EVALUATING PUBLIC FUNDED CONSTRUCTION PROJECT PERFORMANCE THROUGH EARNED VALUE MANAGEMENT

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ABSTRACT

Earned Value Management (EVM), is a systematic approach for integrating cost, schedule and scope measurements that provides an efficient means to implement and monitor project status and performance. The application of Earned Value Management (EVM) in construction projects has emerged as a pivotal approach for project control and performance evaluation. This research paper delves into the utilization of EVM as a systematic methodology to integrate and measure the cost, schedule and technical accomplishments in the context of building construction. A case analysis of a specific public funded building project was conducted, detailing the implementation of EVM through the use of Primavera P6. The research explores the fundamental elements of EVM, including Planned Value (PV), Actual Cost (AC) and Earned Value (EV), analyzing on how these metrics contribute to comprehensive project evaluation. Cost Variance (CV) and Schedule Variance (SV) are analyzed, providing insights into the financial and temporal aspects of project management. The study also considers critical performance indices such as Cost Performance Index (CPI) and Schedule Performance Index (SPI), offering a comprehensive understanding of project implementation. The research engages with the practical steps involved in applying EVM in a project, including the creation of baselines, tracking project progress and updating schedules. Furthermore, the study evaluates the significance of EVM in providing early warnings and corrective action signals, enabling effective project management. The study identifies key factors influencing the adoption of EVM in construction projects, including the level of professional capacity and shortcomings in financial planning and time estimation. The findings strongly suggest for the inevitable establishment of EVM within the Bangladesh construction industry. Such implementation is deemed essential for enhancing project performance, ensuring accountability, leveraging professional tools and conducting thorough project performance reviews.

Keywords: *Project Management, Critical Path Analysis, Earned Value Management (EVM), Cost and Schedule Variance, Construction*

1. INTRODUCTION

The construction industry stands out as one of the most booming sectors globally, generating significant investment opportunities across various related fields. It serves as an important developmental indicator, particularly for emerging economies like Bangladesh. For the advancement of Bangladesh's economic growth, it is indirectly established with the construction sector. Annually, several public funded projects are carrying out which signifies the nation's development. However, the actual implementation of these projects encounters numerous critical issues, leading to the modification of project plans, exceeding budgeted costs, delays in completion and handover, ultimately affecting the public's estimated benefit. So, the importance of closely monitoring the progress of these construction projects is very essential. Historically, project progress was assessed using only two parameters: planned expenditure and actual expenditure. This approach facilitated a comparison between the planned and actual spending, offering insights into budget adherence. However, it lacked the ability to provide a comprehensive understanding of completed work, creating a notable gap in information.

In response to these limitations, Earned Value Management (EVM) emerged as a valuable tool, enabling project managers to overcome the deficiencies. EVM goes beyond mere financial tracking, offering a holistic view by integrating cost, schedule and performance data. This sophisticated approach enhances project control and decision making, ensuring a more accurate assessment of project advancements and resource utilization in the effective activities of construction industry.

In a study by (Shelke, et al., 2015), the focus was on the delay analysis, planning and scheduling of construction projects. The paper introduced the concepts of planning and outlined the steps involved in project planning. It also discussed scheduling, detailing the steps in project scheduling, as well as manpower management and planning. The authors presented a case study involving a residential apartment project, employing MS Project and MS Excel software. The paper concluded with a discussion on factors contributing to delays, including activities, unskilled labour, shortage of workers and materials, improper management, improper planning and weather issues. Another study by (Shaik, et al., 2014) delved into the role of Earned Value Management (EVM) for monitoring and controlling progress in construction projects. The key point highlighted was the ability of Earned Value Analysis to identify potential problems early in a project, enabling corrective actions. The study included a case study of a Duplex Apartment in Whitefield, Bangalore, using Primavera P6 software for EVM calculations. In seperate research by (Vandevoorde & Vanhoucke, 2006) a comparison of different project duration methods was conducted using earned value metrics. The study presented a generic formula to forecast project duration, linked to various project situations. The results indicated similar accuracy for each method in the linear planned value case. Introduction of learning curves leads to varying forecasting accuracies among the three methods. These projects demonstrated that the earned schedule was the sole approach providing satisfactory and dependable results throughout the entire project duration. Furthermore, (Verma, et al., 2014) proposed a process for scheduling and monitoring projects while also discussing the key parameters involved in calculating Earned Value for cost management in civil construction projects. The emphasis was on Project cost, a critical factor in project success and project management, utilized to enhance productivity in human resources and materials. The primary focus was on planned expenditure versus actual costs. The performance evaluation involved a case study of the foundation work utilizing Primavera P6 software for Earned Value Management System (EVMS). The study concluded that for earned value analysis the use of Primavera P6 software aids in achieving project completion within the scheduled time and cost.

Earned Value Management (EVM) serves as a method for systematically measuring performance and progress in projects. It integrates the assessment of cost, schedule, and technical accomplishments in a structured manner. This approach offers both clients and contractors about the capability to scrutinize schedule information, critical program and technical steps and detailed cost data. Initially developed for cost management, EVM has recent research trends indicate a growing interest in utilizing EVM to track performance indicators for predicting the total project duration. Earned value serves as an important tool, providing project managers with significant signals during the progression of work. This early indication allows managers to predict the final required funds within a narrow range of values,

facilitating timely adjustments if forecasted results are deemed unacceptable. The ultimate advantage lies in completing projects with more finalized features when project management actively monitors the true cost performance from the project's initiation. According to the Project Management Institute (PMI, 2008), Earned Value Management (EVM) is endorsed as the global standard for project performance measurement. Several authors, including (Burtonshaw Gunn et al., 2009), have introduced the concept of implementing EVM for cost control and overall performance measurement in construction projects. EVM acts as a monitoring tool for a project's progress against a baseline, encompassing fundamental elements for evaluating technical performance, as outlined by the Project Management Institute (PMI, 2011) and (Vyas & Birajdar, 2016).

In this paper, the investigation commences with an examination of earned value analysis, providing clarity on the parameters integral to the analysis. Within this study, EVM analysis is used for real project data and the findings are explicated through a detailed case study. A genuine project dataset is chosen as the subject of analysis. Following this, Primavera P6 is employed to execute earned value analysis on specific areas of activities pertinent to construction project. The procedural steps involved in conducting EVM analysis through Primavera P6 are outlined and the outcomes are critically evaluated with respect to the efficacy and efficiency of the performed activities.

1.1 Earned Value Management Terms

Earned Value Management stands as a well-established management system, seamlessly integrating schedule, cost and technical performance. This system facilitates the computation of schedule and cost variances, performance index and projections for project schedule duration. Positioned as a program management technique, Earned Value utilizes work in progress to anticipate future project outcomes. It encompasses fundamental elements essential for assessing a project's technical performance. The Earned value management interpretation and formulas are showed in Table 1.

Table 1: EVM interpretations and formula (Bhosekar & Vyas, 2012)

EVM Terms	Formula	Interpretations
Cost Variance (CV)	EV – AC	Negative value demonstrates over budget while positive value demonstrates under budget.
Schedule variance (SV)	EV – PV	Negative value is behind schedule while positive value is ahead of schedule.
Cost performance index (CPI)	EV / AC	Less than 1 demonstrates poor performance while greater than 1 is good performance.
Schedule performance index (SPI)	EV / PV	Less than 1 demonstrates poor performance while greater than 1 is good performance.
Estimate at completion (EAC)	AC + ETC	Actual plus a new estimate for remaining work.
Estimate to complete (ETC)	EAC – AC	Additional amount for the project cost.
Variance at completion (VAC)	BAC – EAC	Amount of over budget at the end of the project.
If SPI = 1, SV = 0; On schedule SPI < 1, SV < 0; Behind schedule SPI > 1, SV > 0; Ahead of schedule		If CPI = 1, CV = 0; on budget CPI < 1, CV < 0; over budgeted CPI > 1, CV > 0; under budgeted

1.2 Case Study

In this research, a case study involves a non-residential building construction project which is a public funded project. The project is anticipated to be completed within twenty-one months with a Budget at Completion (BAC) of 18.495 crore (BDT). The scope of the project encompasses civil works, sanitary works, plumbing, electrical installations, firefighting measures, steel structure assembly and the development of finishing look. The planned completion period of the project was twenty-four months. The Earned Value Management (EVM) analysis delves into 29 project activities, providing a

comprehensive assessment of project performance at various stages. The EVM analysis, conducted at the end of the eighteen months, serves as a crucial evaluation point. This analysis not only reveals the efficiency and pace of project execution but also indicates any additional profit or loss compared to the original project plan.

2. METHODOLOGY

The project is established within the designated division of the enterprise project structure and specific details such as the project plan start and finish dates are assigned. A main aspect involves associating the project with a calendar, which could be global or specific to resources. The process of creating a new project in Primavera includes several key steps.

Initiating a New Project: A project represents a compilation of activities and relevant details outlining a plan for delivering a product or service. This project is generated a distinctive project ID and name. Specific start and obligatory completion dates are allocated to the project. The breakdown of project activities is depicted in Figure 1.

Structure of Work Breakdown (WBS): The WBS is an organized hierarchy of tasks essential for the successful completion of a project. Each project possesses a unique WBS hierarchical structure as illustrated in Figure 2.

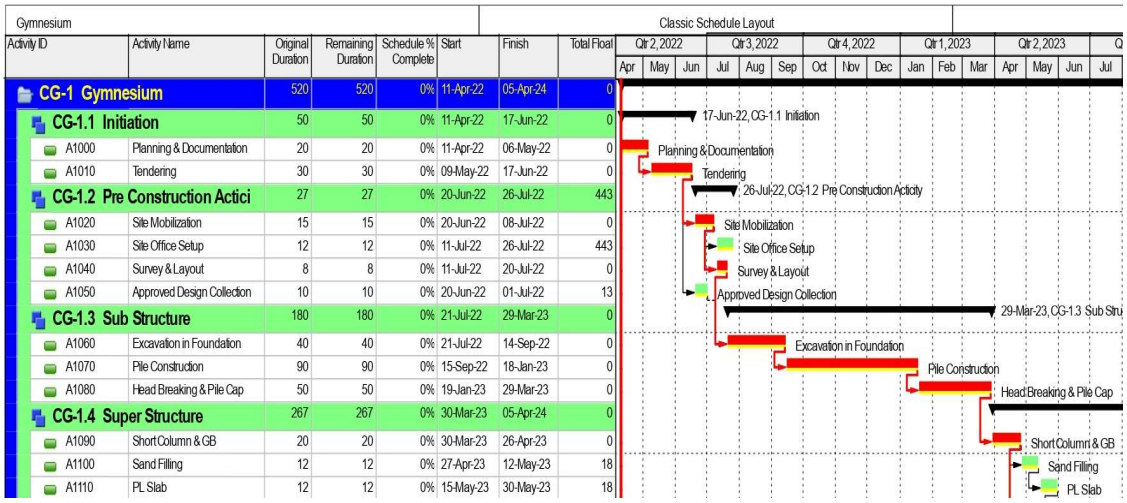

Figure 1: Assigning project activities

Identifying Activities: It contains the essential work components of a project, representing its smallest units. An activity generally encompasses various characteristics, such as activity ID, activity name, activity calendar, start and finish dates, predecessor and successor relationships, resources, and others as illustrated in Figure 3.

Interconnections Among Activities: Constructing a network involves linking activities, accomplished by assigning relationships between them. Common relationship types include Finish to Start (FS), Finish to Finish (FF), Start to Start (SS), and Start to Finish (SF). These relationships among activities are demonstrated in Figure 1.

Determining Activity Duration: When planning, the duration of each activity is entered in the original duration field.

Resource Assignment: Resources constitute the essential elements necessary for activity completion, including labor, equipment, and materials. In Primavera software, the initial step involves defining resources, followed by the assignment of the required resources to each activity.

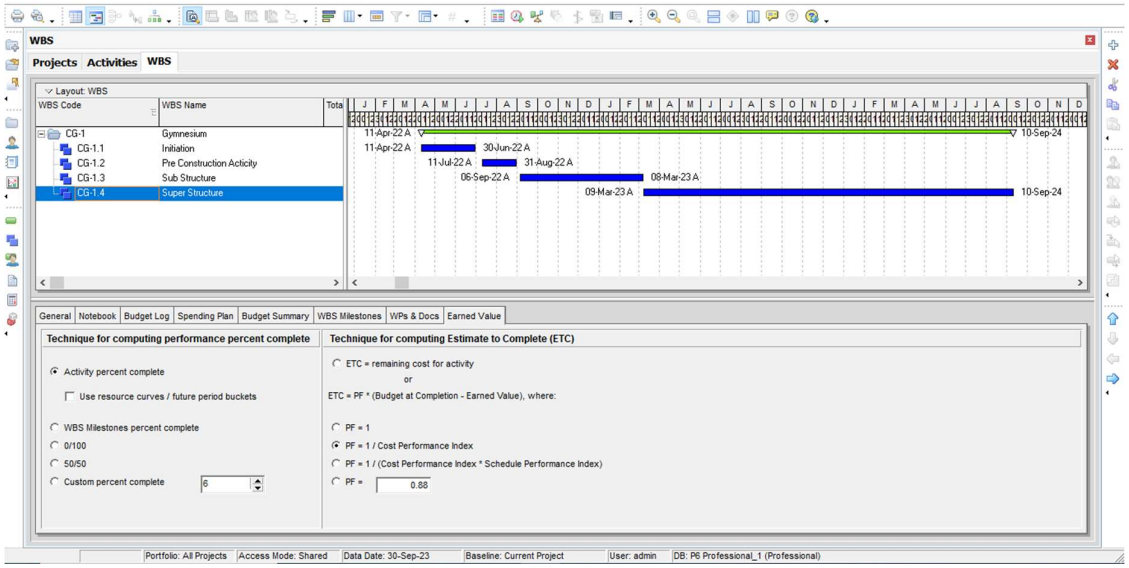

Figure 2: Work Breakdown Structure (WBS) of the project

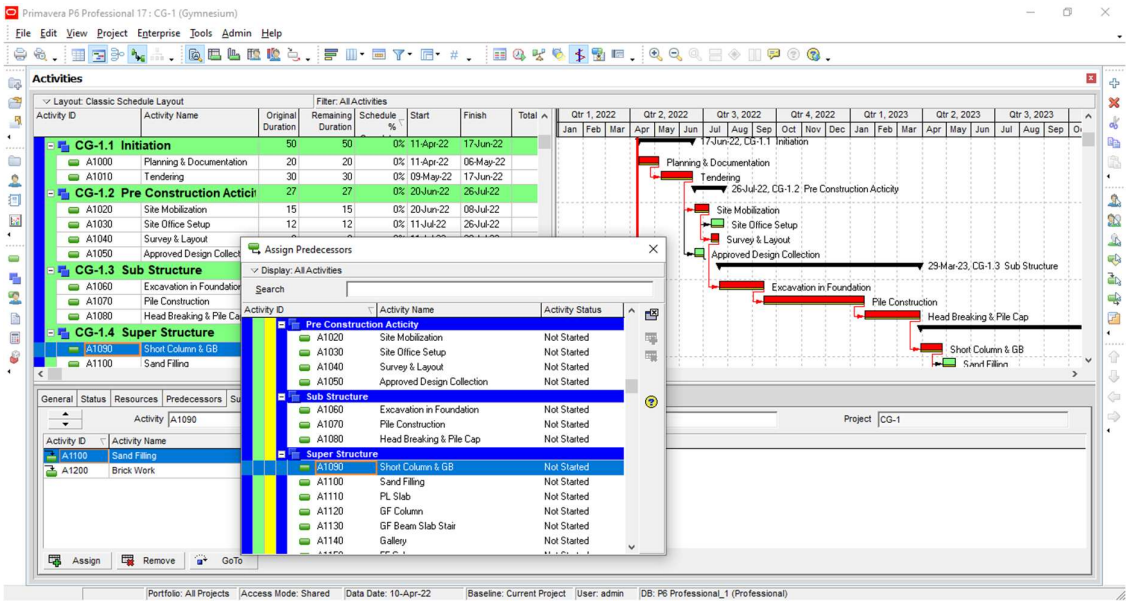

Figure 3: Assigning relationships among activities

Creating Baselines: A baseline serves as a standard benchmark, measuring the project's performance against established norms. To create a baseline, navigate to the project option in the activity toolbar, select baseline, and then assign the baseline to the project.

Update Schedule: Following the assignment of a baseline, the project schedule is updated to reflect changes and maintain alignment with the established baseline. This step ensures that the project's actual progress is in line with the planned baseline.

Tracking: The tracking is an important tool for analyzing a project's ongoing progress. It involves the periodic update and updating of data related to activities, allowing for real-time tracking and analysis.

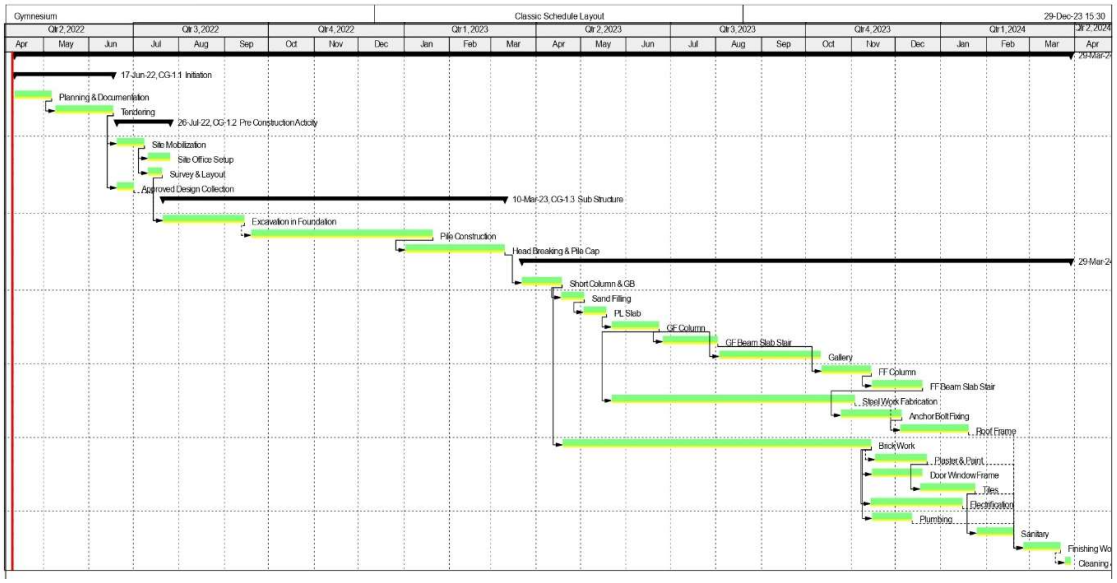

Figure 4: Grant Chart at initial planning of the project

3. RESULTS AND DISCUSSION

3.1 Critical Path

Prior to the project implementation, a detail analysis of the critical path was conducted, revealing fourteen activities essential for the project's successful execution. This initial analysis played a pivotal role in identifying the critical path and allowed for important measures to mitigate any additional delays during the construction project. The critical path during the initial planning phase is illustrated in Figure 5. Given the project's scheduled duration of twenty-four months, the subsequent analysis was conducted after eighteen months of construction. The critical path was then adjusted based on the actual project status, as indicated in Figure 6. Notably, by the end of September 23, it was observed that the critical activities had undergone changes. Six activities were identified as critical for the timely completion of the remaining construction work. The analysis of the critical path not only identified critical activities but also facilitated the formulation of proactive measures to address these activities. This approach enhances the project team's ability to anticipate and manage potential challenges, contributing to improved project efficiency and adherence to timelines.

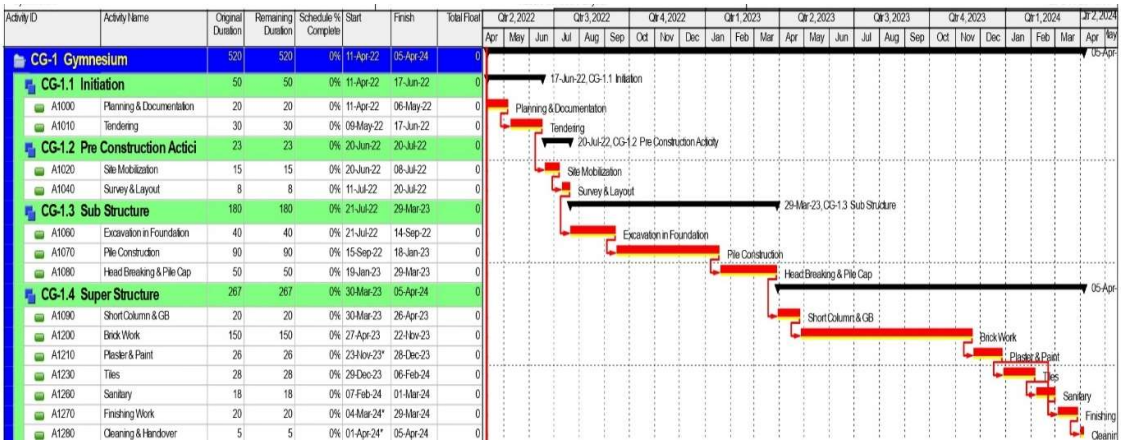

Figure 5: Critical Path at initial planning of the project

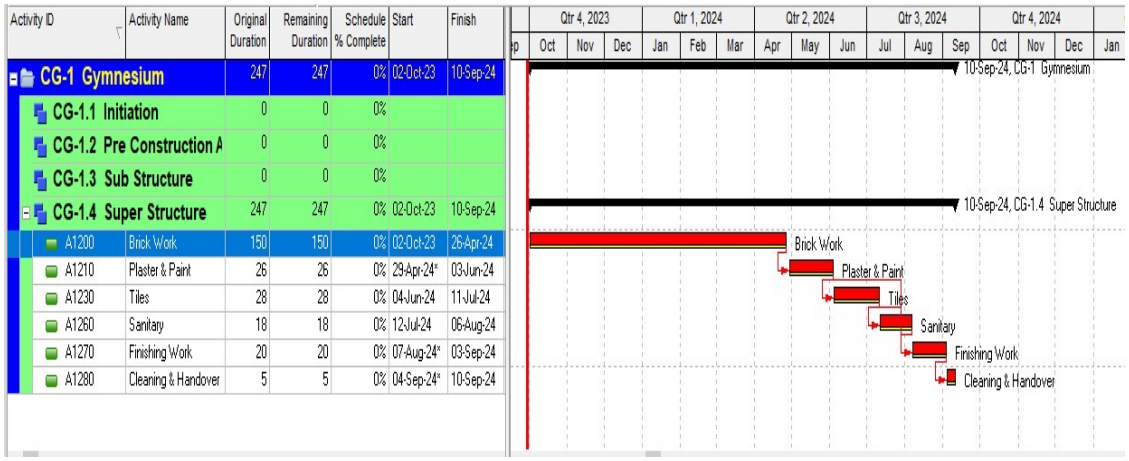

Figure 6: Critical path after the updated schedule

3.2 Cost Analysis

The analysis conducted provides insights into the efficiency of work implementation and the schedule of completion, showing potential additional benefit or loss for contractors, consultants or clients relative to the initial plans. This involves establishing the Cumulative Planned Value (PV) based on the analysis. Subsequently, the actual expenditure was providing the Actual Cost (AC) for the work done at a specific point in time. The derived performance metrics of Earned Value Analysis (EVA) are computed based on PV, AC, and EV. The S-Curve in Figure 7 illustrates the budgeted cost, remaining cost, and actual cost for updated project dates. It shows that within the first six months of project initiation, the actual cost was within the budgeted total cost. However, in the subsequent six months, the actual cost exceeded the project's budgeted cost. Over the next six months, the overall actual cost stayed within the budgeted cost, except for September 2023, where the actual cost exceeded the budgeted cost of the project, signifying a potential budget overrun. Additionally, the earned value cost falls below both the actual and planned value costs, indicating a potential schedule failure.

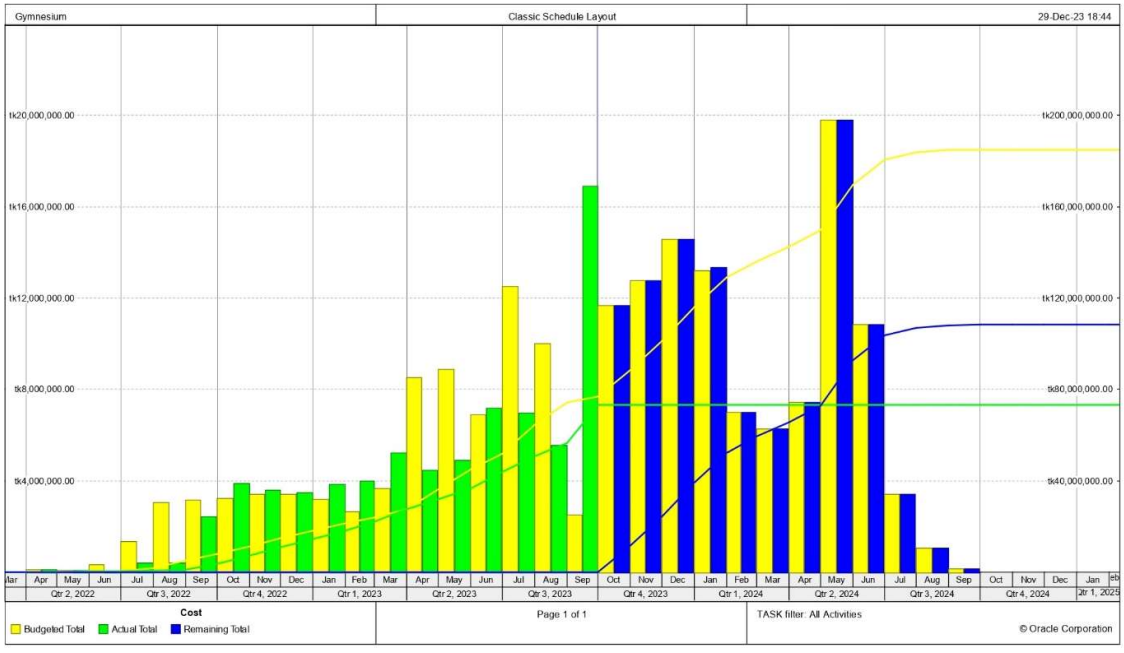

Figure 7: Cost analysis of the project

Figure 8 presents the cost analysis of the project through EVM. It illustrates the measuring elements Planned Value (PV), Actual Cost (AC) and Earned Value (EV) aligned with the construction schedule of the project using Primavera P6, showcasing a comprehensive evaluation of project performance metrics. It was found that the actual cost surpasses the budgeted cost estimated before the project completion, resulting in a negative remaining cost. The negative Cost Variance (CV) indicates that the project is in over budget.

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Earned Value Cost	Planned Value Cost	Actual Cost	Budgeted Total Cost	Cost Performance Index	Schedule Performance Index	Estimate To Complete
CG-1 Gymnesium		632	247	41.57%	tk72,814,868.00	tk76,876,380.00	393,180.00	tk184,953,524.00	0.99	0.95	tk113,509,457.51
CG-1.1 Initiation		50	0	100%	tk240,000.00	tk240,000.00	¢240,000.0	tk240,000.00	1.00	1.00	tk0.00
A1000	Planning & Documentation	20	0	100%	tk160,000.00	tk160,000.00	¢160,000.0	tk160,000.00	1.00	1.00	tk0.00
A1010	Tendering	30	0	100%	tk80,000.00	tk80,000.00	k80,000.0(	tk80,000.00	1.00	1.00	tk0.00
CG-1.2 Pre Construction Actici		27	0	100%	tk720,000.00	tk720,000.00	¢800,000.0	tk720,000.00	0.90	1.00	tk0.00
A1020	Site Mobilization	15	0	100%	tk240,000.00	tk240,000.00	¢280,000.0	tk240,000.00	0.86	1.00	tk0.00
A1030	Site Office Setup	12	0	100%	tk192,000.00	tk192,000.00	¢240,000.0	tk192,000.00	0.80	1.00	tk0.00
A1040	Survey & Layout	8	0	100%	tk128,000.00	tk128,000.00	¢160,000.0	tk128,000.00	0.80	1.00	tk0.00
A1050	Approved Design Collection	10	0	100%	tk160,000.00	tk160,000.00	¢120,000.0	tk160,000.00	1.33	1.00	tk0.00
CG-1.3 Sub Structure		180	0	100%	tk25,799,100.00	tk25,799,100.00	¢2,171,900.	tk25,799,100.00	1.16	1.00	tk0.00
A1060	Excavation in Foundation	40	0	100%	tk5,267,200.00	tk5,267,200.00	1,200,000.(	tk5,267,200.00	4.39	1.00	tk0.00
A1070	Pile Construction	90	0	100%	tk13,875,600.00	tk13,875,600.00	4,195,600.	tk13,875,600.00	0.98	1.00	tk0.00
A1080	Head Breaking & Pile Cap	50	0	100%	tk6,656,300.00	tk6,656,300.00	3,776,300.(	tk6,656,300.00	0.98	1.00	tk0.00
CG-1.4 Super Structure		379	247	31.68%	tk46,055,768.00	tk50,117,280.00	¢0,181,280.	tk158,194,424.00	0.92	0.92	tk113,509,457.51
A1090	Short Column & GB	20	0	100%	tk8,562,080.00	tk8,562,080.00	3,682,080.(	tk8,562,080.00	0.99	1.00	tk0.00
A1100	Sand Filling	12	0	100%	tk4,934,784.00	tk4,934,784.00	4,902,784.(	tk4,934,784.00	1.01	1.00	tk0.00
A1110	PL Slab	12	0	100%	tk4,440,744.00	tk4,440,744.00	4,432,744.(	tk4,440,744.00	1.00	1.00	tk0.00
A1120	GF Column	25	0	100%	tk7,810,600.00	tk7,810,600.00	7,770,600.(	tk7,810,600.00	1.01	1.00	tk0.00
A1130	GF Beam Slab Stair	28	0	100%	tk8,747,872.00	tk8,747,872.00	3,931,872.(	tk8,747,872.00	0.98	1.00	tk0.00
A1140	Gallery	50	13	100%	tk11,559,688.00	tk15,621,200.00	5,461,200.	tk15,621,200.00	0.75	0.74	tk5,432,313.51
A1150	FF Column	24	24	0%	tk0.00	tk0.00	tk0.00	tk4,742,784.00	0.00	0.00	tk4,742,784.00
A1160	FF Beam Slab Stair	25	25	0%	tk0.00	tk0.00	tk0.00	tk6,323,712.00	0.00	0.00	tk6,323,712.00
A1170	Steel Work Fabrication	120	120	0%	tk0.00	tk0.00	tk0.00	tk35,570,880.00	0.00	0.00	tk35,570,880.00
A1180	Anchor Bolt Fixing	30	30	0%	tk0.00	tk0.00	tk0.00	tk11,856,960.00	0.00	0.00	tk11,856,960.00
A1190	Roof Frame	35	35	0%	tk0.00	tk0.00	tk0.00	tk7,904,640.00	0.00	0.00	tk7,904,640.00
A1200	Brick Work	150	150	0%	tk0.00	tk0.00	tk0.00	tk5,434,440.00	0.00	0.00	tk5,434,440.00
A1210	Plaster & Paint	26	26	0%	tk0.00	tk0.00	tk0.00	tk3,161,856.00	0.00	0.00	tk3,161,856.00
A1220	Door Window Frame	25	25	0%	tk0.00	tk0.00	tk0.00	tk4,940,400.00	0.00	0.00	tk4,940,400.00
A1230	Tiles	28	28	0%	tk0.00	tk0.00	tk0.00	tk4,149,936.00	0.00	0.00	tk4,149,936.00
A1240	Electrification	45	45	0%	tk0.00	tk0.00	tk0.00	tk17,785,440.00	0.00	0.00	tk17,785,440.00
A1250	Plumbing	20	20	0%	tk0.00	tk0.00	tk0.00	tk2,964,240.00	0.00	0.00	tk2,964,240.00
A1260	Sanitary	18	18	0%	tk0.00	tk0.00	tk0.00	tk2,667,816.00	0.00	0.00	tk2,667,816.00
A1270	Finishing Work	20	20	0%	tk0.00	tk0.00	tk0.00	tk494,040.00	0.00	0.00	tk494,040.00

Figure 8: Earned value analysis of the project

3.3 Schedule Analysis

The initially planned project duration was 24 months. However, after the updated schedule at the 18-month mark, it is anticipated that a total of 30 months will be required for project completion, reflecting a significant 6-month delay from the initially prescribed project timeline as shown in Figure 9. This raises concerns about the project's adherence to its original schedule.

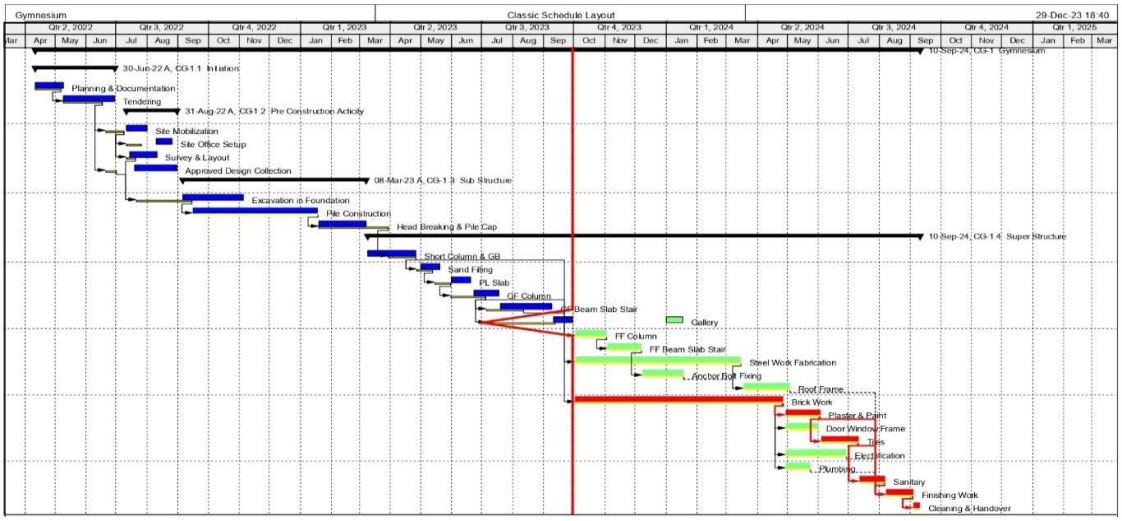

Figure 9: Grant chart of the project after the updated schedule

3.4 Project Overview using EVM

Table 2 provides a comprehensive overview of the project utilizing the Earned Value Management System. Key findings indicate a substantial 6-month delay in the project's construction timeline. The negative Cost Variance (CV) demonstrates a budget overrun, suggesting that the project is exceeding its allocated budget. Furthermore, the negative Schedule Variance indicates a lag in the project's progress according to the original schedule. Both the Schedule Performance Index (SPI) and Cost Performance Index (CPI) values less than 1 emphasize that the project is behind schedule and over budget. This implies that additional costs will be necessary for project completion, which is deemed challenging for effective project implementation.

Table 2: Overview of the EVM analysis

EVM Parameters	Tracking
Project Start Date	11 April 2022
Expected Duration	24 Months
Required Duration after EVM	30 Months
Tracking Date	30 September 2023
Budgeted Total Cost	184953524
Planned Value Cost (PV)	76876380
Earned Value Cost (EV)	72814868
Actual Cost (AC)	73393180
Cost Variance (CV)	-578312
Schedule Variance (SV)	-4061512
Estimate to Complete	186902638
Schedule Performance Index (SPI)	0.95
Cost Performance Index (CPI)	0.99

4. CONCLUSIONS

Through this comprehensive analysis, the research contributes to the growing body of knowledge on the practical application of EVM in the dynamic and complex landscape of public funded construction projects. The findings underscore the efficacy of EVM as a strategic tool for not only monitoring project performance but also for predicting and mitigating challenges, thereby enhancing overall project success.

The critical path analysis identified critical activities, enabling pre measures to avoid delays during the construction project. Changes in critical activities over time were monitored, offering insights into potential challenges to deal with activities and guiding proactive measures.

The project demonstrated a negative Cost Variance (CV), indicating a budget overrun. The S-curve analysis highlighted discrepancies between actual, planned, and earned values, signalling a potential schedule failure. The analysis showcased the efficiency and rate of work completion, along with insights into potential profit or loss variations. An analysis of the project's schedule duration revealed a significant delay of 6 months compared to the initial projection.

The summary table underscored project delay, budget overrun, and poor Schedule and Cost Performance Indices, emphasizing challenges in adhering to the planned schedule and budget.

The EVM analysis is adopted to gain insights into the performance and progress of the project in terms of time, cost and resource management. Primavera is used for calculation as it is an effective way in conducting Earned Value Analysis for projects. Through this technique, it becomes possible to identify and mitigate delays and significant issues related to time and cost. It serves as a means to verify if the project is adhering to its schedule and budget.

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