Castillo, T., Alarcón, L.F., Salvatierra, J., and Alarcón , D., 2015. Analyzing the interrelation between management practices, organizational characteristics and performance indicators for construction companies. In: *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 691-700, available at www.iglc.net

ANALYZING THE INTERRELATION BETWEEN MANAGEMENT PRACTICES, ORGANIZATIONAL CHARACTERISTICS AND PERFORMANCE INDICATORS FOR CONSTRUCTION COMPANIES

Tito Castillo[1], Luis F. Alarcón[2], José Salvatierra[3] and Daniela Alarcón[4]

ABSTRACT

Recent studies have established the importance of best management practices in company performance measured by productivity, safety and other performance indicators. Research about the relationship between the characteristics of the organization and its performance has not yet arrived to definitive conclusions. This research aims to examine the relationship between management practices, characteristics of organizations and the project performance. Knowing these relations is necessary to achieve better management strategies. This paper presents results of the first application of a benchmarking effort carried out among nine Chilean construction companies. Management practices, grouped in fifteen dimensions, were assessed from data obtained through surveys. Weighted average of the responses from each survey was used to obtain scores for each dimension. Social Network Analysis (SNA) was used to capture characteristics of the organization on relevant issues such as communication; planning and personal issues and its metrics were the input for the analysis performed. Project performance was measured using nine key performance indicators (KPI) that were periodically reported by the companies. Correlation analysis was used to analyse the relationship among management practices scores, social network metrics and KPIs. The results show significant relationships that can be useful to design performance improvement strategies for companies and projects.

[1] PhD candidate, Department of Construction Engineering and Management, Pontificia Universidad Católica de Chile, Researcher Universidad Nacional de Chimborazo, Ecuador, Av. Vicuña Mackenna 4860, Macul, Santiago, Chile Phone +56 2 23547041, tocastillo@uc.cl

[2] Professor, Department of Construction Engineering and Management, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Edificio San Agustín 3er Piso, Macul, Santiago, Chile, Phone +56 2 2354 4244, lalarcon@ing.puc.cl

[3] Assistant professor of Civil Engineering, Department of Civil Engineering, Universidad de Santiago de Chile. Av. Ecuador 3659, Estación Central, Santiago, Chile, Phone +56 2 27182818, jose.salvatierra@usach.cl

[4] Project Consultant, Production Management Consultants - GEPRO, Av. Vicuña Mackenna 4860, Edificio Mide UC 3er Piso, Macul, Santiago, Chile, Phone +56 2 2354 7050, dalarcon@gepro.cl

KEYWORDS

Lean construction, flow, network, complex, SNA.

INTRODUCTION

Construction industry has been defined as a complex and apparently unpredictable business (Esa, et al., 2014). Because construction enterprises are project oriented its success depends on the projects performance. Some internal and external factors have been proposed as determinant of project performance but there is still not agreement on the main variables. Among the inside factors, management practices and human related issues are commonly cited such as (Chan, et al., 2004; Orozco, Serpell, and Molenaar, 2011).

In this way, recent studies have established the importance of management practices in the performance of enterprises (Bloom, et al., 2011) and construction projects (Ramirez, Alarcón, and Knights, 2004; AlSehaimi, et al., 2014). Therefore, it has been emphasized the need to understand how human related organizational issues influence projects performance since informal organization traces the routes by which information flows inside the companies (Flores, et al., 2014). From Lean construction (LC) perspective, the flow of information affects all other resource flows (Koskela, 2000) (Dave, et al., 2014). Thus, effective management, with a constant flow of information is necessary for Lean production operations.

The purpose of this study is to reveal the relationship between organization characteristics, management practices and performance in construction projects. Knowing the relationships is a useful piece of information to implement strategies for enhancing project performance.

METHODOLOGY

SAMPLE

The present study was performed during one year in 9 construction companies operating in Chile. Project performance was evaluated in 41 construction projects, ranging from 5 to100 million USD that include housing, buildings and industrial assembly. A total of 712 people participated in surveys of management practices. Also 410 employees were surveyed to determine social network characteristics.

LITERATURE REVIEW

Literature review was carried out in three different fields: construction performance measurement, management practices and corporative social networks. The purpose of the literature review was to identify the most commonly used indicators or metrics and methodologies for data collection.

Key Performance Indicators are measures used to monitor, control project performance and conduct benchmarking. There seems to be a common listing of KPIs for construction companies regardless of the project management perspective (Radujković, Vukomanović, and Dunović, 2010) including both leading or process indicators and lagging or outcomes indicators (Yeung, et al., 2013; Costa, et al., 2014; Nassar and Abou Rizk, 2014).

A management practice is a process or method that is usually applied in the management of a company. With the aim of developing a list of management practices, we did a literature search on the most common dimensions (groups of practices) used in management evaluation. (Bassioni, et al., 2004; Ramirez, Alarcón, and Knights, 2004; Jin, et al., 2013; Kim, 2014)

It has been suggested that social networks portray the organization better than charts (Krackhardt and Hanson, 1993). Most common social network metrics and their meaning associated to graph theory were taken from recent bibliography (Easley and Kleinberg, 2010). Social Network Analysis (SNA) techniques and software references are becoming friendlier and frequently used (Abraham, et al., 2009). In construction industry particular uses of SNA have started to be published recently (Alarcón, et al., 2013; Priven and Sacks, 2013).

SOCIAL NETWORK SURVEY

Social network data were gathered by the Center for Excellence in Production Management – GEPUC. A survey was designed and conducted about the interaction between people working in the construction companies. The questionnaire has six questions to explore communication for: Innovation development, personal confidence, planning and problem solving, relevant information exchange and personal issues. The frequency of the interaction was investigated too.

Through an online survey each member had to report who he/she exchanges information with, instead of relying on the available information such as email exchange. This approach allows the identification of the expected formally identified interactions and the informal interactions that develop during the labor time.

MANAGEMENT PRACTICES SURVEY

To define important management practices four workshops were conducted with managers of participating companies. The selected management practices were grouped into 15 dimensions: quality, communication and information, costs and schedule, suppliers, risk, innovation, leadership, corporate goals, organization and change, planning and programming, production, human resources and corporative learning, labor health and safety, relationship with the owner, and technology.

To measure management practices we developed a survey for each management dimension. Evaluation questions with a 5-point Likert qualitative scale of response ranging from 1: Strongly disagree to 5: Completely agree with the question statement were used. A weighted average of each dimension was used to score the practices.

The companies surveyed were part of the “Collaborative Building Excellence Group” that works with the GEPUC. Surveys were applied via Internet to management staff members of the companies, from the CEO to project managers. Response rates obtained were greater than 60% in all cases, which was good enough to get a 90% of confidence and 5% of error of the sample.

KEY PERFORMANCE INDICATORS SURVEY

The performance evaluation was based on project KPIs used as leading or process indicators. A survey among 21 project managers of the construction companies was conducted to prioritize 9 KPIs out of a 23 literature review list. The selection criterions were: importance for the monitoring of projects and the availability of

information to calculate them. The selected group of KPIs include: cost deviation, schedule deviation, accident frequency index, accident gravity index, and planning effectiveness, constraint release, quality index, productivity and contract change.

Project managers of 41 construction projects during three months filled the form containing the 9 KPIs. Projects having at least 3 months advanced and with at least 3 months before ending were chosen.

SOCIAL NETWORK ANALYSIS

SNA was used for understanding the pattern of relationships within the organizations. The analysis allowed to determine if the social networks are tightly bounded diversified or constricted, to find its density and clustering (Abraham, et al., 2009). Some measures as density, diameter, and average path length are used as indicators to understand how the network structure is related to project performance and management practices. These measurements let us see how far the nodes are from each other and how easy are the communication between them.

CORRELATION ANALYSIS

Analysis of Shapiro-Wilk normality was applied to data obtained in management practices, network surveys and records of KPIs. Pearson correlation index **r** was used to measure how related were the sets of data that presented normal distribution. Spearman correlation analysis was applied to non-normal series after ranking raw data. We describe the strength of the correlation using the guide that (Evans, 2012) suggests for the absolute value of r: 0.00-.19 “very weak”; 0.20-.39 “weak”; 0.40-.59 “moderate”; 0.60-.79 “strong”; 0.80-1.0 “very strong”.

Free software R version 3.1.2 (2014-10-31) was used to obtain the correlations. Only strong ($0.6 <= r < 0.8$) and very strong ($r => 0.8$) correlation values, independent of the sign, are shown ahead. The corresponding significance of pairwise p value for each variable equal to 0.05 or less is considered a high significance relationship.

RESULTS

The results are divided into three groups: first relationship between management practices and project performance, second relationship between organization and project performance and third the relationship between management practices and organization. Here some highlights of the results are presented within each area.

MANAGEMENT PRACTICES AND PROJECT PERFORMANCE.

Correlation was used to measure linear dependence between each management dimension score and the variability of each project KPI. Standard Deviation (SD) was used as measure of process variability. We calculated the standard deviation of each KPI using data from all projects in each company. Since variability is considered production enemy, low variability is assessed as good. Results are shown in Table 1.

Table 1: Correlation for KPI variability vs management dimension development.

Management practice	KPI	Pearson-r	p-value
Innovation	Schedule deviation	-0.840	0.005
Technology	Schedule deviation	0.824	0.006
		Spearman-r	**p-value**

Labor health & safety	Accident frequency	0.920	0.000
Labor health & safety	Accident gravity	0.803	0.009

Additionally, relationship between management dimensions weighted average score and the median of each project KPI were calculated. We present the results in Table 2.

Table 2: Correlation between KPI median and management practices scores.

Management practice	KPI	Pearson-r	p-value
Relationship with owner	Planning effectiveness	0.748	0.033
		Spearman-r	**p-value**
Quality	Contract bid change	0.778	0.014
Communication & information	Quality index	0.943	0.005
Costs & schedule	Quality index	0.943	0.005
Planning & programing	Constraint release	0.753	0.019

Quality KPI is very strongly correlated to communication & information and costs & schedule management. Also, labor & health safety management has very strong relation to accident frequency and gravity indexes. As well schedule deviation has very strong inverse correlation with innovation management. On the other hand curiously, schedule deviation variability is directly related to technology management.

ORGANIZATION AND PROJECT PERFORMANCE

Organization was analyzed as social network inside the company. Some properties of the network are related to easy information movement and other ones are related to confidence and commitment (Alarcón, et al., 2013; Pentland, 2014). Correlations between social networks metrics and project KPIs median are detailed in Table 3.

Table 3: Network metrics vs KPI median correlation

Network metric	KPI	Pearson-r	p-value
Relevant Information Exchange-Mean degree	Planning effectiveness	0.995	0.005
		Spearman-r	**p-value**
Frequent Interaction-Density	Accident frequency	-0.975	0.005
Full Interaction-Density	Accident frequency	-0.975	0.005
Innovation development-Density	Accident frequency	-0.975	0.005
Personal Confidence-Density	Accident frequency	-0.975	0.005
Planning and Problem Solving-Density	Accident frequency	-0.975	0.005
Relevant Information Exchange-Density	Accident frequency	-0.975	0.005
Personal Confidence-Diameter	Accident frequency	0.947	0.014
Frequent Interaction- Mean degree	Contract bid change	-0.900	0.037
Planning and Problem Solving-Mean degree	Contract bid change	-0.900	0.037
Frequent Interaction- Path length	Accident frequency	0.975	0.005
Full Interaction-Path length	Accident frequency	0.975	0.005
Personal Confidence-Path length	Accident frequency	0.975	0.005
Planning and Problem Solving-Path length	Accident frequency	0.975	0.005
Relevant Information Exchange-Path length	Accident frequency	0.975	0.005

KPIs variability was correlated to networks metrics as we try to find ties between organization characteristics and project performance. Main correlations are shown in Table 4.

Table 4: Network metrics and KPIs variability correlation.

Network metric	KPI	Pearson-r	p-value
Innovation development-Path length	Planning effectiveness	-0.893	0.042
Innovation development-Diameter	Planning effectiveness	-0.908	0.033
Full Interaction-Diameter	Productivity	0.938	0.018
		Spearman-r	**p-value**
Frequent Interaction-Density	Contract bid change	0.900	0.037
Full Interaction-Density	Contract bid change	0.900	0.037
Innovation development-Density	Contract bid change	0.900	0.037
Personal Confidence-Density	Contract bid change	0.900	0.037
Planning and Problem Solving-Density	Contract bid change	0.900	0.037
Relevant Information Exchange-Density	Contract bid change	0.900	0.037
Frequent Interaction-Diameter	Contract bid change	-0.949	0.014
Full Interaction-Diameter	Contract bid change	-0.894	0.041
Planning and Problem Solving-Diameter	Contract bid change	-0.949	0.014
Innovation development –Diameter	Accident frequency	-0.975	0.005
Frequent Interaction –Diameter	Accident gravity	-0.949	0.014
Planning and Problem Solving –Diameter	Accident gravity	-0.949	0.014
Full Interaction-Mean degree	Accident gravity	-0.900	0.037
Relevant Information Exchange-Mean degree	Accident gravity	-0.900	0.037
Frequent Interaction-Path length	Contract bid change	-0.900	0.037
Full Interaction-Path length	Contract bid change	-0.900	0.037
Personal Confidence-Path length	Contract bid change	-0.900	0.037
Planning and Problem Solving-Path length	Contract bid change	-0.900	0.037
Relevant Information Exchange-Path length	Contract bid change	-0.900	0.037
Innovation development-Path length	Accident frequency	-1.000	0.000
Innovation development-Path length	Accident gravity	-0.900	0.037

Innovation development network, by its path length, is correlated to accident gravity, accident frequency and planning effectiveness. All are inverse relations, so a large path length corresponds to a worst project performance.

MANAGEMENT PRACTICES AND ORGANIZATION

Networks included in the analysis were: personal planning & problem solving, confidence, innovation development, full Interaction, frequent interaction and relevant information exchange.

Mean degree is the number of edges connected to each node in the network and is related to the ability to communicate. It is closely related to the density of a network. We found out that personal confidence and innovation development networks mean

degree is very strongly correlated to leadership and suppliers management. Also innovation management is strongly correlated to relevant information exchange network mean degree. So far network metrics are strongly correlated to leadership, suppliers, planning and programing, innovation and labor health and safety management.

Table 5: Management practices score vs network metrics correlation.

Management practice	Network metric	Pearson-r	p-value
Planning & programing	Relevant Information Exchange-Diameter	-0.947	0.015
Labor health & safety	Innovation development-Diameter	-0.885	0.046
Innovation	Relevant Information Exchange-Mean degree	0.915	0.030
Leadership	Innovation development-Mean degree	0.909	0.032
Leadership	Personal Confidence-Mean degree	0.912	0.031
Suppliers	Innovation development-Mean degree	0.908	0.033
Suppliers	Personal Confidence-Mean degree	0.924	0.025

A summary of the relationship between project performance, organization characteristics and management practices is shown in Figure 1 as a network.

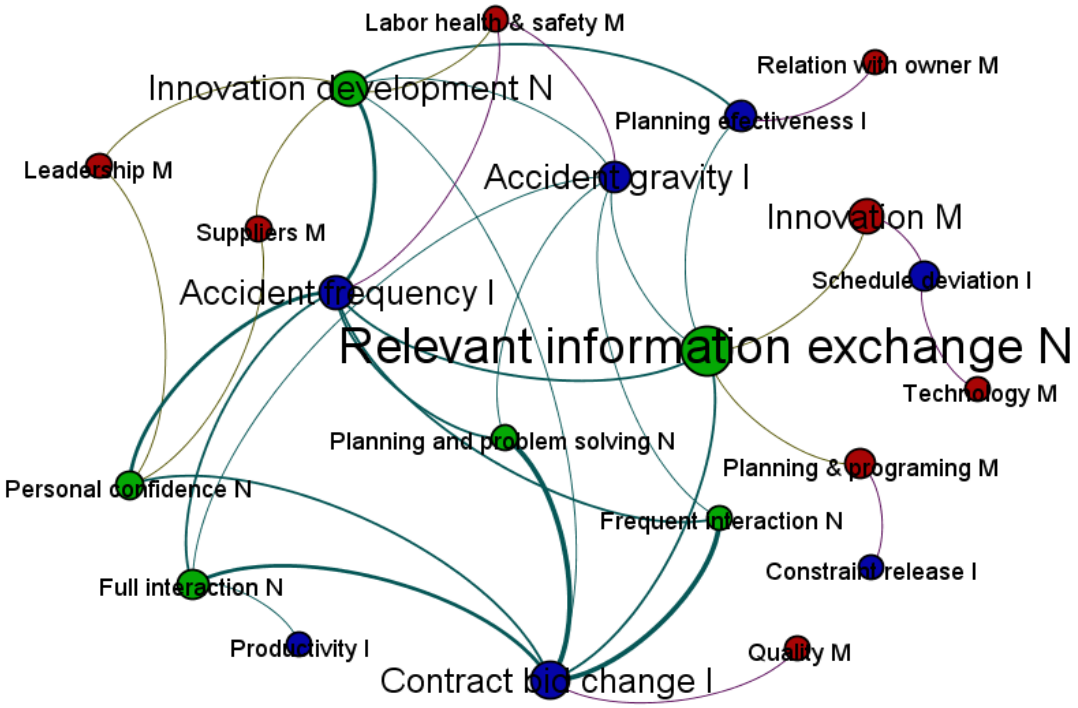

Figure 1: Relations between management practices, social networks and project performance

Management practices (M), social networks (N) and project performance indexes (I) are represented by circular red, blue and green nodes respectively. Bigger nodes correspond to high betweenness centrality and have a large influence on the flow of items through the network. The links appear as lines of different thicknesses

depending on the number of times it has been identified a link between nodes. Pearson or Spearman r index were used to represent tie weight. Gephi 0.8.2 Beta free software was used to create de diagram showing correlations.

In Figure 1, relevant information and innovation development social networks appear as a structure that has direct or indirect ties with most indexes and dimensions of management. Contract bid change, accident gravity and accident frequency project indexes seem to summon the efforts of all internal factors in these companies.

CONCLUSIONS

Our research aimed to establish the existence of significant relationships between management practices of construction companies with its organization and the results obtained in their projects. It was found that organization social networks are the basic structure to which the projects performance indexes and management practices scores are significantly related.

High scores in management practices are associated with better performance KPIs in projects. Into the group of construction enterprises eight out of fifteen management dimensions were related to project KPIs mainly quality, accident-ability, planning and project scope indexes. This kind of relation between management practices and enterprise performance have been established previously in construction industry (Ramirez, Alarcón, and Knights, 2004). Improving management practices should improve enterprise outcomes as was demonstrated in other industries (Bloom, et al., 2011). The inverse relation between schedule deviation variability and technology management may be due to weak degree of readiness of users as reported in the surveys. It is well known that technology readiness is a moderator to organization performance (Kuo, 2013).

Higher densities of the social networks are associated with better performance indicators. Instead long lengths in diameter or path length are correlated with low KPI values in projects. This confirms that the strength of an individual's social group is positively associated to better performance indicators as productivity because it enhances the information flow (Pentland, 2014). For Lean Construction project management, information flow affects all other resources significantly (Dave, et al., 2010). Implementation of the LPS, for example, has demonstrated to play a role in strengthening social networks among the project participants (Priven and Sacks, 2013). In addition, improving employee social networks may increase access to timely information while also reducing monitoring costs (Adler and Kwon, 2002).

The better average degree of social networks is associated with high development of the dimensions of management in the organizations. On the other hand long distance communication among members of the corporation, measured by the diameter or path length, is associated with low scores of management practices. It is known the link between management planning and programming with the network of relevant information (Dave, et al., 2010). Our findings confirm an important relationship between supplier management and the networks of innovation (Morledge, 2011).

Based in results presented herein we recommend that managers in construction enterprises take a holistic approach for strategies of improvement considering the complex system shown in figure 1. Social networks must be regarded since they are

bridging most of the management practices with KPIs and its characteristics are strongly related to better project performance.

The results shown provide an objective basis for relating the performance of projects with organization and management in the construction companies. It not only enhances the understanding of the relation between these variables but also sets a base for managers to measure, monitor, and improve the existing performance of their enterprises and projects.

We are limited to portray the conditions of the companies investigated. Our results represent a temporal reality bounded by the study period of the projects. As social structure evolves during the runtime of projects, a time line tracking should be done to provide better information for management strategies. Causality between network characteristics and management dimensions development should be established too.

ACKNOWLEDGMENTS

We want to thank to the companies that provided access to data collection for this study: AXIS, BASCO, COMIN, EBCO, INCOLUR, MANQUEHUE, PRECON, VVyVIVES-DSD and QUEYLEN.

REFERENCES

Abraham, A., Hassanien, A. E. and Snášel, V. 2009. *Computational Social Network Analysis. Trends Tools and Research Advances.*. London, UK: Springer.

Adler, P. S. & Kwon, S.W. 2002. Social Capital: Prospects for a New Concept. *The Academy of Management Review*, pp. 17-38.

Alarcón, L. F., Alarcón, I. & Alarcón, D. 2013. Social Network Analysis a Diagnostic Tool for information Flow in the AEC Industry. In: *Proc.* 21st *Ann. Conf. of the Int'l. Group for Lean Construction*. Fortaleza, Brazil, Aug. 31-2.

AlSehaimi, A. O., Tzortzopoulos F., P. and Koskela, L. 2014. Improving construction management practice with the Last Planner System: a case study. *Engineering, Construction and Architectural Management*, 21(1), pp. 51-64.

Bassioni, H. A., Price, A. D. F. and Hassan, T. M. 2004. Performance Measurement in Construction. *Journal of Management in Engineering*, 20(2), pp. 42-48.

Bloom, N., Eifert, B., Mahajan, A., McKenzie, D., and Roberts, J. 2011. Does management matter? Evidence from India. [Working paper No. 16658] *National Bureau of Economic Research*, India.

Chan, A. P. C., Scott, D. and Chan, A. P. L. 2004. Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management*, 130(1), pp. 153-155.

Costa, D. B., Formoso, C. T., Lima, H. d. R. and Barth, K. B. 2014. *SISIND-NET Sistema de Indicadores para Benchmarking na construção Civil: Manual de Utilização*, Porto Alegre: Universidade Federal do Rio de Janeiro

Dave, B., Boddy, S. and Koskela, L. 2010. Improving information flow within the production management system with web services. In: *Proc.* 18th *Ann. Conf. of the Int'l. Group for Lean Construction*. Haifa, Israel, Jul. 14-16

Dave, B., Kubler, S., Främling, K. & Koskela, L. 2014. Addressing information flow in lean production management and control in construction. In: *Proc.* 22nd *Ann. Conf. of the Int'l. Group for Lean Construction*. Oslo, Norway, Aug 25-27.

Easley, D. and Kleinberg, J. 2010. *Networks, Crowds, and Markets: Reasoning about a Highly Connected World.*. Cambridge, UK:Cambridge University Press.

Esa, M., Alias, A. and Samad, Z. A. 2014. Project Managers' Cognitive Style in Decision Making: A Perspective from Construction Industry. *International Journal of Psychological Studies*, 6(2), pp. 65-78.

Evans, J. R. 2012. *Statistics, Data Analysis, and Decision Modeling.* 5th Edition ed. New York: Pearson.

Flores, J. et al., 2014. Improving connectivity and information flow in lean organizations:towards an evidence-based methodology. In: *Proc.* 22nd *Ann. Conf. of the Int'l. Group for Lean Construction*. Oslo, Norway, Aug 25-27.

Jin, Z., Deng, F., Li, H. and Skitmore, M. 2013. Practical Framework for Measuring Performance of International Construction Firms. *Journal of Construction Engineering and Management,* 139(9), pp. 1154-1166.

Kagioglu, M., Cooper, R. and Aohuad, G. 2001. Performance management in construction: a conceptual framework. *Construction Management and Economics,* 19(1), pp. 85-94.

Kim, S. B. 2014. Assessment of CII Best Practices Usage in the Construction Industry. KSCE *Journal of Civil Engineering,* 18(5), pp. 1228,1238.

Koskela, L. 2000. *An Exploration Towards a Production Theory and its Application.* VTT Publications ed. Espoo, Finland: VTT Building Technology.

Krackhardt, D. and Hanson, J. 1993. Informal networks: the company behind the chart.. *Harvard Bussiness Review*, pp. 104,111.

Kuo, Y.L. 2013. Technology readiness as moderator for construction company performance. *Industrial Management & Data Systems,* 113(4), pp. 558-572.

Morledge, R. 2011. Colleges as agents for construction innovation. *Construction Innovation,* 11(1), pp. 441-451.

Nassar, N. & Abou Rizk, S. 2014. Practical Application for Integrated Performance Measurement of Construction Projects. *Journal of Management in Engineering,* 30(6), pp. 1,11.

Orozco, F., Serpell, A. and Molenaar, K. 2011. Competitiveness factors and indexes for construction companies: findings of Chile. *Revista de la Construcción,* 10(1), pp. 91-107.

Pentland, A. 2014. *Social Physics: How Good Ideas Spread-The Lessons from a New Science.* USA: Penguin Group.

Priven, V. and Sacks, R. 2013. Social Network Development in Last Planner System Implications. In: *Proc. 21st Ann. Conf. of the Int'l Group for Lean Construction*, Fortaleza, Brazil, July 14-16.

Radujković, M., Vukomanović, M. and Dunović, I. B. 2010. Application of key perofrmance indicators in south-eastern european construction. *Journal of Civil engineering and Management,* 16(4), pp. 521-530.

Ramirez, R., Alarcón, L. F. and Knights, P. 2004. Management evaluation system as a complement to the national Benchmarking of chilean construction companies. *Revista Ingeniería de Construcción,* 19(1), pp. 5-16.

Yeung, J. F., Chan, A. P., Chan, D. W., Chiang, Y. H., and Yang, H. 2013. Developing a Benchmarking Model for Construction Projects in Hong Kong. *Journal of Construction Engineering and Management,* 139(6), pp. 705-716.