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Earned Value Method Management Applied to The Construction of The Multifamily Building – Lima, Peru 2020

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Abstract: This research aims to assess costs and time in the study of the earned value method management applied to the construction of the multifamily building in Lima, it is worth mentioning that the main problem of low productivity rates is the low cost control, that affects directly the performance of projects. The methodology used in this context is the earned value, which allows managing the costs and time of projects, gaining as a result the S curve and the control table, as a conclusion it could be said that the companies should maintein a correct control of time and cost of projects, because as it can be seen, at the end of the project, the company will have a lost of money for S/ 134,176.33 soles from month 06, which represents the 1.94% at the end of the Project.

Keywords: Management, earned value, schedule, control.

INTRODUCTION

In this modern day, most of construction projects in our country presents significant desviations from what is planned in time and costs, which causes increases in expected costs and delay in the delivery of the works [1]. The delays and overcosts in construction projects are the cause of constantly concern for project developers, as they can even affect the viability of these. [2].

Many of the works being built in Peru by some companies suffer large-scale economic losses without knowing for sure the main problem, these companies ignore the project management and don't have a good direction as they wait for a work to be finished to just assess the profit or loss they got. Completion of activities at optimal time and cost plays an important role in construction projects. Recently, project managers have to decrease the total duration and costs of projects more than before due to the competitive environment [3].

Project management is a more important subject everyday due due to the high competitiveness that exists between companies; these companies look for gain big benefits as a result of their operations, improvement of processes, technologies, quality, monitoring and control; in construction projects, the relationship between the cost and duration of the project, which is one of the main factors of the project, are considered the parameters that take the decisions [4].

The industry of Architecture, Engineering y Construction (AIC) has as main problems teh low rates of productivity and a low cost control, which affects directly during project performances.

Tools are sought to reduce and/or solve the current situation in the sector, [5] these companies do not have a structured way of projecting the profit or margin that carry a cost control, that's why the purpose of this article a system based on cost planning and control is implemented, which seeks to take into account all the details of each operation that is analyzed, being the projections the main tool that is made in the course of the work, obtaining a more reliable result and reaching the proposed goals. For applying the Earned Value Method as a control tool, fundamentally requires the instrumentation of independent variables that are defined below:

Planned Value (PV): It is the official budgeted cost admitted for carrying out the work. It includes the costs for works that are assigned to each period while carrying out the work. The general planned value for the work is also known as the budget at completion (BAC) and it must be exhausted in a planned time.

Actual Cost (AC): Represents the real cost incurred in carrying out the work at the time of the analysis. In other words, it is the value directly disbursed to perform and fulfill the assigned tasks, which is why it should not have an upper limit since all costs will be measured to obtain the earned value.

Earned Value (EV): Represents the addition of the completed task expressed in terms of the approved budget to that work for a schedule activity at the time of analysis. The EV can not be higher than the approved budget and is used to calculate the performance of the execution of the work and establish the current status of the work.

Schedule Variance (SV): Represents the performance of the schedule in the execution of the work. This indicator shows whether the work is in delay when compared with the baseline of the valued schedule. It can be

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indicated that when the project has finished the differentiation it is equal to zero, since all the planned values would have been completed.
Schedule Performance Index (SPI): Represents a measure of schedule efficiency that is expressed as the ratio of earned value (EV) to planned value (PV). If the value obtained is below one, it is understood that the amount of work foreseen for that period has not been reached, and if it is above one, it can be indicated that the task performed is greater than the assumed one.
Cost Variance (CV): Represents the performance of the cost while carrying out the work. Consequence of the operation of the earned value (EV) minus the real cost (AC). This indicator shows if the work has suffered cost overruns or savings were obtained in the work. It can be indicated that the CV is specifically critical, since it indicates the relationship between performance and effective costs, if the differentiation is negative while the work is carried out, it is scarcely possible that it can be recovered. The manipulation of the VS and the CV allows to acquire efficiency indicators to show the performance of the cost and the schedule of the work.
Cost Performance Index (CPI): Represents a cost efficiency measure of budgeted resources that is expressed as the ratio of earned value (EV) to actual cost (AC). Measures cost efficiency to get the job done. If the result is below one, it is understood that the effective cost is higher than expected; However, if it is above the unit, it can be indicated that the effective costs are lower than the official budget admitted and a reserve margin has been generated in the execution of the work.

METHOD

Study area

The place of study is in Peru. Surquillo, which is a growing district in the city of Lima (See figure 1).

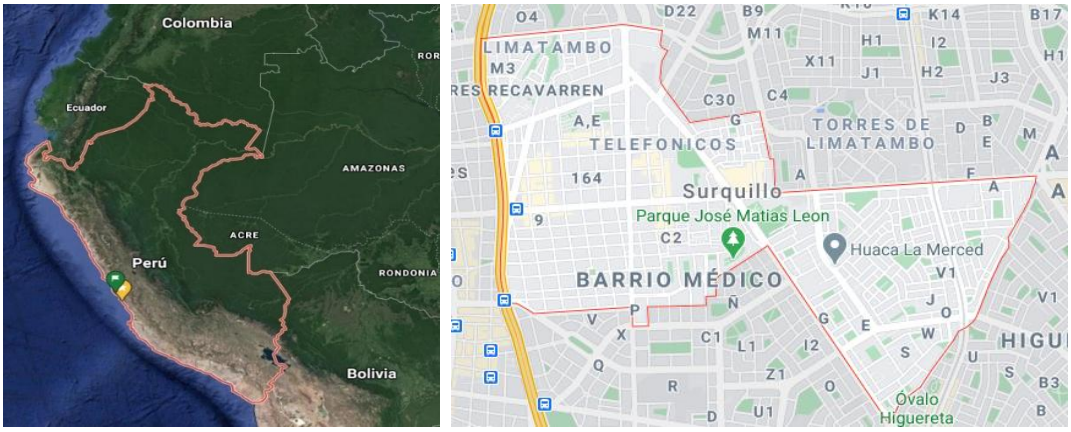


Fig.1: Location of study area. [16].

Type of research

The methodological research is prolective, since it describes the facts as they are observed and can offer the possibility of predictions during the execution of multifamily buildings. That is why in this research the visualization technique is applied that allows us to appreciate and analyze in a correct and concise way in our study, as well as the condition, time, cost, etc. From this data collection, they are processed and the output of the results is defined and then analyzed and interpreted. Likewise, bibliographic information is collected. Therefore, in this work a specific situation is not constructed, but rather those that exist are observed.

Procedure

For this research, we will rely on figure N ° 2 where the parameters are shown according to the Planned Value (PV), which is the estimated value of the work to be carried out and is related to the contractual amount, the Earned Value (EV) which are the valuations executed and approved by the client and finally the Actual Cost (AC) which is the current accumulated value incurred to carry out the work. Once these values have been obtained, the analysis of the state of the costs to date, the balance and the end of the work will be carried out.

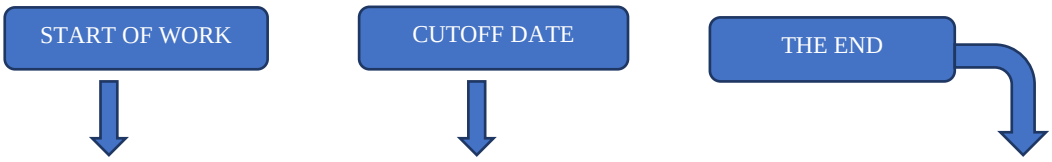


Fig.2: Earned value method formulas.

EARNED VALUE METHOD			
	TO THE DATE	**TO BALANCE**	**TO THE END**
SALE	EARNED VALUE (EV)	BALANCE SALE = BAC - EV	BUDGET AT COMPLETION (BAC)
COST	ACTUAL COST (AC)	ESTIMATED TO COMPLETE (ETC) = EAC - AC	ESTIMATED AT COMPLETION (EAC)

After the summary table of earned value is done, the indicators are calculated to evaluate the corresponding schedule and costs, for that we will use the indicated formulas in table N°1.

Table 1: Formulas.

INDICATOR FOR EVALUATE PROGRAMMING	INDICATOR FOR EVALUATE COST
SV = EV-PV	CV = EV-AC
SPI = EV/PV	CPI = EV/AC
	EAC = BAC/CPI
Schedule Variance, SV	
Schedule Performance Index, SPI	Cost Variance, CV
	Cost Performance Index, CPI
	Estimate at Completion, EAC

Source: Own.

Once the calculations have been performed according to the formulas of earned value, the analysis of the operational reporting method is carried using the formulas shown on figure N°3 in order to see the profit and take action month by month.

OPERATIONAL REPORTING			
	TO THE DATE	**TO BALANCE**	**TO THE END**
PROFIT	CV = EV-AC	BAC-EV-ETC	BAC - EAC
MARGIN %			BAC / EAC %

Fig.3: Operational Reporting formulas.

Afterwards, in figure N°4 it is showed the overall amounts for items to be used in the project. The amounts presented are expressed in soles as a unit of currency.

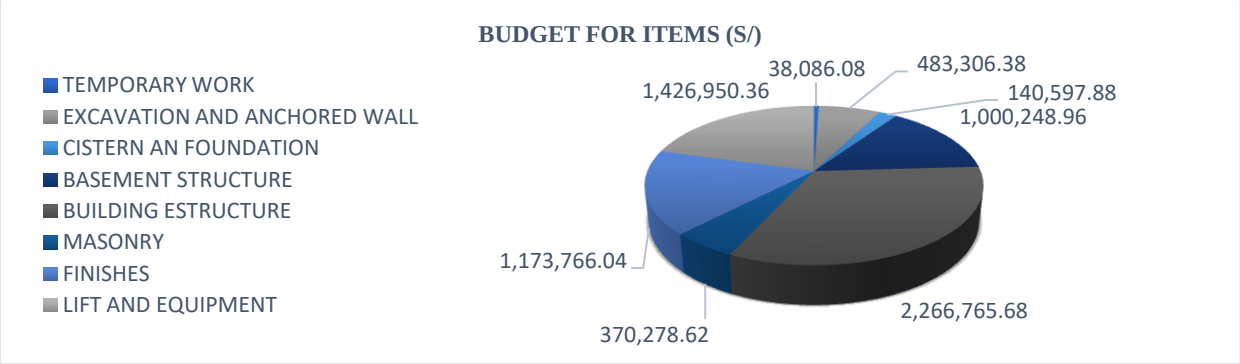


Fig.4: Budget for items (S/).

Afterwards, in table N°2 it starts by reflecting the % planned progress for the project over a 12-month period. Such planning must be fully subject to the correct sequence of progress, taking into account bottlenecks.

Table 2: Planned advance

PALNNED ADVANCE (%)													
WORK BUDGET		**MONTHS**											
DESCRIPTION	**Uni**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
TEMPORARY WORKS	glb	100 %											
EXCAVATION AND ANCHORED WALLS	glb	35 %	30 %	35 %									
CISTERN AND FOUNDATION	glb			60 %	40 %								
BASEMENT STRUCTURES	glb					100 %							
BUILDING STRUCTURES	glb					30 %	20 %	30 %	20 %				
MASONRY	glb							15 %	30 %	45 %	10 %		
FINISHES	glb								22 %	22 %	22 %	19 %	15 %
LIFT AND EQUIPMENT	glb		30 %			20 %			10 %	10 %	10 %	10 %	10 %
TOTAL DIRECT COST S/	**6,900,000.00**												

Source: Own.

During the execution, the % of actual progress was analyzed at the month 05 of the work began (see table No. 3). This table shows the percentage met, by items, each month.

Table 3: Real Advance (%).

REAL ADVANCE (%)													
WORK BUDGET		**MONTHS**											
DESCRIPTION	**Uni**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
TEMPORARY WORKS	glb	100 %											
EXCAVATION AND ANCHORED WALLS	glb	30 %	35 %	35 %									
CISTERN AND FOUNDATION	glb			60 %	40 %								
BASEMENT STRUCTURES	glb					90 %							
BUILDING STRUCTURES	glb					10							

						%							
MASONRY	glb												
FINISHES	glb												
LIFT AND EQUIPMENT	glb		25 %			20 %							
TOTAL DIRECT COST S/	**6,900,000.00**												

Source: Own .

The estimated progress corresponds to a forecast made before starting the production process or a certain period of time with a goal. Actual progress is historical information obtained as progress is made during the execution of the work, while the estimated progress is a projection.
Table N°4 shows the valuations according to the planned % for the project. The planning is expressed in soles to have the amounts recorded and to be able to control the expenses month by month.

Table 4. Valued Planned Advance (S/)

VALUED PLANNED ADVANCE (S/)												
WORK BUDGET	**MONTHS**											
DESCRIPTION	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
TEMPORARY WORKS	38,086	0	0	0	0	0	0	0	0	0	0	0
EXCAVATION AND ANCHORED WALLS	169,157	144,992	169,157	0	0	0	0	0	0	0	0	0
CISTERN AND FOUNDATION	0	0	84,359	56,239	0	0	0	0	0	0	0	0
BASEMENT STRUCTURES	0	0	0	0	1,000,249	0	0	0	0	0	0	0
BUILDING STRUCTURES	0	0	0	0	680,030	453,353	680,030	453,353	0	0	0	0
MASONRY	0	0	0	0	0	0	55,542	111,084	166,625	37,028	0	0
FINISHES	0	0	0	0	0	0	0	258,229	258,229	258,229	223,016	176,065
LIFT AND EQUIPMENT	0	428,085	0	0	285,390	0	0	142,695	142,695	142,695	142,695	142,695
PLANNED ADVANCE TOTAL S/	**207,243**	**573,077**	**253,516**	**56,239**	**1,965,669**	**453,353**	**735,571**	**965,360**	**567,549**	**437,951**	**365,711**	**318,760**
TOTAL ACCUMULATED PLANNED ADVANCE S/	**207,243**	**780,320**	**1,033,836**	**1,090,075**	**3,055,744**	**3,509,097**	**4,244,669**	**5,210,029**	**5,777,578**	**6,215,529**	**6,581,240**	**6,900,000**

Source: Own .

In table N°5 are shown valuations according to the % actually executed in the project.

Table 5: Valued Real Advance (S/).

VALUED REAL ADVANCE (S/)					
WORK BUDGET	**MONTHS**				
DESCRIPTION	**01**	**02**	**03**	**04**	**05**
TEMPORARY WORKS	38,086	0	0	0	0
EXCAVATION AND ANCHORED WALLS	144,992	169,157	169,157	0	0
CISTERN AND FOUNDATION	0	0	84,359	56,239	0
BASEMENT STRUCTURES	0	0	0	0	900,224
BUILDING STRUCTURES	0	0	0	0	226,677
MASONRY	0	0	0	0	0
FINISHES	0	0	0	0	0
LIFT AND EQUIPMENT	0	356,738	0	0	285,390
TOTAL REAL ADVANCE S/.	**183,078**	**525,895**	**253,516**	**56,239**	**1,412,291**
TOTAL ACCUMULATED REAL ADVANCE S/.	**183,078**	**708,973**	**962,489**	**1,018,728**	**2,431,019**

Source: Own.

In table N°6 are shown the real costs used from month 01 to month 05 since the project execution.
The actual cost corresponds to expenses incurred to deploy a service, accurately reflecting the past, calculated until project development is complete.
The importance of actual costs is that, by understanding them, a sales price limiting the optimal one can be established (when is possible). This allows to maximize profits.

Table 6: Actual Cost (S/)

ACTUAL COST (S/)					
WORK BUDGET	**MONTHS**				
DESCRIPTION	**01**	**02**	**03**	**04**	**05**
TEMPORARY WORKS	32,000				
EXCAVATION AND ANCHORED WALLS	150,000	193,333	193,333		
CISTERN AND FOUNDATION			136,500	91,000	
BASEMENT STRUCTURES					819,000
BUILDING STRUCTURES					115,000
MASONRY					
FINISHES					
LIFT AND EQUIPMENT		320,000			265,000
TOTAL ACTUAL COST S/.	**182,000**	**513,333**	**329,833**	**91,000**	**1,199,000**
TOTAL ACCUMULATED ACTUAL COST S/.	**182,000**	**695,333**	**1,025,167**	**1,116,167**	**2,315,167**

Source: Own.

RESULTS

As it could be seen in figure N°5, the S curve is drawn where the blue curve that represents the programmed advance from month 01 to month 12 (it is the only curve that will be completely drawn from the beginning to the end of the term of the work), the red line represents the estimated budget from month 01 to month 05 and finally the green line that represents the real cost and physical progress of the work at month 05 after the start of the project.

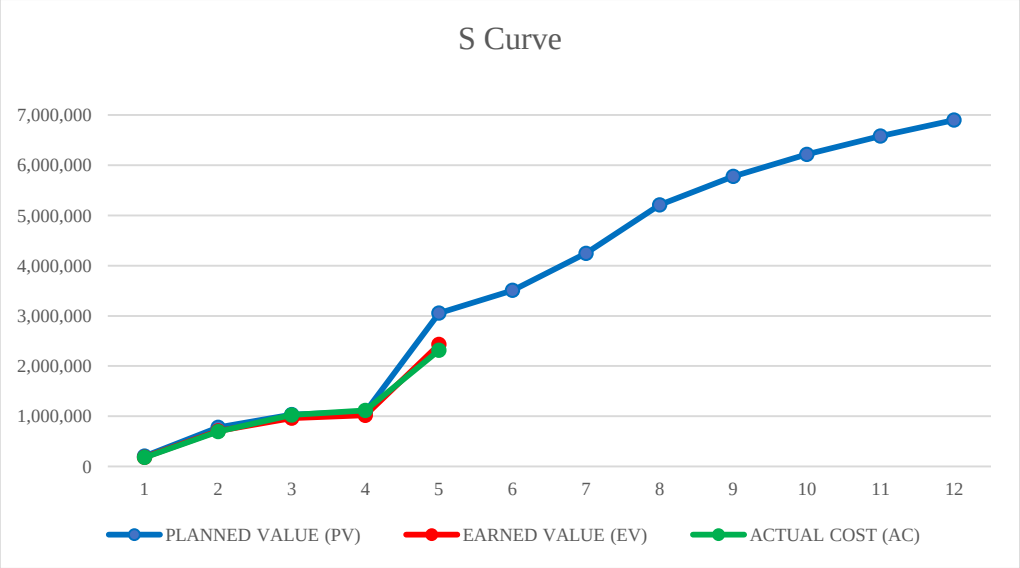


Fig.5: S Curve value analysis.

In table N ° 7, the earned value analysis table is presented where the programming and cost indicators were calculated for the evaluation and analyzed.

Table 7: Earned value.

EARNED VALUE					
	MONTHS				
INDICATORS	**01**	**02**	**03**	**04**	**05**
SV	-24,165	-71,348	-71,348	-71,348	-624,726
SPI	0.88	0.91	0.93	0.93	0.80
CV	1,078	13,639	-62,678	-97,439	115,852
CPI	1.01	1.02	0.94	0.91	1.05
BAC	6,900,000.00	6,900,000.00	6,900,000.00	6,900,000.00	6,900,000.00
EAC	6,859,371.46	6,767,255.18	7,349,332.42	7,559,967.46	6,571,175.46

Source: Own

Table N ° 8 presents the operational report analysis table where the profit to date, the balance and the end of the work and the percentage margin to take the corresponding actions was calculated.

Table 8: Operational Report.

OPERATIONAL REPORT					
	MONTHS				
DESCRIPTION	**01**	**02**	**03**	**04**	**05**
PROFIT AT THE DATE	1,078.00	13,639.49	-62,677.89	-97,438.74	115,851.97
SALE BALANCE (TO BE VALUED)	6,716,922.00	6,191,027.18	5,937,511.22	5,881,272.07	4,468,981.36
BALANCE COST (TO BE EXECUTED)	6,677,371.46	6,071,921.85	6,324,165.76	6,443,800.79	4,256,008.79
PROFIT TO BALANCE	39,550.54	119,105.33	-386,654.54	-562,528.72	212,972.57
PROFIT AT THE END	40,628.54	132,744.82	-449,332.42	-659,967.46	328,824.54
MARGIN % AT THE END	0.59%	1.92%	-6.51%	-9.56%	4.77%

Source: Own.

The Schedule Variance shows us negative values, which means that we are behind in months 01 to 05 with respect to what was initially planned. (See figure N ° 6)

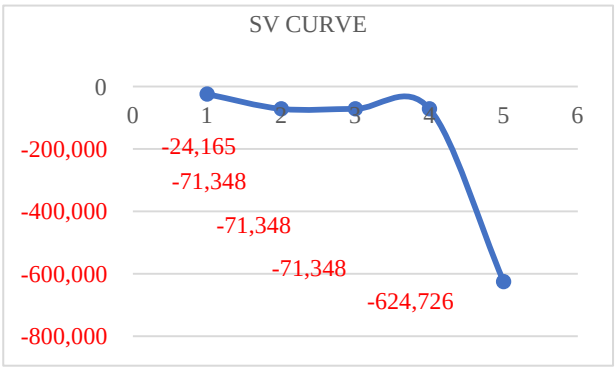


Fig.6: Schedule Variance.

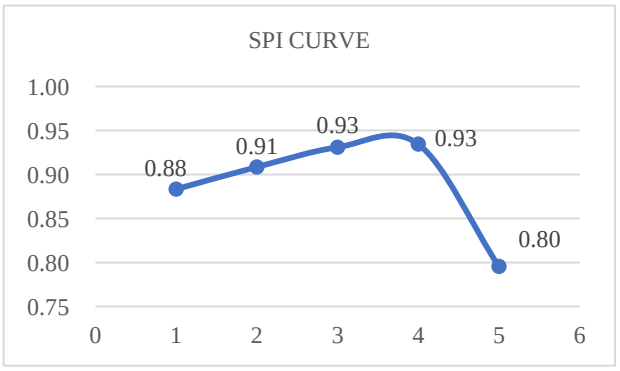


Fig.7: Schedule Performance

Index.

The Schedule Performance Index shows us values below 1, which reinforces what is indicated in the Schedule Variance, that we are behind what was initially planned. (See figure N ° 7)

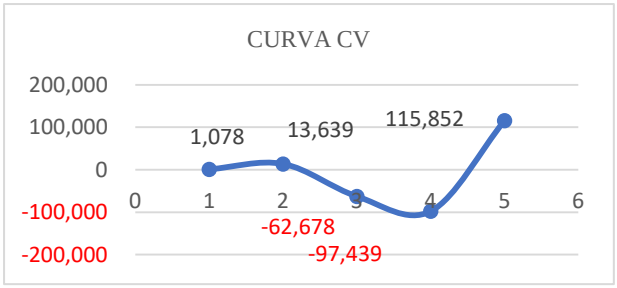


Fig.8: Cost Variance

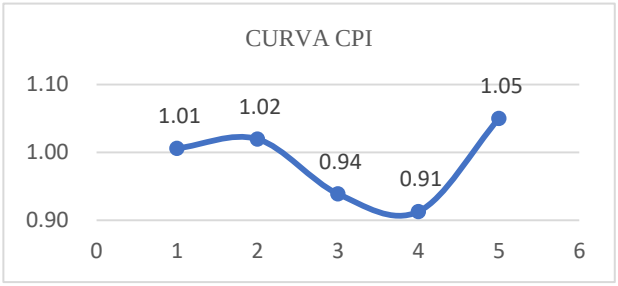


Fig.9: Cost Performance Index.

The Cost Variance shows us that in months 01, 02 and 05 a money gain is generated according to our progress, but months 03 and 04 show us negative values since we are spending more than budgeted. (See figure N ° 8). The Cost Performance Index shows us that in months 01, 02 and 05, the values are above 1 which means that we are saving money, but months 03 and 04 when indicating values less than 1 wich means that we are losing money. (See figure N ° 9).

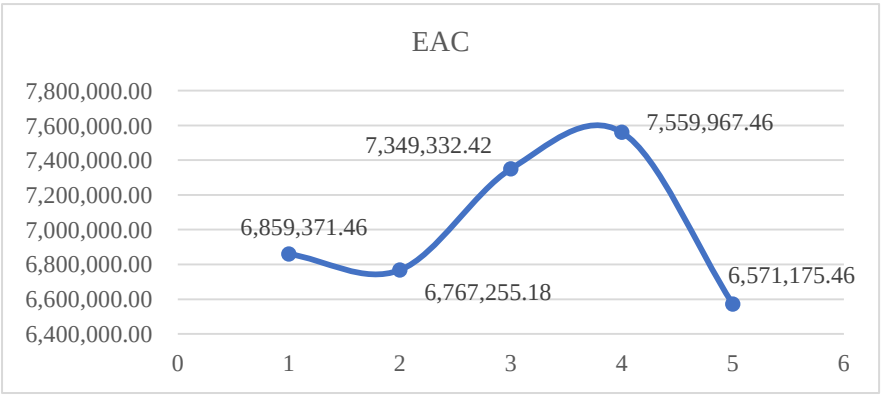
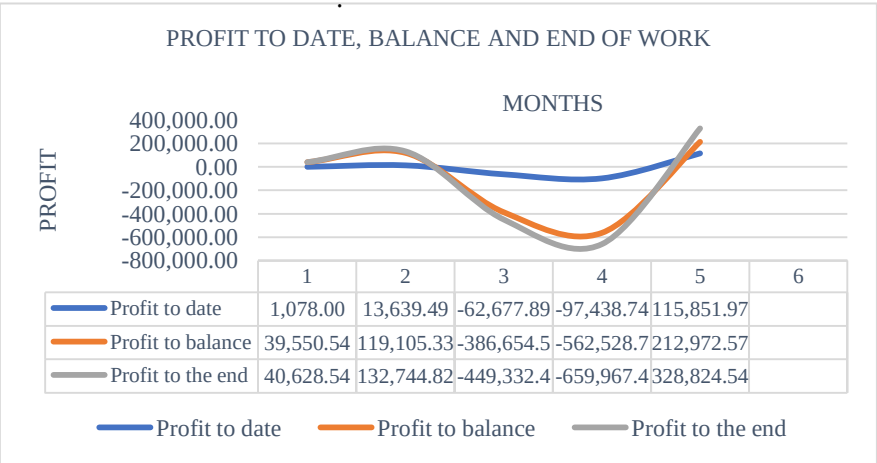


Fig.10: Estimate at Completion

The Estimate at Completion shows us the total estimated cost of the project at the cut-off date where it is seen in month 01, 02 and 05, it saves money, but if we continue working as in months 03 and 04, we would enter into losses since it would be exceeding the total cost of the budget. (See figure N ° 10).



	1	2	3	4	5	6
Profit to date	1,078.00	13,639.49	-62,677.89	-97,438.74	115,851.97	
Profit to balance	39,550.54	119,105.33	-386,654.5	-562,528.7	212,972.57	
Profit to the end	40,628.54	132,744.82	-449,332.4	-659,967.4	328,824.54	

Fig.11: Profit curves.

According to the calculations made, it can be seen that in months 01, 02 and 05 there is a favorable profit, but in months 03 and 04 there is a decrease because the costs used were higher than expected. By month 05, a profit of 115,851.97 was achieved, represented by 4.77%. (See figure N ° 11).

CONCLUSION

Through the earned value method, it will be taken as a starting point to make project reports.In order to obtain a Schedule Variance equal to 0 in the sixth month, 10% of the basement structure work, 40% of the building structure work, and 5% of the lift and equipment work must be completed.

Chieving a balance of what is planned with what is real in the sixth month, a Schedule Performance Index equal to 1 would be obtained, validating our planned scheduled.

If we continue working according to the fifth month after starting the project, by the sixth month there would be a saving (Cost Variance) of S / 293,931, represented by approximately 8.38%.

The Estimate at Completion shows us the total estimated cost of the project at the cut-off date, that is why if we continue working as seen in months 01, 02 and 05, the company would have profits, but if we continue working as in months 03 and 04, the company would enter a loss.

Achieving a balance of what was planned with what was real in the sixth month would achieve a profit of 8.38%.

In the works that are to be completed, a maximum optimization must be sought since, if we maintain the costs of the remaining balances from month 05, we would have a loss of money of S / 134,176.33. The project would be finishing with a total of S / 7,034,176.33, which represents 1.94%.

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