially, when choosing PDSs, clients should take full into consideration client's capability, client's requirement for schedule, risk distribution and client's requirement for cost to meet client's characteristics and requirements, pay high attention to project type and project scale for suiting project characteristics, and attach great importance to influence of laws and regulations and competition in markets for adopting external environment. By pursuing more matching between PDSs and projects in the abovementioned factors, clients will improve their PDSs assessment and selection processes. The results of this research offer more insights into PDS selection, enrich the research methods in the PDS field, and also provide valuable references for the clients in choosing an appropriate PDS. However, the

results may be mainly applicable in the Chinese construction market, owing to the limitation of the sample.

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