

LAST PLANNER SYSTEM, SOCIAL NETWORKS AND PERFORMANCE OF CONSTRUCTION PROJECTS

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ABSTRACT

Last Planner System (LPS) has made significant improvements in project performance worldwide. It is assumed that LPS implementation improves communication among members of the organization. However, the way that LPS management practices and organization’s social networks are related to project performance is still unknown. The purpose of this study is to analyse the relations between LPS implementation, social networks metrics and performance in construction projects. A correlation analysis was applied to implementation levels of LPS, social network metrics and Key Performance Indicators (KPIs) in construction projects. The implementation levels of LPS practices were measured during LPS meetings. Social network data was collected by an on-site survey. The participant companies agreed to a KPIs report, encompassing nine projects over three months. This paper presents significant correlations tying project performance to social network metrics and to LPS implementation levels, in nine projects from two Chilean construction firms. Implementation level of LPS appears related to network average degree and density but that does not always mean better projects performance. The relations found are a tool that could be used to implement improvements in management practices and organizations. Identification of social networks’ optimum metrics related to project performance still requires further research.

• KEYWORDS

Management practices, Last Planner System; Social networks; Key performance indicators; Project performance.

• INTRODUCTION

Construction has been defined as a complex system consisting of many diverse connected and interrelated elements acting in an adaptive way. Despite this reality, construction managers tend towards simplification to a one-dimensional form more conducive to decision making (Bertelsen 2003). In consequence, frequently the measures taken by project managers affect project costs, duration, safety and quality

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and increase project risk (Pons A. 2014). Many studies on pairs of variables involved in the construction projects have been conducted; one example is the effect of management practices on the results of the projects in construction (AlSehaimi et al. 2014). Also, the effect of the temporary organizations acting in the projects has been analysed to establish their influence in construction project results (Bertelsen and Koskela 2005). Influence of lean management practices, such as Last Planner System (LPS), on organizations implementing projects has won recent attention in an approach that involves people, from a lean construction perspective (Priven and Sacks 2015).

It has been established that the implementation of the LPS, that is applied to produce predictable work flow and rapid learning in programming construction of projects, has positive effects on project performance (Alarcón et al. 2008). Also, LPS has shown important improvements in project organizations connectivity measured by social network metrics like density and average degree of actors (Priven and Sacks 2015). Connectivity is important for construction management because it eases information flow and production is conceived as materials and information flow (Koskela 2000). Still, no conclusions have been drawn concerning the relationships between social network strength and work or workflow outcomes (Priven and Sacks 2015).

Project management system is mainly affected by people and production management practices (Aramo-Immonen and Vanharanta 2009). A holistic analysis of construction projects including those factors is needed. However, there are few analyses on how LPS management practices and characteristics of temporary organizations, in conjunction, are related to project performance. Construction management needs to be aware of these factors as they make decisions which affect the construction teams (Radosavljevic and Bennett 2012).

The purpose of this study is to analyse the relations between LPS implementation levels and project social networks metrics related to performance in construction projects. The information generated constitutes a management tool in order to understand project organization and reinforce best management practices for better project performance.

• **BACKGROUND**

LPS is a production management practice regularly applied in construction projects. Production is defined as the set of actions which convert materials and components into a new facility (Radosavljevic and Bennett 2012). It has been highlighted the effects of using LPS in improving production in construction projects as well as their positive influence on the organization in charge.

The interest in analyzing organizational social networks has grown in recent years since that structures depict organizations better than charts (Krackhardt and Hanson 1993). At the same time, Social Network Analysis (SNA) techniques have developed a vocabulary and set of measures for relational analysis (Scott 2013). SNA have been applied in construction projects in order to make visible information flow inside organizations (Alarcón et al. 2013). Information flow is a critical issue from the point of view of lean production (Koskela 2000).

A common approach to evaluate performance in construction industry relies on achievement of client objectives like cost, time and quality (Kagioglou et al. 2001). Usually, KPIs are used to measure performance, or the success of an organization on achieving a particular objective, at different levels inside the firm activity: headline,

operational and diagnostic. Operational KPIs are related with specific production activities and are used for continual improvement (Beatham et al. 2004).

- **METHODOLOGY**

- **CASE SELECTION**

This study was performed in nine construction projects from two construction firms operating in Chile. The participating companies were part of a benchmarking exercise led by the Center for Excellence in Production Management – GEPUC. To avoid the bias of ending or recently starting activities, projects that had advanced at least three months and/or with at least three months before ending were chosen. Each company selected a group of comparable running projects to measure similar indicators. All of the selected projects were for housing buildings. Projects managed with LPS implementation were selected. Organizational and administrative diagnoses were made relying on the staff who ran the projects, from the construction manager to foremen and subcontractors. A total of 190 people participated in surveys to establish social networks' composition and metrics.

- **METRICS ELECTION**

A common list of nine operational KPIs was agreed upon between the two participant construction companies, these included LPS indicators. KPIs were chosen attending to their importance for project monitoring and the availability of information to calculate them. Also, the two participating companies have implemented monitoring systems that report the nine selected indicators monthly. These systems were developed during a benchmarking exercise led by the Centre for Production Excellence Management (GEPUC). Thus construction companies took advantage of the set of indicators without causing work overload for employees. The group of KPIs included cost deviation, schedule deviation, accident frequency index, accident gravity index, planning effectiveness, constraint release, quality index, productivity and contract bid change

A metric of the degree of implementation of LPS, based on Planning Best Practice index checklist of 15 planning and control practices, was applied during LPS meetings (Viana et al. 2010). Each practice was associated with a list of steps that should be met for proper execution. A scale from zero for not implemented to four or fully implemented was associated to this list. A weighted average of these steps was awarded as a percentage of implementing the practice. Practices evaluated were: a) Formalization of the planning and control process, b) Standardization of short-term planning meetings, c) Use of visual devices to disseminate information, d) Corrective actions based on the causes non-completions of plans, e) Critical analysis of data, f) Correct definition of work packages, g) Systematic update of the master plan, when necessary, h) Standardization of the medium-term planning, i) Inclusion of only work packages without constraints in short-term plans, j) Participation of crew representatives in decision making in short-term planning meetings, k) Planning and controlling physical flows, l) Use of indicators to assess schedule accomplishment, m) Systematic removal of constraints, n) Use of an easy to understand, transparent master plan, o) Scheduling a backlog of tasks.

Although a variety of informal networks exist in the workplace. This study analysed four job-site social networks that were identified as important to describe the information flow in projects: general interaction, relevant information sharing, planning

and problem solving, and personal issues. Social network metrics were used to characterize organizations: density and average degree (Abraham, Hassanien & Snášel, 2009). These metrics are used as a tool to establish the communication patterns and ease of information flow (Lin 2015; Priven & Sacks, 2015). Density is a measure of the level of connections within a network relative to the total possible value achievable. Average degree is a measure informing about the average number of connections per node in the network (Cherven 2015).

- **SOCIAL NETWORK SURVEY**

Before the application of the survey, companies were requested to supply the current list of persons having administrative roles in the project. Social network data were gathered by application of an on-site survey conducted by trained personal to improve runtime. The survey questionnaire had four questions related to interaction, which is defined as a communication act or information transaction between individuals, for: total interaction, work relevant information exchange, planning and problem solving and personal issues chat. Each member of administrative personnel in projects had to report who he/she interacted with. This approach allows the identification of the interactions patterns developed during the workday (Alarcón et al. 2013).

- **MANAGEMENT PRACTICES SURVEY**

The degree of implementation of LPS management practices in projects was measured by a trained surveyor during weekly planning meetings. Surveyor perceptions about the absence or presence, whether partial or total, of the proceedings detailed in the checklist were registered. Any aspect not reachable at first sight was asked to the LPS meeting leader after the meeting and/or verified on site. Nine meetings were attended in different dates since some projects used to meet on Friday.

- **KEY PERFORMANCE INDICATORS SURVEY**

The project performance evaluation was based on project KPIs used as leading or process indicators. Project managers of nine construction projects during three months filled out the form containing the nine KPIs and sent them to the research team by internet, attached to corporative emails.

- **SOCIAL NETWORK ANALYSIS**

In social network theory, people are considered as nodes and interaction between them is taken as ties or connections (Easley and Kleinberg 2010). Social networks can be identified by indices such as degree and density that are related to how easy information flows inside the organization. SNA was applied for finding density and average degree of each of the four networks studied (Abraham et al. 2009). Both indicators are associated with information flow and dissemination.

- **DATA ANALYSIS**

The number of projects studied admits non-parametric analysis so the Spearman correlation was applied to the series after ranking raw data. Ranking was assigned, ranging from 1 as the worst performance up to 9 as the best performances. Spearman's r is the correlation coefficient on the ranked data and varies from 0 for no correlation to 1 for full correlation. Only strong ($0.6 \leq r < 0.8$) and very strong ($r \geq 0.8$) correlation values, according to Evans 2012, were considered relevant. The p value, or the probability value, is a statistical measure that helps determine whether correlation

hypotheses are correct or not. Null correlation hypothesis is discarded when p value is equal to 0.05 or less. Statistical software R was used to obtain Spearman r and p values.

• **RESULTS**

• **GENERAL DATA.**

The percentages of implementation of each of the 15 LPS practices were calculated from data collected at weekly meetings. Results are shown in Figure 8.

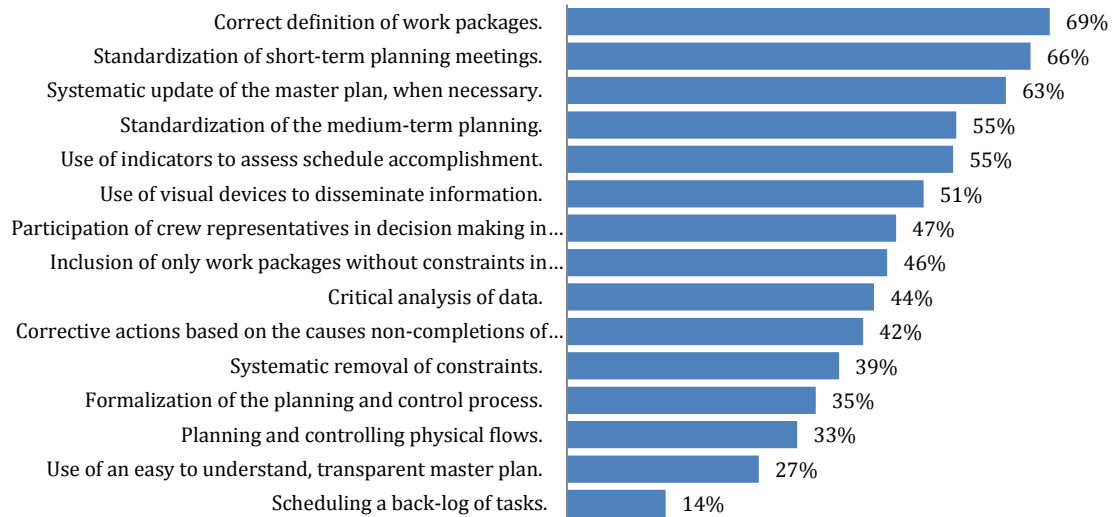


Figure 8 LPS management practices implementation percentage

Short term planning and programming activities is characteristic in all studied projects. Definition of work packages, standardization of short-term meetings and update of master plan are priorities, instead of backlog tasks or use of an easy to understand master plan. This goes with similar conditions reported in construction projects by (Viana et al. 2010)

After SNA, projects social networks density and average degree show appreciable differences and are depicted in Figure 9.

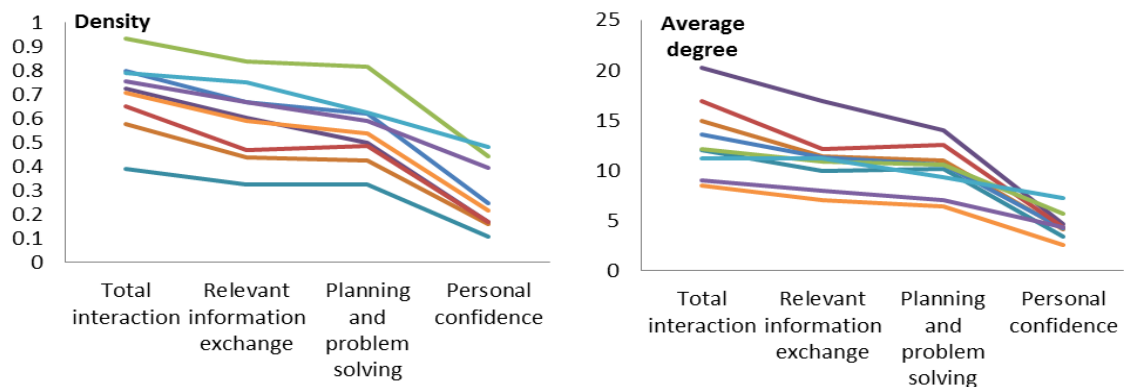


Figure 9 Projects' social networks characteristics

Personal confidence networks had the lowest density and average degree compared to the other three networks, despite its importance on teams' performance (Krackhardt and

Hanson 1993). On the other hand, total interaction network had the highest values in all nine networks. Job-site networks, as relevant for information exchange and planning and problem solving, are at intermediate level. Results indicate that relevant information exchange and problem solving and planning is sometimes done among people that don't trust each other, maybe resulting in low commitment (Zeffane et al. 2011).

• **MANAGEMENT PRACTICES AND PROJECT PERFORMANCE**

Simple linear correlation was used to pair each management practice score and the median of each project's KPIs. Results are shown in Table 1.

Table 1 LPS management practices vs KPIs median

LPS management practice	KPI median	Spearman r	p-valor
Corrective actions based on the causes non-completions of plans	Contract bid change	0.729	0.040
Corrective actions based on the causes non-completions of plans	Accident frequency index	-0.759	0.029
Corrective actions based on the causes non-completions of plans	Constraint release	0.735	0.038
Critical analysis of data	Contract bid change	0.950	0.000
Correct definition of work packages	Productivity FT	0.856	0.007
Systematic removal of constraints	Accident frequency index	-0.903	0.002
Standardization of short-term planning meetings	Quality	1.000	0.000
Planning and controlling physical flows	Cost deviation	0.783	0.022
Use of visual devices to disseminate	Cost deviation	-0.786	0.021
Use of an easy to understand, transparent master plan	Accident frequency index	-0.771	0.025
Use of an easy to understand, transparent master plan	Constraint release	0.856	0.007

A high implementation of LPS management practices appears associated to better KPI values except for accident frequency index and cost deviation. Positive effect of LPS in project performance was reported by Alarcón et al. 2008. The inverse correlation between the LPS practices, accidents and cost deviation KPI requires further search of causes.

• **ORGANIZATION AND PROJECT PERFORMANCE**

The correlations found between the characteristics of social networks of each project and its performance indicators are shown below.

Table 2 Project social network average degree vs KPI median

KPI median	Social network average degree	Spearman r	p-valor
Contract bid change	Total interaction	-0.814	0.008
Contract bid change	Relevant information exchange	-0.882	0.002
Contract bid change	Planning and problem solving	-0.848	0.004
Accident frequency index	Total interaction	0.667	0.050
Accident gravity index	Total interaction	-0.679	0.044
Accident gravity index	Planning and problem solving	-0.775	0.014

Productivity FT	Planning and problem solving	-0.667	0.050
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In Table 2, high social network average degree doesn't mean better results in project measured by KPIs. An exception is the accident frequency index, where a higher average degree in total social network interaction has a positive relation. Maybe this metric's increase must be explained by external factors, such as the fatality presence for example (Rivera and Kapucu 2015). Network density didn't present a significant relation with any KPI median.

• **MANAGEMENT PRACTICES AND ORGANIZATION**

Relations found between LPS management practices and network density are shown in Table 3.

Table 3 LPS management practices vs Project social network density

LPS management practices	Network density	Spearman r	p-valor
Standardization of short-term planning meetings	Personal confidence	-0.752	0.032
Standardization of short-term planning meetings	Total interaction	-0.897	0.003
Use of visual devices to disseminate information	Total interaction	-0.786	0.021
Standardization of short-term planning meetings	Relevant information exchange	-0.829	0.011
Use of visual devices to disseminate information	Relevant information exchange	-0.731	0.040
Standardization of short-term planning meetings	Planning and problem solving	-0.849	0.008
Use of visual devices to disseminate information	Planning and problem solving	-0.762	0.028

Better scores in management practices doesn't mean high density. Maybe current density is a result of poor quality communication or the unintended application of procedures as in Krackhardt and Hanson, 1993. Next, relations between LPS management practices implementation level and networks average degree are detailed in Table 4.

Table 4 LPS management practices vs Project social network average degree

LPS management practices	Network average degree	Spearman r	p-valor
Corrective actions based on the causes non-completions of plans	Total interaction	-0.988	0.000
Corrective actions based on the causes non-completions of plans	Relevant information exchange	-0.916	0.001
Corrective actions based on the causes non-completions of plans	Planning and problem solving	-0.952	0.000
Critical analysis of data	Total interaction	-0.805	0.016
Critical analysis of data	Relevant information exchange	-0.878	0.004
Critical analysis of data	Planning and problem solving	-0.854	0.007
Inclusion of only work packages without constraints in short-term plans	Total interaction	-0.819	0.013
Inclusion of only work packages without constraints in short-term plans	Planning and problem solving	-0.819	0.013

Scheduling a back-log of tasks	Total interaction	-0.846	0.008
Scheduling a back-log of tasks	Planning and problem solving	-0.846	0.008
Use of an easy to understand, transparent master plan	Total interaction	-0.735	0.038
Use of an easy to understand, transparent master plan	Planning and problem solving	-0.711	0.048

Social network average degree is inversely related to high scores on LPS practices. It is assumed that better implementation of practices leads to an increase of average degree and improves communication (Priven and Sacks 2015). But the optimal metrics of a network under normal circumstances has not yet been established. Relation between Management practices, Organization and Project performance.

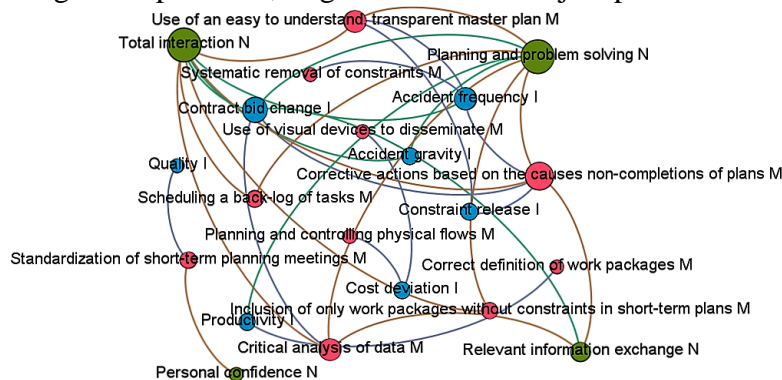


Figure 10 Relation among LPS, social networks and KPIs in construction projects.

Figure 10 shows the relevant correlations detailed above (Tables from 1 to 4). Each variable is represented as a node and the relations are ties. Pink nodes are LPS practices, the green ones are social networks and blue dots are KPIs. Node dimension represents its degree or number of connections to neighbours. LPS practices show high relation with three social networks, and maybe a high influence on their metrics (Priven and Sacks 2015). Note the prominence of total interaction networks as well as planning and problem solving. Most of the LPS management practices present relations with project KPIs, except for the Accident gravity index. Consider the relation of LPS practices on productivity, quality and the accident rate (Alarcón et al. 2008).

• CONCLUSION

The weakness shown by the networks of personal confidence, and a bias towards the use of short-term scope management practices, are the main features of the projects studied. Such conditions promote greedy relationships and construction crews' sense of

no membership to the organization. This conspires against personal commitment and is needed to improve confidence, collaboration and fair share of information.

The high social network metrics of the temporary organization, conformed by project crews and management personnel, does not always mean good news. High values of network average degree or density can mean poor quality communication or reaction to adverse events. Thus a rise in those metrics cannot only be attributed to the effect of implementation of management practices as LPS.

We offer a diagram of the relation of the variables studied. However, pictures don't tell the whole history; a correlation diagram is just one tool among many others. It must be used with management criteria considering the complexity of the relations between management practices and organization characteristics that produce project performance.

This document is limited to portray the conditions of the projects investigated during the study period. Have not been considered in this study, characteristics associated with communication quality within construction projects, these factors should be taken in future research.

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