Shuquan L., Xiuyu W., Shaopei H. and Benzhe H., 2015. Performance evaluation of lean construction projects based on balanced scorecard. In: *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 753-762, available at www.iglc.net

PERFORMANCE EVALUATION OF LEAN CONSTRUCTION PROJECTS BASED ON BALANCED SCORECARD

Shuquan Li[1], Xiuyu Wu[2], Shaopei Hu[3], and Benzhe Hu[4]

ABSTRACT

The development of lean construction theory and tools promote their applications in various countries. Scholars have used case analysis and empirical research to prove the function of lean construction in waste-reduction and value-added. However, performance evaluation of lean construction project still does not have a standard or systematic measurement, and this results in less recognition of its value and more barriers of its applications in many countries. Therefore, the aim of this study is to build an effective scale for its performance evaluation and measure the success of implementing lean construction in different kinds of projects.

This paper used balanced scorecard approach (not only financially and non-financially, but also on long-term and short-term account) to evaluate the performance of 300 construction projects which had adopted lean construction theory in China. It established evaluation index system from five dimensions and determined the weight of indicator of index system by factor analysis. Furthermore, we calculated the score of these individual projects, the results showed that index system was effective, and most of the projects with higher scores were municipal projects, constructed by state-owned enterprises or large private enterprises, which reflects good foundation of collaboration.

KEYWORDS

Lean construction, value, performance evaluation, balanced scorecard, collaboration.

INTRODUCTION

Lean construction is an application of using lean production to construction project management (Koskela, 1992), and the aim of its application is mainly to reduce waste and to improve performance of construction projects. Many scholars have used case analysis and empirical research to prove its role in the aspects of waste-reduction and

[1] Professor, Director of the Management Science and Engineering Department, Tianjin Univ of Finance and Economics, Tianjin,China,+86-13012205754, lsq@tjufe.edu.cn

[2] PhD, Department of Management Science and Engineering, Tianjin Univ of Finance and Economics, Tianjin,China,+86-15620615009, xywu2014@126.com

[3] PhD, Department of Business Administration, Tianjin Univ of Finance and Economics, Tianjin,China,+86-15620506961, hsptjufe@126.com

[4] Master student, Department of Management Science and Engineering, Tianjin Univ of Finance and Economics, Tianjin,China,+86-13821938306, yrds2014@126.com

value-added in many countries, such as Denmark (Bertelsen, 2001; Thomassen, et al., 2003), Indonesia and Australia (Alwi, Hampson and Mohamed, 2002), Chile (Alarcón, et al., 2005), America (Salem, et al., 2005). However, there are various problems in the implementation of lean construction in different states and countries. Alarcón, et al. (2005) assessed the implementation of lean construction in 100 construction projects for 5 years in Chile, and found that the problem of improving PPC value was the lack of the time to implement new technologies, training, self-criticism and to adapt to the changes. Daeyoung and Park (2006) interviewed 42 projects participants, and found that they were not familiar with the concept of lean construction, and there were many difficulties in the implementation of lean construction, such as the preparation, labor force, materials transfer and the precision in planning. Henry (2009) analyzed the construction industry in Uganda, and pointed out that the main hinder factor in lean construction implementation was the accurate supply on time. Salem, et al. (2006) pointed out that many lean construction tools and elements were still in embryonic state. He assessed the values of different lean construction instruments (such as last planner, increased visualization, five S's, et al.) for a general contractor in Ohio, and built a lean assessment tool called spider-web diagram. The researches proved the function of the assessment tool in tracking improvements in lean construction projects.

The lack of assessment tool of lean construction implementation results in less recognition of its value and barriers of applications in many companies. Therefore, the objective of this paper is to build an effective scale for performance evaluation and measure the success of implementing lean construction in different kinds of projects. The balanced scorecard model (BSC) (Kagioglou, Cooper and Aouad, 2001) not only emphasizes the financial and non-financial target balance, but also stresses the balance between short-term benefits and long-term benefits. Based on the particularity of construction project, its performance are not only reflected in the profits of funding, but, in some circumstances, non-financial goals, such as lean construction project quality and schedule, are more significant and become the focus of the performance evaluation. With the balanced scorecard, financial, internal staff's learning and growth, construction project strategic investment, and internal knowledge capacity combined, we can balance the current performance and the long-term performance of enterprises. In view of this, this paper tries to introduce the balanced scorecard theory model to the performance evaluation of lean construction project, and find the rule of the success of implementing lean construction in different kinds of projects.

METHODOLOGY

The research design was exploratory and based on theory analysis and quantitative analysis. First of all, the paper adopted the balanced scorecard (BSC) theory to establish preliminary evaluation index. BSC is a strategic performance measurement system originally, and has been widely received as one of most influential management ideas (Coe and Letza, 2014). BSC considers financial, internal business processes, learning and growth, and customer, these four perspectives, as interrelated and interacted. The internal system of learning and growth determines the quality of the staff, the staff in a certain extent determines the quality of their products, which determines customer satisfaction and loyalty, and all of these determine enterprises' market share and financial position. The coherence of intangible assets between these four dimensions makes internal processes more efficient, thus eventually achieve client objectives.

In order to verify the feasibility and reasonability of BSC evaluation index, the paper made a quantitative analysis by factor analysis, which is a statistical method that can reduce the dimensions of a set of highly correlated data but remain most of the information from the original variables (Thomson, 1935; Barth, 2008). Because of the high correlation among the four dimensions of BSC, factor analysis performs effectively as an evaluation method.

The performance of lean construction project is the effects or outcomes of the implementation of lean construction instruments such as 5S management, Last Planner System, Concurrent Construction, Visual Management, Just-in-time, Total Quality Management (TQM) and Conference Management. The performance of different projects would be different because of their distinctive management ability and culture, and we have investigated 300 projects in 61 cities of China and delivered 770 questionnaires to the first-line managers. The questionnaire contains two parts, the first part is basic information of the project such as the type of the project owner and its size, and the second part is about the project performance, the questions are designed based on BSC evaluation index, and contains 18 questions, which elaborates the following parts. The items adopt 5-Likert Scale scoring 1 to 5 while "strongly disagree" to "strongly agree". The questionnaires are recovered 710 totally and there are 667 valid after screened out. The types of projects contain civil construction projects (57.7%), industrial construction projects (13.6%), municipal government projects (18.4%) and the other else (10.3%). The sample can reflect the status of construction projects in China well. The age of respondents ranges from 18 to 50, most of them were 31-40, the proportion is 43.1%. In addition, the education backgrounds of them are high school (18.6%), junior college (16.3%) and college (16.9%). With the extensive experience and knowledge of construction management, the respondents can reflect the status of construction management accurately.

PERFORMANCE EVALUATION OF LEAN CONSTRUCTION PROJECTS

PRELIMINARY INDEX SYSTEM OF PERFORMANCE EVALUATION

Compared to conventional industrial companies, construction companies are project-based companies, which organize their structures, strategies and capabilities around the needs of projects (Hobday, 2000; Forman, 2013), therefore, we evaluate the performance of lean construction on projects. Due to the complexity and long-term nature of construction projects, it is important and difficult to establish a comprehensive performance evaluation system. The traditional BSC considers performance evaluation from financial, internal management, learning and growth, and customers, and it contains not only financial benefits but also non-financial benefits, as well as short-term benefits and long-term benefits. Regarding the particularity of the construction project and the definition of the lean construction project performance, we divide lean construction project performance evaluation framework into four dimensions: finance, project management process, knowledge and ability, and owner (as shown in Figure 1). The meaning of each dimension is explained as below.

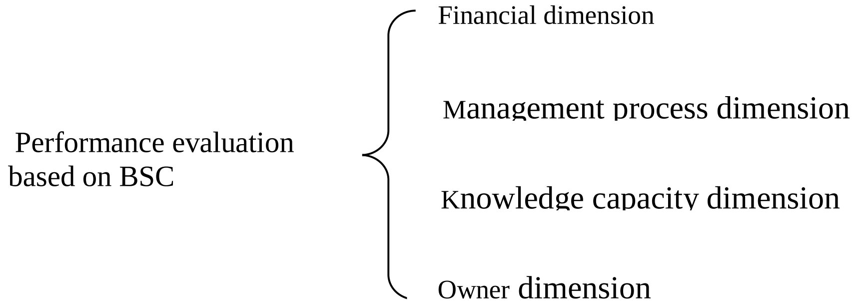

Figure 1: Performance Evaluation Framework based on BSC

Financial dimension: financial dimension means the cost-benefit analysis of the lean construction project. The cost includes direct cost (procurement cost, labour cost) and management cost, and the benefit is main income of the project. Implementation of lean construction brings much benefit to a company, Thomassen, et al. (2003) concluded that MT company in Demark got profit increased by 20%, cost reduced by 15%, and construction time shortened by 10%, the company productivity increased by 25% compared with other construction management model.

Management process dimension: management process dimension is to evaluate the project performance on internal process management, which includes three parts: management, control and coordination. Management contains quality management and safety management, control contains cost control and schedule control, coordination contains coordination with government, owner, subcontractor, community and workers. As lean construction instruments, LPS, TQM and visual management are helpful to improve the construction management process.

Knowledge and ability dimension: knowledge and ability dimension means that the improvement of knowledge and experience of lean construction management, the innovation on construction technologies, and the improvement of construction equipment. This dimension indicates the long-term performance.

Owner dimension: the direct customer of construction project is owner, the final objective of the project is to reach owner satisfactory, which is in accordance with the goal of lean construction, customers value-added. The satisfactory of owner could be measured by complaints or disputes between owner and contractors.

Above all, we established the preliminary index system of performance evaluation (as shown in Table 1), which contained 4 indicators and 18 items. Based on this, we designed the questionnaire to make a survey of some lean construction projects in China, thus we can get the data on the performance of the projects.

FINAL INDEX SYSTEM BASED ON FACTOR ANALYSIS

To properly evaluate the overall condition of the lean construction project performance, we have to analyze and describe it from different perspectives. In many comprehensive evaluation methods, factor analysis method is accepted and given more attention because it can reduce a large number of correlated variables into a smaller subset of uncorrelated variables (Barth, 2008). The main idea of factor analysis is to divide the variables into groups depending on their correlation, and the variables in one group have high correlation while in different groups have low correlation. Each group represents a basic structure, regarded as the main factor or public factor. It is helpful to analyze complex practical problems when we identify a few main factors from the intricate relationship among the elements in the statistics. As the performance evaluation system based on BSC shows strong internal correlation, factor analysis can overcome the impact of the correlation between the indicators on evaluation results, and we use it to build final indicators system of the lean construction project performance. Details are as follows.

Reliability and Validity Analysis

We analyzed the reliability of the raw data by SPSS, the results showed that Cronbach's Alpha was 0.804, and had a higher internal consistency. Then we analyzed the validity of the raw data, KMO was 0.814> 0.5, approximate chi-square was 4138.573, P = 0.000, and passed validity test, therefore, factor analysis could be carried out.

Common Factor and the Final Index System

Selected the principal component as a factor extraction method, the criteria of selected factor extraction was: characteristic value≥ 1. As shown in table2, there are five characteristic values meet the requirement, and their cumulative contribution rate for the sample variance is 59.692%>50%. The results are acceptable statistically and can be interpreted by five common factors.

Furthermore, we should calculate the component matrix for explaining the five common factors, and after the factors rotation by SPSS, we get the factor load matrix. According to the matrix, we can rename the five common factors as knowledge and ability indicators, financial indicators, owner indicators, control in the management process, and management coordination in the management process. The variables of the five common factors are shown in Table 3.

Before evaluating the performance of lean construction projects, we also should calculate the weight of each variable of the final index system. The weight is calculated by the proportion of the variable variance explanation rate to total variance explanation rate.

The formula is as following:

$$\omega_{ki} = \frac{x_i}{\sum_j x_j} \qquad (j = 1, 2, \ldots, n, i = 1, 2\ldots, n, k = 1 \sim 5) \tag{1}$$

Table 1: The Preliminary Indicator System of the Lean Construction Project Performance

Indicators		Items
Financial		Main income is higher than other projects
		Direct cost is lower than other projects
		Management costs is lower than other projects
Management process	Control	The total project overruns
		The sub-project cost overruns
		The completion of schedule for the total project
		The completion of schedule for the sub-project
	Management	Technical specification and functional requirements to meet
		Number of major incidents
	Coordination	Subjected to government or public environmental complaints
		Contract implementation
Knowledge and ability		Technological breakthroughs and innovations in the course of the project
		The development or continuous improvement of templates, procedures, and tools in the implementation of project
		After the completion of the project, participants increase the knowledge and experience of similar projects
		After the completion of the project, participants increase the knowledge and experience of the future cooperation
owner		Owner's satisfaction
		The number of litigation and claims incident with owners
		The mutual complaints rate with the owners during the project

Table 2: Total Variance Explained

Ingredient	Initial eigenvalues			Rotate the sum of squares loaded		
	total	Variance	Accumulatio	total	Variance%	Accumulatio
1	5.105	26.871	26.871	2.761	14.53	14.53
2	2.347	12.353	39.224	2.628	13.83	28.359
3	1.536	8.085	47.309	2.276	11.979	40.339
4	1.228	6.465	53.774	1.857	9.772	50.111
5	1.124	5.918	59.692	1.82	9.581	59.692
6	0.966	5.084	64.776			

Where ω_{ki} stands for the weight of the i-th variable for k-th indicator; x_i stands for the variance explanation rate of the i-th key variable for k-th indicator. Based on the factor load matrix, we calculated the weight of each variable by the formula. They are shown in the last row of Table 3.

Table 3: The Extraction Factor Results of Lean Construction Project Performance

Common	Variables	Weight
The first main factor Knowledge and ability indicators	Technological breakthroughs and innovations in the course of the project	0.234
	The development or continuous improvement of templates, procedures, and tools in the implementation of project	0.215
	After the completion of the project, participants increase the knowledge and experience of similar projects	0.258
	After the completion of the project, participants increase the knowledge and experience of the future cooperation	0.292
The second main factor Financial indicators	The profits during the construction of the project compared with the industry average	0.370
	The direct costs during the construction of the project compared with the industry average	0.337
	The saving costs during the construction of the project compared with the industry average	0.293
The third main factor Owner indicators	The number of litigation and claims incident with owners	0.396
	The mutual complaints rate with the owners during the project	0.504
The four main factor Control in the management process	The total project overruns	0.270
	The sub-project cost overruns	0.267
	The completion of schedule for the total project	0.220
	The completion of schedule for the sub-project	0.243
The five main factor Management coordination in the management process	Technical specification and functional requirements to meet	0.225
	Contract dispute situation	0.270
	The coordinate handing of problem or disputes in the work	0.269
	Owner's satisfaction	0.237

RESULTS OF PERFORMANCE EVALUATION

Based on above index system and raw data of lean construction projects, we can calculate both individual and comprehensive indicator score of 300 projects to evaluate their performance. The calculation formula of individual indicator score is as following:

$$F_k = \sum \omega_{ki} X_i \qquad (i = 1, 2\ldots, n, k = 1 \sim 5) \tag{2}$$

F_i stands for the individual indicator score, ω_{ki} stands for the weight of the i-th variable for k-th indicator, X_i stands for the variable score of each indicator in raw data.

The calculation formula of comprehensive indicator score is as following:

$$F = \sum \omega_k F_k \qquad (k = 1 \sim 5) \tag{3}$$

Where F stands for the comprehensive indicator score, ω_k stands for the weight of k-th indicator to five indicators, λ_i stands for the corresponding characteristic values of the k-th indicator, F_k stands for the indicator score which is by equation (2).

We calculated the individual indicator score and the comprehensive indicator score of the 300 projects, the projects with high score are mostly municipal projects which constructed by state-owned enterprises and large private enterprises. The projects with the highest score on individual indicator are shown in Table 4. In table 4, we can find that there are a few projects performing good individual indicator performance with scoring “5”, and projects with different characteristics show different individual indicator performance: some projects only perform good performance in one indicator, such as Shijiazhuang Museum of Art project performs high performance in financial indicator, the Jinan Century Jiayuan 9 Building project performs high performance in control in the management process; some projects perform good performance in several individual indicators, such as Nanjing Transportation Technology Building project performs high performance in knowledge and ability indicator, financial indicator, control in the management process and management coordination in the management process, Beijing 108 State Road Reconstruction project performs high performance in knowledge and ability indicator, owners indicator and management coordination in the management process. The result can distinguish the difference of the projects’ performance and indicates that it is essential to use BSC-based evaluation index system.

DISCUSSION

To illustrate the reason why projects with different characteristics show different performance, we interviewed the projects with high and low performance score, and we found that even though most projects conducted with parts of lean construction, many of them can not implement lean construction instruments well. As is mentioned above, the projects with high performance were mostly municipal projects that constructed by state-owned enterprises and large private enterprises, because these projects funds and other resources were more adequate, the size of the project was large, and they showed a good collaboration spirits, rich working, operating and negotiating experience, and relevant knowledge, so these projects could achieve higher scores in knowledge and ability, financial, property owners, as well as project management and coordination of the supporting departments, enabling the implementation of lean construction technology, and thus achieved better project performance. In addition, some enterprises got a higher score in project performance the same as in the indicator index. For example, the reconstruction of Beijing 108 highway project, Nanjing Transportation Technology Building and Tianjin University of Finance and Economics Teacher apartment project. It could be speculated that there is a certain correlation between the degree of implementation of lean construction techniques and project performance. This paper provided the basis of this speculation, and made premise work to further verify the relationship between the status of implementation of lean construction technology and project performance.

Table 4: The Individual Indicator Performance of Lean Construction Projects

Indicators	Projects	Score
Knowledge and ability indicator	Nanjing Transportation Technology Building	5
	Guizhou Ota River Health Hydropower Station	5
	Beijing 108 State Road Reconstruction	5
Financial Indicator	Shijiazhuang Museum of Art	5
	Tianjin 2011 Airport Economic Zone heating pipe network	5
	Nanjing Transportation Technology Building	5
owners indicator	The Jinan Century Jiayuan 9 Building	5
	Tianjin University of Finance and Economics Teacher	5
	Beijing 108 State Road reconstruction works	5
Control in the management process	The Jinan Century Jiayuan 9 Building	5
	Tianjin University of Finance and Economics Teacher	5
	Nanjing Transportation Technology Building	5
Management coordination in the management process	Xiamen binhu residential homes	5
	Beijing 108 State Road reconstruction works	5
	Nanjing Transportation Technology Building	5

CONCLUSIONS

This research used BSC and factor analysis to construct the evaluation index system which is more comprehensive for its combined finance, project management process, knowledge and ability, as well as owners. Using the index system, 300 projects were evaluated, and the evaluation results found that the score of lean construction project performance is related to its scale and normative. Combining with the normative of technical implementation of lean construction, we find that lean construction project performance have some correlation with the degree of implementation of lean construction technology. Therefore, strengthening the study of relevance of degree of lean construction technology implementation and lean construction project performance is the concerned issue in the future. In addition, comparative study with other evaluation methods, such as fuzzy comprehensive evaluation, neural network, data envelopment analysis, etc., is worth further exploration.

ACKNOWLEDGMENTS

Support from Natural Science Foundation of China(Grant No. 71171140) is gratefully acknowledged.

REFERENCES

Alarcón, L.F., Diethelm, S., Rojo, O. and Calderon, R. 2005. Assessing the impacts of implementing lean construction. In: *Proc. 13th Ann. Conf. of the Int'l. Group for Lean Construction*. Sydney, Australia, Jul 19-21.

Alwi, S., Hampson, K. and Mohamed, S. 2002. Non value-adding activities: a comparative study of Indonesian and Australian construction projects. In: *Proc. 10th Ann. Conf. of the Int'l. Group for Lean Construction*. Gramado, Brazil, Aug 6-8.

Barth M. 2008. Deciphering student evaluations of teaching: a factor analysis approach. *Journal of Education for Business*, 84(1), pp.40-46.

Bertelsen, S. 2001. Lean Construction as an Integrated Production In: *Proc. 9th Ann. Conf. of the Int'l. Group for Lean Construction*. Singapore, Aug 6-8.

Coe N., and Letza S. 2014. Two decades of the balanced scorecard: a review of developments. *Poznan University of Economics Review*, 14(1), pp.63-75.

Daeyoung K. and Park H. 2006. Innovative construction management method: assessment of lean construction implementation. *Journal of Civil Engineering*, 10(6), pp.381-88.

Forman M. 2013. Inertia and change: lean construction and health and safety work on construction sites. *Construction Management & Economics*, 31(6), pp.647-60.

Henry M. A. 2009. Prioritising lean construction barriers in Uganda's construction industry. *Journal of Construction in Developing Countries*, 14(1), pp.15-32.

Hobday M. 2000. The project-based organization: an ideal form for managing complex products and systems? *Research Policy*, 29(7), pp.871-893.

Kagioglou, M., Cooper R. and Aouad G. 2001. Performance management in construction: a conceptual framework. *Construction Management and Economics*, 19(1), 85-95.

Koskela L.1992. Application of the new production philosophy to construction. Stanf ord, CA: Stanford University Press.

Salem O., Solomon J., Genaidy A. and Luegring M. 2005. Site implementation and assessment of lean construction techniques. *Lean Construction Journal*, 2(2), pp.1-21.

Salem O., Solomon J., Genaidy A. and Minkarah I., 2006. Lean construction: from theory to implementation. *Journal of Management in Engineering*, 22(4), pp.168-75.

Thomson G. 1935. The factorial analysis of human abilities. *Human Factors*, 9(5), pp.180-85.

Thomassen, M.A., Sander, D., Barnes, K.A. and Nielsen, A. 2003. Experience and results from implementing lean construction in a large Danish contracting firm. In: *Proc. 11th Ann. Conf. of the Int'l. Group for Lean Construction*. Blacksburg, VA, Jul 22-24**.**