Use Analytic Hierarchy Process for Subcontractor Evaluation in Construction Industry: A Case Study

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Abstract. In each construction project, the main contractors need to greatly involve several subcontractor companies in different stages to their operations. Since the contribution of subcontracting might account for more than 80 percent of total value of the entire project, the subcontractor evaluation is critical for main contractors to hedging risks in the construction management. This study is to identify criteria in subcontractor evaluation by interviewing managers in construction industry in Mongolia. 16 selected criteria were classified into 4 dimensions: Subcontractor Management, Resources, Quality, and On-site Performance. Then, to rank and weight among these criteria, the analytic hierarchy process is used for a main contractor in Mongolia to calculate aggregated scores accordingly. Two competitive dimensions were found to be critical: Quality, which had the highest weight of 0.346, and Management, with weights of 0.336.

Keywords: subcontractor evaluation, analytic hierarchy process, Mongolia construction

1. INTRODUCTION

Construction is the process of planning and installing the design of buildings and infrastructures in the real world. Different from other industries in the manufacturing sector, the construction works are project-based. Not only the requirements of scheduling and planning are unique for each project, but also the processes can only be implemented on the targeted locations only.

The largest segment of the construction industry is the building construction, which provides residential and commercial complexes typically designed by architects or engineering firms. In building construction projects, there are three major players: clients, designers, and the main contractors. Clients, who are initiators and owners of the projects, determine the objectives of the project based on their own benefits. They are the ones who make strategic decisions for their designer and the main constructors to ensure the financial feasibility of the entire project. Designers, who can be represented as a team of architects and engineers, transfer the clients' requirements into drawings to represent the specifications and regulatory compliances of building designs. For the main contractors, they are responsible for the actual construct works and handle all tasks on the construction site, which includes to supply required materials, equipment and tools, to manage project schedule and required workforce, and to cooperate with various subcontractors.

There are a number of reasons that construction is often referred as a high-risk business with low productivity in the manufacturing industry. The impact of boom and bust economic cycles is often larger and faster on the construction industry. For example, according to the report by U.S. Bureau of Economic Analysis (2015), the growth rate of construction industry in U.S was negative for the first time during the economic crisis years of 2005-2007 and a turning point from a continuously growing since 1990s. Another reason is due to the nature of labor-intensive and the highly dependency on the availability of natural resources, despite the fact that more than 10 percent of works are required to be deconstructed along the process and results in tons of waste materials.

Since late 1990s, construction has become one of the most important industry in the developing countries like Mongolia. Mongolia is located between two big emerging markets: Russia and China. It has a total population of 3 million with

more than 65 percent lives in cities and settled areas. Since 1990, Mongolia has been under the transformation from socialist economics into free-market economics. The economy of Mongolia has traditionally relied on the agriculture and natural resources such as coal and copper. From 2000 to 2008, Mongolian economy had a rapid growth in the private sectors as the mining industry was booming, as shown in Figure 1. In 2014, the construction industry was ranked 2nd, next to the mining industry, in attracting investment. According to the National Statistical Office of Mongolia (2015), construction industry was accounted for 5.8 percent of gross domestic product (GDP) in Mongolia in 2014. At the same time, this number was 3.9 percent for U.S and 6 percent for Taiwan.

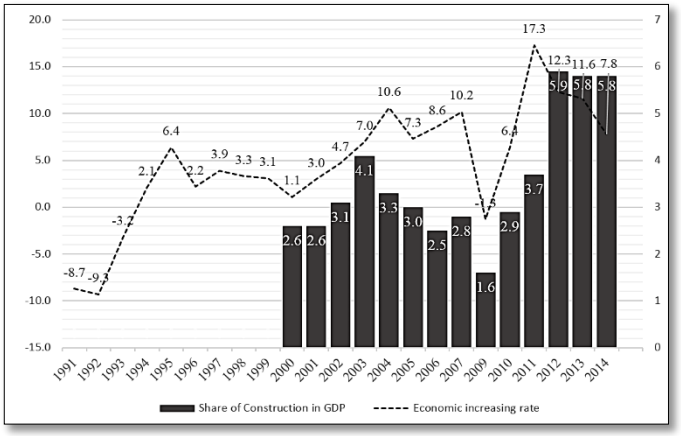

Figure 1: Comparison of Mongolian Economic Growth rate and Shares of Construction in GDP (source: Mongolian Statistical Information Services, 2015)

One of the most critical improvements needed is to define the major performance measures in the construction management. Performance measurement is always being a big issue in this industry. During construction projects, the main contractors greatly involve the subcontractor companies to their operations. It is beneficial for the main contractor companies to work with subcontractors as both revenues and risks are shared across different stakeholders. The previous study showed that the contribution of subcontracting in construction could be counted for more than 80 to 90 percent of total value of the construction project. (Matthews *et. al*., 2006).

The subcontracting process usually involves the following actions.

- To search affordable candidates for the currents tasks,
- To know more about the potential companies
- To select one or few among them based on the fitness to the project.
- To negotiate with selected companies, called subcontractors, during the process of tasks.
- To measure their performance and to give them feedback according to contracts.
- The last step is to keep a good relationship with subcontractors with good records for the future project.

For main contractors, the productivity highly depends on whether they can manage its subcontractors efficiently. Other reasons for this research to focus on the evaluation of subcontractor are as follows.

1. Subcontracting is a real phenomenon in the building construction management in existing situation. As the most of the value of construction process has been completed by subcontractors, each of the subcontractors can have influence to the result of the project.
2. The availability of the information about the subcontractor companies and the experience in performance evaluation during the subcontracting process is often limited or biased. One of the significant factors in a successful construction project is the early involvement of key subcontractors. However, the main contractor could spend too much time in subcontractor selection and the delayed decision or even wrong selection could cost significant project time and money.
3. To remain competitive, a main contractor company needs to develop strong partnership among its subcontractors. The partnership starts from the selection of potential subcontractor for construction projects, and to build relationships by providing their subcontractors with valuable feedback and a fair evaluation.

The evaluation of subcontractors is beneficial for every participant who was involved in the construction project. For the subcontractors, it is an opportunity to let them know what straights need to polish and what weaknesses need to take a more attention. For the main contractors, it helps to achieve their goals through the way of repairing the subcontracting process, supporting and developing its subcontractors, creating a good relationship and, keeping a stable partnership. For the clients, reducing waste of time and cost can be a good factor of to increase the value of investment in the project and to shorten back period of return on investment. It is expected that the benefit of this research is to help improving the current subcontracting process in Mongolia

The main purpose of the research was to identify the most critical factors of the subcontractor's evaluation in Mongolian building construction industry. There are two main objectives. The first, to determine the most important evaluation criteria in subcontractor performance. The second, to weight the criteria in the subcontractor evaluation. Therefore, it helps to facilitate the evaluation process, increasing the profitable of partnership and supporting to the true competition platform.

2. LITERATURE REVIEW

There are many definitions of "subcontracting" within the existing literature. If the heading should run into more than one line, the run-over should be flushed left. Taymaz and Kilicaslan (2002), and Kimura (2002) had suggested that the most formal definition was by Holmes (1986) as following: "Subcontracting is usually defined as a situation where the firm offering the subcontract requests another independent enterprise to undertake the production or carry out the processing of a material, component, part or subassembly for it according to specifications or plans provided by the firm offering the subcontract." (Taymaz & Kilicaslan, 2002; Kimura, 2002)

Eom *et al*. (2008) proposed a subcontracting process as in Figure 2. Starting from the determining of the subcontracting strategy, the firm seeks appropriate subcontractors that fit the strategy and requirements of the project. During the selection process, the firm considers on the subcontractor's organizational evaluation and performance evaluation of the previous project. The firm evaluates the on-site performance of subcontractor in order to support the management. The management responses feedback to the subcontractor for improving the performance.

Figure 2: Flowchart of Subcontracting Process (from Eom *et al.*, 2008)

The most common reasons of the main contractors to involve subcontractors are as follows.

- Workforce: The character of not continuous and repetitious which has led to main contractors concentrating their efforts on managing site operations rather than employing direct labor to undertake construction work. (Matthews *et. al*., 2006)
- Efficiency: Qualified subcontractors are usually able to perform their work specialty more quickly and at a lesser cost than can the main contractor (Hinze & Tracey, 1994).
- Equipment: Involving subcontractor is reducing their cost that takes for limited usage equipment. The construction process is a complex of hundreds of single and related tasks. Every task has required sophisticated technology and equipment for during the completion of the task (Eom *et al.*, 2008).
- Risk: Through the subcontracting, the main contractor transfers its most of responsibility related with performance of current work such as material supplier, equipment rent, and workforce to subcontractors. On the other hand, the risks of current operation are shifted from the main contractor to the subcontractor (Matthews *et. al*., 2006).

Table 1: Subcontractor's Issues in Subcontracting process (Dainty *et al.*, 2001).

Financial related issues	- Delayed payment of Main contractors - Unnecessarily withholding retention payment at the end of contract
Programming/time-related issues	- Lack of supply chain relation, delayed materials - Poor quality inputs
Information flow issues	- Inadequate feedback - Bad quality of information
On-site management issues	- Site manager's most consideration is the shortest completing time - Missed integration, coordination, and innovation

Table 2: Main contractor's Issues in Subcontracting process (Wood & Ellis, 2005).

Safety issues	- To carry responsible of safety for overall construction process, - Subcontractors offend the safety code and unfavorably follow the given safety direction
Waste issue	- Tons of materials inputting on construction has been wasted on the site - Dust and pollution issues arise from the construction process
Subcontractor's management issues	- The uncertainty of subcontractors - The poor management of cash flow

Dainty, Briscoe, & Millett (2001) had examined subcontractor perspectives on supply chain alliances. The researchers observed some issues in subcontractor as a result of the semi-structured interview were held with directors or senior managers of subcontractor companies. Arditi & Chotibhong (2005) had considered on issues in subcontracting practice. The researchers excavated the viewpoint of all the

parties involved, including subcontractors, general contractors, and owners. Wood & Ellis (2005) had studied the main contractor experiences of partnering relationships. They found some issues related with subcontracting process based on the gathered data from 48 managers who worked at main contractor company. As stated by the current researches, occupational issues that probably required a performance evaluation in subcontractor was picked up and showed on Table 1 and Table 2.

Analytic hierarchy process (AHP) is a quantitative tool for decision analysis to deal with users' preferences. To extract the hidden preferences among decisions, this tool requires users to make multiple comparisons among alternatives and then uses mathematical analysis to find the weights for given attributes. This model was proposed by Thomas Saaty in 1971. He was awarded the gold medal of the International Society on Multi-Criteria Decision Making in 2000. AHP helps the decision makers to logically see the importance of every criterion and to find the best solution for application by both qualitative and quantitative data. Many researches had adopted the AHP model in various decision problems such as planning, project selection, and resource allocation.

There are four basic steps in using the AHP: (1) defining an objective; (2) building a hierarchic structure; (3) making pairwise comparisons; and (4) calculating the consistency of matrix (Saaty & Vargas, 2012). In the pairwise comparison, the scales are justified by the preference of responded group based on the Saaty's 9-point rating scale as in Table 3.

Table 3: The fundamental scale of absolute numbers (adopted from Saaty, 2008).

Scale	*Meaning*
1 or 2	Two activities contribute equally to the objective
3 or 4	Experience and judgment slightly favor one activity over another
5 or 6	Experience and judgment strongly or essentially favor one activity over another
7 or 8	An activity is strongly favored over another and its dominance demonstrated in practice
9	The evidence favoring one activity over another is to the highest degree possible of affirmation

The pairwise comparison matrix A derived according to this 9-point scale is then normalized and verified by checking the consistency index (CI) and consistency ratio (CR). The pairwise comparison matrix *A* is acceptable when CR is no more than 0.1.

3. METHODOLOGY

This research includes three main steps: (1) potential criteria identification; (2) criteria classification; and (3) survey design and weight calculation.

The first step is to identify a full list of criteria for consideration. It involves two types of research work: a literature review and interviews with subject experts. From the literature, 15 subcontractor evaluation criteria were focused on developing a management framework for strategic partnering using the balanced scorecard (BSC) management tool and additionally 1 index using it as a criterion (Eom et al., 2008). 4 on-site evaluation criteria were mentioned in the proposed on-site performance evaluation method based on lean principles and partnering practice (Maturana et al., 2007). 2 criteria out of 13 criteria for the subcontractor selection were mostly concerned on government bidding (Shiau et al., 2003), 6 criteria out of 33 sustainable performance criteria were for construction method selection in concrete building (Chen et al. 2010). We further included 4 possible criteria selected from documents related to construction company selection bidding requirements by the Mongolian government. As a result of that, 32 potential criteria have identified from the literature review.

After interviewing with subject experts, 16 criteria were identified and selected for further AHP analysis. Figure 3 shows the AHP structure of this 16 criteria into 4 dimensions: Management, Resources, Quality, and On-site Performance. The detail description for each selected criterion is in Table 4.

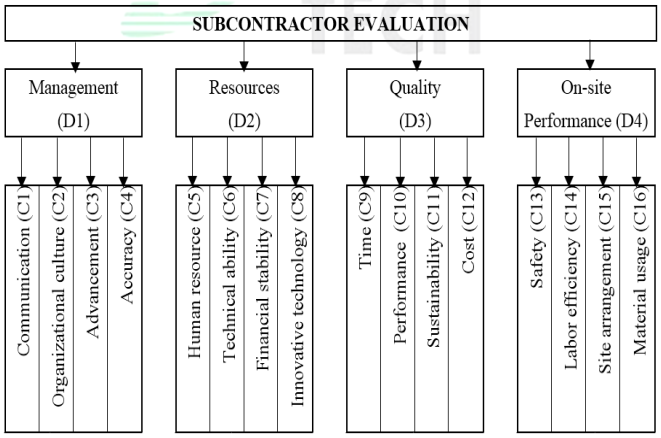

Figure 3: Criteria and dimensions in the AHP structure

(1) Management (D1): this dimension includes criteria related to management in the subcontractor companies. It represents the ability to coordinate and communicate effectively with the main contractors and other subcontractors, and the capability of arranging their employees and accomplishing its goals

(2) Resource (D2): this dimension includes criteria related to whether the subcontractors are able to arrange the required resources for the current task efficiently.
(3) Quality (D3): this dimension includes criteria to the ability to deliver the tasks up to the required quality level and the works they provided are reliable.
(4) On-site performance (D4): this dimension includes criteria related to the actual construction process and real-time performance on the construction sites.

Table 4: Selected criteria and description in the AHP structure.

Code		*Criterion*	*Description*
D1	C1	*Communication*	The ability to communication accessible, ability to deliver information and feedback, also includes flexibility agreement.
	C2	*Organizational culture*	I
	C3	*Advancement*	The potential of continuous improvement in utilizing resources with latest technologies.
	C4	*Accuracy*	The ability to comply safety standards and regulation for the design.
D2	C5	*Human resource*	The skill and professional background of the engineers and technical employees, and sufficiency of manpower.
	C6	*Technical ability*	The ability to provide sufficient and safe machines, equipment and tools.
	C7	*Financial stability*	The potential of taking a financial responsible for unavoidable deviation.
	C8	*Innovative technology*	The willingness to involve innovative technology into tasks performance.
D3	C9	*Time*	The reliability and possible reduction in time estimation and consumption.
	C10	*Performance quality*	The ability to deliver according to the purpose of the design, schedule, and especially the material quality.
	C11	*Sustainability*	The ability to provide solution that requires less energy in maintaining the final construction and minimizes negative impacts for the costumer.
	C12	*Cost*	The ability to complete tasks within budget, and even has the potential for further cost saving.
D4	C13	*Safety*	Compliance in the “Completion of Safety and Health” standard and fulfillment of on-site safety rules.
	C14	*Labor efficiency*	Optimization of labor distribution and delivery.
	C15	*Site arrangement*	Site neatness, effective management of the on-site logistic.
	C16	*Material usage*	Less waste of material.

4. ANALYSIS OF RESULT

The survey was designed in the Mongolian language due to deliver it to the targeted group, as shown in Figure 4. The importance level technique was adapted from Saaty (2008)’s nine like scales method, with 1 as equal importance and 9 as extreme importance. The procedure of comparing the criterion goes through the way like as “If a participant thinks the criterion in the left side is strongly important than the criterion in the right side, he/she should click the cell in the left side and following the column with number 5.”

The targeted group was construction experts who were different positions and from main contractor, subcontractor, and consultant company in Mongolia. The fillable PDF survey document was created by Adobe© Acrobat Pro DC. Out of 30 targeted participants, 10 had completed the survey. Only 4 completed survey passed the consistency check.

Each of the four answers has analyzed by individually using AHP model and obtained dimensions and criteria weight in the pairwise comparison. The finally, the comparisons combine and create a general comparison that comes from sample average calculation. The dimension Quality (D3) were been found highest weight among the comparison analysis which normalized weight is 0.346 but there is a closely competitive dimension which is Management (D1) had been weighted by 0.336 because each of the dimension has placed in top of the two of respondents with an extremely high weight. It is showed on Table 5.

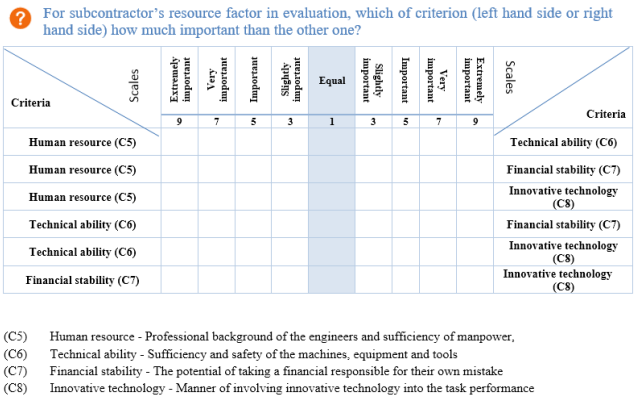

Figure 4: A sample of pairwise comparison table

Table 5: The fundamental scale of absolute numbers (adopted from Saaty, 2008).

Dimensions	*Respondent*				*Final*
	1	***2***	***3***	***4***	*Weights*
Management	0.102	0.448	0.520	0.275	0.336
Resources	0.264	0.152	0.078	0.062	0.139
Quality	0.519	0.125	0.201	0.540	0.346
On-site Performance	0.116	0.227	0.201	0.123	0.167

Figure 5: Ranking among selected criteria according to weights from high to low.

Among all criteria, the most critical issue has found to be Accuracy (C4) in the D1. Its weight is 0.1570. That criteria has not appeared on literature review which is obtained by group discussion and highly recommended by interview process. In the second place C10 - Performance quality (0.1336) and in the third C9 - Time (0.1194) from the dimension of the Quality. C16 – Material usage (0.0113) is determined as the least important criteria. Which is included on the on-site performance dimension. The next following less important criteria are C15 – Site arrangement (0.0234) and C7 – Financial stability (0.0280). The result of the overall weighting is shown on Figure 5.

5. CONCLUSIONS

The purpose of the research was to identify the most critical factors of the subcontractor's evaluation in Mongolian building construction industry. Therefore, two main objectives are follows which are identify criteria and rank it. The research work has motivated by inspiration of facilitating the evaluation process, increasing the profitable of partnership and supporting to the true competition platform in Mongolia.

Regarding to approach the purpose, the literature review study conduct to mining potential criteria and informal group discussion has completed. However criteria identified from group discussion was mostly similar with criteria that found from literature review but there are number of criteria that haven't been mentioned on the literature. There are Accuracy (C4) which are selected into further step and the other one was understanding of payment flexibility which was not selected by interview result.

There are 4 dimensions and 16 criteria which has been sorted into the analyzing process based on the preference of interviewed experts. Where first objective of research has accomplished. Then constructed a Hierarchy structure with determined dimensions and criteria. After that questionnaire survey was designed and conducted to pairwise comparison based on the Hierarchy structure. Once the data collected, producing the all data and calculating normalized weight in the each of comparison has completed by using AHP analysis.

According to the result, the most critical criterion is Accuracy (C4) that expresses the meaning of the subcontractor management and operation fulfill the all the related regulation and standard. The reason, regulation of the construction is not well shaped and couldn't cover the all of the aspects. Nowadays, Issue related with a regulation and standard are phenomena of construction industry in Mongolia regarding to unfair competition problems. The second critical criterion is performance Quality (C10), it is defined as the performance fitting with the purposed design, completing tasks within scheduled time and material quality meets with agreement. The next most critical criterion is Time (C9). Because of the seasonal weather condition, ability of time cutting, completing tasks within expected period is defined one of the most concerned issue.

The criterion Material usage (C16) is named the least important criterion among the 16 criteria. Unfortunately, this type of issue is the one of most concerned one in high developed country. The companies in Europe, the have concerned more on the material resources and implemented reusable disassembled material which is more important than the recycling. In the near future, the material consumption issue will be one of critical issue in the Mongolia by 2020 because Mongolia has signed on the Paris agreement. In case, updated evaluation will be required on the current topic. The recommended future research will be further study about this topic particularly concerning on the evaluation criteria will been tested on the cases. Moreover, evaluation criteria is determined by organization's value and project value and requirement. For the future, the topic considers on different case and implemented in real case will be demanded for further research.

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