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Proposed model to improve the forecast of the planned value in the estimation of the final cost of the construction projects

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Abstract

The productivity of an engineering project is determined by the value assigned to the PV (Planned Value). Since the PV is not precise, mathematical models are used to obtain a final cost forecast and control the project. In this work, the PV value is improved to reduce the error of the forecasts. Statistical confidence intervals were used to determine the standardization of work process times. As a result, this brings a more accurate PV, with a more accurate and lower difference between PV and EV (Earned Value). Two projects of two Mexican companies have been monitored. The resources used were 30 analysts during a two-year period. The proposed model proves to be more accurate at all stages of the project.

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Keywords: Finishing cost accuracy; Working hours; Earned value; Planned value; standardization.

1. Introduction

Any Project has a determined number of time and cost activities assigned to a specific number of workers. During its progress, the return value or project progress must be close to the planned value or the project's budget so that the cost on any cut-off date does not surpass the estimated cost for that date, and the additional costs are only allocated to the increments of unplanned activities from the original project. In terms of construction, extra jobs are denominated, meaning that the impact of these needs to be conformed in the same way as the original activities, without decontrolling the project costs, given that every extra job will need to be charged. Despite the extra Jobs, the effect of

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a smaller planned value is a smaller returned value and a greater value of the actual cost. Given that the planned value is not precise, the use of techniques and mathematical models is necessary to obtain a forecast of the final cost of the project, to determine various actions that allow having an optimal control. The purpose of this work is to improve the planned value to decrease the forecast error. For this objective, a new model is proposed, which implies the standardization of the jobs' cycle time by monitoring and considering upper and lower control limits with high statistic confidence intervals. This means that if it would be possible to standardize the cycle times, the planned value would be more precise and the difference between this and the return value would be minimal. In order to prove the activities standardization, a monitoring in two projects of two Mexican enterprises has been done. The used resources were integrated by 30 analysts during a two year period [1]. The proposed model shows more precision in the estimation of the project's cost in all its stages.

2. Basic concepts

Below is the definition of some terms used throughout this paper [4]

EV – Earned value of the project or work progress (some authors call it as the Budgeted Cost of Work Scheduled (BCWS).
PV – Planned Value of the project
AC – Actual cost or monetary value of the completed job to a determined cutoff date

The PV of a project plays an important role due to its restrictive relationship with the AC and its productive relationship with the EV. The more accurate the PV value, the smaller the difference with the AC, and the final cost forecast will be closer to the real cost. Unfortunately there are no studies to obtain more precise PV values. Generally these values are established conjunctly in a theoretical and experimental way according to each enterprise. In order to calculate the PV, that is, the budget, the monetary value of all materials to be used and all workforce involved in the installation, is required as an input. Normally, to obtain the list of all the necessary materials for the project's development, a visit is required to the place where the work will be done is required, along with the use of isometrics.

The isometrics span little pieces such as a joint, to large pieces that can weight even tons. Once the list of material is finalized, the prices are obtained, and the percentage of gain is added. Nevertheless, to obtain the value of the required workforce, the cycle time of the installation of each component is required in order to add the gain percentage.

To obtain this part of the budget, an estimation of the invested time in other projects is used, without considering the productivity. Practically it would be possible to obtain a correct value of the budget only in case of a productivity of 100%, which is unusual in practice. All in all, one of the main reasons of the need of PV forecasts of a project consists in the fact of not recognizing the real time used in the completion of a determined operation. The objective of our work is to determine the activities productive value, so that when quoted with the conventional methods mentioned before, the standardized values of productivity or unproductivity (whichever is the case) are considered and in this way the differences between the budget and the upfront payment is decreased.

Although there have been no studies to obtain more precise values for the PV, there has been progress in the topic of the EC, for more than 40 years, including the mathematical models to adjust the AC curves [5]. The given adjustments are used to forecast the final cost in order to take the corresponding actions in a determined moment of the Project.

The prevision of the final cost of a project is has a high importance to control and manage a project. In the latest years the development has been centered in terms of the EV. Data series selection and simulation through time and cost series have been used to obtain the final project cost. This technique has some weakness where one of the most outstanding ones is the data relevance and its prolonged monitoring. The obtention of a close forecasts to the real value not only depends on the EV curve, but also on the value that was originally assigned to the PV. A new methodology for the PV assignment is proposed in the next pages, which consists measuring and standardizing each assigned value to the PV so that the distance between curves is minimal.

3. Project control

The proposed methodology for the EV obtention consists in solving the following equation: EV = (PV) x (% progress to the cut-off date). The PV value is obtained in the planning phase, during the cost estimation. This value is an estimate and there have been no improvements to increase the efficiency percentage to determine this value. In other words, these calculations implicitly involve an error margin. The AC value is calculated by reviewing the real monetary disbursements.

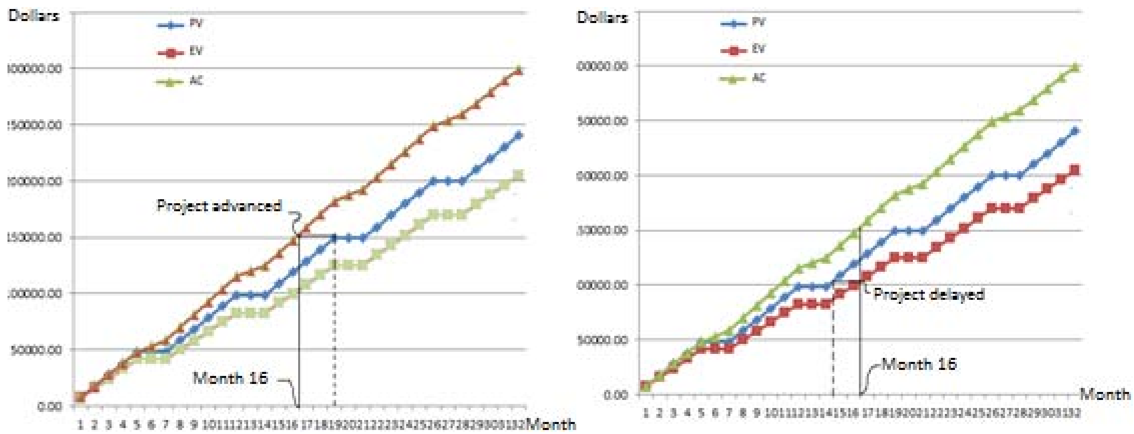

Fig. 1. Delayed Project vs. Advanced Project (own elaboration, 2016).

As mentioned before, the Fig. 1 representation of the budget, upfront cost, and actual cost indicate if the Project is slacking or moving ahead of time. In the first graph, the EV is below the PV and the AC, indicating a delayed project. In the second graph, the EV is above PV and the AC, indicating an advanced project [4].

4. Development

The PV, EV, and AC are required to control the project as shown below in Table 1 and Fig. 2.

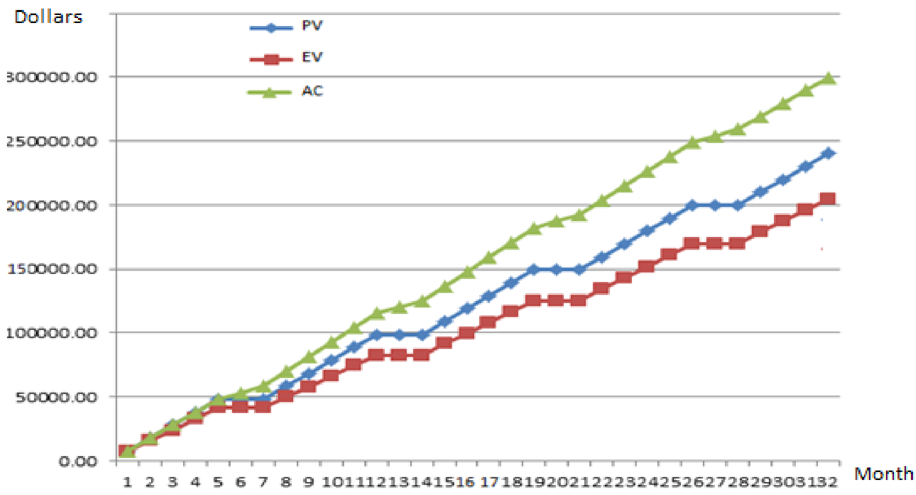

Fig. 2. Representation of the Project's PV, EV and AC values in 32 Months.

Table 1. PV, EV y AC Values of a 32-month duration project month.

Concepts	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Planned Value	7873.20	17988.23	28103.26	38218.29	48333.32	48333.32
Earned Value	7476.61	15664.20	24001.08	32961.75	41628.86	41628.86
Accumulated Cost	7873.20	17988.23	28103.26	38218.29	48333.32	53323.87
	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Planned Value	48333.3	58448.30	68563.38	78678.41	88793.44	98908.47
Earned Value	41628.8	49854.40	57855.37	66085.84	74449.35	82476.87
Accumulated Cost	58314.4	69677.00	81039.75	92818.29	104180.9	115543.6
	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18
Planned Value	98908.4	98908.47	109023.5	119138.5	129253.5	139368.5
Earned Value	82476.8	82476.87	91765.04	99935.64	107967.8	116198.7
Accumulated Cost	120534	125524.7	136887.3	148250.0	159612.7	170975.3
	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24
Planned Value	149483	149483.6	149483.6	159598.6	169713.6	179828.7
Earned Value	124952	124952.1	124952.1	134466.6	143299.9	151918.8
Accumulated Cost	182338	187328.6	192319.1	203681.8	215044.4	226656.2
	Month 25	Month 26	Month 27	Month 28	Month 29	Month 30
Planned Value	189943	200058	200058.7	200058.7	210173.8	220288.8
Earned Value	160957	169980	169980.4	169980.4	178642.7	187395.3
Accumulated Cost	238018	249381	254372.1	259362.6	269477.6	279592.7
	Month 31	Month 32				
Planned Value	230403	240518				
Earned Value	196261	204272				
Accumulated Cost	289707	299822				

The Project final cost is also necessary in a determined month of the Project. To estimate the final cost and compare values for decision making, a cutoff in Month 16 was done (see Table 2).

Table 2. PV, EV, AC, VC, IDC, VT, IDT and B Values of a real project in month 16.

Concept Month 16	Amount (dollars)
Planned Value	119138.50 dollars
Earned Value	99935.64 dollars
Accumulated Cost	148250.00 dollars
Cost Variation	- 48314.36 dollars
Cost Performance Index	0.6741
Time Variation	- 19202.86 dollars
Time Performance Index	0.8388
Balance	- 29111.5 dollars

As observed the Project in place is delayed.

To recall, a function is a correspondence rule which associates an object x to one value in a second set f(x). When a rule for a function is given by an equation in the form of y = f(x), x is the independent variable, and y is the dependent variable. By definition, the value of x completely determines the corresponding value of the dependent y variable. Fig. 3 shows the project's monthly cost incurred based on the values in Table 1.

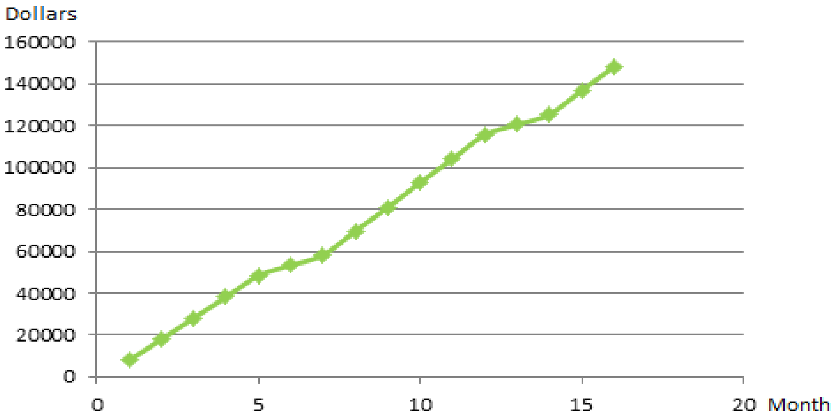

Fig. 3. Representation of the Project's AC values.

The dependent variable is the cost to be finally paid, whereas the independent variable is the total project duration (in terms of months). The independent value is located in the abscissa axis whereas the dependent variable in the ordinate axis (see Fig. 3).

As observed, Fig. 3 shows a perfect straight line. Below its adjustment will be done with the least squares method. Given y= ax + b,the purpose is to obtain the slope "a" y and the intercept value "b".

$$a = 1/D \sum \{x_i-(x)\}\, y_i \qquad b = (y)-a(x) \tag{1}$$

The middle values of x_i, y_i correspond to x and y, that is,

$$(x) = 1/n \sum x_i \quad \text{and} \quad (y) = 1/n \sum y_i \tag{2}$$

$$D=\sum [(x_i-(x))]2 \tag{3}$$

The errors corresponding to the slope (Ea) and to the intercept at the origin (Eb) are determined as follows:

$$Ea = [\sum d2 /D(n-2)]1/2 \tag{4}$$

$$Eb = [(1/n +(x)2/D) \sum d2/n-2]1/2 \tag{5}$$

$$d_i= y_i-ax_i-b \tag{6}$$

The final result of the "a" and "b" values will be the addition or subtraction of their respective errors. The linear regression coefficient r used to determine the quality of the adjustment is presented below as:

$$r= [\sum\{ axi +b- (y) \}2/\sum\{ yi - (y) \}2]1/2 \tag{7}$$

This value allows observe the gap in the line obtained through the least squares method. A minimal gap is the one whose value is close to 1, r=1. From de data in table 1 will be used for the calculations below, but in terms of quarters.

X1 = 1 y1= 38218.29
X2 = 2 y2= 69677.00
X3 = 3 y3= 115543.6
X4 = 4 y4= 148250.0

Based on the previous equation (2)
(X)= 10/4 = 2.5
(Y)= 371688.89/4 = 92922.2225
To obtain the value of D, we will use equation (3)
D= (1-2.5)2 + (2-2.5)2 + (3-2.5)2 + (4-2.5)2 = 5
To obtain the value of a and b, we will use equation (1)
a=1/5[(1-2.5)(38218.29)+(2-2.5)(69677.00)+(3-2.5)(115543.6)+(4-2.5)(148250.0)=37596.17
b=92922.2225 - 37596.17 (2.5) = -1068.2
As a result, the equation y= ax + b would be y= 37596.17x -1068.2
To obtain the error values, we will use equation (6):
d1=38218.29-(37596.17)1 + 1068.2= 1690.32; d12= 2857181.7
d2=69677.00-(37596.17)2 + 1068.2= -4447.14; d22=19777054.2
d3=115543.6-(37596.17)3 + 1068.2= 3823.29; d32=14617546.4
d4=148250.0-(37596.17)4 + 1068.2= -1066.48 d42=1137379.59
∑d2= 38389161.9, replacing values in equation (4) and (5)
Ea=1959.31
Eb= 5365.8
To obtain r, replacing values in equation (7)
r=-0.997295

The values of AC and de adjustments in a real project are shown in Table 3 and Fig. 4

Table 3. Project AC values and adjustments.

Quarter	Cost (Dollar Amount)	Adjusted Cost (dollar amount)
1	38218.29	36527.97
2	69677.00	74124.14
3	115543.6	111720.31
4	148250.0	149316.48

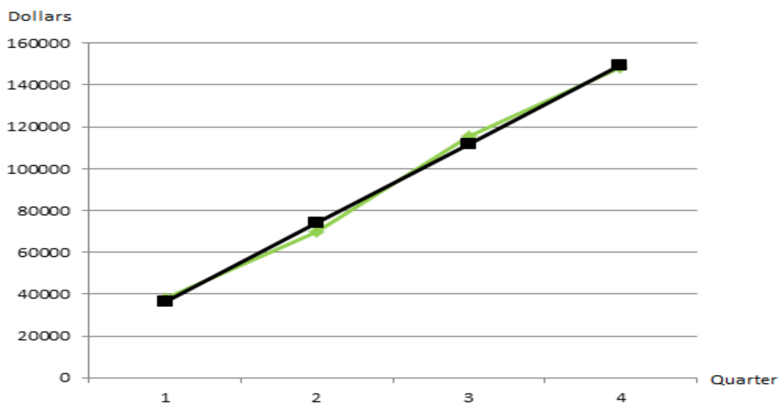

Fig. 4. Project AC value representation.

The data trend of a straight line and the errors allows making forecasts with a reliable certainty according to the obtained value r. All these calculations allows forecasting the Project cost in a determined period of time. The obtained formula y= 37596.17x -1068.2 will be used for the forecast of the Project cost in its final stage, i.e., month 32 or quarter eight, and will be compared with the experimental data to calculate the resulting error. Subsequently the error obtained through the adjustment of PV will be compared against the standardized data (see table 4 and Fig. 5).

Table 4. Project AC, PV and AC forecast values AC

Time	AC	PV	Forecast	Error AC/PV	Error PRO/AC	Error PRO/PV
Quarter 5	187328	149483	186912.65	+20.20 %	-0.22 %	+25-03 %
Quarter 6	226656	179828	224508.82	+20.66 %	-0.94 %	+24.84 %
Quarter 7	259362	200058	262104.99	+22.86 %	+1.05 %	+31.01 %
Quarter 8	299822	240518	299701.16	+19.77 %	-0.04%	+24.60 %

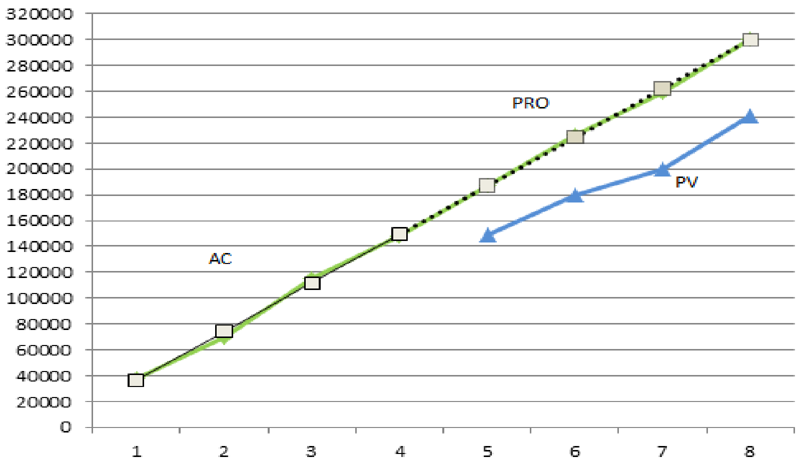

Fig. 5. Project's forecasted AC and its comparison with the PV.

5. Standardization of PV (budget) for the Reduction this value and EV and maximization of the forecast effectiveness

Our model standardized a process defined in 6 different concepts: productive, preparation, work input, management, extraneous element, and unproductive element. (Loera, et al. 2013). The standardization of these processes shows that the set of basic operations can be improved. In the study done in the first facility, 90 workers were measured, where the analysts gathered data every 10 minutes from 15 workers, with a total of 720 daily records. An approximate total of 187200 measurements were done in one year. In another facility, 90 workers were measured as well, with a total of 162200 in one year. As a result, a total of 30 analysts did the study with 349,900 measurements in a lapse of 2 years to improve the productivity of the workforce of diverse specialists. In this study applied to 180 different operators, an average between 120 and 160 different work tasks are done in an 8 hour wage. The measurements done in this study were standardized with the following values: productivity (17.18), preparation (37.36), supplement (4.17), unproductive (26.74), managed (10.87) and UE (2.58). In this way the PV values had to be originally estimated according to the records presented in the following table. These calculations are done considering that to obtain an estimated PV as close as possible to the real one, the standards of productivity, preparations, supplements, administrative and extraneous elements would be added giving a value of 72.16. Subsequently, 27.84 needs to be added to the original PV value in order to obtain the real PV, as show in the table 5

Table 5. Project AC, PV and PVMod values.

Time	AC	PV	Forecast	PVMod	Error PRO/PV	Error PRO/PVMod
Quarter 5	187328	149483	186912.65	191099	+25-03 %	- 2.19 %
Quarter 5	226656	179828	224508.82	229892	+24.84 %	- 2.34 %
Quarter 5	259362	200058	262104.99	255754	+31.01 %	+ 2.4 %
Quarter 5	299822	240518	299701.16	307478	+24.60 %	- 2.5 %

With the values, the percentage error between the forecasted value and the VM is widely reduced so that the impacts of the AC do not radically affect the project as in projects where a standardized PV value is not applied (see Fig. 6).

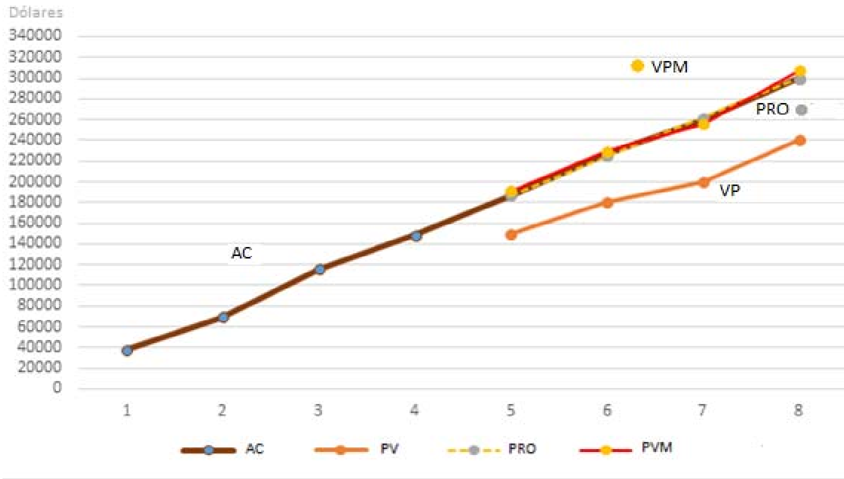

Fig. 6. Improvement in the standardization of the work data.

6. Conclusion

In this paper, it was proved that a project's PV plays an important role in the control of middle and final costs of a project. A more right PV value, leads to a forecast gap with a value up to 2%, which is smaller than the ones from different construction projects. The consideration of the productive value in the work processes of this sector is a a prototype tool suggested to be used in sectors with non-repetitive work tasks that can be standardized in order to find a constant. Forecasts with a reliable certainty can be done according to the obtained r value, even with the adjustment done to the AC curve. All these calculations are useful to forecast the cost of a project in a determined period of time, but without alterating the PV. An obtained forecast does not guarantee or does not have an impact on the PV; the errors between the PRO and the PV are still high, which is why it is recommended to modify the PV so that these errors are smaller. The standardization of work data of a real project and the budget adjustment based on standardized data show a notable improvement between the forecasts AC and the values of PV. As mentioned before, it is recommended to apply standardized data to other types of industry and compare the results between the real and budgeted cost; the more standardized the work data, the smaller the differences between AC and PV.

References

[1] I. Loera, G. Espinosa, C. Enríquez, and J. Rodriguez. Productivity in Construction and Industrial Maintenance. Science Direct. (2013).
[2] I. Loera, G. Espinosa. Key Eng Mater 615 (2014) 139-144.
[3] Y. Lu, J. Yan, Z. Han, P. Gu. J Donghua Univ 32 (6) (2015) 936-939.
[4] J.R. Meredith, S. Mantel. Project Management a Managerial Approach. Wiley U.S.A. (2006).
[5] T. Narbaev, A. De Marco (2014). Int. J. Proj. Manag. 32 (6) (2014) 1007-1018.
[6] R. Vrijhoef. "Effects of Lean Work Organization and Industrialization on Workflow and Productive Time in Housing Renovation Projects." In: Proc. 24 th Ann. Conf. of the Int'l. Group for Lean Construction, Boston, MA, USA, sect.2 (2016) 63–72.