UNDERSTANDING THE RELATIONSHIP BETWEEN PLANNING RELIABILITY AND SCHEDULE PERFORMANCE: A CASE STUDY

Ricardo M. Olano[1], Luís F. Alarcón[2] and Carlos Rázuri[3]

ABSTRACT

The earned-value method (EVA) monitors the progress of the project using dollar value or man hours as the metric by comparing the amount of work completed against the work planned to be complete and indicate if the project is on or behind schedule by means of the Schedule Performance Index (SPI). The Last Planner System (LPS™) increase planning reliability by reducing workflow variability, through analyzing and removing activity restrictions, analyzing causes for not fulfilled plans and monitoring its improvements by means of Percentage of Plan Completed (PPC).

The paper presents two cases studies about the application of the mentioned project control techniques and shows evidence that demonstrates the relationship between planning reliability (PPC) and project schedule performance (SPI). This relationship was tested statistically showing positive trends. The results show that project time is improved by increasing planning reliability during construction phase. These findings can help project managers understand the relationship between workflow reliability and project time, and prove that the role of the professional manager needs to become more proactive.

KEY WORDS

Project control, earned-value, last planner, planning reliability and schedule performance.

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[1] Project Superintendent at Freeport McMoran Americas,PMP, MBA, PhD Student in Management Sciences (ESADE - Spain), E-Mail: Ricardo_Olano@fmi.com

[2] Professor of Civil Engineering, Escuela de Ingeniería, Universidad Católica de Chile, Casilla 306, Correo 22, Santiago, Chile, E-Mail: lalarcon@ing.puc.cl

[3] MSc, Escuela de Ingeniería, Universidad Católica de Chile, Casilla 306, Correo 22, Santiago, Chile, E-Mail: cerazuri@uc.cl

INTRODUCTION

Typically, we begin the planning of a project in function of the scope statement, which defines the work that should be done. The scope is divided into elements of work, called Work Packages, which are hierarchically ordered in the Work Breakdown Structure (WBS). The objective of the plan of a conventional project is to finish the project on time, on budget, and according to the project requirements, commonly called the triple constrain (Shenar and Dvir, 2007).

The traditional focus of project management is based on predictable, relatively simple and invariable models. This means that once the project plan has been created, one establishes the control objectives, and then, the project manager handle the project using the “Management as Planned” philosophy, which means that the advances and performance of the project are evaluated against the plan, avoiding changes to the project plan if possible. This focus has been many times not harmonious with the needs of the business or environmental changes in the project; it is here where the executives and project team are frustrated trying to comply with not realistic expectations of staying within the project plan, mainly regarding execution times, because projects are developed in environments with constant changes, uncertainties, complexities, constant technology innovation and pressure of the markets on reducing product delivery times.

Based on a review of studies on delays in construction, AlSehaimi and Koskela (2008) found that all the studies came to the consensus that ineffective planning and controlling were the main causes of delays, followed by poor site management and problems of supply chain and procurement. Even though, these studies recommendations were given to improve planning and controlling, as well as to improve site management, they have not proposed the necessary tools to facilitate such improvements. According to AlSehaimi and Koskela (2008) the cause of delays in construction goes further than just the deficiency of the processes or the people, but with the theory of production management in construction, which is based on a deficient theory (Koskela 1992, Ballard and Howell 1998, Holy 1999, And Howell 2002), which goes in detriment of the general project performance.

TRADITIONAL PROJECT MANAGEMENT

The traditional systems of construction projects management is based onthe Project Management Body Of Knowledge (PMBOK) Standard. The Guide of the PMBOK divides the project management processes into initiation, planning, execution, controlling and closing (PMI, 2004). The planning process devises the project plan, which is the "input" of the execution process. It is assumed that translating a plan into action is the simple process of issuing “orders”. In the construction projects the planning process usually is executed by professionals unfamiliar to the execution of tasks on site, which generates that the work orders have inherently little reliability for its execution due to the fact that is unlike that a correct review of associated constrains to the conditions of site and necessary resources for its execution has been done.

The execution process is carried out by means of a work authorization system, designed by the projects control office to assure that the work is done at the right time and in the proper sequence. This process utilizes a written authorization to start works, similar to job dispatching in manufacturing industry, where the task is selected to be executed, authorized and communicated. In this process, it is assumed that the necessary resources for the execution of the task exist at the moment of the task and the process is pushing the tasks for their execution, which added to the uncertainty usually results in delays and keeps the project schedule out of time (Koskela and Howell 2002).

The control process, as a performance report, measures the status of the project relative to the baseline (elaborated in base to gradual transformations along the project) and gives recommendations for the recovery when the indexes of the project are outside of the admissible parameters. This control system, based on reactive indexes, identifies problems, but not improvement opportunities in the activities that are inside the project parameters; so this process is not capable of identifying the reasons and the root causes that generated the deviations, that’s why any recommendation of recovery has the risk and the probability of not contributing to the recovery of the project in a satisfactory way.

The described projects management focus consider the production with the focus of transformation, where the workflow management is not considered as also other variables that can affect the production (or the transformation). It’s not kept in mind that the time limits are affected by the uncertainty, as well as the interdependency among activities. In this sense, to maximize the project management is necessary to manage both flow and transformation, to have proactive indicators that measure the efficiency of the workflow management and short term plans as the Percent Plan Complete (PPC), as well as reactive indicators which measure the effectiveness of the project management as the Schedule Performance Index (SPI). This study carried out in two construction projects shows that these variables are related and help the project manager to understand how the improvement of workflow and the reduction of the variability impact positively in the general project performance.

VARIABILITY AND WORKFLOW RESEARCH

The effect of the variability in the performance of construction projects has been demonstrated through simulations and empirical evidence in construction projects. Inside the first group Tommelein et al. (1999) illustrated the impact workflow variability has on performance of construction trades and their successor; Alarcón and Ashley (1999) showed the impact of the uncertainty on the schedule and cost; and Shen and Chua (2005) proposed a model that allows to study the effect of the variability of resources and information in the construction schedule. In investigations carried out in real construction projects, Alarcón et al. (2005), the obtained evidences of the implementation of Lean Construction practices in more than a hundred construction projects, indicated that the Last Planner System (LPS) is an effective tool to improve the planning reliability and the project performance, however, performance measurement was a difficult task for the companies; González et al. (2007) showed that the improvement of the planning reliability impacts positively in the labor productivity in a home building project; Izquierdo and Arbulú (2008) associated the indexes of labor productivity with the weekly PPC of a piping project, finding a relation among production reliability and labor productivity; and Liu and Ballard (2007) of the collection of data of a piping project found that the productivity improves when workflow becomes predictable, thus enabling a better match of variable work load with capacity (labor hours).

DESCRIPTION OF THE CASES STUDIES

The projects case studies, included the construction of a Leaching Pad of 48 million cubic meters of capacity with an budget about US$ 20 million and a schedule of construction of up to 60 weeks; and the construction of 7.1 KM of highway with an approximate budget about on the US$ 7 million and a execution schedule of up to 44 weeks.

The construction of the PAD main objective was to build a PAD for leaching ROM material for a period of 26 years of operation to process part of the reserves of mineral. The approximate area of the PAD is 324.380 m2. The main volumes of work are 1,980.556 m3 of earthworks, 600.986 m2 of geosynthetic placement and 22.636 m of HDPE pipe installation for the collection and irrigation systems, as well as the installation of transformers, medium voltage cells and pumps for the impulsion and irrigation system. The time limit for the construction was 60 weeks.

The construction of a 7,1 Km highway consisted of an structure of asphaltic pavement of 7.500 m3 and 2.000 m3 of concrete works and 494.875 m3 of earthworks, which included 330.627 m3 of rock excavation with explosives.

Both projects were developed in Peru, in middle of adverse weather conditions, strikes, possibility to find archaeological remains, strict governmental control for the use of explosives, uncertain soil conditions and changing market conditions, for which the planning workflow was exposed to multiple external constrains that caused variability in their execution.

PROJECT CONTROL METHODOLOGY

For the project control, we considered the methodologies and tools recommended by the Project Management Institute (PMI) and the Lean Construction Institute (LCI). The specific tools applied in the project include Earned Value Analysis (EVA) and Last Planner System (LPS).

EARNED VALUE ANALYSIS (EVA)

The concept of earned hours was utilized to align in a single unit of measure all the executable quantities involved in the project, so meters of piping, tons of structures, cubic meters of concrete and meters of cables can be converted into a single unit which is the "man-hour" of labor estimated for executing each valuable unit.

By applying the number of associated man-hours to the activities of the schedule, these are distributed in the time, obtaining a histogram that represents the man-hours planned by unit of time (daily man-hours, weekly, monthly, etc.). The S-curve baseline, is a product of the cumulative weekly sum of the estimated man-hours used in the activities of the work schedule. It is sought that as production and/or construction of the work is done, the quantities produced (translated to man-hours) give as a result the earned value (earned hours) equal or over the hours planned.

The calculation of the Schedule Performance Index of the project (SPI) is carried out in base on the hours earned of the project. The earned hours at the time of cut are compared against the hours planned (of the S-curve), and determine whether the project is ahead or behind in the progress.

SPI: Earned Hours / Planned Hours

Earned Hours = QTY_{ToDate} ($MHRS_{BDG}$ / QTY_{BDG})

Where:

QTY_{ToDate} = quantity executed to the date.

QTY_{BDG} = quantity budgeted.

QTY_{BDG} = man-hours budgeted.

The calculation of the SPI can be made both for the total project as well as for specific areas, specialties or packages of specific works defined in the WBS. The practical use of this index is monitoring progress of the construction site, the comparison between planned and actual rates with the purpose of verifying compliance with performance targets (transformation) with respect to the master project schedule. Also, this index provides a general overview of the project and is an element of comparison and measurement that is used in the Balance Scorecard of the Portfolio of the Project Management Office (PMO).

However, under the EVA methodology, the objective is to measure the performance of activities individually in contrast with the work plan and not the performance of the activities themselves and the relations between them. Under this scheme the focus is in "the what" and not in "the how" is being managed the construction project; while the production management is not a major concerns, current EVM ignores the concepts of workflow and value-generation based on customer needs (Kim and Ballard, 2000). It is being promoted that each responsible for activity, group of activities or package of deliverables, take care of their ratios of production, cost and time, with a tight vision or even null, about how each responsible for activity can affect others. In this scenario, get the project back on schedule means fast-tracking and crashing with the costs and risks that it implies.

EVM is an effective tool only under the limiting assumption that every activity or cost account is independent; however, work activities are not discrete independent elements in construction projects (Kim and Ballard, 2000).

According to Howell and Ballard, (1996) we need to control management processes, not only project outcomes. Traditional outcome measures such as cost and schedule can only be used for management decision making on dynamic projects when the project management systems are themselves in control. The primary indicator of such control is the reliability of production planning. Because of this reason, it was decided to complement the projects control through the Last Planner System (LPS).

LAST PLANNER SYSTEM (LPS)

LPS was applied to improve the reliability of planning work by its three types of plans: long-term planning with the master plan, intermediate planning with the lookahead and weekly planning with the weekly work program. The lookahead program allows us to see the activities to be executed in a time window of three weeks in order to ensure the flow of production and increases the reliability of short-term planning (weekly program) through the identification and removal of associated constrains to the long-term planning (master schedule).

The short term weekly planning serves to guide the execution of work. This program provides a more detailed analysis of the lookahead program and it's here where physical resources are assigned (labor, equipment, materials and tools) to the activities planned in the intermediate planning (Campero and Alarcón, 2003).

The measurement of the reliability of the weekly planning of construction is done by the PPC, which indicates what percentage of work packages or activities planned were executed. In this way, the weekly program measures the performance of the activities planned and executed in last week, and planned activities this week based on the release of constrains on the lookahead program. Besides, it serves as support to the construction activities coordination between the different participants (PMO, Contractor, Operations Management, Safety, among others).

PPC = ∑ nº of executed activities / ∑ nº of planned activities

In the weekly planning meetings, the weekly program was reviewed, looking to determine the causes that caused the noncompliance of the activities planned, so, in this way and in a proactive way, apply corrections and preventive actions in the development of the project.

The practical advantages of the application of this methodology in the project were: The identification, monitoring and releasing of constrains according to the site conditions and critical resources with head assigned, insuring workflow.

DATA ANALYSIS AND DISCUSSION

DATA COLLECTION

In both study cases the data were measured weekly by the main contractor of each project and reported to the PMO. The period of data collection for the construction project of the Leaching Pad was 44 weeks until November 28, 2008 when the project was at a 77,93% of advance. For the construction project of the highway, the period of data collection was of 41 weeks until November 21, 2008 when the project was at a 96,8% of advance. Figures 1 and 2 shows the SPI and PPC indexes evolution of the projects in the indicated periods of time.

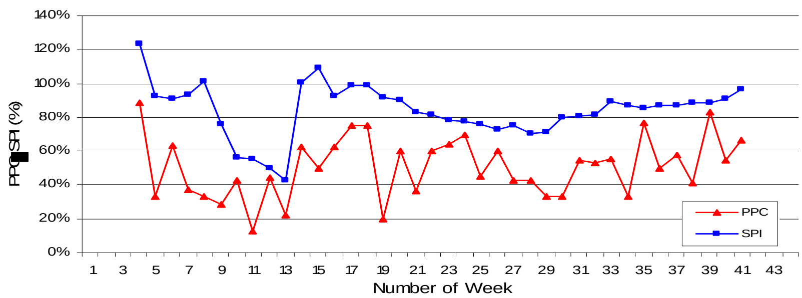

Figure 1: Highway Construction - Time Evolution of the PPC and SPI

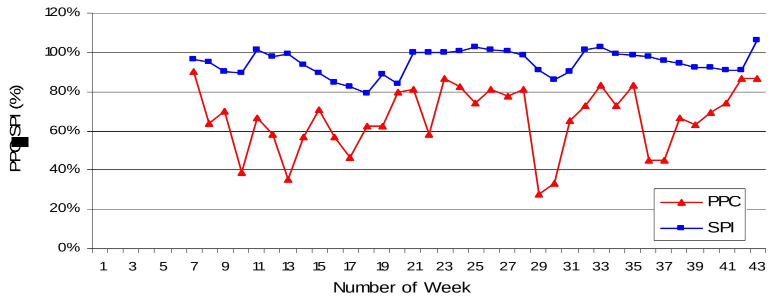

Figure 2: PAD Construction - Time Evolution of the PPC and SPI

The average SPI in the highway construction project was 0,85 (Standard Deviation 0,157) and the average PPC of the project was 0,53 (Standard Deviation 0.192). For the Leaching Pad construction project the average SPI was 0,95 (Standard Deviation 0,064) and the average PPC of the project was 0,66 (Standard Deviation 0.165).

DATA ANALYSIS

The statistical program used for the data analysis was SPSS Version 16 (Statistical Package for the Social Sciences). The correlation analysis is the statistical tool used to describe the degree to which a variable is lineally related to another, that is to say, the degree of association between two variables (Levin and Rubin, 1996). The interpretation of the correlation coefficient and the significance level served to test that a correlation between the variable SPI and PPC of the project exists. The test used to evaluate the relation of different variables was the Pearson correlation coefficient. This coefficient takes values between -1 and 1: a value of 1 indicates perfect positive lineal relation; a value of -1 indicates perfect negative lineal relation; a value of 0 indicates null lineal relation. It is very important to keep in mind that a high correlation coefficient does not imply causation. Two variables can be lineally related (even very related) without one being cause of another (Pardo and Ruiz, 2002). To prove causation between two variables is used the significance level . According to the significance level of the association of two variables, one can draw conclusions about the strength of the relationship between two variables. Essentially, the significance level indicates the probability that the relation between the variables occurs by chance. When the significance level is close to zero, the probability that the relation occurs by chance is smaller (Hinze, 2002). For example, if the significance level between two variables is 0.01 (1%), then there is a probability of 1 in 100 that the relation between these two variables can be attributed to chance. The level of correlation is considered statistically significant if the significance level is under 0.05. However, Hinze (2002) argues that a significance level in the interval between 0,05 and 0,10 is considered an indicator of a trend.

NEW HIGHWAY CONSTRUCTION

The first table provided the value of R and R^2 for the model has been derived. For these data, R has a value of 0.529 and because there is only a predictor, this value represents the simple correlation between Schedule Performance Index (SPI) and Percent Plan Complete (PPC). The value of R^2 is 0.280 which tell us that PPC can account for 28% of the variation in SPI.

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.529	.280	.261	.135

The independent variable is PPC.

Table 1: Highway Construction – Model Summary

The simple lineal regression model has a R^2 of 0.28 with $\rho < 0.05$, son the model is statistically valid. In Table 2, we report the results of regression analysis when the dependent variable is the SPI and the independent variable the PPC, these results corroborate the positive relation between these variables ($\beta = 0{,}434$, $\rho<0.05$).

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
PPC	.434	.113	.529	3.842	.000
(Constant)	.619	.063		9.818	.000

Table 2: Highway Construction – Regression Analysis Results

In Figure 3, we show the graphic relation between the values of the SPI and PPC in the scatter plot under the lineal regression model, this model is the one that presents better adjustment for these two variables, where the correlation coefficient is 0,529, the significance level 0.00 and the R^2 0,28, which means an improvement in the values of the PPC are related in a positive way with the SPI.

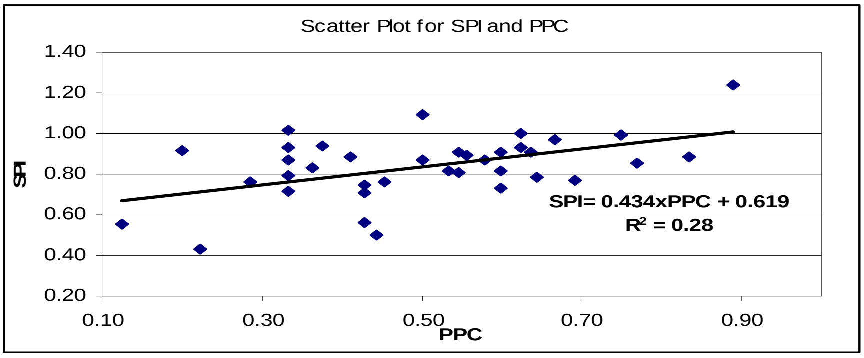

Figure 3: Highway Construction – Scatter Plot for SPI and PPC

LEACHING PAD CONSTRUCTION

In table 3, provided the value of R and R^2 for the model has been derived. For these data, R has a value of 0.397 and because there is only a predictor, this value represents the simple correlation between Schedule Performance Index (SPI) and Percent Plan Complete (PPC). The value of R^2 is 0.158 which tell us that PPC can account for 15.8% of the variation in SPI.

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.397	.158	.134	.060

The independent variable is PPC.

Table 3: Pad Construction – Model Summary

The simple lineal regression model has a R2 of 0,158 with ρ< 0.05, so also the model is statistically valid. In Table 4, we report the results of regression analysis when the dependent variable is the SPI and the independent variable the PPC, these results corroborate the positive relation between these variables.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
PPC	.156	.061	.397	2.562	.015
(Constant)	.844	.042		20.332	.000

Table 4: Pad Construction – Regression Analysis Results

In Figure 4, we show the graphic relation between the values of the PPC and SPI week to week in the scatter plot under the lineal different regression model, this model is the one that offers better adjustment for these two variables, where the correlation coefficient 0,397, the significance level 0.00 and the R^2 = 0,158, which means an improvement in the values of the PPC, are related in a positive way with the PPC.

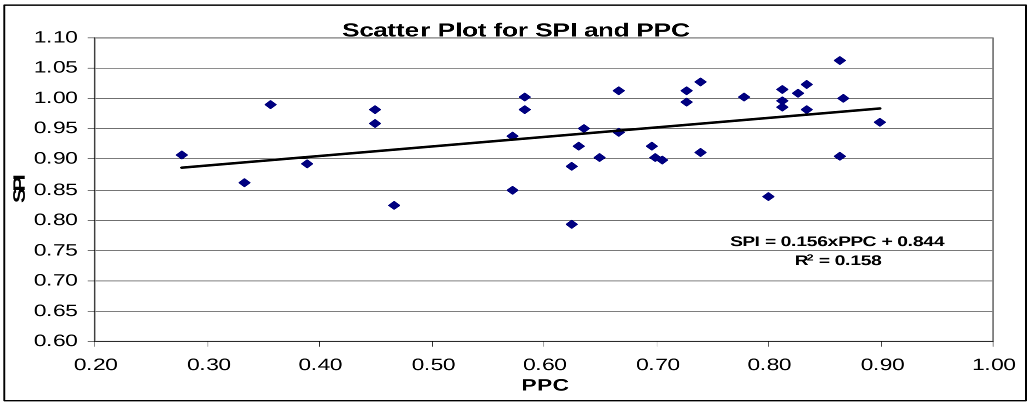

Figure 4: Pad Construction – Scatter Plot for SPI and PPC

RELATIONSHIP BETWEEN PPC AND OVERALL SCHEDULE

Table 5 shows the relationship between average SPI, average PPC and correlation coefficient R for each project. The Leaching Pad Construction ended on time, which is reflected in its average SPI of 0.95 and an average PPC better than the Highway Construction, albeit with a lower correlation coefficient (0397). The Highway Construction ended with a delay of 16%, which is reflected in its average SPI 0.84 and a lower PPC (51%).

Project	SPI (av)	PPC (av)	R	Comment
Leaching Pad	0.95	66%	0.397	Project completed on time
Highway	0.84	51%	0.529	Increased time in 16%

Table 5: Relationship between SPI, PPC and R

A limitation of this paper is that the study is applied to only two projects, in order to corroborate the findings, the authors suggest replicating this study in a larger number of construction projects in various industries and sectors. This provides future research of the authors to work on issues related to improving productivity and controlling the variability in projects.

CONCLUSIONS

It has been confirmed, by quantitative analysis of two cases study that workflow reliability and schedule performance were statistics significantly correlated. It has been shown that in the weeks where there was an improvement of the workflow reliability through the increment of the Percent Plan Complete (PPC), we observed an improvement in the Schedule Performance Index (SPI) of the project.

The methodologies of the traditional systems of project management as the EVA are efficient under the assumption that each activity, package of work or account of costs are independent, they do not keep in mind that time is affected by uncertainty, as well as the interdependency among activities. On the other hand, the LPS is responsible for reducing variability and improving the reliability of planning, by identifying causes of non compliance and releasing constrains that may impede the compliance of the plan and assignments of quality. As it can be observed, both methodologies are complemented and must be managed together to ensure project success.

Like the findings of Liu and Ballard (2008), the understanding of this relation can help the contracts administrators to demonstrate responsibilities at the time to support a claim for extension of time.

RECOMMENDATIONS

For the construction industry which generally operates with traditional projects management standards, it is a contribution because of positive relation that is observed between the PPC and SPI, which gives greater reliability to avoid the delays in projects.

Project Managers (owners and contractors) should be trained and generate skills in the use of project management (EVA) and LPS methodologies because of the combination of these two methodologies, we add value to the planning and control of projects in the construction industry.

Definitively, company's owners of projects should encourage the combined application of production management methodologies and project management among their contractors, this causes them to have greater certainty in project delivery time and therefore the company can maintain their competitive advantage in a sustainable manner.

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