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Earned Value Method (EVM) for Construction Projects: Current Application and Future Projections

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Abstract: The earned value method (EVM) is an internationally known technique for project management that emphasizes the control of project cost performance and duration, thus allowing trends to be identified during execution and warning the project manager of variances that may affect the project so that they can take the necessary corrective measures. In this research, the finished projects of a construction company in the city of Cuenca, Ecuador, were assessed. EVM was applied to projects from a database developed with information from each one to rebuild past events, existing problems, and critical points and evaluate the performance over time. The results of this analysis are meant to determine the project's success, calculating the cost variance at the end. EVM motivates project stakeholders to pay attention to costs and progress so that timely actions can be taken to optimize resources, resulting in the completion of a project within budget and on time. In conclusion, EVM plays an essential role in the integral management of the project in terms of scope, time, and cost. Moreover, there are now guidelines for applying this method as a control tool in future construction projects.

Keywords: earned value management; actual cost; planned value; EVM; performance index; earned value

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1. Introduction

In recent years, the construction business has become competitive in a market saturated with contractors trying to stand out and succeed in completing their projects [1]. Cost overruns and construction delays are recurring problems in the construction industry and can become critical [2].

The analyses in the studies conducted by Doloi et al. [3] and Olatunji [4] showed that variances in time and costs are a common factor in both developed and developing countries. To cite some cases, in India, in a sample of 290 projects, there was an average cost increase of 73%. In addition, about 40% of the projects reported deficiencies in their performance. In Nigeria, 55% of 137 projects had cost overruns ranging from 5% to 808% over the original cost estimate. In Colombia, more than 50% of projects ended up with cost overruns, and more than 80% ended up with delays of between 30 and 80 days [2]. In developed countries such as the United Kingdom, which have multiple techniques and advanced software for project control, it has been noted that many projects, despite having these tools, still do not meet expectations in terms of time and cost [5].

A study by Memon and Rahman [6] highlighted that among the factors that trigger variances in project costs are: the contractor's inadequate administrative management in terms of work supervision, delays in the schedule, inadequate planning of activities and timetables, lack of knowledge on time and cost estimation, and an incorrect definition of the project scope.

If we focus on a similar environment such as Colombia, in Serna et al. [7], research conducted on construction companies showed that among the most significant elements contributing to the variance of both time and cost of a project, the lack of work planning stood out as a major factor (58%) in aspects such as changes in scope (2%), inadequate planning of activities (21%), changes in designs (3%), and the lack of integration of the parties involved (9%) in relation to this factor.

In his research, Picornell et al. [1] reported that for the development of a project, whether small or large, contractors in their usual practice do not follow any management standard that has a baseline to guide the implementation of the project. Instead, professionals in the construction area opt for informality in administrative management and do not adequately monitor and communicate with those involved in the project. All of these factors converge in a lack of knowledge of the actual status of the economic and technical aspects of works at any point of the project during its development [8].

Among the best management practices, one internationally recognized method accepted by the Project Management Institute (PMI) is the Earned Value Management (EVM) method. It provides a methodology for measuring project performance based on the determination of cost and schedule performance indicators that provide forecasts and early warnings of economic and physical progress problems to make timely corrective decisions and complete a successful project [9].

The first version of the EVM method was developed by the U.S. Department of Defense (DoD) in the 1960s as a cost schedule control system called C/SCSC; however, the technique evolved until the PMI adopted it as a standard tool for project performance measurement [10,11]. Currently, this technique is used in several countries. It is known by different names: EVA—Earned Value Analysis; EVM—Earned Value Management; EVMS—Earned Value Management System; and EVT—Earned Value Technique.

This research evaluated projects built in the last 10 years by a construction company in the city of Cuenca, Ecuador. Complete documented information relevant to the time and cost of execution of projects was available. The Earned Value Methodology (EVM) was applied for these projects to reconstruct, analyze, and interpret the facts, thus establishing guidelines for its use in future project assessments. Hence, the aim is to demonstrate that this tool allows measuring the project's performance in terms of costs and duration, enabling timely administrative decision making and thus reducing deviations in money and time.

2. Literature Review

The existence of tools and techniques to manage projects is currently an essential requirement for managers or project managers to carry out effective administration. According to Bryde et al. [12], EVM is a methodology that is gaining traction in several sectors, including construction, since it allows obtaining information on project progress and controlling its performance by integrating scope, cost, time, and schedule control within the same framework [13,14].

According to the study by Sunarti et al. [15], 52% of respondents implemented EVM in their projects; of these, 6% used it for small projects, 28% used it for significant and critical tasks, and 18% used EVM as an organization-wide standard for all types of project control. Conversely, 48% of the respondents did not implement EVM in their projects, perhaps using other tools, such as the S-curve of the Gantt chart, that involve less manipulation of information but do not return informative representative data or alerts that trigger mitigation or prevention.

Kim et al.'s [16] study investigated the acceptance of EVM application by managers and directors of construction projects registered in the PMI at the international level in private and public sectors. They found that 82% of respondents accepted the implementation of

EVM, 52% of which corresponded to the public sector. Most of them considered that EVM applies to large and small projects.

In the Latin American region, Diez-silva et al. [17] conducted a survey of public project managers in Colombia to learn about their perspective and adoption of EVM as a performance measurement system and to analyze the impact of its use on project success. The results indicated that there was a low rate of EVM use, which was about 33%; traditional proposals such as progress reports prevailed. About 19% of managers did not use any performance measurement systems in many cases because they had not established control procedures.

In the literature reviewed, in Sunarti et al. [15], respondents identified three main barriers to implementing EVM: 14% cited a lack of knowledge and experience, 12% indicated a lack of motivation and support from top management, and 11% found EVM challenging to implement due to the tedious process of data collection. In Mahmoudi et al. [18], the limitations of the use of EVM were mentioned, including the high cost of implementation, the measurement of the percentage completion on-site, the type of contract potentially hindering its use, and the obtaining of integrated data on time and cost. This suggests that the lack of familiarity with this technique impedes its widespread use as a construction project management tool.

The study conducted by Teixeira et al. [19] suggested measures to overcome the barriers to the implementation of EVM: the training of those involved in the project, the definition of work procedures, and the use of software for data recording. Similarly, Kim and Reinschmidt [20] indicated that for the application of the method to be effective, it is necessary to have discipline in collecting data and managing information in terms of costs and duration. However, this implies an added operating expense to the contracted amount, but this is compensated for by the resulting benefits. We can find techniques for obtaining the percentage of work progress [21].

In a study conducted by Skaik and El-Hawary [22], EVM was applied to three building projects in the United Arab Emirates. At three stages of the life cycle, they found that cost analysis had favorable results for cases in which EVM was used from the beginning and at 45% of progress. However, some delays allowed corrective actions to be taken for matters concerning physical progress, which were implemented halfway through the improvement; in addition, reviewing the project's status after its completion added value to the project and the management of the company.

In Valle and Soares-Brazil [23], a case study showed that the application of EVM made a relevant contribution to cost management in the project, which ended on time and within budget. Three aspects of its success were highlighted: a correct work breakdown structure by packages that are consistent with a chart of accounts so that the progress of each one is correctly assessed; attention to performance indexes to discuss changes and negotiate with suppliers; and the correct debugging of the information that feeds the analysis.

In Cuadros López et al. [24], EVM was applied to a building project in Colombia, and evaluations were carried out in four stages; the results show that during the project, despite the alerts given by the performance indicators, the success of the method depended mainly on the decisions of project directors or managers to implement timely measures and maintain the cost and schedule of the project.

The study presented by Rezouki and Baqer [25] showed the perception of construction professionals about the factors that influence the implementation of EVM; these factors are linked to the development of a project and generate a significant impact on it. This technique involves an evaluation of costs and time and is also influenced by factors that affect financial liquidity during project execution, such as the quality of the delivered product, risk during execution, safety, and even the social environment. Care must be taken with this aspect, as timely decision making will be sensitive to the financial resources available to the project manager at a specific point in time.

In a similar case, Aramali et al. [26] asserted that the EVM technique can become a handy management tool when controlling a project. However, its implementation can be highly dependent on certain factors; according to several professionals, having an organizational culture that encourages the active participation of project stakeholders is considered the most critical factor for implementing this methodology. Planning, scheduling, and change control are some of the processes that benefit from implementing an effective EVM methodology, allowing the generation of early warnings to deal with possible cost deviations or delays.

In contrast with other authors, Nizam et al. [27] concluded that the use of EVM as a tool in project management is not useful, as there is a large gap between the efforts made to implement it and what is achieved. Conclusions suggest that its usefulness depends on the type of project and the conservative approach that project team members employ to determine the measurement baseline. It is used as a comparison to determine the cost and schedule variances, making it very sensitive to evaluation criteria.

Conceptual Framework for the Earned Value Method (EVM)

EVM is defined as a technique for measuring project performance. It indicates how much of the budget should have been spent, given the amount of work performed and the baseline cost for the task, assignment, and resources [28]. The analysis allows identifying deviations in both price and schedule, i.e., cost and schedule variance.

The fundamental precept of EVM is that the value of a job is equal to the number of resources budgeted to complete the job [29]. Specific key metrics are defined and used to evaluate the schedule and cost performance throughout the project.

Three groups of metrics are determined: basic metrics, performance indicators and variances, and forecast indicators [21]. The most essential types of the previously mentioned metrics are summarized in Tables 1–3.

Table 1. Basic EVM metrics [30].

Metrics	Formula	Interpretation
Planned Value (PV)		Indicates the approved budget for work scheduled to be completed by a specified date.
Earned Value (EV)		Indicates the value of work completed as of a specified date.
Actual Cost (AC)		Indicates the costs incurred for work completed as of a specified date.

Table 2. Performance indicators and variances in the EVM technique [30].

Metrics	Formula	Interpretation
Cost Variance (CV)	CV = EV − AC	Variance indicating whether a project is under (positive) or over (negative) budget.
Schedule Variance (SV)	SV = EV − PV	Variance indicating whether a project is ahead of (positive) or behind (negative) schedule.
Cost Performance Index (CPI)	CPI = EV/AC	This index measures the efficiency with which economic resources are used. If it is less than 1, the project has a higher actual cost than budgeted (cost overrun); if it is equal to 1, the project has an actual price equal to the projected cost; and if it is greater than 1, the project has a lower actual cost than budgeted.
Schedule Performance Index (SPI)	SPI = EV/PV	An index that measures efficiency in the use of time. If it is less than 1, the project is behind schedule; if it is equal to 1, the project is on schedule, and if it is greater than 1, the project is ahead of schedule.
Cost Variance (VAC%)	VAC = (BAC − EAC)/BAC	Indicates the variance in the final cost of the project with respect to the original.

Table 3. Forecast indicators in the EVM technique [30].

Metrics	Formula	Interpretation
Estimated cost to complete the project (ETC)	ETC = (BAC − EV)/CPI	Estimated cost required to complete the remainder of the project.
Estimated cost at project completion (EAC)	EAC = AC + (BAC − EV)/CPI	Indicates how much the project will cost in the end if the cost performance index (CPI) remains the same.

The Figure 1 outlines the main EVM concepts over time and at a given analysis point.

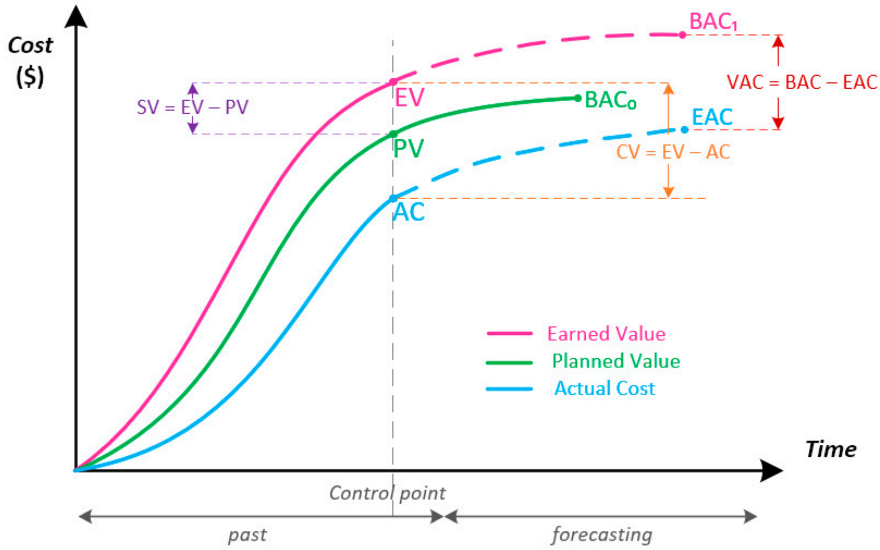

Figure 1. Key metrics of the EVM technique [31].

In the research of Lipke et al. [32], which was carried out on several projects during the application of EVM to obtain the CPI and SPI performance indicators, evaluations using statistical tests showed that at 60% completion, the variability of these indicators stabilized. However, after 80% completion, close to the end of the project, slight variability was reintroduced to these indicators.

While EVM proposes a methodology for the project manager to identify project variance in terms of cost and duration, it is necessary to establish when deviations from planned values are significant enough to require corrective action or, in the case of good performance, to identify the sources that favor this in order to take advantage of them [31].

Colin and Vanhoucke [33] and Kim and Pinto [34] presented interpretations of the CPI and SPI performance indicators. Although the ideal scenario is for these indicators to be around 1.0, there are suggested tolerance limits. For values between 0.8 and 1.0 or between 1.0 and 1.2, the project is considered to be well controlled and executed, and its efficiency is very good; if, on the contrary, they are below 0.8 or above 1.2, this is a signal to take corrective measures. Values below 0.5 or above 1.5 imply that there is a critical situation, but values below 0.2 or above 2.0 indicate a problem in the conception of the baseline measurement, from which unrealistic situations are inferred, such as a very poor and unrealistic estimation of the execution of the project, activities that can be carried out in much less time than specified, or expenses that are much lower or higher than planned, all of which can lead to the wrong interpretation of the execution.

3. Materials and Methods

The methodology applied in this research was the case study approach, which allows the analysis of a contemporary situation in real life. Regarding the research objectives, this work is classified as exploratory research with quantitative data, where generalizations were made from particular cases to theory, and according to its purpose, it is classified as fundamental. This study will help organizations to better understand how to apply EVM in construction projects.

The company used as a case study was chosen because it is one of the most representative companies of the city according to the size of the sales declared before the state control entity. In the economic sector in which it is registered, this company has executed projects of great importance for the city and is one of the few companies with contract amounts in this location. Additionally, the company was open to providing information for the analysis without withholding any negative results found.

Four stages were defined for the development of the research, which are detailed below:

Stage 1: Data collection. The development of this research began with a request for information from the construction company of the projects under study. The following information was collected for each project: estimated schedule of planned work, work progress sheets, expenses incurred by the company, execution time, reference budget, and time extensions, if applicable (contractual documentation).

Stage 2: Data processing. The information collected was organized in tables through observation sheets. The EVM methodology requires working with direct cost values, which are those associated with physical progress, so the data were broken down in this way and grouped according to the execution periods of each project. At this stage, the information was organized by work packages or deliverables up to the third level of discipline according to the work breakdown structure (WBS). Additionally, changes in the overall project budget at this stage due to modifications in the scope of each project were identified.

Stage 3: Methodology application. The procedures followed for the development of this study were defined. The guidelines for using the EVM methodology and organizing and processing the information collected from the projects were determined. The parameters to be obtained and how they would be related in order to interpret and discuss the results, which finally led to conclusions, were also described at this stage.

Stage 4: Data analysis and results. With the information processed in stage 2, analysis tables were generated for each project according to the guidelines required by EVM to determine the basic metrics PV, AC, EV, and new BAC due to increases in scope, which are used to evaluate the cost and schedule of the project, and performance indicators CV, SV, CPI, and SPI, which are used to evaluate the status of the project in terms of cost and performance. Graphs were generated that relate the basic metrics vs. periods and the performance indicators vs. periods to provide better visualization and to be able to conduct the evaluations.

One of the fundamental aspects of the EVM's application is the EV's determination. For this purpose, Avelar Ambriz [35] detailed the techniques that can be applied to determine it, depending on the characteristics of the deliverables and the duration of the task. According to the data collected, the percentage completed based on the rate of physical units achieved was chosen for this case study.

Stage 5: Conclusions. The results shown in the graphs were analyzed, and partial conclusions were obtained on how the projects were developed and what errors were evident in their management. Based on this, guidelines were suggested for applying the Earned Value Method to construction projects as a tool for better controlling the project management process.

4. Results and Discussion

4.1. General Description of the Projects

The construction company is located in the city of Cuenca and has been in the construction industry for a little more than 10 years. During this time, it has executed several projects, mainly on earthmoving. Two of the most representative projects in this period with relevant importance due to the type of structure that they represent were studied. These are buildings for public and private use with an execution cost of more than USD 5 million and with an execution period of more than two years. Hence, it is interesting to apply the control and evaluation methods to this project since they could show a considerable monetary gain or loss. These projects are the most representative at the city level. Table 4 shows these projects in detail:

Table 4. General description of projects (source: Proaño-Narváez).

Ident.	Type of Project	Type of Construction	Original Amount	Amount Executed	Start Date	Duration (Months)	Enlargement
Project 001	Building / Public	Bus Terminal	USD 4,965,804.15	USD 5,848,818.71	January/ 2016	27	3
Project 002	Building / Private	Private University	USD 8,979,208.53	USD 9,435,306.51	July/ 2018	24	

The WBS defined for each project was classified by specialty areas, such as architectural, structural, hydrosanitary, electrical, electronics, and HVAC, and each of these areas was broken down by deliverables at the level of detail corresponding to the initial budget of each project.

4.2. Evaluation of Project 001

This project consisted of constructing a building for the country's public sector. It is a bus terminal that provides interstate transportation service, located in the province of Morona Santiago in the city of Macas. According to the documentation collected, its original term was 18 months; there were three extensions to the term and three changes in its scope. It was extended to 27 months, which was approved by the supervisor and the contracting entity. The first change in scope was due to the creation of a complementary contract for the execution of new deliverables that were modified to improve the quality of the road structure. The second change was due to developing a second complementary contract to execute new deliverables that were evaluated and were necessary to complement the sanitary, electrical, and electronic systems of this project. The third change was due to an increase in the quantities of the existing deliverables. There were no fines reported for delays or non-compliance in the final product. For the execution of this project, neither the company nor its directors used progress control tools or methodologies; they adhered to the requirements of the contracting entity.

Figure 2 shows the S-curve, which is the cumulative baseline of expected resource consumption over time; the initial planned budget (BAC_0) and the original budget plus the implemented changes (BAC_1) are presented. The detailed information of this study is in Supplementary Materials.

Figure 3 shows the basic metrics PV, AC, and EV. If the execution time criterion is analyzed, it shows that the project remained on schedule throughout the execution period, from periods 1 to 23, in terms of its progress, and it was ahead of the planned schedule (EV > PV). However, from periods 24 to 27, a trend was maintained in which EV $\approx$ PV, and a lack of delays allowed the project to be completed on time. Regarding the execution cost criterion, the project remained within budget (EV > AC) until period 24, after which the costs began to exceed the forecast value (EV < AC), closing with an economic gap of VAC% = -3.24%, which resulted in an execution cost overrun.

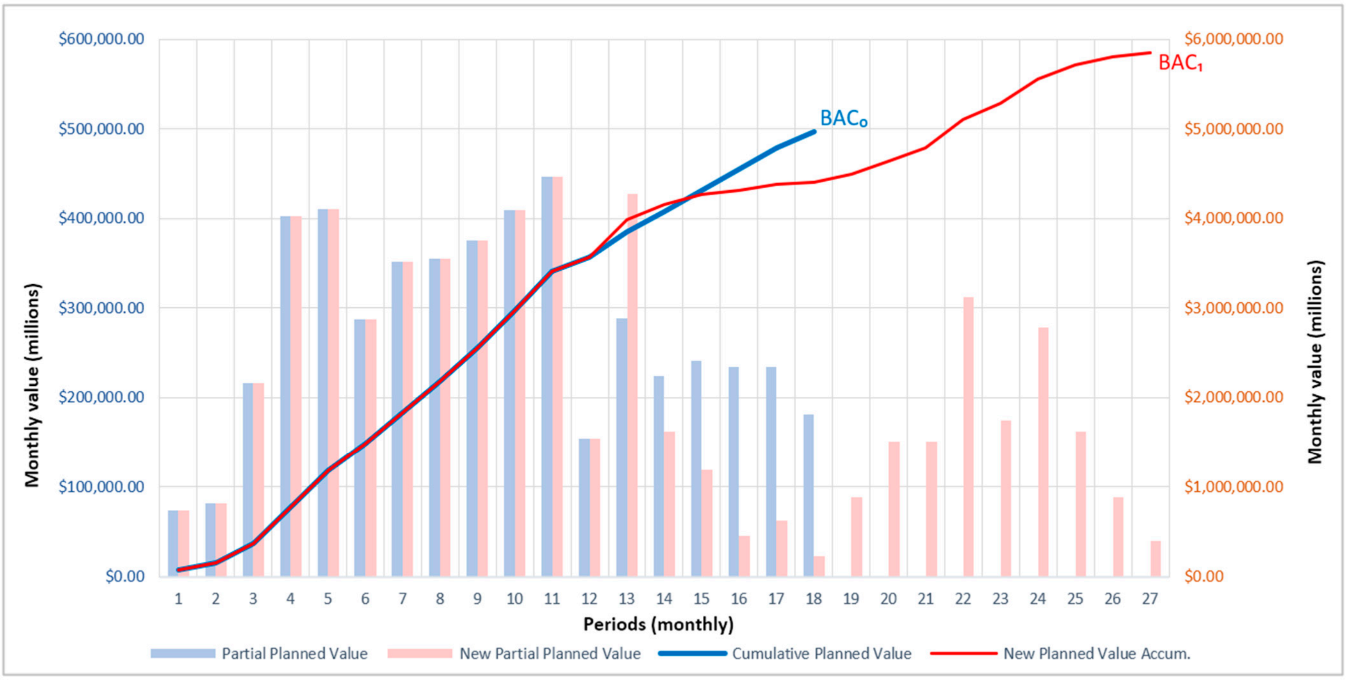

Figure 2. Original and final planned S-curve: Project 001 (source: Proaño-Narváez).

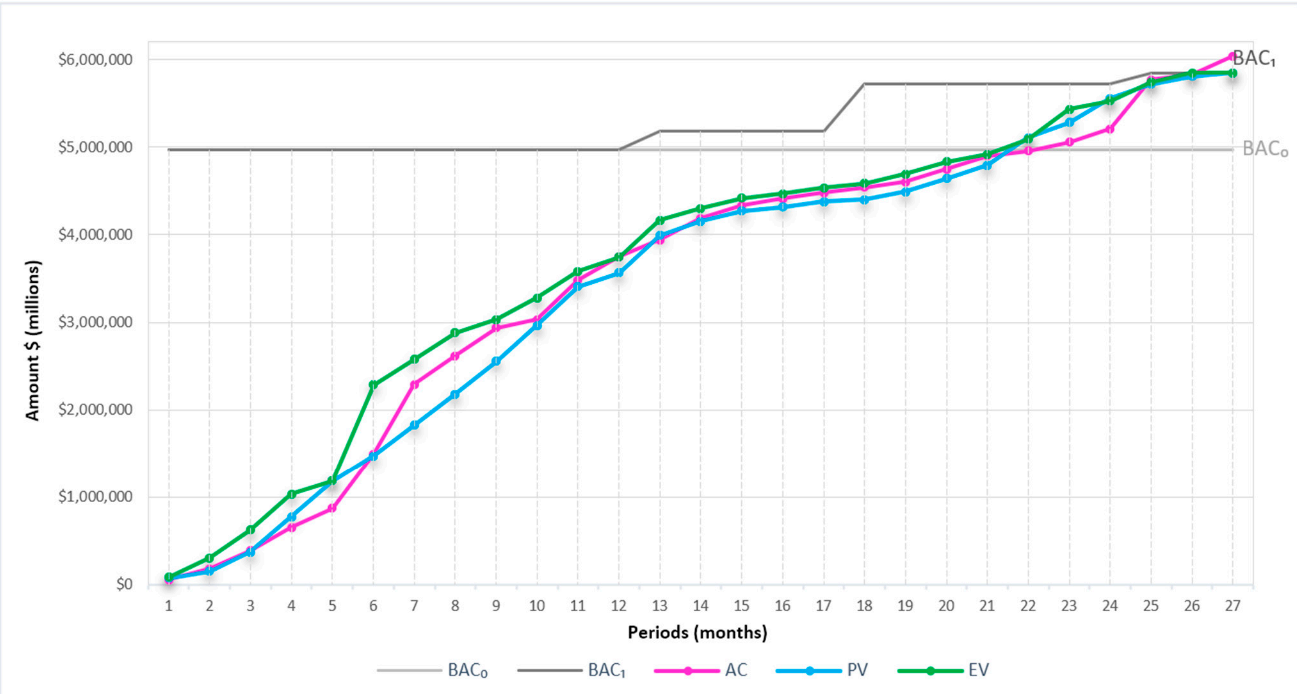

Figure 3. Basic metrics PV, EV, and AC: Project 001 (source: Proaño-Narváez).

The company assumed that the project's performance was successful because the analysis was limited to an evaluation of the financial year and the value entered for payment of work certifications minus expenses recorded under the scheme. At the end of the project, a favorable balance was obtained as a profit. When applying EVM, it was possible to infer that this conclusion was wrong, and the project showed the opposite result to the value mentioned above. Although the total value received is composed of the budgeted direct and indirect costs, the value as a percentage of indirect cost should not be considered a project's profit since this value is related to business management and its collaboration on the project. EVM allows the analysis to be performed considering this particular aspect.

Figure 4 plots the performance indicators resulting from the basic metrics obtained previously. Here, we analyzed the reconstructed facts in greater depth by interpreting the cost and schedule performance indicators that would have been generated throughout the execution period. It is evident that the project indeed finished on time, since at the last period, SPI = 1; however, in relation to the cost, CPI = 0.97 shows that in the previous period evaluated, it ended with the price exceeding the budget. Four stages were analyzed:

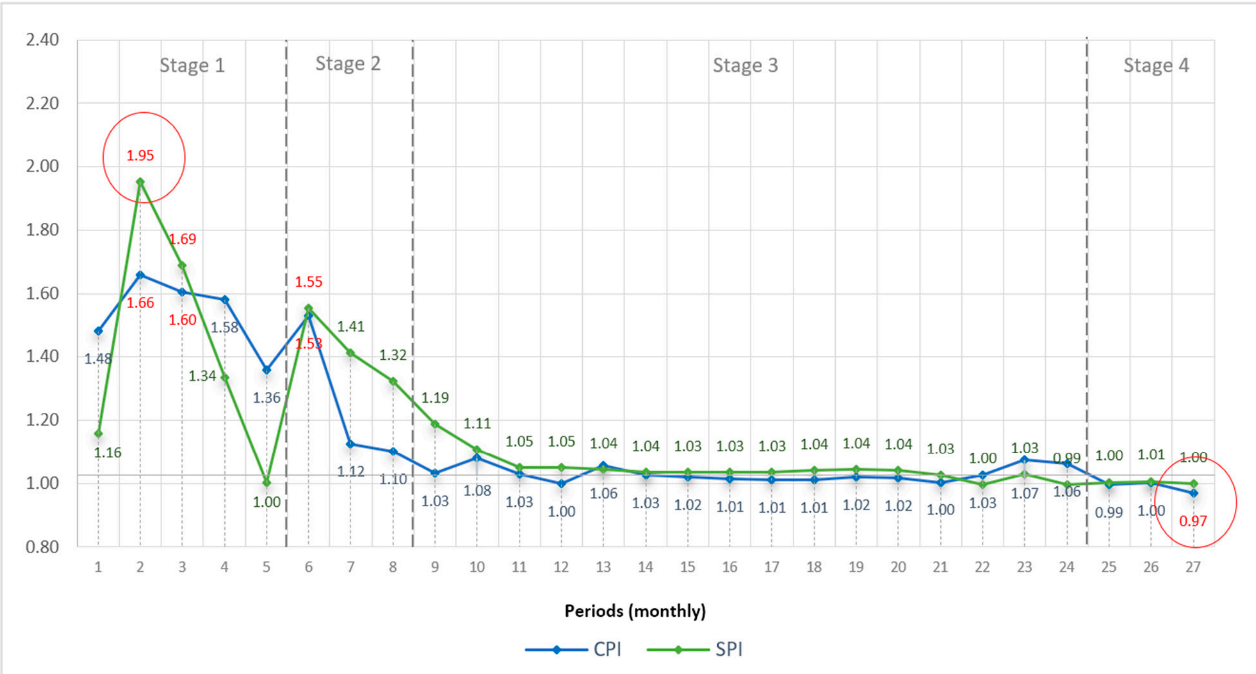

Figure 4. CPI and SPI performance indexes: Project 001 (source: Proaño-Narváez).

Stage 1: The indicator SPI > 1.0 indicates that the project is well ahead of schedule. In periods 2–4, the values above 1.5 are close to 2.0, which, according to theory, suggests a critical situation that may indicate that the director poorly established the baseline measurement of the project or that there was an increase in effort that was not necessary. The information was analyzed, and this production corresponded to the earthmoving deliverable. This activity is one of the company's strengths since it has its own machinery, which is used for more significant physical progress. The planning is very conservative at this stage, so the indicators are elevated. This is also reflected in the CPI indicator, which shows values higher than 1.0, specifically between 1.2 and 1.5, for the reason cited above. Given the alerts of the indicators in periods 2 and 3, actions should have been taken to correct the baseline and better distribute resources to remain within efficiency limits.

Stage 2: In periods 6–8, there is another peak in the SPI and CPI indicators, with values between 1.2 and 1.5, a situation that suggests a need for revision. The analysis shows that this was due to the execution of unplanned deliverables. However, with an overestimated value that raised the indicators and gave a false sense of physical progress, which, at the same time, favored the CPI indicator since no costs were recorded for work not yet executed, this was agreed upon by those involved in the project. One of management's shortcomings was recording the recognition of work not yet foreseen. In the analysis, EV altered the calculation of performance indicators and led to erroneous decisions by the director. With the alert generated in periods 6–7, the manager should have reconsidered the progress and recorded the expenses of the activities to better evaluate his performance.

Stage 3: The indicators SPI ≈ 1 and CPI ≈ 1 show a stable trend, which implies that the project was controlled and performed well, even though two approved changes were made to its scope. The decisions made allowed the company to be efficient in the use of its resources. The planning was successful since it was completed on schedule and within the estimated cost.

Stage 4: In this period, there is a new change in the scope of the project requested by the contracting entity due to increases and decreases in the deliverables recorded in the WBS; SPI ≈ 1.0 and ends at that value, but because CPI < 1.0, it is inferred that the director was forced to make decisions and inject economic resources to meet the deadline on time and not incur fines for delays. The information collected was analyzed; this stage corresponds to the implementation of deliverables of the electronic system and changes in the scope of some deliverables. In period 27, CPI = 0.97, and it remains within the allowed margins, so no mismanagement is assumed.

The application of EVM during the execution of the project could have highlighted the issues observed in the stages analyzed and encouraged the director to make timely decisions, such as a reassessment of the baseline, to take measures regarding the investment of economic resources and avoid the economic gap of −3.24%.

4.3. Evaluation of Project 002

This project consisted of constructing a building for the country's private sector. It is a new campus of the second most important university in Cuenca, in the province of Azuay, the capacity of which is around 2000 students pursuing different careers. This project had a change in scope due to increases and decreases in the quantities of existing deliverables. The original term was 24 months; there were no extensions to the term, but there were changes in the scope approved at the time, and the project was completed within the original period. There were no fines for delays or non-compliance in the final product. A particularity of this case study is that the company chose to follow control guidelines for project management organization of the work team in the field and the office.

In this case, the management of this project managed the EVM criteria. It worked throughout the project to update the information related to PV according to the increases and decreases in the work on the deliverables recorded in the WBS to represent the initial planned budget (BAC_0) and the original budget plus the implemented changes (BAC_1), as shown in Figure 5.

In public sector projects, changes in scope are only recorded with the approval of the contracting entity, unlike in the private sector, where there is no such limitation; for the analysis of this case, it was revealed that the company updated its BAC on a period-by-period basis in order to better control its planning.

In Figure 6, the results for the basic metrics PV, AC, and EV are plotted; regarding the execution time criterion, it is observed that the project remained on schedule throughout the executed term, although from periods 1 to 16, a trend is maintained in which EV ≈ PV. In general, the activities were completed within the planned periods, with slight variances. From period 17 to the end of the project, in terms of physical progress, EV > PV, which is indicative of good production and completion of the project on time, even though at this stage, the scope changes due to increases were considerable.

Concerning the execution cost criterion, up to period 5, the AC values are slightly higher than EV, which indicates that the investment at the beginning was higher, without affecting the rest of the execution, since this curve changed considerably after period 6. The trend EV > AC was maintained with a marked difference between the two values until the end.

Figure 5. Original and final planned S-curve: Project 002 (source: Proaño-Narváez).

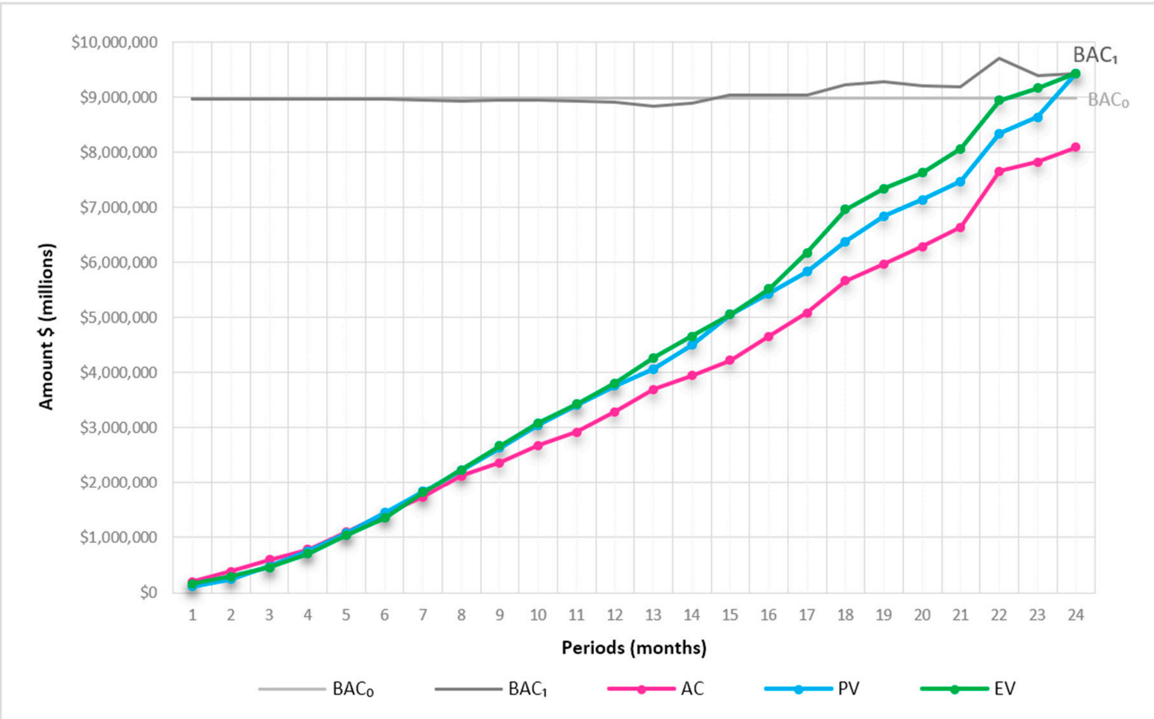

Figure 6. Basic metrics PV, EV, and AC: Project 002 (source: Proaño-Narváez).

In the analysis performed by the company at the closing of the project, the performance was considered successful. The result of the financial year reflected a favorable balance. The value determined using indirect cost was not included in this analysis. In this case, the fact that the project was carried out under EVM guidelines during its administration contributed to cost and time control, which was beneficial. By applying EVM to evaluate the performance of this project, it confirmed a favorable economic variance of VAC% = 14.20%. This represents a saving in resources invested in obtaining the final product, but the contribution that could result from the value determined when using indirect costs, which was not part of this study, remains to be determined.

Figure 7 analyzes the cost and schedule performance indicators for a more in-depth review of how this project was carried out. The indicators for the last period show that the project was completed on time (SPI = 1) and within budget (CPI = 1.17), resulting in savings in the resources invested in obtaining the final product. Three stages are analyzed:

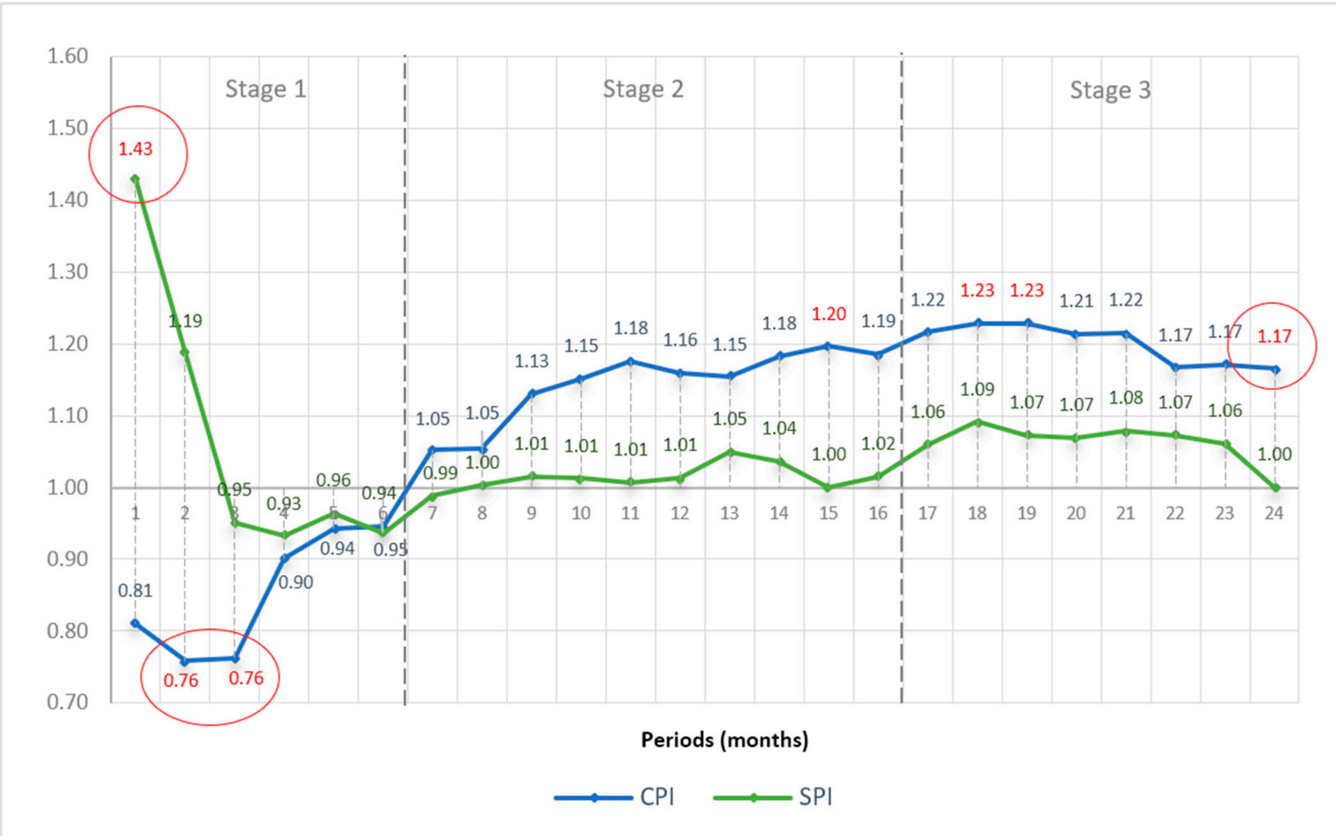

Figure 7. CPI and SPI performance indexes: Project 002 (source: Proaño-Narváez).

Stage 1: In period 1, the SPI value is between 1.2 and 1.5, which suggests the need for a review. The analysis of the information for this period corresponds to the earthmoving work, and as mentioned in the previous case, the company has an advantage in this deliverable; as this was an alert, the director took measures, and in the following periods 2–6, the SPI indicator remained in the ranges that indicate efficient management.

In the case of the CPI indicator, another scenario was analyzed. For period 1, the indicator is at the limit of the tolerance band, but in periods 2–3, a value of 0.76 is shown. This suggests the need for a review of how the project is being executed. From the analysis, the decision made by the director was to provide high investment in the early acquisition of materials such as reinforcing steel and porcelain tiles, taking advantage of beneficial opportunity costs. From periods 4–6, he took measures to improve the indicator, and thanks to the result of the previous benefit, he achieved it, staying within the tolerance range.

Stage 2: In periods 7–16, the SPI indicator remains positive, with an SPI $\approx$ 1 trend, which suggests that management was efficient and kept execution on schedule as a result of the solid initial investment made to acquire the necessary inputs; this is also reflected in the CPI indicator, which remains higher than 1.0 and within the limits that suggest efficient management. The company managed to take advantage of its human resources to the extent that it maintained its physical productivity and reduced the cost of producing that physical progress.

Stage 3: The SPI and CPI indicators remain above 1.0 and within tolerable limits for good management. The CPI indicator between periods 17 and 21 has a value slightly higher than 1.2, but in the final quarter, it decreases due to project closure costs. In the last period, the SPI indicator = 1.0, indicating that the project was completed on schedule, and the CPI indicator closes above 1.0, meaning that there was a considerable economic benefit compared to the previous experience.

The low variance in the indicators suggests that the director determined a correct baseline for measuring the project, executed the activities according to his plan, with particular cases, as seen in stage 1, and took advantage of competitive advantages in the market, and the decision made at the time favored him in the future.

Table 5 shows a summary comparison of the main aspects evaluated in each project regarding the type of structure. Both are building projects but differ in other parameters, such as the construction industry sector. There is a private project and a public one, and the characteristic that differentiates them is that the public administration in Ecuador is managed in accordance with a specific contracting law. In contrast, the private sector is not aligned with this law. In fact, it has independent management that is governed by the general rules of the state and allows the contractor greater freedom in directing resources during the administration of projects.

Table 5. Comparison between Project 001 and Project 002 (source: Proaño-Narváez).

Parameter	Project 001	Project 002
Type of structure	Building	Building
Construction industry sector	Public Sector	Private Sector
Changes in scope	3	1
Time of execution	27 months	24 months
Cost of execution	USD 5,848,818.71	USD 9,435,306.51
Organization Structure	Technical staff	Project Manager, project team, technical staff
WBS	Classified by specialty	Classified by specialty
CPI	0.97	1.17
SPI	1	1
%VAC	−3.24%	+14.20%

One particularity is that the public sector limits the percentage of quantity increases to 15%. In contrast, there is no limit in the private sector. Thus, both projects have benefits and disadvantages.

The analysis provides indicators that allow comparisons between projects that are different in terms of duration, cost, and regulations. It is inferred that the implementation of EVM generated a positive impact for Project 002, in addition to characteristics such as the structural organization of the company. A WBS classified according to the area of construction specialty for better monitoring and control of the measurement baseline, which could be constantly updated because there was a team assigned to it, enabled corrective actions to be taken to address deviations that were generated during the construction process. This was not the case for Project 001 since it had limitations regarding control of the measurement baseline, which was governed by the initial budget. Its changes required the approval of control agencies.

An additional aspect of measurement is that the private sector has a better flow of financial liquidity than the public sector, where delays in payments limit the company's liquidity.

4.4. EVM Application Guidelines

From the research carried out, in order to implement the EVM method during project management, it is necessary to take specific considerations into account in its application so that it can be an effective control tool that provides valuable information and allows the project manager to make timely decisions, avoiding money and time deviations.

It is essential to organize the information through a work breakdown structure (WBS) in packages of deliverables at different levels so that they can be matched with a proper chart of accounts that records the costs of each. Long-range deliverables should be broken down so that the cost allocation process corresponds to their actual execution. The WBS does not necessarily correspond to the overall budget in the public sector; it should be handled separately.

To make the method effective, the delivery costs must be recorded in the same period that they were executed, independently of the record corresponding to the accounting process. This is one of the most common errors since cost control is assumed to be the same as accounting management. At that point, due to financial or tax criteria, the record is usually postponed, so it is advisable to keep this control independent and always coordinated with the WBS [36].

Adequate project planning is organized according to the WBS. When changes to the original scope or unforeseen events are detected that trigger a change in the execution deadline, evaluations and updates to the actual BAC should be performed from the point of change. Otherwise, we mistakenly involve past events concerning the cost and schedule for the entire project.

The correct establishment of the percentage of work progress must follow what was executed as actual physically measured work. The appropriate procedure for data collection must be determined according to the type of information available [21]. Payment certifications (progress reports) often do not necessarily reflect the actual physical work measured.

Finally, the organization should be clear on the establishment of responsibilities of those involved in the project. The commitment and training of the people who will carry it out are essential for implementing this methodology so that the expected results are reflected; a process of continuous improvement based on the lessons learned must be established.

5. Conclusions

From the analysis of projects executed by a construction company in Cuenca in the private and public sectors, it is concluded that the application of the EVM method as a tool for project control and evaluation is practical in terms of costs (CPI indicator) throughout the project since, in the end, it allows determining the variance of the price relative to the planned value. However, the SPI indicator, which is used to monitor the schedule, loses effectiveness towards the end of the analysis. Although it continues showing a reference value, at the end of the project, it always reaches 1.0.

From the evaluation of the first case study (Project 001), in which no methodology was applied for cost and schedule control within project management, the management was able to deliver the project on time in order to avoid fines. However, the cost analysis result reflected losses; a valuation was conducted, and a gap of −3.24% compared to the original estimated cost was obtained. The main problems identified were a very conservative project measurement baseline that did not correspond to what was executed. The result was an inadequate distribution of resources, which caused a heavy investment at the end to adjust to the execution time, and a lack of organization of information. This led to the conclusion that although the company managed the organization at the beginning, the inexperience and lack of knowledge of project management tools prevented it from taking better advantage of its resources or taking actions in time to change the course of management.

In the second case study (Project 002), the company applied the EVM methodology for cost and schedule control; after the evaluation, it was determined that the management was successful, obtaining an economic benefit of 14.20% relative to the original estimated cost and completing the project within the deadline. The main aspects identified were a high investment of resources, which caused a budget overrun in the first few months, but this was promptly corrected, and the resources were used to achieve greater profitability. The baseline measurement was updated promptly and resembled what was executed, which provided more accurate information for decision making; another aspect was the better organization of the work team, which improved the level of control over the project's performance and scope.

As shown in the case studies analyzed, projects undergo frequent and sometimes unusual changes in scope and schedule throughout their execution. These unforeseen changes increase or decrease the planned cost. In the evaluation of this construction company, it was found that the use of the EVM tool improved the profitability of this particular project by +14.20%.

Although the use of EVM allowed the company to have better cost and schedule control, the main identified disadvantage in the use of this method is that it must be complemented with the expertise of the project manager, as a vital factor in decision making using information resulting from its application. The project manager is the one who will define the necessary corrective actions, will take the risk of not acting on the alerts generated, and will decide to take advantage of the competitive advantages that are presented, such as opportunity costs in materials, machinery, or other inputs that will generate greater profitability in the future. Another weak point of EVM is in the registration and control of costs, which is the core of the administration and is the weakest link that must be taken care of so that it can be complemented with technical information and lead to the success of the project.

Although the weaknesses of using EVM are pointed out, it is necessary to recognize that its application benefits all those involved in a project, from the construction to the operation phase. EVM does not only entail applying a measurement technique based on obtaining indicators that measure the project status to compare them against a standard measurement baseline, determine if there are deviations, and take actions to correct them. It also involves other aspects of cost and duration, such as human, economic, and material resource management, risk management, quality, safety, and social environment. All elements complement each other to determine whether the project is successful. This study allowed us to see that these aspects favor or detract from the achievement of the project's objective, so in future research, we suggest conducting interviews with the project managers or the project team to obtain valuable information on what aspects they considered when making decisions, how they turned out, and what guidelines they suggest applying or considering when implementing the EVM technique on a project.

The main beneficiaries of the implementation of EVM are project managers, who improve their administrative management; there are other beneficiaries, such as project promoters, who obtain better financial or economic performance due to the suitable and strategic decisions made by the project manager. Finally, another beneficiary is the end-user who uses the product and benefits from a space that is adapted to his or her needs, is of good quality, is delivered at a reasonable cost, and provides satisfaction and security.

Supplementary Materials: The following supporting information can be downloaded at: https://drive.google.com/drive/folders/1fQw3ecDay_BEPpFvFotEbr5Aad2x66M4?usp=sharing.

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References

1. Picornell, M.; Pellicer, E.; Torres-Machí, C.; Sutrisna, M. Implementation of Earned Value Management in Unit-Price Payment Contracts. *J. Manag. Eng.* **2017**, *33*, 06016001. [CrossRef]
2. Shehu, Z.; Rohani, I.; Akintoye, A.; Holt, G.D. Cost overrun in the Malaysian construction industry projects: A deeper insight. *Int. J. Proj. Manag.* **2014**, *32*, 1471–1480. [CrossRef]
3. Doloi, H.; Sawhney, A.; Iyer, K.C.; Rentala, S. Analysing factors affecting delays in Indian construction projects. *Int. J. Proj. Manag.* **2012**, *30*, 479–489. [CrossRef]
4. Olatunji, O.A. A comparative analysis of tender sums and final costs of public construction and supply projects in Nigeria. *J. Financ. Manag. Prop. Constr.* **2008**, *13*, 60–79. [CrossRef]
5. Olawale, Y.A.; Sun, M. Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. *Constr. Manag. Econ.* **2010**, *28*, 509–526. [CrossRef]
6. Memon, A.H.; Rahman, I.A. SEM-PLS Analysis of Inhibiting Factors of Cost Performance for Large Construction Projects in Malaysia: Perspective of Clients and Consultants. *Sci. World J.* **2014**, *2014*, 165158. [CrossRef]
7. Serna, S.L.; Galindo, I.P.; Gómez-Cabrera, A.; Torres, A. Identificación de factores que generan diferencias de tiempo y costos en proyectos de construcción en Colombia. *Ing. Cienc.* **2018**, *14*, 117–151. [CrossRef]
8. Przywara, D.; Rak, A. Monitoring of time and cost variances of schedule using simple earned value method indicators. *Appl. Sci.* **2021**, *11*, 1357. [CrossRef]
9. Project Management Institute. *La Guía de los Fundamentos Para la Dirección de Proyectos (Guía del PMBOK)*, 6th ed.; Project Management Institute, Inc.: Newton Square, PA, USA, 2017; ISBN 978-1-62825-194-4.
10. Sutrisna, M.; Pellicer, E.; Torres-machi, C.; Picornell, M. Exploring earned value management in the Spanish construction industry as a pathway to competitive advantage. *Int. J. Constr. Manag.* **2018**, *3599*, 1–12. [CrossRef]
11. Fleming, Q.W.; Koppelman, J.M. Earned value for the masses a practical approach. *PM Netw.* **2001**, *15*, 28–32.
12. Bryde, D.; Unterhitzenberger, C.; Joby, R. Conditions of success for earned value analysis in projects. *Int. J. Proj. Manag.* **2017**, *36*, 474–484. [CrossRef]
13. Solís-Carcaño, R.G.; Morfín-García, S.C.; Zaragoza-Grifé, J.N. Time and cost control in construction projects in southeast Mexico. *Ing. Investig. Tecnol.* **2017**, *18*, 411–422. [CrossRef]
14. De Marco, A.; Narbaev, T. Earned value-based performance monitoring of facility construction projects. *J. Facil. Manag.* **2013**, *11*, 69–80. [CrossRef]
15. Sunarti, N.; Pakir Mastan, Z.; Seon Cin, L. The Application and Challenges of Earned Value Management (EVM) As Cost Monitoring Tool in the Construction Industry. *Int. J. Eng. Technol.* **2018**, *7*, 96–100. [CrossRef]
16. Kim, E.; Wells, W.G.; Duffey, M.R. A model for effective implementation of Earned Value Management methodology. *Int. J. Proj. Manag.* **2003**, *21*, 375–382. [CrossRef]
17. Diez-Silva, H.M.; Pérez-Ezcurdia, M.A.; Gimena Ramos, F.N.; Montes-Guerra, M.I. Medición del desempeño y éxito en la dirección Perspectiva del Manager público Performance and success measurement when managing projects Mesure du rendement et de la réussite en gestion de projets: Le cas des cadres de la fonction publique Medição de. *Rev. Esc. Adm. Neg. EAN* **2012**, *73*, 60–79.
18. Mahmoudi, A.; Bagherpour, M.; Javed, S.A. Grey Earned Value Management: Theory and Applications. *IEEE Trans. Eng. Manag.* **2019**, *68*, 1703–1721. [CrossRef]
19. Teixeira, J.; de Oliveira, N.L.F.; Freitas, A.P.A.; dos Santos, J.A.N. Critical Factors and Benefits in the Use of Earned Value Management in Construction. *Braz. J. Oper. Prod. Manag.* **2020**, *17*, 1–10. [CrossRef]
20. Kim, B.-C.; Reinschmidt, K.F. Combination of Project Cost Forecasts in Earned Value Management. *J. Constr. Eng. Manag.* **2011**, *137*, 958–966. [CrossRef]
21. Project Management Institute. *Practice Standard for Earned Value Management*; Project Management Institute, Inc.: Newton Square, PA, USA, 2005; ISBN 1930699425.
22. Skaik, S.; El-Hawary, M.S. Validating the impact of EVM on Project life cycle. In Proceedings of the CIB 2014: Proceedings of the 2014 International Conference on Construction in a Changing World, Dambulla, Sri Lanka, 4–7 May 2014; pp. 1–15. Available online: https://www.researchgate.net/publication/262242719%0AValidating (accessed on 15 December 2021).
23. Valle, J.A.; Soares, C.A.P. The Use of EVA—Earned Value Analysis in the Cost Management of Construction Projects. 2006. Available online: https://www.pmi.org/learning/library?industries=Construction (accessed on 1 December 2021).

24. Cuadros-López, A.; Rangel-Collazos, L.V.; Aguilar-Valencia, C.I. Performance control considering risks for construction projects. *Sci. Tech.* **2019**, *24*, 225–231. [CrossRef]
25. Rezouki, S.E.; Baqer, S.M. The Factors Affecting on Earned Value Management. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Najaf, Iraq, 2020.
26. Aramali, V.; Gibson, G.E.; El Asmar, M.; Cho, N. Earned Value Management System State of Practice: Identifying Critical Subprocesses, Challenges, and Environment Factors of a High-Performing EVMS. *J. Manag. Eng.* **2021**, *37*, 04021031. [CrossRef]
27. Nizam, A.; Aburas, H.M.; Elshennawy, A.K. Earned value in a project manufacturing environment: A case study assessing the effectiveness of EVM. *J. Mod. Proj. Manag.* **2020**, *8*, 58–65. [CrossRef]
28. Acebes, F.; Pajares, J.; Galán, J.M.; López-Paredes, A. Beyond Earned Value Management: A Graphical Framework for Integrated Cost, Schedule and Risk Monitoring. *Procedia Soc. Behav. Sci.* **2013**, *74*, 231–239. [CrossRef]
29. Chen, H.L.; Chen, W.T.; Lin, Y.L. Earned value project management: Improving the predictive power of planned value. *Int. J. Proj. Manag.* **2015**, *34*, 22–29. [CrossRef]
30. Novinsky, M.; Nesensohn, C.; Ihwas, N.; Haghsheno, S. Combined Application of Earned Value Management and Last Planner System in Construction Projects. In Proceedings of the 26th Annual Conference of the International Group for Lean Construction, Chennai, India, 16–22 July 2018; Volume 49, pp. 775–785.
31. Cândido, L.F.; Mählmann Heineck, L.F.; de Barros Neto, J.P. Critical Analysis on Earned Value Management (EVM) Technique in Building Construction. In Proceedings of the 22nd Annual Conference of the International Group for Lean Construction 2014 (IGLC-22), Dallas, TX, USA, 3–5 November 2014; Fagbokforlaget: Oslo, Norway, 2014.
32. Lipke, W.; Zwikael, O.; Henderson, K.; Anbari, F. Prediction of project outcome The application of statistical methods to earned value management and earned schedule performance indexes. *Int. J. Proj. Manag.* **2009**, *27*, 400–407. [CrossRef]
33. Colin, J.; Vanhoucke, M. Setting tolerance limits for statistical project control using earned value management. *Omega Int. J. Manag. Sci.* **2014**, *49*, 107–122. [CrossRef]
34. Kim, B.-C.; Pinto, J.K. What CPI = 0.85 Really Means: A Probabilistic Extension of the Estimate at Completion. *J. Manag. Eng.* **2019**, *35*, 04018059-18. [CrossRef]
35. Avelar Ambriz, R. La gestión del valor ganado y su aplicación: Managing earned value and its application. In Proceedings of the PMI®Global Congress 2008—Latin America, São Paulo, Brazil, 11–13 August 2008; Project Management Institute: Newton Square, PA, USA, 2008.
36. Villegas Oliveros, Á.M.; Rincón de Parra, H.C. Gestión de Costos en los Proyectos: Un abordaje teórico desde las mejores prácticas del Project Management Institute. *Rev. Visión Gerenc.* **2011**, *10*, 85–94.