USING LAST PLANNER INDICATORS TO IDENTIFY EARLY SIGNS OF PROJECT PERFORMANCE

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ABSTRACT

Reducing uncertainty is a very important issue in construction projects and recently some methods have been developed to deal with it. Particularly, the Last Planner System (LPS) which has been designed to improve planning reliability and project performance; however, its use does not guarantee a total success of projects. Thus, there is still an opportunity to develop new tools that can help to further reduce uncertainty and reliably predict project performance for the decision making process. This paper reports the results of a data analysis from more than thirty six Chilean projects that used LPS, where weekly information was available, in an attempt to identify indicators and patterns that could best anticipate project performance. Indicators included in this research were strategically chosen to analyze patterns regarding reliability of planning in the LPS and performance index from conventional planning methods. The indicators include: PPC (Planned Percent Complete), SPI (Schedule Performance Index), PCR (Percent Constraint Removed), and curves of actual & scheduled progress. Data and indicators were extracted from IMPERA (a software tool used based on the Last Planner methodology). The projects were classified as "Successful" or "Unsuccessful" according to their schedule performance in order to perform statistical analyses. Specifically, this research considers that projects are deemed successful when planning, organization, direction and control are developed in such a way that allows for the compliance of initially established objectives for Costs and Schedule.

The results indicate that there is a close relationship between the variability of PPC, SPI and success of the projects. Additionally, different indicators trends were identified for "Successful" and "Unsuccessful" projects in different stages of projects progress. Consequently, comprehension of the relationship between the indicators and project performance could make it possible to predict whether or not a project will be "Successful" at different stages of its life cycle.

KEYWORDS

Last Planner System, Planning, Project Performance

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INTRODUCTION

As a result of decisions based in improvisation, inexperience and other critical factors, as construction projects move forward, planning losses its direct relation with expected results. Additionally, various issues occurring in projects are not noticed until late stages, resulting in cost and schedule overruns. The need of seeking solutions based in Lean philosophy to deliver effective solutions to the aforementioned issues arises in this area. Thus, tools such as the earned-value method (EVM) have been proposed to control projects performance through integration of schedule and cost. However, this modern technique still has some problems which have been previously discussed in the literature (Kim and Ballard, 2000)

During the last 15 years, the Last Planner System (LPS) created by Ballard and Howell (1998) has been studied, analyzed and applied by *Centro de Excelencia en Gestión de Producción de la Pontificia Universidad Católica, (GEPUC)* [Center for Production Management Excellency Pontificia Universidad Católica] developing a computer software for Project Planning and Control based on this methodology, called IMPERA. This software allowed attaining global knowledge of projects, as it compiles all information generated by them, in order to obtain information of their performance.

With the objective of identifying patterns that enable predicting possible delays or progress in early stages of projects, a chronological analysis of 36 Chilean projects using IMPERA software is developed. Initially, research efforts were directed towards identifying common behavioral patterns in different projects stages, in order to analyze possible relations between progress control indicators, that underlie the studied behavior and predict it in future projects. Specifically, two analyses were performed: the first one analyzed the variability patterns of PPC (Percent Plan Complete) and SPI (Schedule Performance Index) and their relationship with success or failure in thirteen projects with statistically valid data; the second one consisted of statistical analysis of PPC, PCR (Percent Constraint Removed) and Scheduled Progress Curve in thirty six projects. Once the analyses were finished and based on the "success" definition of this research, it was possible to identify statistically significant differences between the indicators analyzed for "Successful" and "Unsuccessful" projects.

This study allowed the identification of patterns and performance indicators that can help to identify, early in the project lifecycle, potential failures and successes in projects. The identification of patterns and process indicators that are good predictors of project failures and successes can be very helpful to focus our attention and efforts on improving performance in the right place, in early stages of projects.

METHODOLOGY

The methodology used in the development of this research includes the following stages:

i. Literature review: Lean Construction, Last Planner and IMPERA software.

- Sample selection through base parameter compilation from studied projects: Data is collected from different sources including participation of different members involved along the projects (from project site to technical department). Data is collected from progress monitoring of job

packages, information which is managed by client companies and subcontractors. Data collected is registered in IMPERA software by technical office.

ii. Project classification according to type (e.g. High-rise building, extension building, etc.) and compilation of indicators throughout their global progress:

- Project selection from database for each kind of projects, taking into consideration that results represent more than 50% of database, with a confidence level of 99% and confidence interval lower than 5%.
- Compilation of data from percentage of project progress.
- Calculation of mean, median and standard deviation of the indicators for full or cumulative sample along real project progress.

iii. Statistical analysis of common patterns identified in projects performance and searching of success trend indicators along progress control of different projects stages.

iv. Analysis of results and conclusions

INDICATORS SELECTED FOR THE STUDY

The following indicators were selected for the specific analysis of studied projects:

a) General evolution of Plan Percent Complete (PPC[1])

PPC as a binary indicator shows the fulfillment of commitments (Alarcón et al. 2005; Ballard, 2000). Every week, the degree of fulfillment of the project is notified and recorded in IMPERA, for every short-term unit or weekly plan. Therefore, it is possible to analyze PPC's general evolution along the time.

b) Evolution of the Percent Constraint Removal (PCR)

Every week the intermediate planning (Look ahead) helps to visualize forthcoming activities in the Master Plan, in a period beyond 3 weeks. The analysis of management activities or constraints allows for the definition of responsibilities and release dates. Verification of the latter allows for visualization of their behavior and evolution along the time.

c) Progress Curve

It is a graphical representation of cumulative progress of projects in relation to time and it is very useful to compare real progress and expected progress. The most widely used methodology for the creation of programed and real progress curves of projects loaded on IMPERIA, is considered a "relevant factor", based in the timeframe of every activity determined in the project's initial programming.

[1] PPC indicates a degree of accomplishment of the planning by the responsible participants of a project.

Schedule Performance Index (SPI)
It is the proportion between real and projected progress measured in every short-term unit. If its value is higher than 1.00, more tasks are being performed in said period. On the contrary, lower values mean that the projected progress is not being accomplished.

SAMPLE SELECTION

The thirty six projects included in the study come from two main sources:

1. Database from previous investigation, which objective was to analyze progress control indicators in time (Cisterna, 2013; Cisterna et al., 2013)
2. Total database of projects using IMPERA (259 projects developed by 21 companies up to September 23rd 2013)

DETERMINATION OF SIZE OF THE REQUIRED SAMPLE

Of all projects included in the databases, 115 projects have three indicators: PPC, PCR and Progress Curve. In order to ensure that the results of the analysis were representative enough, samples compliant with the following requirements were analyzed: Confidence level 99%, percentage distribution 50%, and confidence interval 5%. Therefore, the required sample size was determined to be 561 short-term periods (STP), with an initial population of 3998 PPC.

It is important to remark that due to confidentiality reasons, all aforementioned companies shall be named with capital letters ranging from A to R, and for every company "i", their n_i projects will be numbered from 1 to n_i. Therefore, every project will have a code related to its respective company in the following fashion: A1, A2, B1, B2, B3, C1, etc.

SIZE OF THE SAMPLE TO BE ANALYZED

From total PPC population, the statistically valid sample size to be analyzed was determined to be 1453, distributed according to the following project classification: Civil Works (285), Light Industrial (218), High-rise Building (583), and Extension Building (367).

ANALYSIS OF RESULTS

To analyze the behavior of the indicators, performance of each one was measured period to period. This method is intuitive for PPC, but not for SPI. Therefore, the form of measurement of SPI for each short-term period was the calculation of the proportion between real and projected progress for the referenced period[2].

Out of the aforementioned classification, 36 projects have more than three pairs of data sets (PPC, SPI) minimum amount required for statistical analysis. For each of the projects, charts showing "SPI vs PPC Dispersion" and "Evolution in time of indicators" were made, in order to have visual backup of the simple linear correlation between both variables, prior to statistical analysis, and to observe the behavior of variability in time of both indicators.

100% of the projects had a positive Pearson correlation coefficient, meaning PPC and SPI were correlated. Therefore, there was a general trend to have high SPI values in short terms featuring high PPC and vice versa.

There was a trend indicating that in short-term periods where there are high values of PPC, the SPI is also high, and vice versa.

STATISTICAL VALIDATION OF RESULTS

Given the positive correlation between the pairs of data sets (PPC, SPI) the significance level was calculated using a linear regression with SPSS v16 Software (DEMRE, 2008). Of the 36 statistically analyzed projects, 13 had a significance level lower than 0.10. Consequently, in 36% of the projects PPC and SPI's positive correlation resulted to be a trend indicator.

It is important to remark that, in order to achieve a more complete analysis the average and the median of each indicator was calculated, as data per project amounted to between 11 and 54 sets of data. For samples under 30 sets, it is advisable to use median as the central tendency measurement.

VARIABILITY OF PPC AND SPI INDICATORS AND THEIR RELATION TO PROJECT SUCCESS

In order to make a comparative analysis of variability of indicators, it is necessary to underline a definition of "Successful" project used in this particular study.

A project is deemed "Successful" when planning, organization, direction and control of the project is developed in such a way that allows for the compliance of initially established objectives, generally linked to two concepts: Costs and Schedule.

In order to comply with IMPERA's classification, a project has been defined as "Successful" when two requirements are fulfilled simultaneously:

- "Proportion between A and B is higher or equal to -10%", with A being Schedule deviation for X [%] and B the Planned Schedule for progress of X [%].
- Accumulated SPI of the project equal or higher than 0.90.

To summarize, the calculation to determine success of a project is shown below:

$$\frac{A}{B} = \frac{Planned\ date_{X\%} - Real\ Date_{X\%}}{Planned\ Date_{X\%} - Planned\ Starting\ Date} = \begin{cases} < -10\% , & Unsuccessful \\ \geq -10\% , & Successful \end{cases}$$

$$SPI_{final\ accumulated} = \frac{X}{Y} = \begin{cases} < 0.90 , & Unsuccessful \\ \geq 0.90 , & Successful \end{cases}$$

The calculation for all studied projects was made, with X [%] being the last real progress recorded and Y [%] the projected progress to that date. Therefore, five Projects are considered "Successful" (I2, M19, P13, M3 and O21), and eight projects are considered "Unsuccessful" (M20, M26, P2, A6, A7, I1, D2 and D3).

INDICATORS AND VARIABILITY

The analysis of the aforementioned indicators is shown below:

PPC and Variability

The results of the studied projects, differentiated according to level of success, are shown below.

Table 1: Projects PPC and variability according to level success

Project according to Success level	PPC Average (%)	PPC Median (%)	PPC Standard Deviation (%)
Successful	76	78	21.3
Unsuccessful	61	64	26.9

From the results of the table above, it can be concluded that:

- Both PPC average and median have higher values for "Successful" than for "Unsuccessful" projects. This result agrees with the fact that the higher the completed activities percentage in short-term periods is, the better the project complies with planning, therefore making it more prone to success, according to the used criteria.
- Regarding standard deviation, it is possible to remark that in "Successful" projects, there is less variability. Therefore, in order to achieve "Success" in a project, not only a high average PPC is required, but it is also important to maintain values within a variation range close to 22% or less. Hence increasing the probability of success construction projects.
- When studying PPC behavior in "Successful" and "Unsuccessful" projects, there is a similar variability (between 22% and 27% in average), so the real success indicators are PPC median and average. This is because both "Successful" and "Unsuccessful" a project, difference between the average and median is very low, which is attributed to a low general variability and/or to symmetry in the value sample. Therefore, it is possible to infer that in order to attain success in projects it is essential to have a high PPC median and average t.

SPI and Variability

The results of the studied projects, differentiated according to level of success, are shown below.

Table 2: Projects SPI and variability according to project success

Project according to Success level	SPI Average	SPI Median	PPC Standard Deviation
Successful	1.064	1.003	0.419
Unsuccessful	1.108	0.920	1.109

It is important to remark that the existence of SPI values far superior to 1.00 is not necessarily an indicator of project success. Because, it could indicates that project plan reliability is changed, and there is a lack of coordination between planning in technical offices and the execution of the project. For the project to be successful, a rescheduling of the plan is required whenever necessary.

Based on the data above, it can be concluded that:

- Unlike PPC analysis, only SPI median value is higher for “Successful" projects than for “Unsuccessful” projects. On the other hand, SPI average for "Successful" projects is lower than for “Unsuccessful" projects. Regarding standard deviation, it is possible to notice that in case of “Successful” projects, variability, in spite of reaching approximately 42%, is much lower than in “Unsuccessful” projects. This result is very important, because it makes evident that in order to achieve “Success" in a project, not only a high average SPI is required, but it is also important to maintain values within a variation range close to 42%. This increases the success probability of projects.
- Despite the median being lower in “Successful” projects than in “Unsuccessful” projects, there is no difference significant enough to make conclusions solely based on that parameter. The indicator for success is SPI variability, as it is essential to have a low standard deviation instead of increasing SPI weekly value, in order to have a “Successful” project.

GENERAL EVOLUTION OF PPC AVERAGE IN PROJECTS

When analyzing the behavior of PPC average in construction projects throughout their progress, it was possible to detect that a “Unsuccessful” project will have a lower PPC average than a “Successful” project in its entire life cycle, with a difference that mostly surpasses 10%. Despite the existence of two non-significant ranges (0-20% and 60-70%), the shown tendency in significant ranges is maintained in the other ranges. The chart allows making simple and intuitive conclusions such as: “If 25% of progress is reached, and PPC averages 60%, it is highly probable that the project will not be successful. Therefore, proper corrective actions are required to change this and take the project’s curve closer to “Successful” curve.

General Evolution of PPC Variability in Projects

The chart below allows for observation of how PPC variability behaves in building projects throughout their progress.

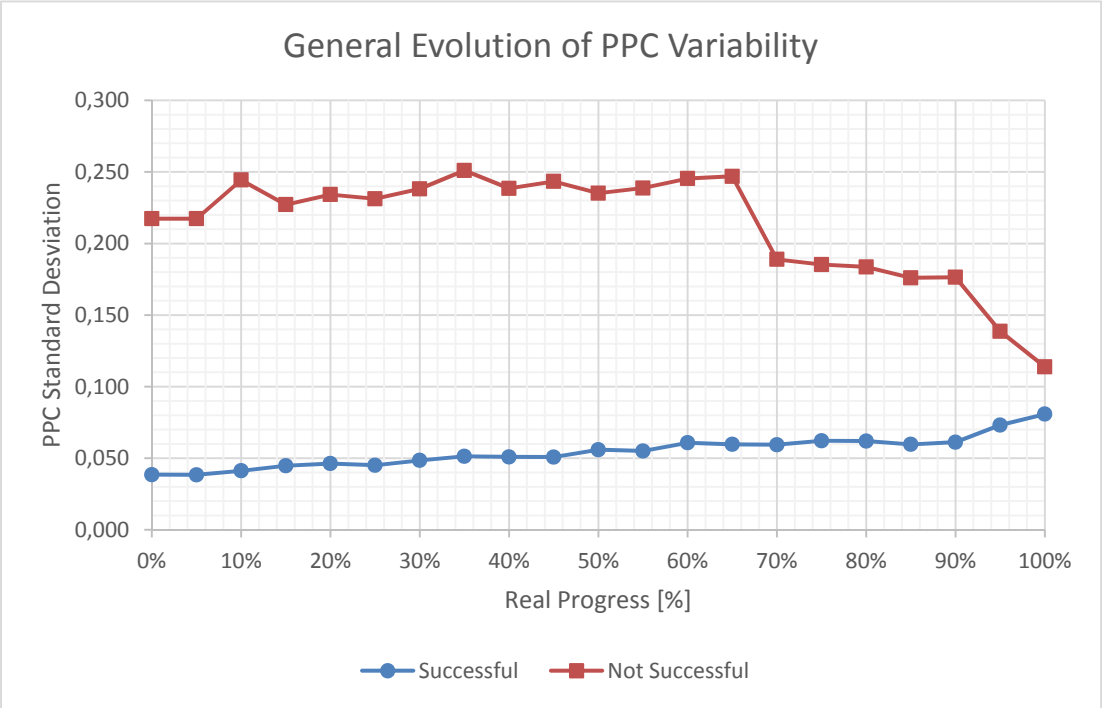

Figure 1: General Evolution of PPC Variability Average.
Source: Elaborated by the Authors

It is observed in the chart that a “Successful” project has a relatively low and constant variability (below 10%) throughout the project duration. In contrast, “Unsuccessful” projects have variability close to 25% throughout most of their life cycle, approaching 10% towards the end of the project. Consequently, it is not enough to have a low PPC variability throughout the project, but it is also important for a project to be "Successful”, that PPC variability is low and without drastic variations throughout its entire development.

General Evolution of PCR Average in Projects

PCR study is made along with the real progress evolution of every project. The form of measurement and data-pair creation methodology is analog to PPC’s method. It is important to remark that the following analysis is mainly focused in global behavior of building projects, using the results of total of the samples. When analyzing the general evolution of PCR in projects, it was possible to observe that project success is defined in its early stages. In this manner, “Successful” projects have a PCR average above 35% starting 10% progress, while “Unsuccessful" projects do not achieve that average in any part of their life cycle.

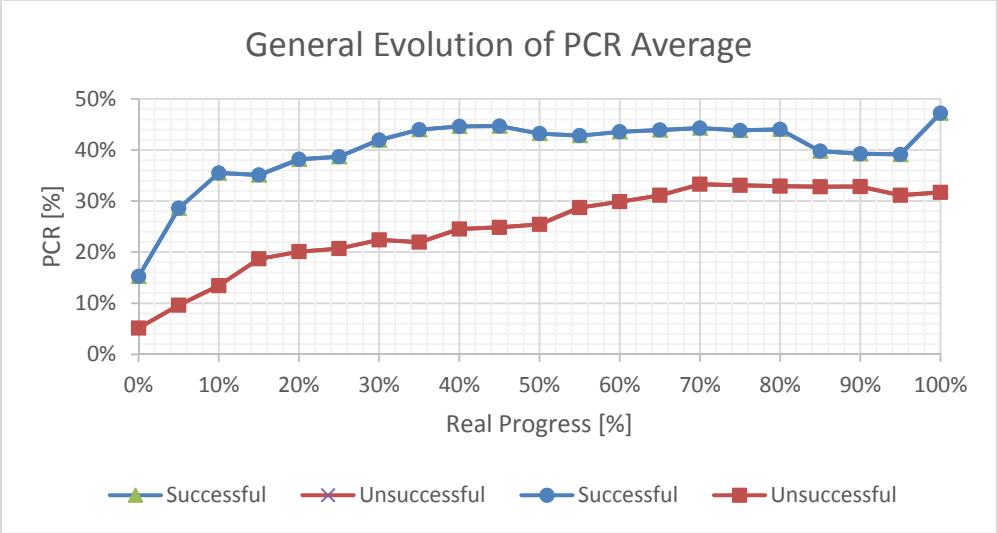

Figure 2: General Evolution of PCR Average.
Source: Elaborated by the Authors

GENERAL EVOLUTION OF PCR VARIABILITY IN PROJECTS

Regarding PPC in “Successful" projects, it is vital to maintain a low and constant variability throughout its life cycle (in this case, under 15%.) For “Unsuccessful” projects, variability generally exceeds 30%, despite PCR variability being close to 20%. It is observed that PCR standard deviation analysis for the complete project is not enough, since the difference between “Successful" and "Unsuccessful” projects is small (ranging from 15% to 20%.) Therefore, in order to predict success, it is essential to continuously control the variability of this indicator, preventing it from surpassing 15%.

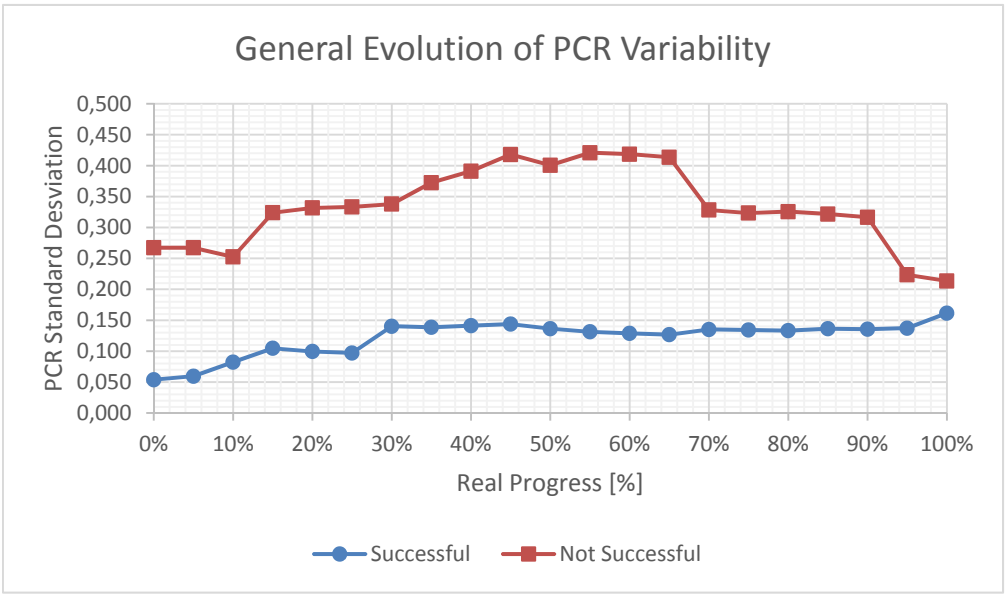

Figure 3: General Evolution of PCR Variability Average.

Source: Elaborated by the Authors

PROJECTED PROGRESS CURVE

Projected Progress Curve study is made along with the real progress / evolution of each project. When analyzing Projected Progress Curve throughout the progress of construction projects, it is possible to notice that "Successful" projects tend to progress as programed, following a curve of m≈1. Moreover, they are susceptible to delay of approximately 5% compared to the program. In contrast, "Unsuccessful" projects, despite having a similar behavior to "Successful" projects during the first half of their progress start to deviate from program during the second half of their life cycle, being susceptible to delays of 15% compared to the program.

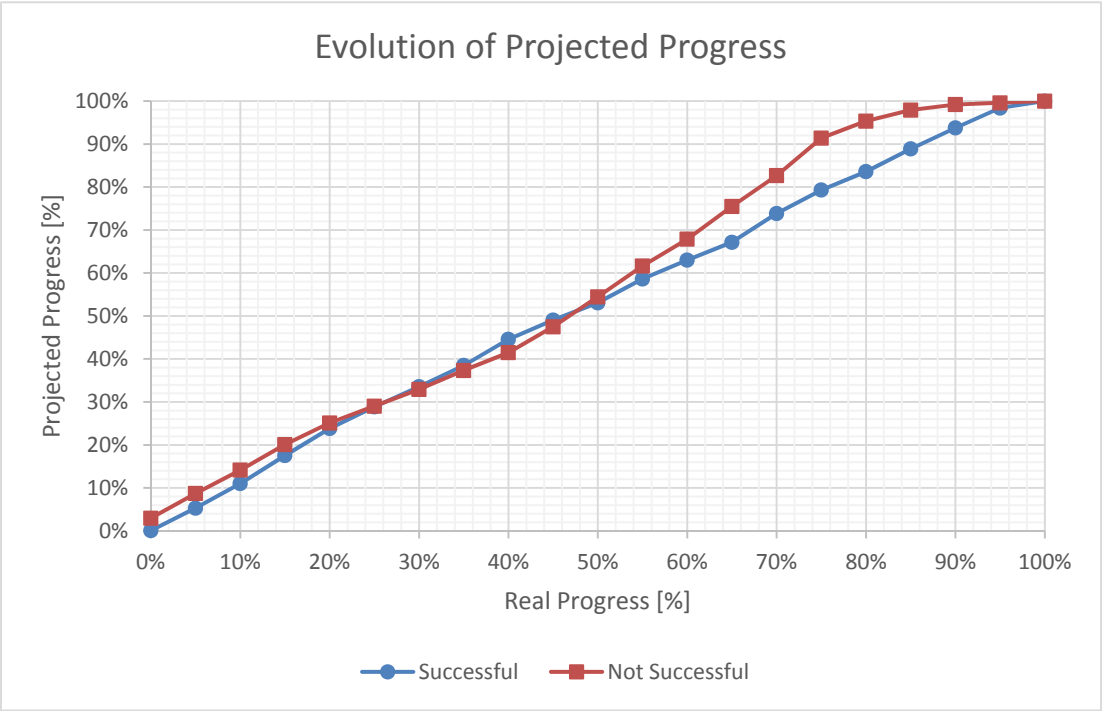

Figure 4: Evolution of Projected Progress

Source: Elaborated by the Authors

It is important to remark that the projected progress curve is a good indicator of success for projects from 75% of their progress, as there is a more notorious difference in project behavior, and data are significant in this stage.

CONCLUSIONS AND FINAL COMMENTS

Seeking to identifying sings of success on projects at early stages, this study has been focused on the analysis of patterns from indicators obtained in different projects. From the analysis above, it is possible to conclude about the following key points:

PPC and SPI

In the complete analyzed sample, it is confirmed that in short terms where there was an improvement in planning reliability through an increase of PPC, there was also an increase of SPI. Therefore, it is observed that improvement in progress related to the program is due mainly to an increase in planning reliability.

PPC and SPI Variability

Regarding this topic, it is possible to conclude that for PPC and SPI, median and standard deviation in "Successful" projects are higher and lower, than in "Unsuccessful" projects, respectively. PPC represents planning reliability, therefore, the higher the percentage of completed activities in short-term periods, the more reliable the planning is, and the project has better possibilities of success.

Moreover, the fact that PPC variability in "Successful" projects is lower than in "Unsuccessful" projects, allows for concluding that it is not enough to only have a high period-to-period PPC, but it also is important that values remain in a small variation range. Nevertheless, the difference between variability of "Successful" and "Unsuccessful" projects is small (22% vs 27%), in relation to the difference between the projects' median (78% vs 64%). In this way, it is possible to presume that median is a more powerful indicator of PPC success than variability.

This study concludes that it is possible to predict the success of projects in their early stages. Significant ranges of results for the different indicators studied allowed analyzing projects performance at any stage of real progress. Indicators were strategically chosen in order to enable the analysis of a project's success, based on the fulfillment of planning and responsibilities of the latter planners. Graphs as very valuable tools were created in order to predict success of a construction project. Their separate use allows for a reference of success for each indicator. However, use in conjunction is advisable, as it allows for further reduction of uncertainty and improvement of project control and planning reliability. Therefore, the use of graphs is proposed as a complement previous tools such as Earned Value Method which could be considered and effective tool only under the limiting assumption that every activity or cost account is independent.

Additionally, it is possible to observe that, in order to attain success in projects, it is not enough to achieve a high general percentage in time indicators, but it is also essential to control their variability. This means that for a project to be successful, the value of all indicators must be high, but they also must remain within small variation range from period to period.

Finally, it is possible to conclude that the variability throughout the project is similar in "Successful" and "Unsuccessful" projects. The difference in "Successful" projects is determined during their development, because "Unsuccessful" projects have a high initial variability and improve in their final stage, as opposed to "Successful" projects, that have a constant variability throughout their progress. Therefore, it is not enough to analyze standard deviation of the whole projects, but it is also necessary to constantly control projects variability in its complete progress, in order to manage their final success.

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