EVALUATION OF THE IMPACT OF THE LAST PLANNER SYSTEM ON THE PERFORMANCE OF CONSTRUCTION PROJECTS

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ABSTRACT

The Last Planner System of Production Control has been used in many different countries since the mid Nineties. However, most research studies developed so far have emphasized the analysis of qualitative data, based on a small number of case studies. Very few quantitative analyses have been undertaken on the impact of its implementation and on the factors that affect its effectiveness. Based on the construction of a large project database, this article presents the main results of an investigation that aimed to assess the impact of LPS based production planning and control systems on the performance of construction projects in terms of cost and time. This investigation has also analyzed the impact of a set of production management practices on the effectiveness of those planning systems. The database contains the following indicators: PPC, cost deviation, time deviation, and site management best practices index. Several analyses were carried out using regression analysis techniques. As main conclusions, the study provided some evidences on the way production planning and control influences project performance, and the importance of site management best practices on the effectiveness of planning and control. Despite the fact that some of the analyses indicated a fairly low correlation index, due to some limitations on the data available, the regression models produced were very consistent.

KEY WORDS

Last planner, planning and control, production management, project performance.

INTRODUCTION

In IGLC annual conferences, many papers have reported the use of Last Planner system (Ballard, 2000), indicating that this system have been successfully implemented in a large number of projects from different countries, such as USA, Brazil, Chile, Ecuador, England, Finland, Denmark, among others. This system is able to increase the reliability of short term planning by shielding planned work from upstream variation, and by seeking conscious and reliable commitment of labour resources by the leaders of the work teams involved (Ballard and Howell 1998). At

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the medium term level, constraints are identified and removed, ensuring that the necessary materials, information and equipment are available (Ballard, 1997).

There are some indications that the Last Planner has many advantages over traditional CPM based planning and control systems. The way it manages commitments, and the stability that it creates in production systems are among the main reasons for its success (Vrijhoef *et al.*, 2001). Also, it adopts a fairly simple planning and control approach, and, similarly to the Toyota Production System (Wiendahl *et al.*, 2005), emphasizes organisational aspects instead of the application of complex software systems.

Although the Last Planner System is well described in the literature (Ballard and Howell, 1998; Ballard 1997; Ballard, 2000), much needs to be discussed on the core ideas that are underneath this system. In fact, there is a continuing effort to further improving it, for instance, by integrating other managerial functions (Marosszeky et al., 2002; Saurin et al., 2004), extending to other managerial levels (Ballard and Howell, 2003), and developing software tools that support its implementation.

Moreover, there is very little quantitative evidence on the impact of the Last Planner System on the performance of construction projects. Despite its dissemination across industry, most research studies developed so far were based on a small number of case studies, using mostly qualitative evidences. In fact, Ballard (2000) pointed out that it is necessary to quantify and understand the benefits of greater plan reliability for safety, quality, time and cost. There seems to be a good opportunity for investigating those benefits by comparing measures of plan reliability to projects goals.

The main objective of this article is to assess the impact of the Last Planner system on the performance of construction projects in terms of cost and duration, using indicators that are routinely employed by construction companies. It also seeks to identify factors which affect the production planning and control effectiveness by using indicators of production management best practices. This study was conducted as part of the development of a benchmarking initiative which involved the implementation of performance measurement system for benchmarking performance in the construction industry, named SISIND-NET (Costa *et al.,* 2006). Over the three years of this project, a database of production management indicators was produced in partnership with construction companies, which was drawn upon to develop this study.

RESEARCH METHOD

This research work was divided into three main stages. In the first stage, data available in the SISIND-NET database were initially analyzed, and a number of visits to construction companies was undertaken, in which the quality of the data provided was checked, and the possibility of obtaining additional data from the companies was discussed. In the second stage, the data available was organized, considering the variables that were selected, and a set of hypotheses were formulated. The third stage of the study consisted of data analysis.

HYPOTHESIS

The following hypotheses were formulated for this study:

- **Hypothesis 1:** the greater the planning effectiveness, measured by the percentage of plans completed (PPC), the lower tends to be the cost deviations, measured by the indicator DC;
- **Hypothesis 2:** the greater the planning effectiveness of, measured by the percentage of plans completed (PPC), the lower tends to be the time deviation, measured by the indicator DP;
- **Hypothesis 3**: the implementation of a set of site management best practices, measured by the indicator IBPC, positively influences the planning effectiveness, measured by the PPC;

INDICATORS

Besides the Last Planner metrics (PPC and the causes for the non completion of work packages), three indicators were used to test the hypotheses presented above. The cost deviation indicator is given by the ratio between the cost incurred and the budgeted cost[3], while time deviation is calculated by a similar formulae[4] using an S-curve produced according the earned value method, which compares the expected duration of the project and the actual one. Both indicators are widely used by construction companies in Brazil for assessing project performance and, for that reason, were adopted in the SISIND-NET Project.

The IBPC[5] was initially proposed by Saurin (1997), the objective being to evaluate the degree of organization of construction sites based on the application of a checklist of best practices. This list originally had 127 items, classified into three broad categories: (a) temporary facilities, (b) safety at work, and (c) handling of materials (i.e. storing and moving). Several revisions were made to this list over time. In the SISIND-NET project, a list was put forward with 162 items, which was adopted as a standard for companies participating in it. One of the main alterations was to add a fourth item on the management of solid waste on site, since this has become an important item in the management of construction sites in recent years. A global IBPC is calculated for each site, as well as some sub-indices for each of the major items.

DATA PREPARATION AND ANALISYS

Before starting the data analysis, much effort was spent on preparing the database. The decision was made to adopt the month as the period of analysis. Thus, the PPC, which is collected weekly, had to be converted to a monthly base by calculating the average of 4 or 5 weeks. Moreover, all variables were transformed so that they were on the same scale. The scale chosen as a standard was from zero to ten. Table 1

[3] DC = (Real Cost – Budgeted Cost) / Budgeted Cost * 100
[4] DP = (Real duration – Expected duration) / Expected duration * 100
[5] IBPC = Σ points obtained / Σ items assessed * 10

describes the data available for each indicator. Each case represents the set of data available for a project in a given month.

Table 1: Characterization of the Data Available for each Indicator

Variable	Companies	Sites	Cases
Total	28	119	868
IBPC	19	69	375
PPC and causes	19	75	512
DC	1	29	181
DP	2	36	242

In total, data were obtained from 119 projects, undertaken between 2002 and 2007. Most of them were residential projects (31%) and industrial and commercial projects (46%). The DC and DP metrics were obtained in only one and two companies respectively, which considerably limited the testing of the corresponding hypotheses.

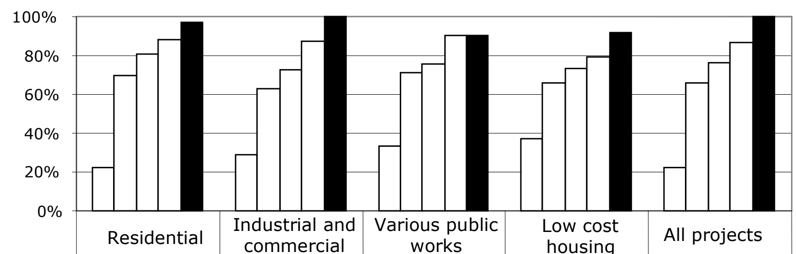
Data analysis involved three steps: (a) descriptive analysis of the variables, (b) analysis of the Pearson correlation to assess the degree of relationship between two variables (Downing and Clark, 2005), and (c) application of the multivariate regression technique to discover the relationship between a dependent variable and one or more independent variables (Hair *et al.,* 1998). Assessing the precision of the regression equation was performed by the method of least squares, in which the coefficient of determination (R^2) represents the percentage of the dependent variable which is explained by the independent ones (Hair *et al.*, 1998).

RESULTS

DESCRIPTIVE ANALYSIS

Figure 1 presents the PPC statistics for each one of the market segments. PPC tends to be lower in industrial and commercial projects and in low-cost housing projects. In the first case, the low PPC can be explained by the fact that this type of work is characterized by high complexity, short lead-times and high uncertainty. In the case of low-cost housing, the companies are small, many of which have difficulty in implementing planning systems based on the Last Planner. These indicators are of the same order of magnitude of those presented in other quantitative studies (Bortolazza and Formoso, 2006; Alarcón *et al.,* 2005; Botero and Alvarez, 2005).

The causes of non-completion of work packages were classified into eight categories. Figure 2 shows the average percentages for each of these categories. Similarly to the results presented by Bortolazza and Formoso (2006), the two categories of causes with the highest number of occurrences are labor (42%) and planning (28%). The majority of the problems (81%) are of predominantly internal origin (including the categories labor, materials, equipment, design and planning) while only 19% are of external origin (client interference, weather problems and suppliers). These figures indicate that, in general, there is a large potential for improving the performance of production planning and control, since most problems are primarily internal to the organization. This result is consistent with what has been observed in other quantitative surveys. In the study of Bortolazza and Formoso (2006), the percentage of internal problems reached 77%, while in the study by Botero and Alvarez (2005), held in Colombia, this percentage reached 63%. Ballard (1997), in a study conducted in the United States, reported that more than 80% of the causes were of internal origin.



	Residential	Industrial and commercial	Various public works	Low cost housing	All projects
□ Minimum	22.14%	29.23%	33.33%	36.85%	22.14%
■ Q1	69.51%	62.81%	70.83%	65.72%	66.19%
■ Median	81.03%	72.83%	75.28%	73.62%	76.03%
■ Q3	88.46%	87.30%	90.08%	79.34%	86.79%
■ Maximum	97.18%	100.00%	90.56%	91.67%	100.00%

Figure 1: PPC Statistics for Different Market Segments

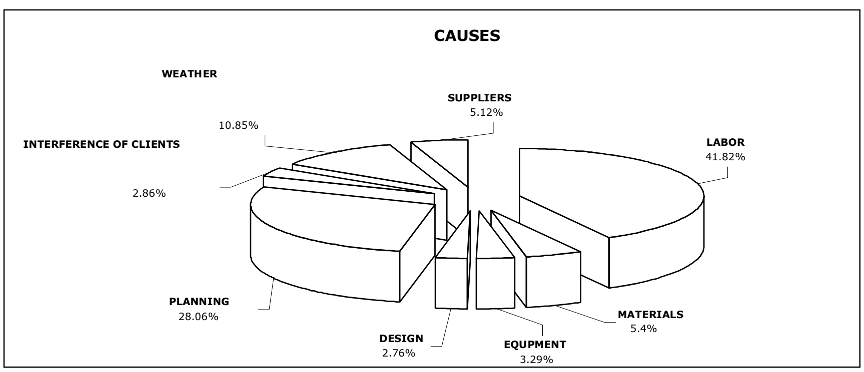


Figure 2: Distribution of the Causes of Non-Completion of Work Packages

The DC data used in this study refer only to Company C, and total 181 cases relative to 28 building projects. This is a medium sized company from Porto Alegre (South of Brazil) that builds a wide range of industrial and commercial projects. The median DC was 0.07%, corresponding to 4.05 in the transformed scale, well below the average of the other variables.

The indicator of time deviation (DP) was available only from Companies A and C, forming a sample of 242 cases relating to 36 different building works. Table 2 below presents the statistics for the two companies. Company A is a large house-building company also based in Porto Alegre, which both develops and builds residential projects for the medium and higher-medium class. Both companies are well known in the country for the successful implementation of lean construction ideas.

Table 2: Descriptive Statistics of DP (Time Deviation)

	Company A	Company B
Nr. Cases	69	173
Nr. projects	7	29
Average	9.29	8.55
Median	9.29	8.95
Minimum	9.24	0.00
Maximum	9.32	10.00

The IBPC had records of 375 cases, totaling 69 projects of 19 companies. The practices classified in the environmental management category were not taken into consideration due to the small number of sites that had data referring to them. Table 3 shows the main descriptive statistics of IBPCS and also for the three categories of items that were considered. The handling of materials category had the lowest average among them. Paradoxically, the practices included in this category is the one that has the greatest potential to contribute to the elimination of non value adding activities, and could have a strong positive influence on planning effectiveness and productivity.

Table 3 – Descriptive Statistics of the IBPC and Sub-Items for the Total Sample.

	IBPC	(a) Temporary facilities	(b) Site safety	(c) Materials handling
Average	7.90	8.22	7.86	7.61
Standard deviation	1.33	1.38	1.81	1.60
Minimum	2.80	1.90	0.50	0.00
Q1	7.40	7.60	7.20	6.70
Median	8.20	8.60	8.30	7.80
Q3	8.90	9.20	9.10	8.80
Maximum	9.80	10.00	10.00	10.0

TESTING THE HYPOTHESES

Hypothesis 1

This analysis consisted of cross-matching between the PPC and the causes of non-completion of work packages with cost deviation, with the objective of testing the hypothesis that project performance in terms of costs can be influenced by the effectiveness of planning. DC is the dependent variable and PPC and causes of non-completion of work packages are the independent variables. In the database there were 54 cases of 10 sites, all from Company C.

The first step was the analysis of the Pearson correlation between PPC and DC. The value p found was quite high (0.826), indicating that there was no linear correlation between these two variables. However, visual analysis of the data indicated that there were three points which showed strong discrepancies from the others. These divergent points belonged to projects from the same client, which is quite distinct from the others because, for various reasons, it often requests the site activities to stop. For that reason, the decision was made to remove these points from the sample, which left 51 cases. After this step, the Pearson correlation was again performed between PPC and DC and it reached a *p* value below 0.05, showing that there is a linear correlation between two variables. The result of this correlation is given in Figure 3. Regarding the linear regression of the two variables, only 8% of the independent variable is able to explain the dependent variable - in fact, Figure 3 indicates that there does not appear to be a strong correlation between these two variables.

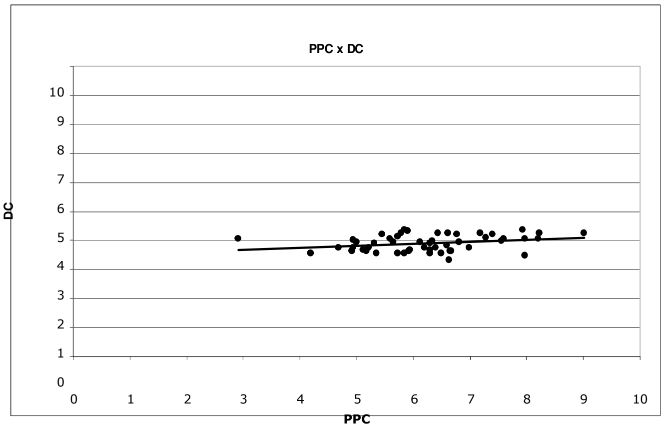


Figure 3: Dispersion Graph PPC x DC (Company C, without Spurious Data)

The correlation between the causes of non-completion of work packages and the DC was also tested. Correlation tests were applied between DC and the individual causes, grouped into eight categories as well as being grouped into internal and external ones. The individual causes that had the highest correlation were: (a) absenteeism, (b) flaws in materials programming, (c) lack of design drawings, (d) changes in production plans, (e) inadequate work supervision, and (f) delays in decision making by the client. Regarding the groups of causes, those which showed a correlation with DC were labor, planning and design.

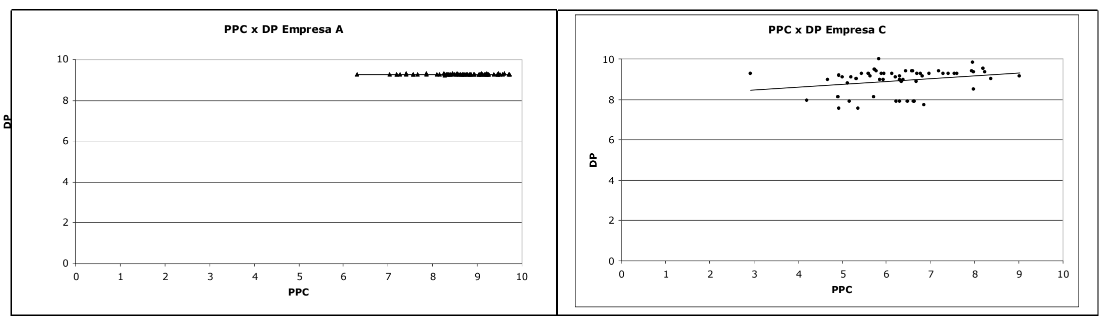
In the test of regression models for separate causes, the coefficient of determination of this model was around 45%. It means that the higher the incidence of those six individual causes, the worse the project performance with regard to costs. By contrast, the coefficient of determination was very low for the regression analysis made for the causes classified into eight groups or grouped as either internal or external. Thus, among the models tested, the model which predicted the DC with greatest precision was the one in which each of the cases was considered separately. This type of model provides indications about the problems that must be eliminated so that a given company might improve its performance with regard to cost. For example, the importance of problems related to design calls attention to itself in the models tested, although these problems represent only a small portion of the causes of non-completion of work packages (on average 3%). This is possibly a problem typical of the market niche in which Company C operates, in which in general there is a great deal of simultaneity between design and production.

Hypothesis 2

This analysis consisted of cross-matching between the PPC and the causes of the non-completion of work packages with time deviation, with the objective of testing the hypothesis that the performance of the project in relation to the schedule may be influenced by the effectiveness of planning. The DP is the dependent variable, and the

PPC and the causes of non-fulfillment of the tasks the independent variables. The decision was made to analyze separately data from companies A and C, due to the difference between the market segments in which these two companies operate. Figure 4 presents the graph of dispersion between DP and PPC for Company A and Company C. While in the former the value of PPC tends to be fairly high (above 90%) independently of the performance of the project in terms of time, in the latter one there is a trend of improving that type of performance to the extent that PPC increases (Pearson´s correlation: 0,275).

In Company A, the lack of correlation can be explained by the relatively long project duration, which is strongly dictated by the ability of their clients to pay, and also by the rigor adopted by the company as to keeping to schedules. In addition, the building sites of this company tend to be very similar, with a high level of process standardization, which facilitates control and the estimation of durations. The comparison between Figures 6 (a) and 6 (b) may indicate that the impact of the effectiveness of PCP is more noticeable on more complex building sites, in which uncertainty is higher and completion times are shorter, such as is the case for the projects of Company C. A model of regression between PPS and DC was also tested. It was found that the regression model is weak in forecasting the DP: the PPC was responsible for forecasting less than 10% of the dependent variable.



(a) Company A (b) Company C

Figure 4: Graph of Dispersion PPC x DP

Only for Company C, correlation tests were also applied between the DP and the causes of the non-completion of work packages for individual causes, grouped into eight categories as well as into internal and external causes. With regard to the groups of causes, what showed the highest correlation with the DP was "interference by the client" (Pearson´s correlation: -0.647). In the test of regression models for separate causes, two causes included in the model, "poor quality of the design" and "delays in decision making by the client" were able to explain about 51% of the deviation from schedule. This result is consistent with the characteristics of the segment of industrial and commercial projects, in which Company C operates. Clients tend to interfere much in those projects, and there is a need for simultaneity between the design and production. The model offers signs that those problems are the ones on which production management should focus attention, so as to influence positive compliance with schedules. For the analysis undertaken on the causes grouped into eight groups, the regression model had a very low coefficient of determination, with a power of explanation of just 10% of the deviation from schedule. Therefore, similar to the analysis performed for cost deviation, the best regression model is the one in which separate consideration was given to the causes for the non-completion of work packages.

Hypothesis 3

This analysis consisted of cross-matching between the IBPC and both PPC and the causes for the non-completion of work packages, with the objective of evaluating the impact of site management best practices on the effectiveness of planning. The PPC and the causes for the non-completion of the work packages are dependent variables and the IBPC and its sub-indices the independent variables. The sample size was 244 cases, referring to 40 projects of eight different companies.

Figure 5 shows a graph of dispersion between PPC and IBP, indicating that there is a strong correlation between the two indicators, although the points are very scattered.

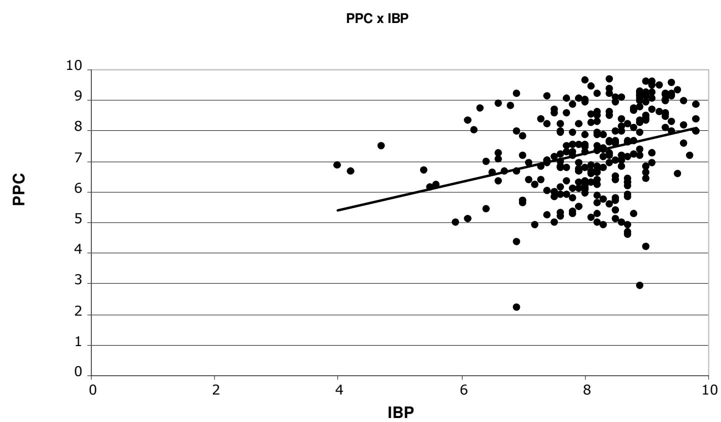


Figure 5: Graph of Dispersion PPC x IBPC

A number of regression model were tested. However, the coefficient of determination of the best regression model was very low, around 10%. Some models were also performed for the segment of residential projects, since the IBPC indicator was originally drawn up especially for this type of project. In the best regression model, the coefficient of determination was still fairly low (around 27%). This indicates that other variables not considered in this analysis influence the value of the PPC. However, this analysis points again to the existence of a positive correlation between the best practice of building sites and the effectiveness of planning.

Some analyses were also conducted taking into separate consideration the three groups of items - temporary facilities (A), site safety (B) and materials handling (C). On taking these three parts into account, it was sought to adjust the best regression model. The IBPC of the temporary facilities proved to be non-significant, possibly because they do not have a direct relationship with production management properly speaking. Therefore, in the final model, consideration was given only to those variables related to site safety and materials handling best practices. However, the precision of prediction of the model is weak, with R^2 being a little more than 10%. Another set of linear regression models were tested for residential projects. The predictive precision of the model exclusive to the niche cited was 28.8%, slightly higher than for the sample as whole. In this model only the IBPC for site safety was significant, indicating that the safety best practices have a positive impact on the effectiveness of planning. Different from what could have been expected, the materials handling IBPC had no significant influence on the PPC. Regarding the causes of the non-fulfillment of the packages of work, no significant correlation with the IBPC and its sub-indices was found.

CONCLUSIONS

This study presented some statistical analysis of production planning and control indicators, which can be used as benchmarks, since some of them are widely disseminated in the construction sector. Several tests were performed, which set out to analyze the impact of the effectiveness of planning, measured by the PPC on project performance in terms of cost and time, and the influence of site management best practices on the effectiveness of planning. In spite of some limitations in the available data, results showed some significant correlations between indicators.

Some evidence, although not very conclusive, was found that the Last Planner System positively affects the performance of construction projects in terms of cost and time, in the case of industrial and commercial complex projects Given the limitations in the analyses conducted, there is a need to perform more quantitative analyses, by using larger databases. Moreover, the causes of non-completion of work packages are shown to be an important source of information, yielding significant results in the regression models. Through the analyses of correlation and linear regression, it was possible to identify the causes that have a more significant influence on the effectiveness of planning.

With regard to the site management best practices, the analyses performed indicated that these significantly impact the effectiveness of planning. The correlation between the IBPC and the PCP variables tends to increase to the extent that the residential building market is analyzed separately, since they represent more homogeneous projects, and when the site safety practices are considered separately.

Despite the correlations found, the results of the linear regressions indicated a very weak predictive power. This indicates the existence of other factors that influence the dependent variables (DC, PA and PCP) and that were not considered in the analyses. This may also be a sign that the analyses performed are affected by some degree of subjectivity that exists in some of the variables used, such as the PPC and the indices of best practices. For example, in the case of PCP, the result of the weekly indicator may be influenced by the degree of detail of the short term plans, the quality of the definition of the work packages as well as the existing level of control of implementation. These problems were accentuated by the fact that this study used a database constructed from indicators collected by the companies themselves and not by the research team. However, the analyses proved to be very consistent with regard to the signal of the coefficients, the great majority of which proved to be of the kind forecast in the formulation of hypotheses.

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