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Time and Cost Management in Water Resources Projects Utilizing the Earned Value Method

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Abstract

Today, the development of infrastructure and construction projects in developing countries is of paramount importance. Water projects, in particular, play a crucial role in advancing agriculture, industry, and the economy. The success of these projects hinges on the effective management of time, cost, and quality. The most critical indicator of a project's success is its completion within the forecasted time and budget leading up to its operation. This study aims to assess the impact of Earned Value Management (EVM) 's impact on managing project schedules and budgets in water resource projects. The earned value method was employed to ascertain if the project was ahead or behind schedule and whether the costs were within the budget or had overrun. The values of the Earned Value Index were analyzed at three stages of project implementation. Examining the Schedule Variance (SV) at various phases indicates that a lower percentage is more advantageous for the project. Initially, the SV was 40%, signaling a delay mainly due to the delayed start of operations in the injection gallery and access points. This improved to 25% in the second stage, with the commencement of previously lagging activities. The schedule variance decreased to 11.6% in the final stage, aligning closer to the project schedule's end. Additionally, the Schedule Performance Index (SPI) value, which reflects the efficiency of project management in terms of timeliness, improved from a weak start of 0.6 to 0.88 (with 1.0 indicating that project performance is on target).

1. Introduction

The construction industry has numerous challenges, including project delays and cost overruns. Extensive research reveals that many construction projects significantly exceed their budgetary allocations and fail to meet their predetermined timelines. It is widely recognized that accurately assessing a project's duration and cost during its implementation is essential for making informed decisions and mitigating potential delays and budgetary overruns [1]. Value Management (VM) has a rich history in the construction sector, with proven success in project planning, cost control, conflict management, and dispute resolution.

Nevertheless, its adoption is still nascent in many countries [2]. Value management holds the promise of expediting design and construction processes by placing a stronger emphasis on meeting the client's foremost requirements [3].

One deterministic method that harnesses data from specific project activities is Earned Value Management (EVM). EVM relies on key inputs such as ongoing activity costs, durations, and work completion percentages. When an activity reaches completion, its progress, reflected as a percentage, reaches 100%, and the actual cost and duration are documented. EVM then analyzes these data points to determine if the project is on schedule or ahead, whether it is under or over budget, and it provides long-term projections regarding the project's eventual cost and duration if it continues at its current pace [4].

Earned Value Management (EVM) is a robust tool for monitoring and managing project progress, offering real-time insights into a project's performance. EVM leverages the three critical constraints of time, scope, and cost to assess the project's status and utilizes historical data to forecast future project parameters, including the ultimate cost [5]. Effective control of a project's requirements, encompassing time, budget, and scope, is fundamental to sound project management. Project management techniques must also evolve as projects need to evolve to meet these changing demands. Earned Value Management (EVM) is a widely used project oversight and management approach. EVM facilitates a comparison of planned work (Planned Value), actual completed work (Earned Value), and the cost incurred for the work done (Actual Cost) at a specific point in time. Project managers can monitor both cost and schedule variances in monetary terms. Despite the evident advantages of EVM, scholars have identified limitations and proposed various enhancements and alternatives. For instance, while EVM can track schedule compliance, its schedule projections tend to change as projects progress [6].

The Critical Path Method (CPM) is one of the most commonly employed planning techniques in construction projects, primarily focusing on determining the project's timeline based on the longest path theory. Costs for individual activities are aggregated to ascertain the project's overall cost [7]. In project management, activity durations are one of the most prevalent sources of uncertainty. For instance, project managers often struggle to estimate activity durations in novel and distinct projects due to the absence of empirical data. Even in projects with a track record, predicting the duration of each activity can be challenging. Weather conditions, material availability, and human variables frequently lead to delays in construction projects [8].

The Earned Schedule (ES) methodology, introduced in 2003, has gained international recognition over time, owing to its inclusion in various project management, earned value management (EVM), and scheduling standards [9]. These challenges and opportunities in project time and cost management are the backdrop for this research on applying the Earned Value Method in water resources projects.

2. Materials and Methods

EVM is one of the most frequently used methods to evaluate a project's performance as it is being carried out. Organizations like the National Aeronautics and Space Administration (NASA) use it for project management. The US Department of Defense (DoD) introduced the fundamentals of this method in the 1960s, which was improved and further expanded in the 1970s and early 1980s. Guidelines for EVM were released in 1998 by the Electronic Industries Alliance (EIA) and the American National Standards Institute (ANSI). The Project Management Institute (PMI) added the EVM language and fundamental formulas in 2000 [10].

2.1. S-Curve Chart

A valuable method for assessing the efficient use of financial resources in a construction project involves illustrating planned financial flows over time using a cumulative cost chart, commonly known as the S-curve. This curve visually depicts the project's progression from the initiation of construction works to their completion. The S-curve, named for its characteristic shape resembling the letter "S," features a variable slope that signifies the changing pace of work over time [11].

The S-curve typically exhibits a gentler slope at the project's commencement and conclusion, becoming steeper during the intermediate phase. This variation is attributed to the gradual start of traditional construction projects. In the initial stages, efforts focus on organizing human resources, preparing the construction site, and executing basic preparatory tasks. As time progresses, work intensifies, with multiple work fronts operating concurrently and various teams engaged. Contractors undertake an increasing number of tasks simultaneously, resulting in a notable rise in costs compared to the initial implementation phase. According to the state of AC and EV values compared to PV, as depicted in Figure 1, at any given point in the project being worked on, one can ascertain the cost and time variances from the expected values and, consequently, assess performance indicators.

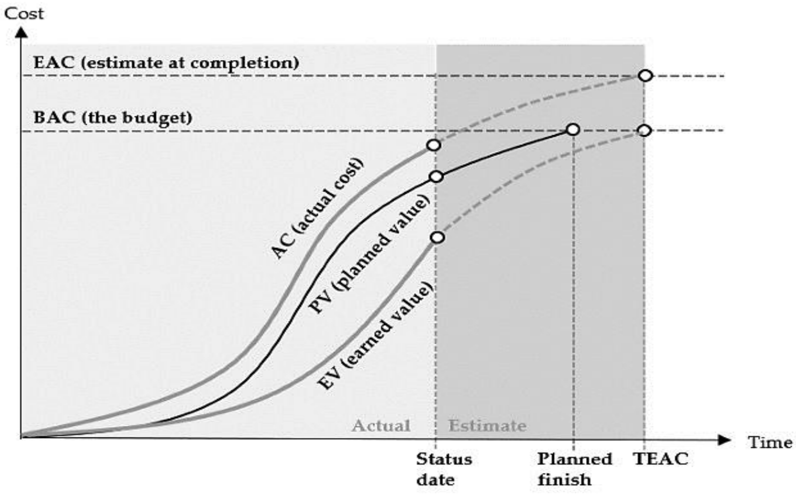

Figure 1. Cost and time indicators [12].

2.2. Earned Value Analysis Indicators

The earned value analysis indicators are presented as follows:

2.2.1. Variances

2.2.1.1. Schedule variance

Schedule Variance, abbreviated as SV, serves as an indicator to determine if a project is adhering to its schedule. From the beginning, it's important to highlight that Schedule Variance exclusively reflects a project's advancement in financial terms without delving into the aspect of quality. The index demonstrates the difference and variance between the related project's Earned Value (EV) and Planned Value (PV) [13]. (Equation 1)

$$SV = EV - PV \tag{1}$$

Table 1. Interpretation of Schedule variance.

Performance Indicator	Interpretation		
	Ahead	On plan	Delay/Overrun
Schedule Variance (SV)	positive	=0	negative

The project is typically ahead of schedule if the schedule variance is positive; however, if it is negative, it is likely behind schedule. If the schedule variance equals zero, the project proceeds as planned.

2.2.1.2. Cost variance

Cost Variance (CV) assesses the extent to which a project's expenditures align with its budget, measuring the variance between the planned and actual expenses at a specific point in time. It represents the disparity between the earned value and the actual cost. It is a monetary amount expressed as the difference between the actual cost of the work and the estimated cost of completion [14]. (Equation 2)

$$CV = EV - AC \tag{2}$$

Table 2. Interpretation of Cost Variance.

Performance Indicator	Interpretation		
	Ahead	On plan	Delay/Overrun
Cost Variance (CV)	positive	=0	negative

The Cost Variance Outcomes in Earned Value Management (EVM), as shown in Table 2, are Positive, which means under budget; Negative, which means Over budget; and zero, which means on budget.

2.2.2. Indices

2.2.2.1. Cost Performance Index (CPI)

This index has no dimensions and compares the value of the physical work done with the real costs directly incurred to complete that task. If more money had been spent than the physical work had been done, the results would indicate that the budget had been exceeded. The CPI cost performance index is determined by dividing the cumulative earned value by the cumulative real cost of a project up to the present date (Equation 3) [15].

$$CPI = EV/AC \tag{3}$$

Table 3. Interpretation of Cost Performance Index.

Performance Indicator	Interpretation		
	Ahead	**On plan**	**Delay/Overrun**
Cost Performance Index (CPI)	>1	=1	<1

As shown in Table 3, a CPI ratio exceeding 1 signifies effective budget performance in a project. A CPI value of 1 implies that a project is precisely on budget, while a CPI value below 1 indicates that the project exceeds the budget.

2.2.2.2. Schedule Performance Index (SPI)

This dimensionless index is employed to forecast project timing outcomes. This index evaluates the work completed by the project's fundamental plan. The SPI schedule performance index is determined by dividing the cumulative earned value by the cumulative programmed cost of a project or work package up to the current date (Equation 4).

$$SPI = EV/PV \tag{4}$$

Table 4. Interpretation of Schedule Performance Index.

Performance Indicator	Interpretation		
	Ahead	**On plan**	**Delay/Overrun**
Schedule Performance Index (SPI)	>1	=1	<1

As shown in Table 4, if the SPI value is less than one, the project is behind schedule; equal to one means the project is on schedule; and if it is greater than one, it means the project is ahead of schedule.

2.2.3. Forecasting Methods

2.2.3.1. Estimate at Completion (ETC)

The project team can estimate the cost to finish the project as it moves forward using prior performance. For EAC estimates, SPI and CPI are typically employed as project performance indicators [16].

$$EAC = AC + (BAC - EV)/CPI \tag{5}$$

2.2.3.2. Estimate to Completion (ETC)

The Estimate To Complete (abbreviated as ETC) is a financial performance index and project management metric, indicating the anticipated cost required to finish a project. When considered alongside schedule variance, it provides insights into the project's progression. The cost required to finish the remaining work is determined by Equation 5 [14].

$$ETC = (BAC - EV)/CPI \quad (6)$$

2.2.3.3. Variance at completion (VAC)

Variance at Completion (VAC) serves as a forecast of the budget surplus or deficit, calculated as the variance between the Budget at Completion (BAC) and the Estimate at Completion (EAC). In project management, this principle represents the distinction between the initially anticipated or baseline project cost and the current estimated cost.

$$VAC = BAC - EAC \quad (7)$$

Table 5. Interpretation of Variance at Completion Index [17].

Variance Indicator	Interpretation		
	Savings	On Budget	Over Budget
Variance at completion (VAC)	=+ve	=0	=-ve

Understanding the outcome of Variance at Completion (VAC) is straightforward. For example, a positive VAC indicates that the project is operating under a budget, while a negative value suggests exceeding its budget. The magnitude of the VAC's distance from zero reflects the margin of error in budget calculations; therefore, the VAC should approach zero, signifying a more accurate estimate.

2.3. Microsoft Project Software

MSP 2019 software, one of the most powerful project management software, includes all project stages, from planning to completion and transfer of final reports. This program is a valuable tool for organizing plans, scheduling work, allocating resources and costing work, setting up the plan to estimate limitations, and preparing reports to transfer the final plan to all those who must implement the desired plan.

2.4. Location of the Project

Due to data confidentiality commitments to the relevant organization, the name and location of the project are not disclosed in this article.

3. Results and Discussion

3.1. Planning Phase

Paying attention to preparing a readable breakdown structure increases program manageability and simplifies the extraction of control information. In this study, the breakdown structure has been developed based on 31 activities, activity summaries, and the milestones of the dam. Additionally, relationships between activities have been defined based on their execution prerequisites.

3.2. Setting the Project Calendar

The project calendar has been defined in Microsoft Project 2019 to be a 6-day work per week, from 8 AM to 5 PM, with a one-hour break. Fridays and official holidays are considered non-working days, and during Ramadan, working hours are from 8 AM to 4 PM.

3.3. Setting the Duration of the Activities and the Start time of the project

Based on the predicted start and end times of each activity and considering the executive prerequisites that activities had relative to each other, the duration of planning for each activity was determined, and the summary of activities' durations was allocated from the total related activities. The project started on December 11, 2020, and the total project planning duration is 615 days, with the project ending on August 16, 2022.

3.4. Planned Progress of the Project

By entering the estimated project costs, saving the program baseline, and specifying the status date in the MSP 2019 software, the planned cost of the planned activities was calculated to be 5,991,613.4 USD. The planned progress chart and the total planned cost were drawn using BCWS (Figure 3).

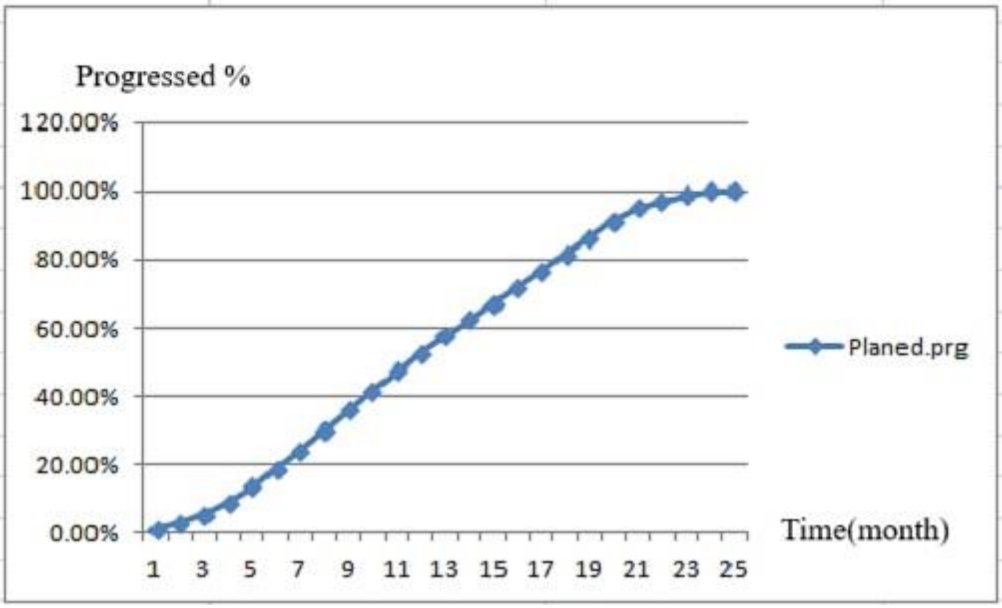

Figure 3. Planning progress chart (S-chart).

The progress chart, which has an S-shaped form, has a normal state. Initially, progress was slow due to fewer activities at the beginning of the project. After a while, with an increase in the number of concurrent activities, the slope increases, and in the end, with a decrease in them, the slope decreases (Figure 3).

3.5. Actual Information Recording

3.5.1. First Stage

With the recording of actual costs and real progress percentage on September 11, 2021 (Nine months after the project commenced), the initial comparison was made between the planned and actual progress up to this date (Figure 4).

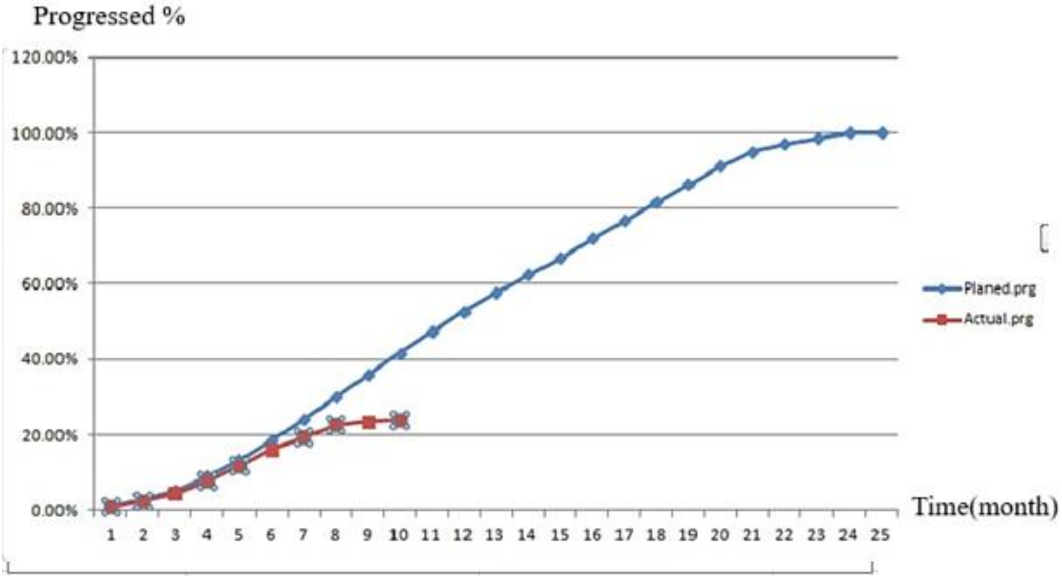

Figure 4. Planned progress with the actual progress of the first stage.

The actual progress curve, as shown, lies flatter than the planned progress curve, indicating a project delay so that by the tenth month of operation, an expectation of 41.64% has reduced to 23.95%. As observed, this chart does not provide much insight into project management, so it is necessary to examine earned value parameters. At this stage, the project's schedule performance is 40%, indicating a time deviation that the project is 40% behind schedule. This delay is due to the non-commencement of the grouting gallery and access gallery operations with an SV (Schedule Variance) of 100%. Only excavation and grouting of the subfloor and foundations with SV=0% have been done as planned. The project's time performance index, which is 0.60, means that 60% of the expected time has been achieved. During this period, work progress has been entered into the software. These operations have been carried out on the foundation of the dam and dam body, while the remaining activities are behind schedule and have not yet started. Considering the physical weight of the work, the project shows a 21% progress.

3.5.1.1. Checking the cost amount of the first stage

Based on the results obtained from the MSP software (Table 6), the planned project cost for this period is 2,389,016.19 USD, while the actual cost is 1,239,545.15 USD, with an earned value of 1,435,127.47 USD.

Table 6. Cost indicators of the first stage

Item	Duration days	Baseline cost	BCWS	BCWP	AC
Project	615	5,991,613.4	2,389,016.19	1,435,127.47	1,239,545.15
Beginning	0	0	0	0	0
The main body of the Dam	615	5,991,613.4	2,389,016.19	1,435,127.47	1,239,545.15
Foundation of the Dam	606	2,230,461.92	852,503.08	508,800.87	547,794.84
Drilling and grout curtain	606	2,072,409.49	817,336.42	476,654.18	484,940.49
Drilling and reinforcement grout of the sides of the floor and foundation.	400	128,589.26	28,611.11	28,611.11	59,392.43
Concreting the filling of the sides of the floor and the foundation	400	29,463.17	6,555.56	3,535.58	3,461.92
Dam body	615	3,761,151.48	1,536,513.10	926,326.59	691,750.31
Clay core embankment	440	516,853.93	157,405.52	144,719.10	159,300.87
Filter and vertical drain	440	268,314.61	81,713.99	72,444.94	65,917.60
shell embankment	460	2,424,968.79	943,629.16	703,240.95	460,269.66
Riprap execution	440	53,832.71	7,830.21	5,921.60	6,262.17
Grout gallery	448	433,341.24	282,094.02	0.00	0.00
Part A	175	111,302.54	64,251.66	0.00	0.00
Reinforcement work of part A	150	77,556.39	30,505.51	0.00	0.00
Molding work of part A	150	2,618.39	2,618.39	0.00	0.00
Structural concreting work of part A	150	31,127.76	31,127.76	0.00	0.00
Part B	448	322,038.70	217,842.36	0.00	0.00
Communicating the plans of part B	0	0.00	0.00	0.00	0.00
Tunnel excavation and stabilization operations	150	75,156.05	75,156.05	0.00	0.00
Reinforcement work of part B	130	180,024.97	123,247.86	0.00	0.00
Molding work of part B	130	5,236.79	3,021.22	0.00	0.00
Tunnel lining work	130	34,987.52	16,417.22	0.00	0.00
Drilling and grouting part B	140	26,633.37	0.00	0.00	0.00
Access Gallery	210	63,840.20	63,840.20	0.00	0.00
Access gallery plans	0	0.00	0.00	0.00	0.00
The substructure of the access gallery	90	4,131.50	4,131.50	0.00	0.00
reinforcement works of access gallery	90	36,870.58	36,870.58	0.00	0.00
Molding works of access gallery.	90	1,697.88	1,697.88	0.00	0.00
Structural concreting works of access gallery.	90	21,140.24	21,140.24	0.00	0.00
Ending	0	0.00	0.00	0.00	0.00

According to the calculations performed in equations 8 and 9, the cost variance (CV) is 13.6%.

$$CV = EV - AC \tag{8}$$

CV= 1,435,127.47-1,239,545.15 = 195,582.32

$$CV\% = CV/EV \tag{9}$$

CV%= 195,582.32/1,435,127.47 = 13.6%

In other words, the expenditure on the work performed is under the estimated amount by 13.6%. On the other hand, the expenses related to shell embankment had a positive impact, reducing the cost deviation. The Cost Performance Index (CPI), calculated in Equation 10, indicates resource utilization efficiency. Since this index is greater than one, it implies that, up to this point, the incurred costs are lower than the earned value of the work accomplished. However, a CPI value exceeding one is a cautionary signal that quality control may not have been adequately managed.

The total planned cost of the project is the Budget at Completion (BAC), which is utilized to derive the Cost Performance Index to Complete (TCPI). This forward-looking index assists in determining the level of effort required for the remaining work to meet performance expectations. The TCPI value, obtained from Equation 11, suggests that to attain the BAC, the CPI needs to decrease from 1.158 to TCPI 0.96. This implies that performance must be sustained to fulfill the financial commitment from a management perspective. However, up to this point in the project, this ratio is less than one, considered a positive indicator.

$$CPI = EV/AC \tag{10}$$

CPI= 1,435,127.47 / 1,239,545.15 = 1.158

$$TCPI = (BAC - EV)/(BAC - AC) \tag{11}$$

TCPI= (5,991,613.4 – 1,435,127.47)/ (5,991,613.4 – 1,239,545.15) = 0.96

$$CR = SPI * CPI \tag{12}$$

CR = 0.6 * 1.158 = 0.695

3.5.1.2. Project status forecast

Estimating the remaining cost to complete the project (ETC): From equation 13, the value of ETC is obtained.

$$ETC = BAC - EV \tag{13}$$

ETC= 5,991,613.4 - 1,435,127.47= 4,556,485.93

For the remaining works, 4,556,485.93 USD should be spent to complete the project.

Estimating total Completion Cost (EAC): The value of EAC is obtained from Equation 14.

$$EAC = AC + (BAC - EV)/CPI \tag{14}$$

EAC= 1,235,545.15 + (5,991,613.4 – 1,435,127.47)/1.16 = 5,174,334.38

EAC=5,174,334.38 USD, the project's new BAC, shows that the project will be completed with this cost. In other words, the variance in the completion of the project is VAC = (817,279.02) USD (Equation 15).

$$VAC = BAC - EAC \tag{15}$$

VAC = 5,991,613.4 – 5,174,334.38 = 817,279.02

The chart of the earned value of the first stage is shown in Figure 5.

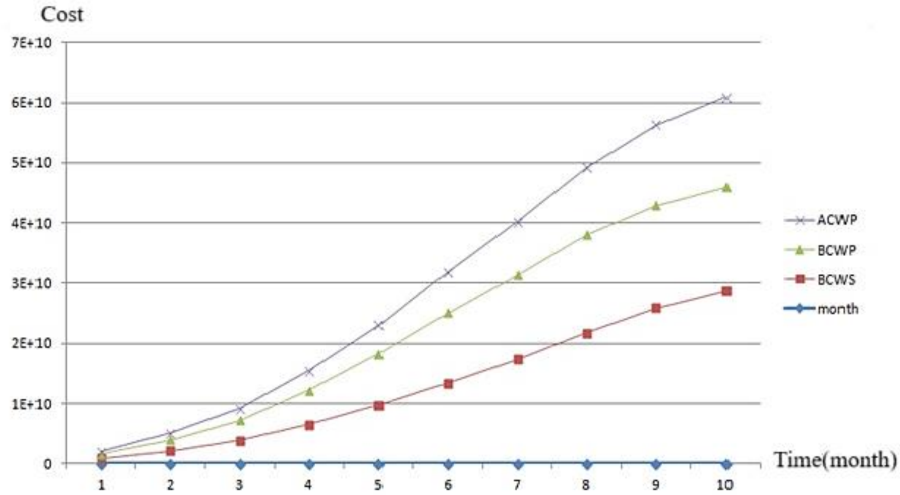

Figure 5. Chart of the earned value of the first stage

3.5.2. Second Stage

The scheduling and financial aspects of the project were reviewed and examined on March 11, 2022. By comparing the planned progress with the actual progress of the first and second stages based on the weighted completed work, actual progress was 55%, as summarized in Table 7, it became evident that there is a 25% delay within a 15-month timeframe, compared to the planned 25 months. This delay is because, despite predictions, the grout gallery and access gallery have not yet commenced, and they are behind schedule. The only activity that has been completed is the substructure of the access gallery.

The most significant impact, regarding physical weight, is related to the Clay core embankment, filters, and shell embankment. Additionally, while the dam's foundation has a progress rate of over 60%, its lower physical weight has limited the overall progress. This highlights the importance and influence of weight in this context.

Furthermore, the SPI (Schedule Performance Index) calculated in this stage is 0.75, according to equation 16, meaning that three-quarters of what was planned has been achieved, indicating a delay in the schedule, primarily due to the delayed start of the grouting gallery at this stage. The time variance (SV) of 25% confirms this, as calculated according to Equation 17. This contrasts the 0.60-time performance index in the initial stage, which indicates an improvement in time performance compared to 0.75 in this stage, as shown by the time variance.

Table 7. Cost indicators of the second stage

Item	Duration days	Baseline cost	BCWS	BCWP	AC
Project	615	5,991,613.40	4,200,422.85	3,139,187.56	3,285,469.00
Beginning	0	0.00	0.00	0.00	0.00
The main body of the Dam	615	5,991,613.40	4,200,422.85	3,139,187.56	3,285,469.00
Foundation of the Dam	606	2,230,461.92	1,432,375.29	1,354,019.35	1,373,835.21
Drilling and grout curtain	606	2,072,409.49	1,337,148.70	1,264,169.79	1,265,335.00
Drilling and reinforcement grout of the sides of the floor and foundation.	400	128,589.26	77,475.03	77,475.03	92,581.77
Concreting the filling of the sides of the floor and the foundation	400	29,463.17	17,751.56	12,374.53	15,918.44
Dam body	615	3,761,151.48	2,768,047.56	1,785,168.21	1,911,633.79
Clay core embankment	440	516,853.93	335,955.06	263,595.51	337,203.50
Filter and vertical drain	440	268,314.61	174,404.49	134,157.30	165,017.06
Shell embankment	460	2,424,968.79	1,744,923.19	1,357,982.52	1,378,776.53
Riprap execution	440	53,832.71	26,426.97	25,301.37	26,383.69
Grout gallery	448	433,341.24	422,497.65	0.00	0.00
Part A	175	111,302.54	111,302.54	0.00	0.00
Reinforcement work of part A	150	77,556.39	77,556.39	0.00	0.00
Molding work of part A	150	2,618.39	2,618.39	0.00	0.00
Structural concreting work of part A	150	31,127.76	31,127.76	0.00	0.00
Part B	448	322,038.70	311,195.11	0.00	0.00
Communicating the plans of part B	0	0.00	0.00	0.00	0.00
Tunnel excavation and stabilization operations	150	75,156.05	75,156.05	0.00	0.00
Reinforcement work of part B	130	180,024.97	180,024.97	0.00	0.00
molding work of part B	130	5,236.79	5,236.79	0.00	0.00
Tunnel lining work	130	34,987.52	34,987.52	0.00	0.00
Drilling and grouting part B	140	26,633.37	15,789.79	0.00	0.00
Access Gallery	210	63,840.20	63,840.20	4,131.50	4,253.02
Access gallery plans	0	0.00	0.00	0.00	0.00
The substructure of the access gallery	90	4,131.50	4,131.50	4,131.50	4,253.02
Reinforcement works of access gallery	90	36,870.58	36,870.58	0.00	0.00
Molding works of access gallery.	90	1,697.88	1,697.88	0.00	0.00
Structural concreting works of access gallery.	90	21,140.24	21,140.24	0.00	0.00
Ending	0	0.00	0.00	0.00	0.00

$$SPI = EV/PV \quad (16)$$

SPI= 3,139,187.56 / 4,200,422.85 = 0.747

$$SV\% = (EV - PV)/PV \quad (17)$$

SV%= (3,139,187.56 – 4,200,422.85) / 4,200,422.85 = (-0.25)

3.5.2.1. Analysis of cost indicators of the second stage

Table 8 shows that this phase's actual cost (AC) is 3,285,469 USD, while the planned cost (EV) is 3,139,187.56 USD. The project is behind schedule and has incurred additional costs on this date. This cost overrun is evident in most activities. The cost variance has been calculated in Equation 18.

$$CV = EV - AC \quad (18)$$

CV = 3,139,187.56 – 3,285,469 = (-146,281.44)

The negative variance of the additional cost represents the amount spent on the project. If the cost variance is expressed as a percentage, CV = -4.5%, the project has spent 5% more than the budget allocated for the planned work, indicating a cost performance index (CPI) of 95.5%. This means 95.5% of the incurred costs were within the initial budget (Equation 19).

$$CPI = EV/AC \quad (19)$$

CPI = 3,139,187.56 / 3,285,469 = 0.955

The To-Complete Performance Index (TCPI) of 1.05% indicates that if the executor wants to complete the project with the same initial estimate without incurring a loss, the performance should reach TCPI equal to 1.05 for the remaining work (Equation 20).

$$TCPI = (BAC - EV)/(BAC - AC) \quad (20)$$

TCPI = (5,991,613.4 – 3,139,187.56) / (5,991,613.4 – 3,285,469) = 1.05

The critical ratio of the second stage of the project: The critical ratio is obtained from equation 21.

$$CR = SPI * CPI \quad (21)$$

CR = 0.955 * 0.745 = 0.71

This value indicates the critical status of the project. A project with a CR of less than one suffered from being either behind schedule, over budget, or both. However, considering the values of CPI and SPI, the project is more critical in terms of time.

3.5.2.2. Forward forecasts using earned value indicators

Estimating Remaining Cost to Complete (ETC): The estimated cost to complete the remaining part of the project is obtained from Equation 22.

$$ETC = BAC - EV \quad (22)$$

ETC = 5,991,613.4 – 3,139,187.56 = 2,852,425.84

After this, the above cost should be spent until the project is completed.

A new estimate of the final cost: The estimated project cost at the end of the project is obtained from equation 23.

$$EAC = AC + (BAC - EV)/CPI \quad (23)$$

EAC = 3,285,469 + (2,852,425.84 / 0.955) = 6,272,302.34

From now on, the project will be completed with the above amount instead of 5,991,613.4 USD. In other words, the variance in the completion of the project is VAC = (-280,688.94) USD (Equation 24).

$$VAC = BAC - EAC \quad (24)$$

VAC = 5,991,613.4 – 6,272,302.34 = (-280,688.94)

A positive VAC means the entire budget will not be spent when the project is finished. When VAC is set to 0, the entire budgeted amount will have been spent by the time the project is finished. A negative VAC indicates that the project's final cost will be higher than anticipated.

The chart of the earned value of the second stage is shown in Figure 6.

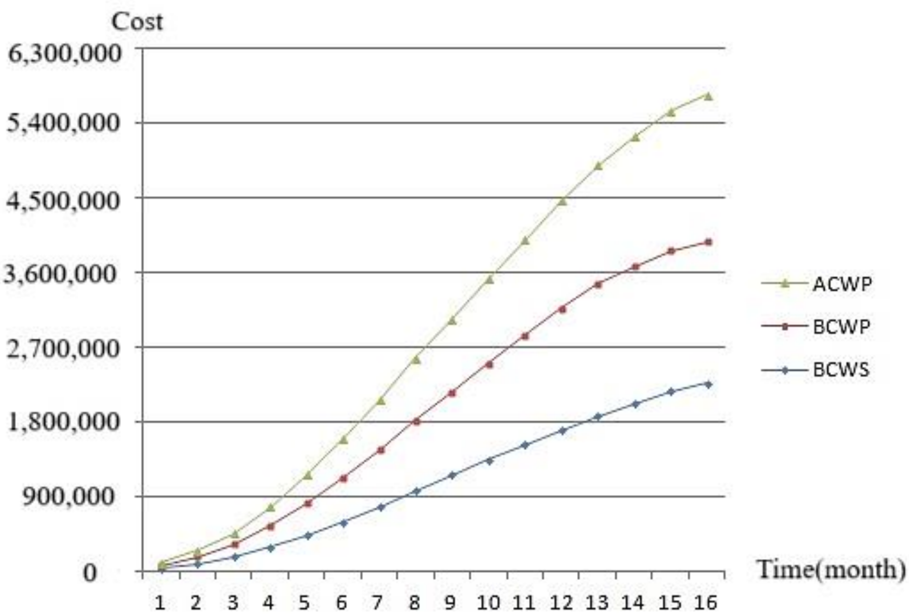

Figure 6. Chart of the earned value of the second stage

3.5.3. Third Stage

The project's scheduling and financial aspects were reviewed and reevaluated on October 26, 2022), and the results are summarized in Table 8.

Table 8. Cost indicators of the third stage

Item	Duration days	Baseline Cost	BCWS	BCWP	Actual Cost
Project	615	5,991,613.40	5,795,693.22	5,124,405.38	5,246,302.79
Beginning	0	0.00	0.00	0.00	0.00
The main body of the Dam	615	5,991,613.40	5,795,693.22	5,124,405.38	5,246,302.79
Foundation of the Dam	606	2,230,461.92	2,042,371.95	2,039,800.17	2,153,053.68
Drilling and grout curtain	606	2,072,409.49	1,884,319.52	1,884,319.52	2,001,178.53
Drilling and reinforcement grout of the sides of the floor and foundation.	400	128,589.26	128,589.26	126,017.48	126,242.20
Concreting the filling of the sides of the floor and the foundation	400	29,463.17	29,463.17	29,463.17	25,632.96
Dam body	615	3,761,151.48	3,753,321.27	3,084,605.21	3,093,249.11
Clay core embankment	440	516,853.93	516,853.93	403,146.07	408,156.47
Filter and vertical drain	440	268,314.61	268,314.61	211,968.54	214,005.49
shell embankment	460	2,424,968.79	2,424,968.79	2,012,724.09	2,024,227.22
Riprap execution	440	53,832.71	46,002.50	45,219.48	45,779.53
Grout gallery	448	433,341.24	433,341.24	361,864.47	358,702.70
Part A	175	111,302.54	111,302.54	96,000.02	96,041.12
Reinforcement work of part A	150	77,556.39	77,556.39	68,249.62	67,861.84
molding work of part A	150	2,618.39	2,618.39	2,225.63	3,511.78
Structural concreting work of part A	150	31,127.76	31,127.76	25,524.76	24,667.50
Part B	448	322,038.70	322,038.70	265,864.46	262,661.59
Communicating the plans of part B	0	0.00	0.00	0.00	0.00
Tunnel excavation and stabilization operations	150	75,156.05	75,156.05	65,385.77	59,055.76
Reinforcement work of part B	130	180,024.97	180,024.97	149,420.72	152,069.91
molding work of part B	130	5,236.79	5,236.79	4,241.80	4,253.35
Tunnel lining work	130	34,987.52	34,987.52	27,640.14	28,639.20
Drilling and grouting part B	140	26,633.37	26,633.37	19,176.03	18,643.36
Access Gallery	210	63,840.20	63,840.20	49,682.56	42,377.69
Access gallery plans	0	0.00	0.00	0.00	0.00
The substructure of the access gallery	90	4,131.50	4,131.50	4,131.50	4,253.02
reinforcement works of access gallery	90	36,870.58	36,870.58	29,496.46	34,996.25
Molding works of access gallery.	90	1,697.88	1,697.88	1,256.43	1,555.39
Structural concreting works of access gallery.	90	21,140.24	21,140.24	14,798.17	1,573.03
Ending	0	0.00	0.00	0.00	0.00

3.5.3.1. Comparing the planned progress with the actual progress of the first and second stages

With the implementation of physical weight and physical progress during this period, which is 71 days past the end of the scheduling program, most activities have not been completed except for the Concrete, the filling of the sides of the floor and the foundation, and the Substructure of the access gallery. The project has achieved 87% progress through physical progress activities.

3.5.3.2. Analysis of the earned schedule in the third stage

The time indicators at this stage are as follows (Equations 25 and 26).

$$SV = EV - PV \tag{25}$$

SV = 5,124,405.38 – 5,795,693.22 = (-671,287.84) <0

Negative Schedule Variance indicates the project is behind schedule.

$$SPI = EV/PV \tag{26}$$

SPI = 5,124,405.38 / 5,795,693.22 = 0.88 <1

SPI value less than (<) 1 indicates the project team is less efficient in utilizing the time allocated to the project.

3.5.3.3. Calculating the estimated end date of the project

The activities have led to the project's earned value amounting to 5,124,405.38 USD with their advancements. If there is a value close to this from the calculations table performed in MSP (Microsoft Project), we can see that this value is on day 562, and the examination time is on day 652. Therefore, the project's SPIt will be 85.5%, equation 27. According to equation 28, the project's duration will reach 719 days.

$$SPIt = EVt/PVt \tag{27}$$

SPIt = 5,124,405.38 / 5,991,613.4 = 0.855

$$Estimated\ project\ duration = Initial\ project\ duration\ /SPIt \tag{28}$$

Estimated project duration = 615/0.855 = 719 days

3.5.3.4. Analysis of cost indicators of the third stage

The project's physical progress has been achieved by applying the progress of each activity to 86%. In comparison, the percentage of planned progress was estimated at 97%, which means the project is 11% behind schedule. The table of MSP calculations shows that only the concreting of the filling of the sides of the floor and the foundation and the substructure of the access gallery have been completed. At the same time, it was expected that all operations of the grouting gallery and the access gallery would be completed, which caused a delay in the schedule. Cost changes are obtained from Equation 29.

$$CV = EV - AC \tag{29}$$

CV = 5,124,405.38 – 5,246,302.79 = (-121,897.41)

It means that 121,897.41 USD has been spent, more than the work done. The cost performance index is obtained from equation 30.

$$CPI = EV/AC \tag{30}$$

CPI = 5,124,405.38 / 5,246,302.79 = 0.976

It means that for every dollar spent, 0.976 dollars of work has been done. The additional cost index is obtained from Equation 31.

$$TCPI = (BAC - EV)/(BAC - AC) \tag{31}$$

TCPI = (5,991,613.4 – 5,124,405.38) / (5,991,613.4 – 5,246,302.79) = 1.16

This means that if the manager wants to complete the project within the budget, they must improve the project cost performance index from 0.976 to 1.16 in the future.

3.5.3.5. The critical ratio of the third stage

The critical ratio of the third stage is obtained from equation 32.

$$CR = SPI * CPI \tag{32}$$

CR = 0.88 * 0.976 = 0.86

This value indicates the critical status of the project. By comparing the critical status of the project in the second stage, which was 0.71, with the critical status of this stage, it is observed that the project has been significantly improved in terms of criticality.

3.5.3.6. Forecasting using earned value indicators of the third stage

Estimating Remaining Cost to Complete (ETC): The forecasted cost for completing the remaining part of the project is determined from Equation 33. Which shows the cost of continuing the project until its completion.

$$ETC = BAC - EV \tag{33}$$

ETC = 5,991,613.4 – 5,124,405.38 = 867,208.02

Estimate the new final cost: The estimated project cost at the end of the project (EAC), based on equation 32, is 6,134,835.6. Henceforth, the project will be completed with a budget of 6,134,835.6 USD, less than the previous-stage prediction, indicating an improvement in the project's status between the two stages. Compared to the project planning, VAC, the cost variance is -143,222.2 USD until the project is completed (Equation 34).

$$EAC = AC + (BAC - EV)/CPI \tag{34}$$

EAC = 5,246,302.79 + (5,991,613.4 – 5,124,405.38) / 0.976 = 6,134,835.6

$$VAC = BAC - EAC \tag{35}$$

VAC = 5,991,613.4 – 6,134,835.6 = (-143,222.2)

3.6. Comparison of Indicators of Three Stages

The comparison of the indicators of the three stages has been done in Table 9.

Table 9. Amounts of time and cost indicators for the review stages.

Indicators	First stage	Second stage	Third stage
Project progress percentage	21%	55%	87%
SV	40%	25%	11.6%
SPI	0.60	0.747	0.88
CV%	13.6%	-4.5%	-2.3%
CPI	1.158	0.955	0.976
TCPI	0.96	1.05	1.16

The variance in project scheduling (SV) from different stages, the less it shows in percentage terms, the better for the project. This value was 40% in the first stage and indicated a lag in the project, mostly due to the delay in starting the grouting gallery and access gallery operations. This value is 25% in the second stage, showing some improvement with the commencement of delayed activities. In the third stage, the time deviation reduces to 11.6% when approaching the project's scheduling deadline. Additionally, the Schedule Performance Index (SPI), which reflects project management efficiency in meeting scheduling objectives, has gradually improved from 0.6, despite a weak start, to 0.88.

Using the SPI (Schedule Performance Index), the project completion time at each stage is calculated in Table 10.

Table 10. Project completion time at each stage according to SPI of the stages

Stages	Project completion time (Days)
First stage	615/0.6 = 1025
Second stage	615/0.747 = 823
Third stage	615/0.88 = 699

Considering the schedule performance index, the project completion time increased significantly in the first and second phases. However, in the third phase, it decreased noticeably to 699 days, indicating an 84-day delay in project completion. In the cost analysis, the cost variance (CV) for the first phase decreased from 13.6% to -2.3% in the third phase. This is also evident in the cost performance index (CPI). In the first phase, this index was greater (1.158), which decreased to 0.955 and 0.976 in subsequent phases. Since the value of the cost performance index in the first phase is 1.16, indicating a failure to start some activities, it reflects a cost performance deficiency in the first phase. To maintain costs at the predicted budget at the same level (BAC), using the To-Complete Performance Index (TCPI), TCPI should be set to 0.96 so the project returns to the planned schedule. This technique will help to adjust the CPI in the later stages.

The forecast values in three stages are summarized in Table 11.

Table 11. Forecast values of different stages

Earned value indicators	First stage	Second stage	Third stage
BAC	5,991,613.4	5,991,613.4	5,991,613.4
EAC	5,174,334.38	6,272,302.34	6,134,835.6
VAC	817,279.02	-280,688.94	-143,222.2
ETC	4,556,485.93	2,852,425.84	867,208.02
CR	0.695	0.71	0.86

According to Table 11, the estimated completion cost (EAC) values in the first stage are lower than the initial budget (BAC). The cost variance at completion (VAC) value is +817,279.02 USD due to the delay in some activities per the scheduled plan. With the commencement of delayed activities in the second stage, the cost of completing the project is estimated to be 6,272,302.34 USD, which has been reduced to 6,134,835.6 USD in the third stage through proper cost and time management.

VAC incurred on the project is -143,222.2 USD. The remaining cost to complete (ETC) is estimated to be 867,208.02 USD.

4. Conclusion

A project's time and cost variances can be effectively determined by plotting a chart that compares actual project progress with the planned progress. This chart mirrors the project's performance, underscoring its successes and areas of improvement. Concurrently, it serves as a pivotal control tool in project management.

None of the methods used for measuring progress accurately depict actual project advancement as an amalgamation of time and cost parameters. However, as demonstrated in the earned value analysis, project progress can be effectively measured by integrating these two essential parameters: cost and time.

The Cost Variance (CV) over different periods is instrumental in identifying cost overruns and facilitating their control in subsequent phases. In this study, the first stage's cost variance percentage was 13.6%, indicating that the expenditure on work performed was below the estimated amount. In contrast, the second and third stages recorded CVs of -4.5% and -2.3%, respectively, signifying cost overruns. The Cost Performance Index (CPI) exceeded one in the first stage, denoting better-than-expected performance. However, it decreased to 0.955 in the second stage and to 0.976 in the third stage, indicating increasing cost deviations. To align costs with the initially estimated Budget at Completion (BAC), it is recommended that project management should implement a Time-Phased Cost Performance Index (TCPI). The TCPI was 0.96 in the first phase and increased to 1.05 and 1.16 in the subsequent phases. A TCPI of 0.96 is necessary if the project is to be completed within the budget and return to the planned schedule.

The Schedule Variance (SV) from different stages indicates that a lower percentage is preferable. Initially, the SV was 40%, reflecting a delay mainly due to the late start in the grouting gallery and access gallery operations. This figure improved to 25% in the second stage with the commencement of delayed activities and further reduced to 11.6% in the third stage as the project neared its scheduling deadline. The Schedule Performance Index (SPI), a measure of project management's efficiency in meeting scheduling goals, improved from a weak start of 0.6 to 0.88. Despite this improvement, the project completion time increased substantially in the first two phases but decreased significantly to 699 days in the third phase, marking an 84-day delay in project completion.

By comparing progress against the baseline plan, the earned value method allows for appropriate responses to the observed variances. This approach leverages actual progress for accurate time and cost forecasting, preventing the recurrence of past errors in future stages. It facilitates corrective actions to ensure that future time and cost-related issues are preemptively addressed, thus safeguarding the project.

Declaration of Competing Interest: The authors declare that they have no known competing of interest.

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