QUANTIFYING IMPACTS OF LAST PLANNER™ IMPLEMENTATION IN INDUSTRIAL MINING PROJECTS

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ABSTRACT

Over the years an increasing number of companies have implemented the Last Planner System™ (LPS) and several research efforts have provided evidence of its impact on performance in construction projects. However, very scarce evidence exists of the impacts in industrial mining projects. These projects are generally schedule driven with tight schedules, complex and diverse in construction challenges, frequent scope changes, high logistic complexity and very high economic impact. These characteristics seem to be an obstacle to a sustained implementation of the LPS in this type of projects.

This paper reports on research focused on industrial mining projects, in an effort to quantify the impacts of the LPS implementation on several aspects of project performance. Over a period of two years, the authors investigated the implementation of the LPS and its impacts in several projects of a single company, comparing projects with and without implementation and assessing the impacts of implementation with statistical data obtained from the projects before and after implementation.

Statistical data from three projects with LPS implementation was used to explore quantitative impacts. The research confirmed correlations, explored in previous studies, between LPS planning reliability measure, Percent of Plan Completed (PPC), with performance measures used in traditional project management practices such as Schedule Performance Index (SPI) and Cost Performance Index (CPI). All the projects with LPS implementation finished on schedule and with no accidents. These projects reached company objectives and obtained an increase in profit margins compared with company historic performance. Client satisfaction was also studied and measured showing an important increase when projects with LPS implementation were compared with projects without implementation.

KEY WORDS

Lean Construction, Implementation, Last Planner System, Industrial mining projects.

INTRODUCTION

In the last 15 years important efforts of incorporation of Lean Construction practices have been made by construction companies worldwide with the objective to introduce improvements in project management processes (Alarcón et al. 2002). Within a number of Lean practices, the Last Planner System™ (LPS) (Ballard 1994, 2000) has

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been implemented in hundreds of projects in Chile (Alarcón et al. 2005) reporting improvements in performance of several project indicators. From the implementation of LPS, statistical relation between Percentage of Plan Completed (PPC) and project performance have been explored, including Schedule Performance Index (SPI) (Olano et al. 2009) and indicators of productivity (González et al. 2008) (Ballard and Kim 2007). One of the few reports of the impact in Mining Projects is the study of Izquierdo and Arbulu (2008), where the implementation of LPS is associated with positive impacts on schedule and productivity, nevertheless, the limited number of cases do not allow to obtain more general conclusions. This paper reports on research focused on industrial mining projects, in an effort to quantify the impacts of the LPS implementation on several aspects of project performance. Over a period of two years, the authors investigated the implementation of the LPS and its impacts in several construction projects of a single company, comparing projects with and without implementation and assessing the impacts of implementation with statistical data obtained from the projects before and after implementation.

The data captured over an extended period in the field contributed to obtain new and extended evidence of the impact of Lean Practices in construction projects and allowed the authors to confirm previous exploratory research results in a more controlled environment of a single company. It also allowed to obtain data that was not available before for industrial mining projects, and examine an larger number of performance indicators than in previous studies.

INDUSTRIAL MINING PROJECTS

Industrial mining projects present distinct characteristics in relation to other areas of construction in Chile and the world. They are usually Fast Track, complex projects of manufacturing and processing plants that represents great challenges to the construction industry, since the conditions of fast change and uncertainty are extreme.

Some aspects that characterize projects of industrial assembly, and which are present in Mining are:

- Extensive and complicated supply chains.
- Many involved actors. High disciplinary interdependence
- Pressure to construct to meet market windows.
- Numerous changes in design. In most cases construction changes have smaller economic impact than improvements in production through changes to engineering.
- High variability in scope definition, construction usually begins before design and materials are available
- Manufacturers optimize the production schedule according to their internal restrictions and not according to project needs
- Construction market with global competition of companies.
- Remote geographical locations
- Context of fragile atmospheres and social responsibility

- Requirement of zero accidents operations.

The characteristics of industrial mining projects introduce greater complexity and uncertainty for project execution and traditional practices project management are insufficient (Ballard and Howell 1994) (Izquierdo and Arbulu 2008). One of the main strategic aspects in the scope of industrial mining projects is the context of zero accidents in which these projects must be developed. The accidents indexes of the companies are key parameters in performance evaluation of contractors and they become main target of projects and companies that participate in this market. Good safety performance provides value to the client and increased competitiveness to construction companies.

RESEARCH HYPOTHESIS AND OBJECTIVES

This research seeks to contribute to the understanding of the impact of Last Planner in industrial mining construction projects in Chile, considering the importance and levels of investment associated to these projects and the scarce knowledge on the application of these practices in these projects available up to now.

The research hypothesis were:

- Industrial mining projects where the LPS is implemented will present better performance than those where the LPS is not implemented, in the same company.
- There is a correlation between PPC and the schedule and cost performance indexes in industrial mining projects.

The research objectives, related to those hypothesis were:

- Evaluate the impact of the implementation of the Last Planner System on performance of Industrial Mining Projects.
- Evaluate the relationship between planning reliability, measured as Percent of Plan Completed (PPC), and Schedule and Cost Indexes: SPI (Schedule Performance Index) and costs CPI (Cost Performance Index).

DESCRIPTION OF THE CASE STUDIES

The LPS was implemented by a construction company for international mining clients located in the North of Chile. Implementation in three projects are reported in this paper:

- Case 1. The project considers the construction of a system of piling up of copper mineral for its later leaching process in batteries. It included the transport strap, electrical systems and emergency pools (180,000 MH).
- Case 2, Project Assembly Plant of Sand Flotation. The project considered the construction of a copper extraction process plant by means of the sand flotation of concentrated and electrical rooms associated. The project was located inside of the existing processing facilities (85,000 MH).
- Case 3, Project Port Warehouses: The project considered the construction of new warehouses for copper mineral and transportation systems in Port (95,000 MH).

The data from these three cases was compared with company historical data and with other projects executed in parallel by the company where the LPS was not implemented.

DATA COLLECTION AND ANALYSIS

Data collected and analysis for the three cases of study where the LPS was implemented is presented below. It includes information about key project performance, results of client satisfaction surveys and weekly evolution of indicators PPC, SPI and CPI. The performance indicators were recorded during the period of construction of the mining infrastructure. The data of project key performance indicators and the results of client satisfaction surveys were registered when projects were ended and final evaluations were completed.

PROJECT KEY PERFORMANCE INDICATORS

The implementation of LPS had a positive impact on project performance indicators: safety, profit margins, labour efficiency and project productivity. Each one of the projects achieved its objectives.

Table 1: Summary Results of Performance Projects Indicators

	Indicators	Case N°1	Case N°2	Case N°3	Parallel Case Without LPS N°1	Parallel Case Without LPS N°2	Historic Company Average
1	Global Schedule Variance	9,60%	8,20%	5,90%	42,60%	9,70%	N/D
2	Profit Margin Variance	148,7%	31,0%	85,40%	-318,3%	-301,5%	-4,90%
3	Project Productivity Index	3,55	1,86	2,68	1,28	0,79	2,17
4	Labour Efficiency Index (PF)	0,96	1,12	1,02	1,42	1,65	N/D
5	Accident Rate Index	0,0%	0,0%	0,0%	0,80%	0,60%	0,40%
6	Accident Frequency Index	0	0	0	10	1,3	3,01
7	Accident Severity Index	0	0	0	160	5	31,56
8	Temporary Disability Rate	0,0%	0,0%	0,0%	10,0%	2,0%	3,4%

(1) Global Schedule Variance = (Actual Schedule- Contractual Schedule/ Project Contract Duration) x100
(2) Profit Margin Variance = (Actual Profit Margin- Initial Profit Margin / Initial Profit Margin) x100
(3) Project Productivity Index = Production /Used Resources = (Total Cost – Material Cost / (Dir. Labour + Ind. Labour + Equipment)
(4) Labour Efficiency Index (PF) =Used Labour/Earned Labour
(5) Accident Rate Index== N ° Accidents / N ° Workers x 100.
(6) Frequency Index= N ° accidents x 1 million / total hours worked
(7) Severity Index= lost days x 1 million / total hours worked.
(8) Temporary disability claims rate = lost days / N ° workers x 100

Global Schedule Variance

An average 7.9% deviation was observed in project schedule with respect to the contractual duration equivalent to 15 days in average. In general, these deviations were explained mainly by external causes or client requests and therefore they were accepted by the client without penalties. The projects obtained an average 82.8% of Client Satisfaction in contractor Schedule Performance. In the three cases where LPS was implemented schedule deviation was smaller than in contemporary projects where LPS was not implemented.

Profit Margin Variance

Profit margin increase in projects that implemented LPS varies between 31% and 148% with respect to original estimates. These results represent a significant improvement with respect to the historical indicator of the company of -5% and the results of two projects executed without LPS in parallel to the studied projects, whose results were negative variations of -318% and -301% respectively in their profit margins.

Project Productivity Index

An increase of project productivity index with respect to the historical average of the company was observed in two of the three cases. In the three cases where LPS was implemented the index of global productivity was higher than in those projects where LPS was not implemented.

Labor Efficiency Index (PF)

A higher efficiency in the use of labor was observed in the three cases where LPS was implemented. This is the main cost variable in this type of projects and performed close to the established goal of PF=1,05. The three cases presented better performance than projects where LPS was not implemented.

Safety Indicators

The three cases achieved the objective, defined by the company and clients, of zero accidents. From the results of these projects, new contracts were assigned to the contractor based on its record of zero accidents. The projects where LPS was not implemented presented accidents with lost time, even above to the historical average of the company.

Safety results are better than previous cases reported in the literature (Thomassen et al 2003) (Nahmens and Ikuma 2009) and considering the importance of this performance aspect in this type of projects, it should be the focus of increased attention in future implementations.

CLIENTS PROJECT PERFORMANCE EVALUATIONS

Significant improvements with respect to historical project evaluations were obtained from project performance evaluation conducted by clients. The aspects that present greater positive variation were: Organization, Conflicts resolution, Execution Time and Commitment with Project. There was a perception of improvement in all the variables used for historical evaluation of the company and the results of the projects where the LPS was implemented. In parallel, Case without LPS N°2 presented a high satisfaction of the client but with a high cost for the company due to important economics losses generated by the project.

Table 2: Customer Satisfaction Survey Results

	Key Aspect	% of Customer Satisfaction						
		Case N°1	Case N°2	Case N°3	LPS Cases Average	Parallel Case Without LPS N°1	Parallel Case Without LPS N°2	Historic Company Average
1	Organization	92%	95%	75%	87%	44%	94%	70%
2	Response to client suggestions	100 %	95%	81%	92%	63%	94%	80%
3	Response capacity	100 %	95%	75%	90%	56%	88%	77%
4	Conflicts resolution	100 %	100 %	88%	96%	63%	88%	80%
5	Safety	75%	95%	88%	86%	56%	100%	77%
6	Quality	92%	100 %	81%	91%	63%	100%	78%
7	Execution time	83%	90%	75%	83%	63%	75%	67%
8	Commitment with project	100 %	100 %	88%	96%	56%	88%	81%
9	Global project satisfaction	83%	95%	81%	87%	50%	88%	69%
	Projects Client Satisfaction	**92%**	**96%**	**81%**	**90%**	**57%**	**90%**	**75%**

Evolution of PPC / SPI / CPI Indicators

Figures 1, 2 and 3 show the evolution of PPC, SPI and CPI for the three cases:

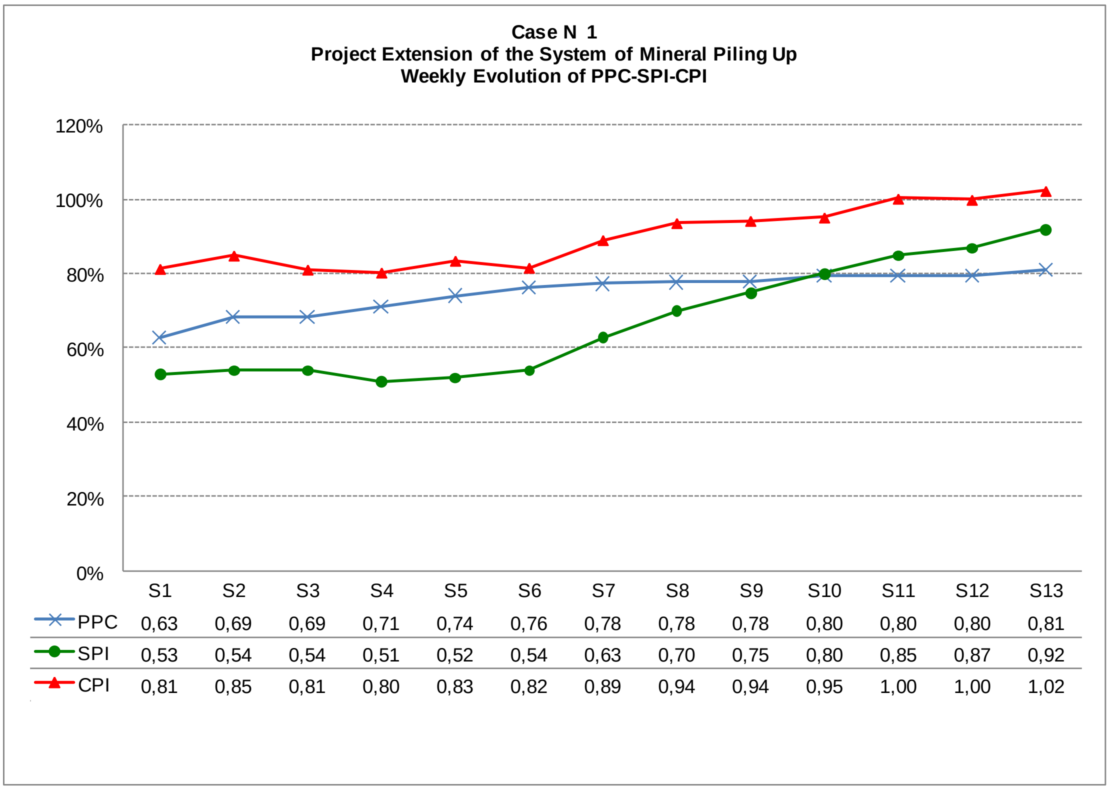

Figure 1: Case N°1, Weekly Evolution of PPC /SPI /CPI Indicators

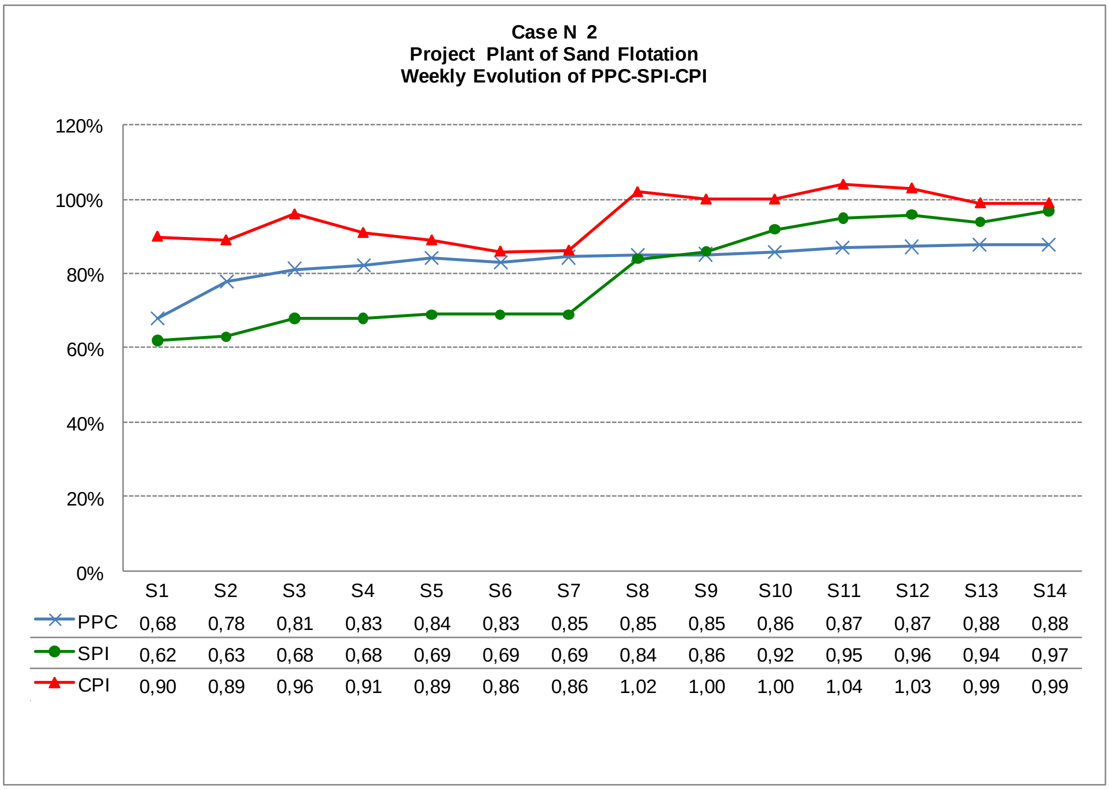

Figure 2: Case N°2, Weekly Evolution of PPC /SPI /CPI Indicators

Figure 3: Case N°3, Weekly Evolution of PPC /SPI /CPI Indicators

According to the weekly data for the three cases, Correlation and Regression Analyses for the relation between PPC (x) and SPI/CPI (y) for the three cases of study were performed:

Table 3: Summary Linear Correlation and Regression PPC - SPI

Case	r	r^2	Std. Err. Of Estimate	P One-Tailed
Case N°1	0.79	0.624	0.0977	0.0007
Case N°2	0.744	0.554	0.0949	0.0012
Case N°3	0.699	0.488	0.0367	0.0027

Table 4: Summary Linear Correlation and Regression PPC - CPI

Case	r	r2	Std. Err. Of Estimate	P One-Tailed
Case N°1	0.806	0.65	0.0507	0.0005
Case N°2	0.529	0.279	0.0572	0.026
Case N°3	-0.063	0.004	0.0592	0.416

The statistical analysis confirmed a significant degree of correlation between PPC-SPI for Cases N°1, Case N°2 and Case N°3, and PPC-CPI in Cases N°1 and Case N°2. The degrees of correlation between PPC-SPI were similar in the three projects (between 0.79 and 0.69). In Case N°3 correlation PPC-CPI did not exist. This can be explained by the increase of earned value in a context of high production variability. This result was affected by initial external factors that were not included in the analysis.

In the three projects indicators SPI and CPI tend to 1 which fulfills the objectives indicated for these projects. Also, planning reliability continuously increased in Case N°1 and Case N° 2 and was sustained at a level close to 80 % in Case N°3) in spite of the greater uncertainty present at the project finishing stage.

The correlations between PPC and SPI and CPI are probably related with the relationship previously demonstrated between PPC and productivity (Gonzalez et al 2009) (Ballard and Kim 2009), productivity has a direct impact on cost and schedule. However, productivity improvements not always are directly translated into global performance improvements, therefore, the verfication of the existance of this correlations is a finding that help to reinforce that strategies focused on improving work flow reliability are effective means to improve more conventional global performance measures.

CONCLUSIONS

The study of the statistical data from implementation of LPS in industrial mining projects in Chile identified significant impacts in performance indicators compared with projects executed in parallel and historical indicators from previous projects of the same company. The results confirmed the research hypothesis and other results reported in previous studies but provided acces to data of a large number of indicators, over an extended period of study, in a more controlled environment of a single company, which enabled the researchers to develop different types of analyses.

The positive impact of LPS implementation on compliance of project objectives was recognized not only by the contractor but also by the clients, which was reflected in an important improvement in the results of the customer satisfaction survey. Safety performance was particularly remarkable resulting in zero accidents in the projects where the LPS was implemented, situation that was not reported in previously in the literature. This was an strategic result for the company under study due to the primary importance of safety for clients of these type of projects. As a result, the contractor was awarded new contracts based on superior safety performance obtained in these projects.

The relation between planning reliability (PPC) and schedule and cost performance indicators (SPI, CPI) was confirmed. These relationship with conventional performance indicators can be very important to demonstrate the importance of focusing attention on managing workflow reliability to obtain superior performance to project managers that use traditional project management practices and have not been exposed to Lean Practices.

A relationship between planning reliability and compliance of project objectives was also observed. The positive results of the projects where LPS was implemented, in the aspects of safety, profits and productivity contributed to extend the range of application of this planning system in the area of indutrial mining projects, due to a proactive attitude of some of the clients that are now requiring the use of this system to their contractors.

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