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Barriers of Last Planner System: A Survey in Vietnam Construction Industry

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Abstract: Construction industry is overwhelmed by delay and often has suffered cost and time overrun. In this context, Last Planner System (LPS) has been considered as a very useful tool for the management of the construction process. Many previous studies have reported its effectiveness in construction performance. This study aims to evaluate the level of importance of the Last Planner processes in the Vietnam construction industry (VCI), and analyze the existing barriers when implementing these processes in construction management. These barriers were collected based on previous studies from International Group for Lean Construction (IGLC). A survey was carried out through questionnaire. The respondents are been experienced people in construction project management. There are four processes of LPS that were investigated including master schedule, phase schedule, lookahead plan, and weekly work plan. The results showed that master schedule is the most important item when performing a construction project in the VCI. The highest degree of agreement belongs to 'owner – contractor' pair with 77.1% importance indices; whereas the lowest belongs to 'consultants – contractors' pair with 63.8% importance indices. Eventually, three barrier factors were extracted from factor analysis technique with 62.2% of variance explained.

Keywords: Lean Construction, Last Planner, Planning and Control, Construction Workflow, Vietnam

I. INTRODUCTION

Significant amounts of project values have been lost due to weak management, defective design, poor quality of work, inferior working conditions, poor safety arrangement, etc [23]. In reality, many methods have been used to search for new techniques and tools that can guarantee the organizational competitiveness in the long run through the systematic decrease of losses and wastefulness, improvement of the product quality, and improvement of the environmental and safety conditions [22]. In this context, Last Planner System (LPS) was adopted as a very useful tool for the management of the construction process, and continuous monitoring of the planning efficiency [3].

The Last Planner is a production planning and control tool used to improve the reliability of the construction workflow [26]. It has been implemented in a large number of projects from various countries such as United States, Brazil, Chile, Ecuador, England, Finland, Denmark and Korea. This tool was able to increase the reliability of commitment in production planning and control by the leaders of the work teams [7]. In order to gain the expected reliability, constraints of activity must be identified and removed so that the necessary materials, information and equipment are ensured to be available [6]. However, Salem et al (2005) have stated that the current lean construction is still in early stage of development, and tools such as Last Planner have been tested in the field and refined over last decade [28]. Formoso and Moura (2009) has claimed that a multitude of publications focus on the success of Last Planner, and indicated that the success of this tool is due to the way it manages the commitments [14].

Based on above discussion, two objectives of this study are as follows: (1) evaluate the level of importance of the LPS in current construction performance; and (2) analyze the existing barriers when using the LPS processes in the VCI. In this paper, the selected construction projects for studying are been under execution phase. The outcome of this study would help professionals for improvement in planning and managing the construction schedule for all project parties.

II. CURRENT PRACTICE

In Vietnam, the principles and techniques of lean construction, especially in the Last Planner, are still a very new category for scholars and individuals in construction industry. However, as one of the problems that emerged, the LPS was applied in construction practice without recognizing the structural difference between management and production control system [25]. Furthermore, there is no specific plan for LPS implementation in Vietnam construction industry (VCI) detailing the general items to be considered prior to such

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implementation was proposed. Therefore, an unclear practice existing in the construction industry is that whether or not the LPS have been implemented in planning and controlling construction production. Regarding this practice, the current construction efficiency may increase.

Study on lean thinking and LPS shows no evidence into its practical application within construction industry in Vietnam, but there is obviously the similar philosophy in planning and controlling production between the process of LPS and the process of traditional system. Therefore, to the best knowledge of the authors, the study here reported is the first survey about lean thinking in construction aiming to improve the current planning practice, and provide a basis for the development of research in the field of lean construction in Vietnam.

III. Last Planner in Construction

In lean construction, planning and control are considered to be complementary and dynamic processes maintained during the course of the project. Planning defines the criteria and creates the strategies required to reach the project objectives. At the same time, control makes sure that each event will occur following the planned sequence [8, 19]. Ballard and Howell (1994) proposed a concept in planning and control called "Last Planner" to shield workers from the uncertainty of work flows. It is the last in the decision chain of the organization because the output of planning process is not a directive for a lower level planning process, but results in production [5]. Furthermore, Ballard (2000) argued that LP is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of those procedures [8]. On the other hand, Kalsaas et al. (2006) stated that LPS is the person or team that produces construction assignments of work to be carried out [20].

The LPS comprises four levels of planning processes with different chronological spans: master scheduling, phase scheduling, lookahead planning, and weekly work planning (WWP) [8]. Bolivar (2007) has indicated that the master and phase scheduling are undertaken in setting milestones and identifying handoffs, and the lookahead and weekly work plans are closer to the situated planning model where plans take into account changes in the environment affecting inputs and outputs of construction activities [10]. Furthermore, Ballard (2000) and Hamzeh et al. (2008) have defined each planning process of LPS as follows [8, 17]:

- *Master scheduling* is to identify major milestones based on relevant documents to see what should be done.
- *Phase scheduling* is to generate covering each project phase such as foundation, structural frame, and finishing.
- *Lookahead planning* is to set up a schedule with time frame from 4 to 6 weeks to understand what can be done. The result is a workable backlog formed.
- *Weekly work plan* is to show interdependence between the works to clearly understand what will be executed.

Despite the advantages of the LPS, the current practice on many construction projects shows a poor implementation of lookahead planning resulting in a wide gap between long-term planning (master and phase schedule) and short-term planning (weekly work plans) reducing the reliability of the planning system and the ability to establish foresight [1, 15].

Extensive research has been undertaken in LPS in the past nearly 20 years. These studies can be grouped in, but be not limited to, the following topics: (1) LPS theory [5, 7-10, 12, 15, 19, 22, 29], (2) LPS implementation [2, 3, 13, 20, 21, 25, 26, 28], (3) LPS evaluation and assessment [4, 11, 14, 27, 30], and (4) LPS models and measurement [17, 19]. These previous studies show the barriers when implementing LPS in construction industry as presented in Table I [2, 3, 27].

TABLE I
List of barriers when implementing LPS

#	Barriers
1	Lengthy approval procedure by clients
2	Involvement of so many parties joined the project, especially subcontractors and suppliers
3	Low understanding of the process planner to the concepts of Last Planner
4	Weak communication and transparency among participants of the production process
5	Lack of integration of the production chain between client, consultant, contractor and supplier
6	Inadequate administration of the necessary information to generate a "learning cycle" and to take corrective actions
7	Low implementation of advanced technology in construction
8	Language and cultural issues when performing a project
9	Lack of the training for the managers when planning and controlling a project
10	Over-commitment to the work which can be done in a lookahead plan

IV. Research Methodology

A questionnaire (in Vietnamese) was prepared to find out the appropriate data for two study objectives as mentioned above. It was distributed to three principal project parties including owner, consultant and contractor. The respondents of this survey are been the individuals who have a lot of experience in execution and management of construction projects in Ho Chi Minh city, Vietnam. They are project managers, site managers and site engineers. The surveyed projects involved industrial project, residential project, and civil project. The non-probability sampling was applied in this study because of its certain limitations. A total of 185 questionnaires were distributed, then got 48 of feedbacks from respondents. Thus, rate of response has been found as 26%.

The first step is the evaluation of importance level of the LPS in construction performance. To do this, the respondents were requested to answer both frequency of occurrence and severity. The analysis method used in this situation was index analysis. The ranking was made to find out the most important item. The Spearman's coefficient was then employed to analyze the correlation between agreement and disagreement of pair of parties for their answers. The next step is the analysis for the existing barriers when applying the LPS in the current construction performance. The barriers were collected from previous studies as shown in Table I. The respondents were requested to answer the five-point question for each barrier factor. The factor analysis was employed in this situation to sort out the main barriers.

The data were analyzed by three types of indices:

- Frequency index: This index expresses occurrence frequency of factor. It is computed as per following formula:

$$F.I = \frac{\sum_{i=1}^{5} a_i n_i}{5N}$$

where: a = constant expressing the weight assigned to each response (ranges from 1 for "No happen" to 5 for "Always"), n = frequency of each response, and N = total number of responses.

- Severity index: This index expresses severity of factor. It is computed as per following formula:

$$S.I = \frac{\sum_{i=1}^{5} a_i n_i}{5N}$$

where: a = constant expressing the weight assigned to each response (ranges from 1 for "Very little" to 5 for "Very much"), n = frequency of each response, and N = total number of responses.

- Importance index: This index expresses the overview of factor based on both their frequency and severity. It is computed as per following formula:

$$IMP.I = F.I \times S.I$$

V. Analysis and Findings

A. Level of Importance

The first objective of this study is to evaluate the level of importance of LPS in construction projects. The respondents were requested to answer the occurrence frequency and severity of LPS process performance that affect project efficiency. A five-point Likert scale from 1 to 5 is adopted. These numerical values are assigned to the respondents' rating: '1 = No happen; 2 = Rarely; 3 = Sometimes; 4 = Often; 5 = Always' for frequency, and '1 = Very little; 2 = Little; 3 = Moderate; 4 = Much; 5 = Very much' for severity. Table II and III present the results of analysis for the frequency and severity indices of four planning processes as well as their rankings. These factors are rated by three different respondent groups. It can be seen from these two tables that master and phase schedule are the two most top orders by overall. It means that long-term schedule is almost performed in the construction projects in the VCI. Furthermore, there is no difference in the ranking orders of occurrence and severity by overall. It means that the more the long-term schedule frequently performs, the more it severely impacts the project efficiency. The third and fourth order respectively belong to weekly work plan and lookahead plan for both occurrence and severity ranking. The deviation of the occurrence ranking order from the severity ranking orders in each respondent group is small and can be negligible. Whereas, the deviation between groups are quite large. These deviations are possibly due to the role and responsibility of a party in the project are totally different with others. Especially, these results show lookahead plan that plays an important "bridge" when connecting long-term plans and weekly work plan is not much attended by employees in construction projects.

TABLE II
FREQUENCY INDEX AND RANKING

LP process	Overall		Owners		Consultants		Contractors	
	F.I	Rank	F.I	Rank	F.I	Rank	F.I	Rank
Master schedule	0.908	1	1.000	1	0.867	2	0.947	1
Phase schedule	0.892	2	1.000	1	0.800	1	0.913	2
Lookahead plan	0.763	4	0.760	3	0.733	3	0.760	4
Weekly/daily work plan	0.846	3	0.960	2	0.733	3	0.873	3

TABLE III
SEVERITY INDEX AND RANKING

LP process	Overall		Owners		Consultants		Contractors	
	S.I	Rank	S.I	Rank	S.I	Rank	S.I	Rank
Master schedule	0.875	1	0.880	1	0.733	3	0.927	1
Phase schedule	0.858	2	0.840	2	0.767	2	0.913	2
Lookahead plan	0.758	4	0.800	3	0.700	4	0.767	4
Weekly/daily work plan	0.796	3	0.880	1	0.800	1	0.800	3

TABLE IV
IMPORTANCE INDEX AND RANKING

LP process	Overall		Owners		Consultants		Contractors	
	IMP.I	Rank	IMP.I	Rank	IMP.I	Rank	IMP.I	Rank
Master schedule	0.875	1	0.880	1	0.733	3	0.927	1
Phase schedule	0.858	2	0.840	2	0.767	2	0.913	2
Lookahead plan	0.758	4	0.800	3	0.700	4	0.767	4
Weekly/daily work plan	0.796	3	0.880	1	0.800	1	0.800	3

TABLE V
SPEARMAN RANK CORRELATION COEFFICIENTS

Comparison pair	Frequency index		Severity index		Importance index	
	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Owners – Consultants	0.801	0.01	0.636	0.01	0.667	0.01
Owners – Contractors	0.754	0.01	0.706	0.01	0.771	0.01
Consultants – Contractors	0.759	0.01	0.577	0.01	0.638	0.01

Table IV shows the importance indices and rankings of LPS processes consistent with various parties. As importance index is calculated from multiplying frequency index by severity index, rankings of importance level have mostly no change. All parties met an agreement that master schedule is the first ranking order, and lookahead plan is almost the fourth ranking order. This proves that master schedule is the most important item among LPS processes when performing a construction project in the VCI.

Spearman's coefficient of rank correlation is used to demonstrate whether there is the agreement or disagreement among each pair of parties. Table V illustrates the results of Spearman coefficient and significance level calculations. A conclusion inferred from these results is that there is a very good agreement between parties in ranking the LPS processes. Although some slightly contrary opinions exist between owner and contractor, the highest degree of agreement belongs to this pair with 77.1% importance indices. Whereas, the lowest degree of agreement appears between consultants and contractors with 63.8% importance indices.

B. Analysis of Existing Barriers

Existing barriers of LPS in construction management were identified and analyzed from previous studies. Data were collected through five-point Likert scale with a value being 1 for 'Strongly disagree' and 5 for 'Strongly agree'. Factor analysis technique is used to sort out the main barrier. However, before applying this technique, suitability of data must be enquired. In this regard, Barlett's test of sphericity having significance at 0.000 indicates that the correlation matrix is not an identity matrix. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is sufficient with the value of 0.674. Both of these parameters justify that the factor analysis can be applicable.

Principal component factor analysis technique is employed. By using latent root criterion, three factors can be extracted with eigenvalues greater than 1.0. Fig. I is the scree plot of ten items as mentioned in previous section. Statistics of initial variance explained and after rotation are shown in Table VI. With three extracted factors, 62.2% of variance is accounted for the existing barriers of LPS. Table VII shows the three factor loadings extracted from factor analysis technique except for loading values less than 0.5. The varimax orthogonal rotation of principal component analysis is used in this study to group factors. These three factors are named as PC1, PC2 and PC3.

In PC1, 'low implementation of advanced technology' is a reason for low efficiency in construction projects. Vietnam is a developing and emerging country; therefore, advanced technology for construction industry, as well as other industries, is quite backward comparing with developed countries. 'Language and culture issues' often happen when project participants come from various regions or countries. 'Lack of training for the project managers' is considered as the barrier related to the development policies of their organization.

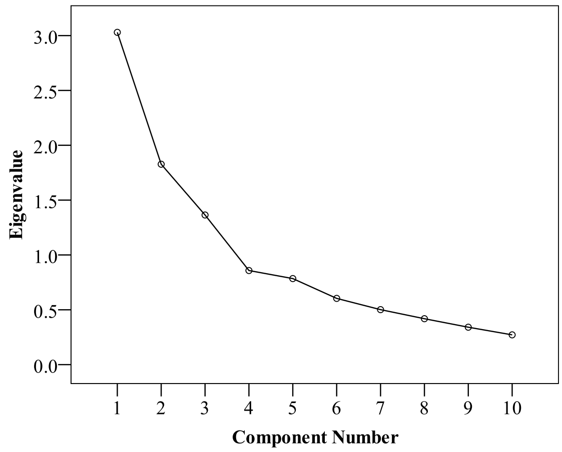

FIGURE I
SCREE PLOT OF FACTOR

TABLE VI
TOTAL VARIANCE EXPLAINED

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.030	30.297	30.297	2.228	22.284	22.284
2	1.827	18.272	48.569	2.227	22.271	44.555
3	1.364	13.643	62.212	1.766	17.657	62.212
4	0.858	8.580	70.791			
5	0.784	7.845	78.636			
6	0.604	6.039	84.675			
7	0.501	5.013	89.689			
8	0.419	4.186	93.874			
9	0.341	3.411	97.286			
10	0.271	2.714	100.000			

TABLE VII
ROTATED COMPONENT MATRIX

#	Barriers	Factors		
		PC1	PC2	PC3
1	Lengthy approval procedure by clients			0.869
2	Involvement of so many parties joined the project, especially subcontractors and suppliers			0.776
3	Low understanding of the process planner to the concepts of Last Planner		0.587	
4	Weak communication and transparency among participants of the production process		0.668	
5	Lack of integration of the production chain between client, consultant, contractor and supplier		0.720	
6	Inadequate administration of the necessary information to generate a "learning cycle" and to take corrective actions		0.743	
7	Low implementation of advanced technology in construction	0.736		
8	Language and cultural issues when performing a project	0.770		
9	Lack of the training for the managers when planning and controlling a project	0.770		
10	Over-commitment to the work which can be done in a lookahead plan [a]	-	-	-

Extraction method: Principal component analysis.
Rotation method: Varimax with Kaiser normalization.
Rotation converged in 7 iterations.
[a]: loading less than 0.5

In PC2, 'low understanding of the Last Planner concepts' is a barrier when implementing LPS in current construction industry. This is due to the LPS is totally new concepts for the practitioners in the VCI as well as other lean construction concepts. Thus, they have done the planned work mainly through their working experience. 'Weak communication and transparency among participants' is the most common problem when performing a construction project in Vietnam. The contractor expedites his work without discussion with the consultants as well as among his employees, this may lead to the completed work not meet the requirements. 'Lack of integration of production chain among project parties' shows that the coordination between client, consultant, contractor and suppliers is necessary when making a work plan. If the production chains of all parties were not considered together, the construction workflow would not be smooth due to difference in plan between them. Information administration is to take corrective actions when performing an activity and to generate learning cycle after completion. Thus, 'inadequate administration of information' leads to a misunderstanding for people who are undertaking the work.

In PC3, 'lengthy approval procedure by client' is considered as a barrier when planning and controlling a project. In this circumstance, if any delay happens in construction schedule due to this reason, the client must be completely responsible for it. 'Involvement of so many parties joined in the project' is a reason for confusion in construction sites. The more participants involved, the more difficult the schedule is planned and controlled. This is possibly due to weak coordination between them.

Eventually, 'over-commitment to the work' is not a principal barrier factor. This barrier often belongs to the contractor. After identifying what work could be done in lookahead plan window, the contractors had to make a commitment that shows the reliability to finish the work as planned. In practice, the contractors frequently do not keep their promise as committed; therefore, the work is congested in next plan.

VI. CONCLUSIONS

In a construction project where time truly equals money, the management of time is critical [16], thus planning and controlling the schedule play a key role towards project success. Therefore, a distinct need has emerged to develop processes for planning and controlling the project schedule better. The major objective of this study is to assess the barriers of LPS processes in the VCI. The main results of the study are as follows:

- Among LPS processes, master schedule is the most important item when performing a construction project in the VCI. The second, third and fourth order belong to phase schedule, weekly work plan and lookahead plan. The Spearman's coefficient analysis shows that the highest degree of agreement belongs to 'owner – contractor' pair with 77.1% importance indices, and the lowest degree of agreement belongs to 'consultants – contractors' pair with 63.8% importance indices.
- With factor analysis technique, three factors, namely PC1, PC2 and PC3, are extracted from ten collected barriers with 62.2% of variance explained. PC1 includes low implementation of advanced technology, language and culture issues, and lack of training for the project managers. PC2 includes low understanding of the Last Planner concepts, weak communication and transparency among participants, lack of integration of production chain among project parties, and inadequate administration of information. PC3 includes lengthy approval procedure by client, and involvement of so many parties joined in the project.

It is recommended that contractors should clearly understand their responsibility to provide materials and equipment on time and be well-prepared for this financial responsibility in order to prevent the circumstance of uncompleted works. Owners need to focus on their responsibility for monthly payment to contractors as an effective solution to eliminate delay in construction projects. Moreover, it should be noted that all parties should focus on the communication when planning and controlling the project as a way of preventing uncertainty in work plan.

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REFERENCES

[1] L.F. Alarcon, J.C. Cruz, "The impact of project planning performance on project outcomes", 10th World Productivity Congress, Santiago, Chile, pp. 12-15, 1997.

[2] L.F. Alarcon, S. Diethelm, O. Rojo, R. Calderon, "Assessing the impacts of implementing lean construction", Proceedings of the 13th Annual Conference of International Group for Lean Construction, Sydney, Australia, pp. 405-411, 2005.

[3] A. Alsehaimi, P. Tzortzopoulos, L. Koskela, "Last Planner system: experiences from pilot implementation in the middle east", Proceedings of the 17th Annual Conference of International Group for Lean Construction, Taiwan, pp. 53-65, 2009.

[4] G. Ballard, "The Last Planner", Spring Conference of the North California Construction Institute, Monterey, CA, USA, 1994.

[5] G. Ballard, G. Howell, "Implementing lean construction: stabilizing work flow", in Lean Construction, Eds. L. Alarcon, A.A. Balkema, Rotterdam, The Netherlands, pp. 101-110, 1994.

[6] G. Ballard, "Lookahead planning: the missing link in production control", Proceedings of the 5th Annual Conference of International Group for Lean Construction, Gold Coast, Australia, pp. 13-26, 1997.

[7] G. Ballard, G. Howell, "Shielding production: an essential step in production control", *Journal of Construction Engineering and Management*, ASCE, vol. 124, no. 1, pp. 11-17, 1998.

[8] H.G. Ballard, "The last planner system of production control", PhD Dissertation, University of Birmingham, Birmingham, UK, 2000.

[9] G. Ballard, G. Howell, "An update on last planner", Proceedings of the 11th Annual Conference of International Group for Lean Construction, Blacksburg, VA, USA, pp. 10-19, 2004.

[10] A.S. Bolivar, "Implications of action theories to lean construction applications", Proceedings of the 15th Annual Conference of International Group for Lean Construction, East Lansing, Michigan, USA, pp. 13-26, 2007.

[11] S.K. Cho, G. Ballard, "Last planner and integrated project delivery", *Lean Construction Journal*, pp. 67-78, 2011.

[12] A.S.I. Conte, "Last planner, look ahead, PPC: a driver to the site operations", Proceedings of 6th Annual Conference of International Group for Lean Construction, Gramado, Brazil, pp. 1-10, 1998.

[13] C. Fillao, V. Revelo, "Applying LPS to a construction project: A case study in Quito, Equador", Proceedings of the 10th Annual Conference of International Group for Lean Construction, Gramado, Brazil, retrieved June 13, 2013 at: http://iglc.net/?page_id=101, 2002.

[14] C.T. Formoso, C.B. Moura, "Evaluation of the impact of the last planner system on the performance of construction projects", Proceedings of the 17th Annual Conference of International Group for Lean Construction, Taiwan, pp. 153-164, 2009.

[15] V. Gonzalez, L.F. Alarcon, F. Mundaca, "Investigating the relationship between planning reliability and project performance", *Journal of Production Planning and Control*, vol. 19, no. 5, pp. 461-474, 2008.

[16] F.E. Gould, "Managing the construction process: estimating, scheduling and project control", Prentice Hall, New Jersey, USA, 2002.

[17] F.R. Hamzeh, G. Ballard, I.D. Tommelein, "Improving construction workflow-the connective role of lookahead planning", Proceedings of the 16h Annual Conference of International Group for Lean Construction, Manchester, UK, pp. 635-646, 2008.

[18] F.R. Hamzel, "The lean journey: implementing the last planner system in construction", Proceedings of the 19th Annual Conference of International Group for Lean Construction, Lima, Peru, p. 246, 2011.

[19] G. Howell, "What is lean construction?", Proceedings of the 7th Annual Conference of International Group for Lean Construction, University of California, Berkeley, CA, USA, retrieved June 13, 2013 at: http://iglc.net/?page_id=107, 1999.

[20] B.T. Kalasaas, J. Skaar, R.T. Thorstensen, "Implementing of last planner in a medium-sized construction site", Proceedings of the 17th Annual Conference of International Group for Lean Construction, Taiwan, pp. 15-30, 2009.

[21] Y.W. Kim, J.W. Jang, "Case study: an application of last planner to heavy civil construction in Korea", Proceedings of the 13th Annual Conference of International Group for Lean Construction, Sydney, Australia, pp. 405-411, 2005.

[22] L. Koskela, "Application of new production philosophy to construction", Technical Report, No 72, CIFE, Stanford, CA, USA, 1992.

[23] L. Koskela, "Lean production in construction", in Lean Construction, Eds. L. Alarcon, A.A. Balkema, Rotterdam, The Netherlands, 1993.

[24] L. Koskela, "An exploration toward a production theory and its application to construction", PhD Dissertation, University of Technology, Espoo, Finland, 2000.

[25] C.W. Lim, J.H. Yu, C.D. Kim, "Implementing PPC in Korea's construction industry", Proceedings of the 14th Annual Conference of International Group for Lean Construction, Santiago, Chile, retrieved June 13, 2013 at: http://iglc.net/?page_id=50, 2006.

[26] M. Liu, G. Ballard, "Improving labor productivity through production control", Proceedings of the 16th Annual Conference of International Group for Lean Construction, Manchester, UK, retrieved June 13, 2013 at: http://iglc.net/?page_id=40, 2008.

[27] S.B. Mohan, S. Iyer, "Effectiveness of lean principles in construction", Proceedings of 13th Annual Conference of International Group for Lean Construction, Sydney, Australia, pp. 421-429, 2005.

[28] O. Salem, J. Solomon, A. Genaidy, M. Luegring, "Site implementation and assessment of lean contruction techniques", *Lean Construction Journal*, vol. 2, no. 2, pp. 1-19, 2005.

[29] I.D. Tommelein, G. Ballard, "Lookahead planning: screening and pulling", Technical Report, No. 97-9, Construction Engineering and Management Program, Civil and Environmental Engineering Department., University of California, Berkeley, CA, USA, 1997.

[30] D.D. Viana, B. Mota, C.T. Formoso, M. Echeveste, M. Piexoto, C.L. Rodrigues, "A survey on the last planner: impacts and difficulties for implementation in Brazilian companies", Proceedings of the 18th Annual Conference for International Group of Lean Construction, Haifa, Israel, pp. 497-507, 2010.