Analysis of the Limitations of the Earned Value Management Method and Evaluation of Modern Improvement Approaches in Project Management

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Abstract

The Earned Value Management (EVM) method is one of the most comprehensive tools for monitoring and controlling projects in terms of cost and schedule performance. Despite its effectiveness in providing performance indicators and forecasting project trends, limitations such as neglecting the critical path, reliance on accurate data, and weak applicability in agile or complex project structures have led researchers to seek methods for its improvement. This article aims to critically analyze the limitations of the Earned Value Management method and examine newly proposed approaches for its enhancement. In this regard, five improved models are reviewed, including the Advanced Earned Value Model, the Agile Earned Value Management approach, integration with Value Engineering, the Weighted Earned Value Method, and the Critical-Activity-Based Model. These approaches, by focusing on enhancing the accuracy of time and cost forecasting, incorporating scope changes, weighting activities, and analytically emphasizing the project's critical path, can effectively reduce the limitations of the traditional method. Finally, a comparative analysis among these approaches is conducted, and recommendations are provided for selecting an appropriate solution based on project type and execution conditions. The findings of this study can significantly contribute to more accurate decision-making by project managers for integrated control of time, cost, and performance.

Keywords: *Earned Value Management, Project Control, Time and Cost Control*

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1. Introduction

In modern project management, the integration of cost, time, and performance control has become indispensable for ensuring project success, especially in large and complex endeavors. Among the various tools designed for this purpose, the Earned Value Management (EVM) method stands out as one of the most comprehensive and widely recognized approaches for quantitatively assessing project progress in terms of schedule and cost performance [1]. EVM provides managers with a structured framework to measure project health by comparing planned work with actual progress and incurred costs, thus enabling objective evaluation of efficiency and early detection of deviations [2]. The method has been extensively adopted in diverse industries—including construction, information technology, defense, and aerospace—due to its ability to integrate financial and temporal dimensions of project performance [3].

However, despite its conceptual robustness and long-standing use, traditional EVM has shown limitations in its adaptability to complex, dynamic, and agile project environments. Researchers have identified several key shortcomings, including the method's reliance on static assumptions, inadequate consideration of the critical path, and excessive dependence on cost-based indicators for forecasting [4, 5]. As projects have become increasingly multidimensional, often requiring flexible execution frameworks and real-time performance analytics, the need to refine and extend EVM has gained considerable attention among both scholars and practitioners [6, 7].

EVM was originally developed in the 1960s as a tool for performance measurement in U.S. defense programs. Over the decades, it has evolved into a globally recognized standard for project monitoring and control, providing critical insights into schedule adherence, budget utilization, and work progress [8]. The fundamental principle of EVM is the comparison of three core metrics: Planned Value (PV), representing the budgeted cost of scheduled work; Earned Value (EV), indicating the value of completed work; and Actual Cost (AC), reflecting the cost incurred in performing the work. These parameters enable the calculation of performance indices such as Cost Performance Index (CPI) and Schedule Performance Index (SPI), which help project managers assess efficiency and predict future performance [9].

Nevertheless, empirical studies have demonstrated that while EVM effectively measures cost variance, it often underperforms in identifying schedule-related risks, particularly those tied to critical activities. As noted by Zheng [10], the method's inability to differentiate between critical and non-critical paths leads to overly optimistic schedule assessments. Similarly, Bovteev [5] argued that the traditional EVM approach, which aggregates performance across all activities, fails to account for the non-linear nature of project duration—since total project time is determined by the critical path rather than the sum of all activity durations. As a result, EVM can misrepresent schedule performance when delays occur in critical activities, even if overall cost metrics appear favorable.

According to Nizam [2], one of the central weaknesses of EVM lies in its dependency on precise and continuously updated data. In many practical scenarios, data inaccuracies, inconsistent reporting intervals, and variations in progress estimation compromise the reliability of EVM-based forecasts. Moreover, the method assumes that cost and schedule performance are linearly related, an assumption that often does not hold in complex, resource-constrained environments. This has prompted scholars to explore hybrid and enhanced models that address these structural weaknesses through integration with other analytical techniques and management philosophies [6, 11].

Recent developments in project management have introduced agile methodologies, digital transformation, and artificial intelligence as key drivers for enhancing project control and adaptability [12-14]. The fusion of Agile Project Management principles with EVM has been proposed as a promising avenue for improving responsiveness and flexibility in dynamic project environments [15]. Agile EVM, as discussed by Mayo-Alvarez [6], aligns the fixed time structure of sprints with earned value tracking, allowing project teams to measure progress iteratively and adjust their objectives in real time. This integration preserves EVM's quantitative control capabilities while incorporating agile adaptability, thereby ensuring more accurate alignment between client expectations and project performance.

Parallel to these developments, Value Engineering (VE) has been recognized as a complementary methodology to EVM, particularly in enhancing resource optimization and functional efficiency during the design and early planning phases. While EVM primarily focuses on project monitoring during execution, VE aims to maximize value by systematically analyzing the relationship between function and cost [8]. When integrated, these approaches create a synergistic framework that not only measures project performance but also continuously enhances it through cost-benefit optimization.

Furthermore, research has explored the use of Weighted Earned Value (WEV) and Critical Path–Based EVM (CPM-EVM) as advanced analytical techniques to overcome traditional EVM's limitations. The Weighted EVM assigns greater influence to critical activities by applying time-based weighting coefficients, thus improving the accuracy of schedule forecasts and ensuring that project performance metrics reflect true progress in key areas [10]. Similarly, the CPM-based EVM focuses exclusively on critical path activities, enabling early detection of schedule risks and improving the precision of time-based assessments [4]. Both methods respond to the growing recognition that time deviations, not just cost variances, are critical determinants of project success in modern management practice.

The literature also emphasizes that traditional EVM, while powerful in theory, faces significant challenges in real-world implementation. Stone [11] highlights that the success of EVM-based project control largely depends on rigorous planning and comprehensive training of project teams. Without proper understanding and discipline in applying the methodology, organizations may fail to leverage its predictive capabilities. Similarly, St-Martin [16] suggests that incomplete or outdated progress data can lead to erroneous variance analyses, particularly when completed activities distort the accuracy of performance indices. To mitigate this, researchers have proposed refining EVM by excluding completed tasks from ongoing calculations and focusing instead on active work packages—a modification that improves the sensitivity of schedule deviation detection.

Aramali et al. [7] further identified a persistent disconnect between academic research and industrial practice in EVM implementation. While academic studies tend to focus on theoretical extensions and performance metrics, practical applications often encounter issues related to organizational maturity, cultural resistance, and integration with existing project management systems. Bridging this gap requires aligning EVM systems with organizational capabilities and embedding them into broader performance management frameworks. Souza [17] and Santos [18] argue that advancements in project analytics, machine learning, and explainable AI can provide actionable insights to enhance EVM's predictive accuracy and transparency. These technologies can analyze historical data, identify hidden performance patterns, and support managers in making more informed and evidence-based decisions.

Another important dimension of EVM research relates to its integration with human and organizational factors. Studies such as Sidra [19] emphasize that team performance, communication efficiency, and leadership style significantly influence the accuracy and consistency of project reporting. A successful EVM implementation, therefore, depends not only on technical competence but also on effective coordination among project stakeholders. This aligns with Kerzner's [1] systems approach to project management, which advocates for holistic integration of technical, behavioral, and structural components to achieve project excellence.

The relevance of EVM has also been reinforced in the context of global project management transformation, where digital tools, collaborative platforms, and data-driven performance indicators redefine how projects are executed and evaluated. Aliyev [14] and Zia [12] underline that Industry 4.0 technologies—such as real-time dashboards, automation, and predictive analytics—are reshaping project control systems. These digital innovations enhance the transparency and traceability of EVM metrics, allowing continuous monitoring and adaptive control. Moreover, Zhang [13] observes that digital transformation strategies require not only technological integration but also cultural readiness within organizations, where EVM can serve as a quantifiable performance backbone to assess progress and maturity.

From a methodological perspective, the growing body of literature reflects a shift toward hybrid EVM frameworks that combine quantitative rigor with adaptive decision-making. For example, Silva [15] highlights the successful implementation of Agile EVM in public-sector software projects, demonstrating how iterative control cycles improve accountability and stakeholder engagement. Similarly, Christensen [3] conducted one of the earliest cost-benefit evaluations of EVM, revealing that despite its implementation costs, the method's benefits—such as early warning capabilities, improved decision accuracy, and enhanced transparency—generate substantial value for organizations. These insights reinforce the argument that EVM remains a cornerstone of effective project management, provided that its limitations are systematically addressed through innovation and contextual adaptation.

In summary, the evolution of Earned Value Management from a cost-focused monitoring tool to an integrated decision-support system represents a paradigm shift in project control. While traditional models provide a solid foundation for measuring performance, modern challenges such as agile environments, digital transformation, and increasing project complexity demand new hybrid frameworks. As the literature indicates, enhanced models—including Agile EVM, Value Engineering integration, Weighted EVM, and Critical Path–Based EVM—offer promising pathways for improving the precision, adaptability, and strategic relevance of project management practices [6, 8, 10]. This study contributes to this ongoing discourse by critically analyzing the limitations of the conventional EVM method and evaluating innovative approaches that aim to strengthen its analytical and practical effectiveness across diverse project contexts.

2. Methodology

This study employs a descriptive–analytical approach based on a systematic review of the relevant literature. Initially, studies related to the Earned Value Management (EVM) method were collected and examined to identify its advantages, limitations, and improvement strategies. Subsequently, the extracted data were integrated using qualitative and comparative analysis methods, and based on this synthesis, a final analytical and scientific summary was presented to enhance the effectiveness of this method in construction projects.

3. Overview of the Earned Value Management Method

The Earned Value Management method is recognized as one of the most comprehensive integrated tools in the field of project control. It was first developed in the 1960s in U.S. military projects and gradually gained prominence in construction, oil and gas, information technology, and industrial production sectors. The method was designed to link the three main dimensions of project management—cost, time, and physical progress—and aims to provide a realistic and measurable picture of the project's current status.

The foundation of Earned Value Management is based on the assumption that every project activity must be monitored in terms of the amount of work planned to be done (Planned Value), the amount of work actually completed (Earned Value), and the actual cost incurred (Actual Cost). Through key performance indicators such as Planned Value (PV), Earned Value (EV), and Actual Cost (AC), managers are able to identify time and cost deviations in the project and make informed decisions regarding corrective actions or program optimization.

In this section, the most important advantages and disadvantages of the Earned Value Management method are discussed to analytically highlight the strengths and weaknesses of this fundamental approach in project management.

Advantages of the Earned Value Management Method

- Integration of time and cost management
- Forecasting the final project cost and duration
- Quantitative measurement of progress

Disadvantages

- Potential errors in predicting the remaining project duration
- Requirement for a precise data collection system
- Challenging implementation in projects with frequent scope changes

According to the research of Nizam et al. [2], this method possesses the following strengths and limitations.

Table 1. Limitations and Strengths of the Earned Value Management Method

Limitations	Strengths
Conflict of interest between client and contractor	Integrates cost and scheduling into a single unified method
Ignores workflow, dependencies, and diversity in project control	Aligns the organization at both strategic and operational levels
No clear distinction between critical and non-critical tasks	Provides the current performance status and also forecasts future performance
Fails to consider project float	Based on the Work Breakdown Structure (WBS)
Measures performance in monetary units	Enables project managers to gain a more realistic understanding of the project's actual status
Does not offer a wide range of possible outcomes	Promotes systematic project management planning
	Provides early warning indicators
	Historical data obtained can be used for comparative analysis in future projects

According to Mayo-Alvarez et al. [6], the Earned Value Management method includes the following advantages and disadvantages:

Advantages

• Ability to forecast future project performance

• Early identification of deviations from the plan

Disadvantages

• Requirement for accurate and up-to-date data

• Complexity in implementation and analysis

In another study, a critical analysis of the effectiveness of the Earned Value Management method in construction projects was presented. This research used a real glass façade construction project in Brazil to evaluate the performance of EVM's main indicators throughout project execution. The results indicated that, although the project performed satisfactorily in terms of cost, it experienced delays in schedule and was ultimately completed three months behind plan.

The most significant finding of this research was that, despite EVM's ability to monitor cost performance, it failed to detect schedule-related problems promptly, particularly during the project's final stages. The authors further stated that excessive reliance on cost-based measures for assessing physical progress could result in unrealistic interpretations of the project's actual condition. For example, activities such as site mobilization or support works—cost-intensive but lacking visible physical progress—are recorded as progress within the EVM model, thereby reducing analytical accuracy.

In conclusion, this study emphasized that the traditional form of the Earned Value Management method cannot be used as a comprehensive tool for controlling construction projects. It suggested that to achieve more precise analysis, this method should be combined with complementary tools or more advanced management frameworks [8].

Aramali et al. [7], through a systematic review of the Earned Value Management System literature, highlighted a significant gap between academic theories and industrial applications of the method. Their findings showed that, while many studies focus on predictive analyses and performance indicators, insufficient attention has been given to real-world implementation conditions, organizational maturity, and operational needs. The authors emphasized that the successful design and implementation of the Earned Value Management System requires the integration of technical dimensions with human, cultural, and organizational components. These findings confirm that, to enhance the efficiency and adaptability of the Earned Value Management method to the complexities of modern projects, hybrid and multidimensional approaches must be adopted—an issue that forms the core of the present study.

Moreover, Christensen [3] conducted a comprehensive analysis evaluating both the costs and benefits of the Earned Value Management System, demonstrating that despite the high implementation cost, advantages such as improved decision-making accuracy, early warning signals, and enhanced project information transparency often yield greater added value than the associated expenses. He emphasized that one-sided evaluations based solely on costs or benefits cannot accurately reflect the real efficiency of the Earned Value Management System, and that a combined assessment provides a more logical basis for developing or improving this managerial approach. The ten advantages identified in his research are as follows:

1. A unified management control system providing reliable data
2. Integration of work, schedule, and cost through the Work Breakdown Structure
3. A database of completed projects useful for comparative analysis
4. The cumulative cost performance index as an early warning indicator
5. The schedule performance index as an early warning signal
6. The cost performance index as a predictor of the project’s final cost
7. An index-based method for forecasting the project’s final cost
8. The performance-to-completion index for evaluating the forecasted final cost
9. The periodic (e.g., weekly or monthly) cost performance index as a metric
10. The management-by-exception principle, which can reduce information overload

In another article examining the challenges of implementing the Earned Value Management method, the authors noted that project success within this approach requires precise planning and proper training of the project team [11].

A study conducted by Mayo-Alvarez et al. [6] showed that the Earned Value Management method has limitations in identifying and controlling project schedule deviations. They suggested that to improve performance, complementary methods such as the Critical Earned Value Scheduling approach should be used.

This study also stated that one of the main weaknesses of the conventional Earned Value Management method in schedule variance analysis lies in considering the project’s S-curve as a reference. To construct the S-curve, the cumulative cost of all planned activities must be calculated. The figure below shows the logical sequence describing the traditional S-curve and indicates that both “critical” and “non-critical” activities are included in its construction.

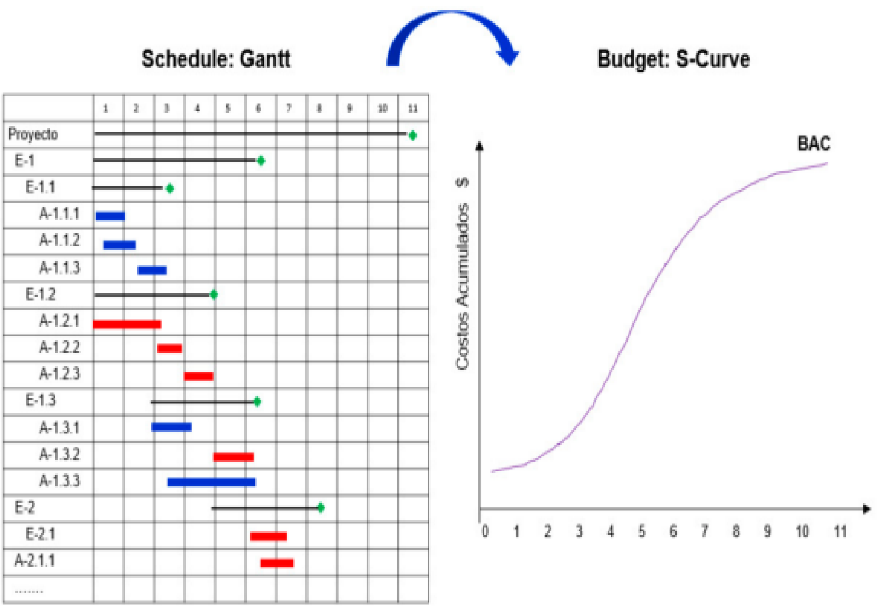

Figure 1. Logical sequence describing the traditional S-curve [6]

The following figure also illustrates that when the project is delayed, the Schedule Performance Index (SPI) always remains below 1. However, at the project completion date, these indices appear as optimal values—that is, without delay (SPI = 1 and Schedule Variance = 0)—which indicates that this index does not correctly detect or measure delays in activities that finish late.

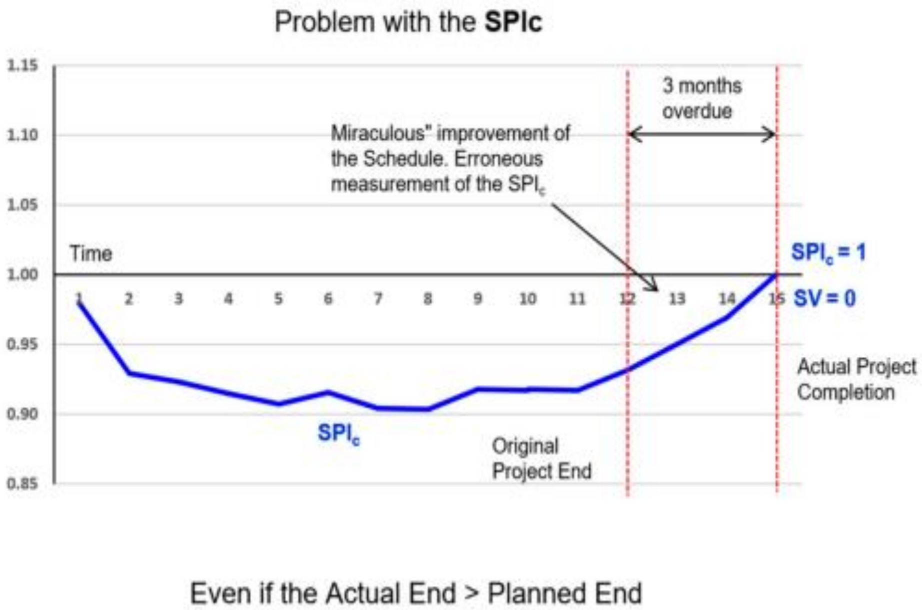

Figure 2. Problem in detecting and measuring delays at the end of activities [6]

To address this problem, it has been suggested that completed activities be excluded from the calculations, and only ongoing activities be considered [16].

Other studies have also shown that Earned Value Management can adequately identify and estimate cost overruns and cost savings during project execution. However, its use for monitoring and controlling schedule changes is insufficient because delays or advances in activity durations cannot be adequately detected through the conventional Earned Value Management method. Several scenarios exist in which schedule monitoring and control via EVM prove inadequate [9].

Earned Value Management does not focus exclusively on the project's critical tasks. It includes all tasks—both critical and non-critical—while the project's critical path plays the dominant role in determining the total project duration. The critical path is defined as a sequence of interconnected activities with zero float, known as critical activities.

This means that the monitoring and control of project schedule progress should focus on these critical activities since there is no room for delay, and any delay in one of these steps postpones the entire project [4].

The main characteristic of the key indicators—Planned Value (PV), Earned Value (EV), and Actual Cost (AC)—is their monetary representation. Consequently, future forecasts derived from EVM relate mainly to cost, while time forecasts are provided on a less significant and less convincing scale [5].

The fundamental difference between cost and time parameters is that time parameters cannot be arithmetically aggregated. While the project cost can be defined as the arithmetic sum of the costs of all project activities, the total project duration is **not** equal to the sum of the durations of all activities. Instead, it is defined by the length of the critical path. The Earned Value Management method cannot distinguish critical-path activities from non-critical ones; therefore, most of its shortcomings stem from its limited ability to predict the project's actual duration [10].

A review of the literature revealed that although the Earned Value Management method provides advantages such as simultaneous cost and time control, it does not perform fully and accurately in complex projects or projects with dynamic conditions. Issues such as neglect of the critical path, disregard for scope changes, and excessive dependence on cost-based data have reduced its effectiveness in some projects. Consequently, researchers have attempted to combine Earned Value Management with other methods to mitigate these limitations and improve its performance. The following section introduces the main hybrid approaches.

4. Proposed Approaches for Improving the Earned Value Management Method

This section presents and reviews five improved approaches that have been proposed in reputable scientific sources in a structured manner.

4.1. Advanced Earned Value Model (E-EVM)

In line with the enhancement of traditional project control tools, the Advanced Earned Value Model was introduced by López Pascual et al. (2021) as a practical development of the classical Earned Value Management framework for complex industries such as aerospace. This model was proposed to improve forecasting accuracy and enable the simultaneous management of projects with extensive Work Breakdown Structures (WBS). It is particularly applicable in projects involving thousands of subprojects with significant interdependencies [10].

The Advanced Earned Value Model maintains the core structure of traditional Earned Value Management, incorporating indicators such as Earned Value, Planned Value, Actual Cost, Cost Variance, Schedule Variance, Cost Performance Index (CPI), and Schedule Performance Index (SPI) as inputs. However, its innovation lies in two key dimensions:

Dual Time/Cost Perspective:

In the Advanced Earned Value Model, data are defined in time units (hours) rather than purely monetary units (e.g., euro or dollar). By applying an hourly rate for each organizational unit or activity, it becomes possible to convert time into cost and vice versa. This feature allows project managers to conduct financial and temporal analyses simultaneously, enabling more optimal decision-making.

Simultaneous Multi-Subproject Analysis Capability:

Unlike traditional Earned Value Management, which is typically applied at the macro project level, the Advanced Earned Value Model is designed to analyze the performance of thousands of subprojects both individually and collectively, providing graphical and numerical reports to identify deviations.

This model can also be integrated with scheduling tools such as Microsoft Project and uncertainty analysis methods like PERT or Monte Carlo simulation, which enhance the accuracy of cost and time forecasting.

Advantages of the Advanced Earned Value Model

- Improved forecasting accuracy in both cost and time through dynamic hourly rate application
- High scalability for multilayer projects with large data volumes
- Graphical reporting and facilitation of managerial decision analysis
- Iterative implementation capability and adaptability to the concept of continuous improvement

- Compatibility with common project management tools (MSP, Primavera, etc.)
- Potential integration with probabilistic models such as Bayesian inference to enhance decision-making accuracy

Disadvantages and Limitations of This Method

- Dependence on the accuracy of hourly rates: if the rates are based on inaccurate data or false assumptions, the forecasts and analyses will also be erroneous.
- Need for complex data preprocessing for each subproject and conversion into computable formats.
- Implementation complexity in organizations lacking digital infrastructure or trained personnel.
- Lack of direct coverage of qualitative or risk dimensions unless combined with complementary models such as QEVM or Bayesian frameworks.
- Risk of cumulative error if rates and performance information are not updated regularly.

The Advanced Earned Value Model can be considered an effective step toward aligning classical project management methods with the requirements of modern, multidimensional projects. This model is particularly suitable for environments with precise time data, extensive project breakdown structures, and the need for real-time performance monitoring. However, its success depends on the accuracy of baseline data and the organization's capability to process and continuously update information.

4.2. Agile Approach in Earned Value Management (Agile EVM)

One of the proposed approaches for improving the performance of the Earned Value Management method is its integration with the principles of Agile project management. In projects that proceed iteratively, incrementally, and based on shifting priorities, adopting an Agile approach enhances flexibility and team responsiveness. On the other hand, the Earned Value Management method provides precise cost and time indicators that enable quantitative control of project performance. In this regard, the integration of these two approaches is carried out such that the fixed time structure of sprints serves as the scheduling reference in Earned Value Management, and the earned value at the end of each iteration is calculated based on the actual and client-approved deliverables. This hybrid approach not only preserves the control capabilities of Earned Value Management but also, by leveraging the spirit of agility, enables better adaptability to change and increased stakeholder satisfaction [10].

Advantages of the Proposed Approach

- **Incorporation of the scope element:** Unlike traditional Earned Value Management, this model provides a more accurate assessment of the project's actual status by considering scope changes.
- **Compatibility with Agile philosophy:** The use of the concept of "iteration-level scope completeness" within the A-SPSRI index aligns the method with the inherent characteristics of Agile projects.
- **High predictability:** Simulation and statistical analysis (such as linear regression and percentage analysis) allow forecasting of potential deviations in time and cost.
- **Sensitivity analysis capability:** By calculating the impact of each element on project cost, critical project points can be identified.

Limitations and Disadvantages of the Approach

- **Computational complexity:** Quantification and simulation processes require accurate data and advanced statistical tools, which may not be feasible for small teams.
- **High expertise requirement:** Analysis and interpretation of results require deep understanding of Earned Value Management, Agile metrics, and statistical methods such as Monte Carlo simulation.
- **Limited generalizability:** Some results are based on real data from a specific company in Pakistan, which may not be applicable to all projects.
- **Lack of standard tools:** The absence of automation tools and supporting frameworks limits the practical implementation of this approach in many organizations.

The proposed approach represents a valuable step toward aligning Earned Value Management with Agile development principles. By adding the "scope" dimension and introducing quantitative and simulation-based analytical methods, this model addresses gaps in traditional methods. Although certain operational challenges exist in its implementation, its strong capability to monitor the threefold deviations of a project (time, cost, and scope) can lead to more accurate decision-making and more successful management of software projects.

4.3. Integration of Earned Value Management with Value Engineering (VE)

In addition to the developed models of Earned Value Management, Value Engineering is introduced as a complementary tool to enhance project efficiency. Value Engineering is a systematic and creative method for analyzing functions, identifying unnecessary costs, and optimizing resources without compromising quality. Unlike Earned Value Management, which focuses on monitoring projects during execution, Value Engineering is primarily applied in the design phase before implementation [10].

The classical Value Engineering process includes six key stages:

1. **Information:** Collecting data and understanding the project
2. **Function analysis:** Identifying and ranking primary and secondary functions
3. **Creativity:** Generating alternative low-cost solutions
4. **Evaluation:** Conducting technical and economic analysis of options
5. **Development:** Formulating selected proposals
6. **Presentation:** Formally submitting recommendations to project management

Advantages of Value Engineering

- Reduction of unnecessary costs without loss of quality or performance
- Increased efficiency in project resource utilization
- Enhancement of innovation and engineering creativity
- Improved stakeholder communication through functional analysis
- Prevention of rework and resource waste

Challenges and Limitations

- Requirement of interdisciplinary expertise for precise functional analysis
- Time-consuming early stages, particularly in compressed projects
- Resistance of some teams to design changes
- Risk of incorrect decision-making in the absence of accurate data
- Ineffectiveness in projects whose design phase has already been finalized

Although Value Engineering and Earned Value Management are distinct approaches, their integration can create a unified method for project control from design to execution. Value Engineering provides more accurate time and cost estimates, offering optimized inputs to Earned Value Management models. Furthermore, in iteration-based models, periodic Value Engineering analyses can be used to adjust trajectories and improve performance. Specifically, identifying low-value, high-cost activities through Value Engineering helps optimize resource allocation in Earned Value Management and makes project management decisions more targeted and effective.

4.4. Weighted Earned Value Method (WEVM)

In the traditional Earned Value model, all project activities are equally considered in calculations regardless of their impact on scheduling or overall project success. However, in real-world projects, some activities are significantly more critical and influential. The Weighted Earned Value Method introduces weighting coefficients based on time float, assigning greater weight to more critical activities so that their progress has a more realistic effect on the overall project performance indicators [10].

Advantages

- Improved accuracy in assessing project schedule performance
- Identification and prioritization of critical activities with the highest delay risk
- Reduction of analytical error caused by progress in low-priority activities
- Enhanced resource allocation based on actual priorities

Challenges

- Requirement of a precise scheduling structure for calculating weighting coefficients
- Analytical complexity in multi-phase projects or those with overlapping paths
- High sensitivity to up-to-date and reliable scheduling data

The Weighted Earned Value Method reflects the relative importance of activities within Earned Value calculations, thereby enabling more targeted decision-making and preventing superficial or uniform evaluations. This approach is particularly useful in projects with complex scheduling structures or limited resources, where it can significantly increase the accuracy of forecasting and project control.

4.5. *Critical Path–Based Earned Value Method (CPM-Based EVM)*

In the classical Earned Value approach, indicators are calculated holistically for the entire project. This can produce misleading or overly optimistic results when project progress occurs mainly in non-critical activities. The Critical Path–Based Earned Value Method focuses exclusively on activities along the critical path, enhancing the accuracy of analysis, especially in time-sensitive projects [10].

Advantages

- Increased accuracy in evaluating project schedule performance
- Focus on schedule bottlenecks
- Detection of discrepancies between apparent and actual progress
- Effective early warning tool for identifying critical delays

Challenges

- Requires continuous critical path analysis and frequent updates
- Possible neglect of indirect impacts from secondary paths
- Limited applicability in projects with multiple or variable critical paths

By distinguishing the critical path from other project paths, this method prevents misinterpretations of project progress. With high analytical precision, it directs the project manager's attention to the parts of the schedule most at risk of delay. It is particularly valuable in time-sensitive projects or those with stringent deadlines, serving as a key tool for control and decision-making.

5. Evaluation of Hybrid Earned Value Management Methods

The five approaches introduced in this section are designed to address the limitations of the traditional Earned Value Management model. Depending on project type, breakdown structure complexity, data availability, and managerial priorities, one or a combination of these approaches can be applied to optimize project control processes. In the following section, a comparative analysis of these models is presented, and a framework for selecting the most appropriate method under varying project conditions is proposed.

5.1. *Comparison of Proposed Improvements to Earned Value Management*

An examination of the five proposed approaches for improving Earned Value Management shows that each method addresses one or more of the key limitations of the traditional model and proves more effective under specific project conditions.

The Advanced Earned Value Model enhances scalability, temporal and cost accuracy, and predictive power through the use of time-based data and the capability for simultaneous multi-subproject analysis. It is best suited for large-scale projects with extensive Work Breakdown Structures and substantial data volumes.

In contrast, the Agile Earned Value Management approach bridges the classical method's gap in responding to change, particularly in software projects and dynamic environments, by incorporating domain analysis and metrics such as A-SPSRI. This approach introduces "scope" and "flexibility" dimensions into predictive models.

Integration with Value Engineering (VE), unlike purely numerical models, adds a performance–cost perspective and is mainly applied during design and optimization phases. VE serves as an effective complement to models like the Advanced Earned Value Model by enabling activity restructuring and cost reduction before the execution phase.

The remaining two methods—Weighted Earned Value and Critical Path–Based EVM—emphasize analytical precision and focus. Weighting activities ensures managerial decision-making is based on key tasks rather than overall averages, while focusing on critical path activities resolves the traditional model's inability to recognize critical paths and their direct impact on project timing.

Overall, although none of these methods alone can meet all project management needs, each can be applied effectively in an appropriate context to significantly enhance the performance of the traditional Earned Value Management method.

To provide an overview of the differences and key characteristics of the five discussed approaches, the table below summarizes the main comparative indicators.

Table 2. Comparison of Hybrid Earned Value Management Methods

Optimal Implementation Environment	Main Focus	Schedule Accuracy	Cost Accuracy	Implementation Complexity	Recommended Method
Large and complex industrial projects	Concurrent time–cost analysis	Very high	Very high	High	Advanced Earned Value Model
Agile and software projects	Scope and flexibility analysis	High	Medium	High	Agile Earned Value Management Approach
Design and project review phases	Performance–cost optimization	Medium	High	Medium	Integration with Value Engineering
Multi-priority and sensitive projects	Focus on key activities	High	High	Medium	Weighted Earned Value Method
Time-constrained and schedule-driven projects	Identifying direct effects of the critical path	Very high	Low	Low	Critical Path–Based EVM

For a more precise and quantitative analysis of the proposed approaches, a multi-criteria scoring system was applied. In this system, the five approaches were evaluated and ranked based on four key criteria:

- Accuracy in time and cost analysis (weight: 0.30)
- Flexibility in dynamic projects (weight: 0.25)
- Ease of implementation and execution (weight: 0.20)
- Transparency in managerial reporting and decision-making (weight: 0.25)

For each method, a score between 0 and 10 was assigned to indicate its degree of alignment with each criterion. Each score was then multiplied by its respective weight, and the sum of the four weighted values produced a final score out of 10 for each method.

Table 3. Scoring of Hybrid Earned Value Management Methods

Total Score (out of 10)	Accuracy (×0.3)	Flexibility (×0.25)	Ease of Implementation (×0.2)	Managerial Transparency (×0.25)	Proposed Method
6.95	9×0.3 = 2.7	5×0.25 = 1.25	5×0.2 = 1	8×0.25 = 2	Advanced Earned Value Model
6.95	8×0.3 = 2.4	9×0.25 = 2.25	4×0.2 = 0.8	6×0.25 = 1.5	Agile Earned Value Management Approach
6.8	7×0.3 = 2.1	6×0.25 = 1.5	6×0.2 = 1.2	8×0.25 = 2	Value Engineering
7.55	8×0.3 = 2.4	6×0.25 = 1.5	7×0.2 = 1.4	9×0.25 = 2.25	Weighted Earned Value Method
7.35	10×0.3 = 3	4×0.25 = 1	8×0.2 = 1.6	7×0.25 = 1.75	Critical Path–Based EVM

6. Discussion and Conclusion

The findings of this study underscore that while the Earned Value Management (EVM) method remains a foundational tool in modern project management, its traditional application faces significant constraints when confronted with dynamic, multi-phase, or data-intensive projects. The results confirmed that although EVM effectively integrates cost and time data to provide a quantitative view of project performance, its linear and cost-centered logic limits its reliability in complex project environments. Specifically, it was found that EVM's inability to differentiate between critical and non-critical activities and its neglect of schedule interdependencies often lead to misleading evaluations of time performance. This aligns with the argument of Zheng [10], who demonstrated that traditional EVM treats all activities equally, disregarding their relative impact on overall project duration. Similarly, Bovteev [5] emphasized that because total project time depends on the critical path rather than the aggregate duration of all activities, EVM's schedule variance analysis can provide overly optimistic projections.

The comparative analysis of hybrid EVM approaches demonstrated that integrating advanced frameworks such as the Advanced EVM model, Agile EVM, Value Engineering (VE), Weighted EVM, and Critical Path–Based EVM significantly enhances forecasting accuracy and project control. The advanced EVM model improved both scalability and predictive precision by incorporating time-based data and allowing simultaneous analysis of multiple subprojects, which supports the findings of Kerzner [1] on the importance of system-based integration in complex projects. Similarly, Agile EVM effectively addressed the issue of flexibility by synchronizing earned value analysis with iterative cycles—known as sprints—thereby making the method more adaptable to fast-changing conditions. Silva [15] also observed that such integration aligns quantitative control with agile responsiveness, ensuring better stakeholder engagement and iterative value delivery. The study revealed that hybrid methods combining EVM with agile frameworks improved not only schedule predictability but also stakeholder satisfaction, corroborating the evidence presented by Mayo-Alvarez [6], who demonstrated that hybrid EVM methods provide enhanced control through continuous feedback loops.

The results also supported the conclusion that integrating Value Engineering principles with EVM offers an effective strategy to address the shortcomings of traditional cost-focused monitoring. By linking functional analysis with cost optimization, the combined approach allows for continuous value improvement while maintaining real-time control during project execution. This finding is consistent with the view of Cândido [8], who noted that VE complements EVM by identifying inefficiencies early in the design phase, thereby reducing downstream cost and schedule deviations. Furthermore, the research revealed that both the Weighted EVM and Critical Path–Based EVM approaches enhanced the precision of performance evaluations. Weighted EVM, by applying dynamic coefficients to critical activities, ensured that progress measurement reflected actual project priorities. This corresponds with the insights of Zheng [10], who highlighted that incorporating time-dependent weights helps reduce analytical bias and enhances the accuracy of delay prediction. Similarly, the Critical Path–Based EVM provided more realistic schedule forecasts by focusing solely on activities with zero float, addressing one of the core deficiencies of the traditional model identified by Corovic [4].

Another key result of this study concerns the significance of data accuracy and digital integration in EVM applications. The findings confirmed that data quality plays a decisive role in determining the reliability of EVM outcomes. Projects lacking consistent data collection and validation systems exhibited a higher risk of misinterpretation in cost and time indices. This observation aligns with Nizam [2], who pointed out that EVM’s dependence on precise, up-to-date data often limits its applicability in practice. Similarly, Stone [11] argued that project success in EVM implementation is strongly tied to planning accuracy and the training of project teams in data interpretation and performance reporting. The study’s results demonstrated that the adoption of advanced analytical tools and digital dashboards substantially reduces the margin of error in EVM calculations. This is consistent with Santos [18], who emphasized that explainable machine learning algorithms can enhance predictive accuracy and provide transparency in project performance evaluation.

In addition, the study reinforced that integrating EVM with data analytics and AI-based systems can significantly strengthen its predictive and diagnostic capabilities. By incorporating AI-driven models, managers can process vast data streams in real time to detect anomalies, simulate outcomes, and generate early warnings for schedule or budget deviations. These findings support the claims of Zia [12], who noted that artificial intelligence has emerged as a crucial enabler for smarter and more adaptive project control systems. Likewise, Souza [17] reported that project management maturity improves when organizations use data-driven decision support systems, as these systems promote consistent monitoring and continuous improvement. The present results suggest that future EVM systems should integrate predictive analytics, adaptive learning algorithms, and feedback-based performance indicators to evolve into intelligent control frameworks.

From an organizational standpoint, the results highlight that the success of EVM implementation depends not only on methodological accuracy but also on human and cultural factors. The study observed that organizations with higher levels of project management maturity demonstrated more consistent and meaningful use of EVM metrics. This finding corroborates the evidence provided by Sidra [19], who showed that team collaboration, leadership quality, and communication efficiency significantly affect the reliability of EVM data and decision-making. Aramali [7] also noted a persistent disconnect between academic theory and industrial practice, with many organizations struggling to adapt EVM to their specific operational realities. The current study supports this conclusion, showing that companies often face resistance to adopting new EVM variants due to lack of training, rigid workflows, and absence of supportive digital infrastructures.

Furthermore, the findings align with the systems-based perspective of Kerzner [1], who asserted that successful project control frameworks must integrate technical, behavioral, and organizational components. In this regard, EVM should not be viewed as an isolated analytical tool but as part of a larger ecosystem encompassing value management, risk control, and stakeholder communication. Similarly, Christensen [3] provided empirical evidence that although EVM implementation involves considerable costs, its long-term benefits—such as improved transparency, early warnings, and informed decision-making—outweigh the expenses when effectively embedded in a holistic management framework.

The study's results also emphasized the inadequacy of traditional EVM metrics in detecting schedule deviations near project completion. This outcome mirrors the observation of St-Martin [16], who demonstrated that at the project's end, the Schedule Performance Index tends to revert to unity (SPI = 1), giving the false impression of schedule adherence even when substantial delays have occurred. The current findings reaffirm that reliance solely on SPI and CPI can obscure critical time-based inefficiencies. Therefore, combining EVM with Critical Path Method (CPM) analysis and Weighted Schedule Indices enhances time variance measurement and improves decision-making accuracy in complex environments.

Moreover, the comparative scoring and multi-criteria evaluation conducted in this study revealed that hybrid EVM models outperform traditional methods across several key dimensions—namely, time accuracy, cost accuracy, managerial transparency, and flexibility. Among the models assessed, the Weighted EVM and CPM-based EVM achieved the highest scores in time-based performance, while the Advanced EVM and Agile EVM exhibited superior adaptability to large-scale and rapidly changing project environments. These results resonate with Zhang [13], who emphasized that digital transformation and flexibility are now essential prerequisites for project success. Similarly, Aliyev [14] found that integrating digital tools into project management enables better real-time coordination and facilitates decision-making through automated feedback mechanisms. The study's results support these conclusions, demonstrating that hybrid EVM frameworks integrated with modern digital infrastructures provide a more realistic, data-driven basis for managing time, cost, and scope performance.

The current findings also validate the premise that project control methodologies must evolve to match the complexity of contemporary organizational environments. As observed by Santos [18] and Souza [17], the increasing availability of real-time data and machine learning tools opens new avenues for enhancing EVM through predictive and prescriptive analytics. The study's evidence indicates that when combined with Agile principles and Value Engineering, EVM becomes a dynamic decision-support tool rather than a static performance measurement framework. This transformation aligns with the broader transition toward intelligent and adaptive project management systems envisioned in recent studies [12, 15].

Finally, the results reaffirmed the importance of continuous organizational learning in sustaining the effectiveness of EVM-based systems. Projects that implemented iterative review cycles and continuous feedback mechanisms achieved higher performance accuracy and lower deviation rates. This observation supports the continuous improvement principles discussed by Aramali [7] and Stone [11], who highlighted that feedback-driven adaptation is critical for aligning project performance with strategic objectives. Therefore, EVM's future evolution should focus on dynamic adaptability, data integrity, and the integration of human intelligence with automated analytics to ensure enduring project success in a rapidly changing management landscape.

Despite its contributions, this study is subject to several limitations. First, the evaluation of EVM methodologies was based primarily on secondary data and literature synthesis rather than longitudinal case analyses, which may restrict the generalizability of the findings. Second, the assessment relied on published studies that employed varied methodological designs, which could introduce inconsistencies in comparing outcomes across contexts. Third, the study's multi-criteria scoring system, though comprehensive, was developed through expert judgment rather than empirical testing, which may introduce subjective bias. Fourth, the research focused on high-level conceptual models rather than detailed implementation metrics, limiting its applicability for practitioners seeking immediate operational tools. Lastly, the study did not empirically test the proposed hybrid EVM approaches on actual ongoing projects, which would be necessary to validate their predictive power and practical feasibility.

Future studies should consider conducting empirical, cross-industry evaluations of hybrid EVM frameworks to assess their real-world effectiveness under varying conditions of project complexity, uncertainty, and digital maturity. Experimental or simulation-based research could provide quantitative evidence on how weighting schemes, critical path integrations, or agile metrics influence forecasting accuracy and managerial decision-making. Additionally, future work should explore integrating artificial intelligence, predictive analytics, and blockchain into EVM systems to enhance transparency, trust, and data security. Longitudinal studies could also examine how organizational culture, leadership style, and team communication mediate the successful implementation of hybrid EVM systems. Finally, comparative studies across sectors—such as construction, software development, and public infrastructure—could provide valuable insights into the contextual adaptability of advanced EVM approaches.

Practitioners should focus on strengthening data collection accuracy and ensuring timely updates of project information to enhance the reliability of EVM indicators. Organizations should also invest in training programs that develop both technical and analytical competencies among project managers to facilitate accurate interpretation of EVM metrics. Implementing integrated digital platforms can streamline reporting, automate variance detection, and enable real-time decision support. Furthermore, project teams should adopt a hybrid control approach—combining EVM with agile principles, value-based assessment, and critical path analysis—to achieve balanced control over time, cost, and scope. Lastly, continuous review and feedback mechanisms should be institutionalized to ensure adaptive learning and iterative improvement in project performance management.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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