Exploring Benefits, Critical Success Factors and Barriers of Earned Value Management in Construction Projects: A Preliminary Evaluation

Chitti Babu Kapuganti[1], Balaji KVGD[2], Sudhakar Mogili[3*], Santhosh Kumar Thainana[1]

[1]School of Architecture, GITAM University, India
[2]Director, RGUKT, Andhra Pradesh, India
[3]Department of Civil Engineering, P.V.P. Siddhartha Institute of Technology, Vijayawada, India

ABSTRACT: Timely and cost-effective completion of projects is crucial for achieving project goals. Earned Value Management (EVM) has been accepted as a very successful quantitative technique for monitoring, measuring, and managing project performance across several industries. The use of EVM in construction projects is on the rise due to its considerable importance. However, there is still the potential to improve its implementation in construction projects. This paper aims to identify the key benefits, critical success factors and barriers of adoption of EVM in construction projects. A set of 10 benefits, critical success factors and barriers was initially created in the first phase. In second phase, Subject matter experts evaluated the content of these items based on their relevance, clarity, and simplicity using a 4-point Likert grading scale. Each item's content validity index and interrater reliability were computed, and five benefits, critical success factors and barriers which maintained content validity in the final version of the questionnaire. In third phase, 73 valid responses from construction project stakeholders in India with the help of Google Forms. The data was analysed using the Jamovi 2.3.26 software, Finally, in forth phase, mean weighted value and relative importance index analysis yielded two key benefits, two barriers and two critical success factors. The research sample consisted solely of construction project stakeholders from India. This study will be useful for stakeholders' decision-making in adopting of monitoring methods for construction projects.

KEYWORDS: Construction Projects, Cost Monitoring, Earned Value Management, Questionnaire Survey, Relative Importance Index, Schedule Monitoring

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I. INTRODUCTION

Project performance is one of the fundamental considerations in project management, alongside time and money (Rashid et al., 2021). An established project management plan is expected to be implemented with the commencement of a construction project. However, deviations can occur from management's initial plan throughout the implementation of a project, as several internal and external elements impact the project's performance. To ensure the successful completion of projects within the designated timeframe and financial constraints, it is vital to monitor the project's performance. The Earned Value Management (EVM) methodology has been recognized as a very effective quantitative tool for evaluating, assessing, and managing project performance (Lennon and Francis, 2010).

EVM is a method of project management that connects resources, deadlines, and financial and technical constraints (Gowan, Mathieu and Hey, 2006). EVM technique provides project managers with a valuable tool for assessing the overall progress of a project (Chen and Zhang, 2012). EVM relies on performance data, such as the actual cost of completed work and the associated predicted earned value, to predict the overall duration and cost of the project upon completion (Wibiksana, 2012). It assists organizations in assessing project progress by comparing planned value to earned value and actual cost. This practice facilitates making well-informed judgments and implementing appropriate adjustments to ensure the project remains on its intended trajectory (Giammalvo, 2022).

EVM provides a database of past projects for evaluation and comparison, allowing for early detection of schedule and cost overruns (Rashid et al., 2021). EVM is a project management control system that monitors project performance, focusing on schedule adherence, cost control, and estimation of projected final cost (Aramali et al., 2022).

EVM can be utilized in various contexts, including but not limited to energy projects (Lewis and Hazzard, 2013), oil and gas refineries (Jasim, Ibrahim and Hatem, 2023), construction (Rashid et al., 2021), manufacturing sector (Suenaga, Tei and Honiden, 2018), defence, underground mining (Wibiksana, 2012), software (Stanek and Kuchta, 2020), data warehouse management (Gowan, Mathieu and Hey, 2006), and NASA projects (Jones, 2023).

The adoption of EVM in construction projects has been increasing in recent times. However, there is still potential for enhancing its application in construction projects. It is crucial

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to recognise the benefits, barriers and critical success factors of using EVM in construction projects to increase the use of EVM in future projects.

The purpose of this research is to identify the key benefits, key barriers, and key critical success factors for implementing EVM in construction projects. The methodology used begins with a list of items representing the benefits, critical success factors, and barriers of EVM in construction projects based on a literature review, followed by eight construction project experts who were asked to comment on the items' relevance, clarity, and simplicity. The expert responses were evaluated using the Item Content Validity Index (I-CVI) and the Modified Kappa Statistic (k*). The selected items from the analysis were framed as a questionnaire and obtained 73 valid answers from construction project stakeholders in India with the help of Google Forms. The data was analysed using the Jamovi 2.3.26 software, which used Kaiser-Meyer-Olkin (KMO) tests, Bartlett's sphericity, Cronbach's alpha, and McDonald's ω. The questionnaire results revealed two key benefits, two critical success factors, and two major barriers to using EVM in construction projects. This paper is divided into four sections: literature review of benefits, critical success factors and barriers to implementing EVM in construction projects, research methodology, results and discussions, and conclusions.

II. LITERATURE REVIEW

A. Benefits of adopting EVM in construction projects

The earned value (EV) project control method can avoid delays and budget overruns. The schedule performance index (SPI) and the cost performance index (CPI) are fundamental in EV systems. However, the information provided by such metrics is not necessarily reliable. The difficulties arise when applying theory, such as assessing updated schedules, analysing cash flows, or determining the Schedule Performance Index (Lennon and Francis, 2010). EVM compares the executed work with the planned and actual work to depict the deviation in cost and time. It facilitates the project team in reaching its cost goals and also helps the project team in achieving its schedule objectives (Anbari, 2004).

EVM integrates work, schedule, and cost using a work breakdown structure, providing reliable data for comparative analysis. EVM provides an early warning signal of performance problems, contributes to achieving project cost objectives, and enables the integration of work, schedule, and cost (Kapuganti et al., 2023). EVM is crucial for timely project completion and complies with statutory requirements for proof of costs (Teixeira Netto et al., 2020). EVM aids in meeting project deadlines by monitoring buffer utilization and mitigating potential risks to project deadlines (Martens and Vanhoucke, 2017). The identified benefits of implementing EVM in construction projects from the literature are given in Table 1.

B. Critical Success Factors of adopting EVM in construction projects

EVM implementation requires alignment with industry standards, internal rules, regulatory requirements, customization, training, and technology use. Active support from senior management and project managers is crucial for effective EVM implementation (Kapuganti et al., 2024). Team members' acceptance of EVM is vital for effective deployment (Morad and El-Sayegh, 2016). Organizational resources are essential for training, technology, personnel, and other crucial elements (Alzraiee, 2018). Evaluating EVM maturity is essential for enhancing project management and decision-making (Vaibhava and Prakash Rao, 2019).

An adaptable EVM system is crucial for managing project changes. Advanced training in EVM offers comprehensive education, including fundamental principles, real-world implementations, software tool mastery, data analysis, and problem-solving (Priyo, 2021). Project managers need specialized knowledge, technical expertise, effective communication skills, strong leadership qualities, and administrative abilities (De Marco and Narbaev, 2013). The training and awareness strategy for the EVM system includes formal sessions, workshops, modules, awareness campaigns, executive briefings, continuous learning initiatives, documentation, feedback mechanisms, and evaluation processes (Proaño-Narváez et al., 2022). Strategic utilization of software aligns with the organization's requirements, ensuring effectiveness, cooperation, and overall achievement (Ying, 2017). The identified critical success factors of implementing EVM in construction projects from literature are given in Table 2.

C. Barriers of adopting EVM in construction projects

EVM prioritizes non-critical activities to enhance the Schedule Performance Index (SPI) of a project (Zhan et al., 2019). EDM provides increased adaptability in schedule management, potentially offsetting any delays in crucial tasks. Organizations considering EVM should be aware of the significant expenses associated with it, including financial outlay and resource allocation (Lei et al., 2022). The implementation of EVM requires meticulous preparation, efficient communication, and strategies to tackle opposition and technical problems. Contracts that are ambiguous, offer little adaptability, or do not conform to EVM principles can hinder its effective implementation (Lei et al., 2022). Firms must invest in strong project management systems, foster good communication, and develop automated data gathering and reporting methods (Proaño-Narváez et al., 2022).

Strategic utilization of EVM facilitates project management decision-making by directing resources towards activities that provide high value while incurring minimal costs (Yang and Lai, 2023). Ambiguity in data can lead to substantial fluctuation in project data due to partial, inconsistent, or untrustworthy data sources (González, Tovar and Tapia, 2022). Top management may not have a comprehensive understanding of the core principles, measurements, and the incorporation of cost and schedule effectiveness (Wendell, Lowe and Gordon, 2022). EVM main focus is on metrics linked to cost, requiring a holistic approach to project monitoring. Divergent interpretations of EVM measures and their implications may result in disagreements when understanding and giving importance to EVM data (Morad and El-Sayegh, 2016). Managers lacking proficiency in EVM concepts may raise concerns about their capacity to utilize it to its fullest potential (Mahmoudi, Javed and Deng, 2021). The identified barriers of implementing EVM in construction projects from literature are given in Table 3.

Table 1. List of Selected Benefits of EVM in construction projects from literature review.

Item No.	Item	Reference
Benefit-1	EVM aids in meeting project deadlines	(De Marco and Narbaev, 2013)
Benefit-2	EVM aids the project team in achieving its schedule objectives	(Kapuganti et al., 2023)
Benefit-3	EVM facilitates the project team in reaching its cost goals	(Giammalvo, 2022)
Benefit-4	EVM indices are more effective than complex calculations	(Aramali et al., 2022)
Benefit-5	EVM is more effective and efficient in reporting project progress	(Jones, 2023)
Benefit-6	EVM provides a database of past projects for evaluation and comparison	(Teixeira Netto et al., 2020)
Benefit-7	EVM works well when the guidelines are in line with clients	(Giammalvo, 2022)
Benefit-8	Project costs can be estimated using the Cost Performance Index (CPI)	(Kapuganti et al., 2023)
Benefit-9	The Cost Performance Index serves as a benchmark	(Martens and Vanhoucke, 2017)
Benefit-10	Visual graphical reporting of EVM is more effective than other monitoring methods	(Jones, 2023)

Table 2. List of Selected Critical Success Factors of EVM in construction projects from literature review.

Item No.	Item	Reference
CSF - 1	Applicable rules and methods for implementing EVM	(Priyo, 2021)
CSF - 2	Consistent encouragement from the top management and project managers	(Morad and El-Sayegh, 2016)
CSF - 3	EVM adoption by team members	(Morad and El-Sayegh, 2016)
CSF - 4	EVM implementation requires sufficient organizational resources	(Alzraiee, 2018)
CSF - 5	EVM maturity of the organization in projects	(Chen and Zhang, 2012)
CSF - 6	EVM system should be flexible to make changes when needed	(Morad and El-Sayegh, 2016)
CSF - 7	Extensive instruction on using EVM.	(Priyo, 2021)
CSF - 8	Project managers' technical and administrative competencies	(De Marco and Narbaev, 2013)
CSF - 9	Training and awareness raising of the EVM system	(Proaño-Narváez et al., 2022)
CSF - 10	Use of appropriate software	(Ying, 2017)

CSF, Critical Success Factors

Table 3. List of Selected Barriers of EVM in construction projects from literature review.

Item No.	Item	Reference
Barrier - 1	EVM promotes high-progress, non-critical activities to ensure more Schedule Performance Index (SPI).	(Zhan et al., 2019)
Barrier - 2	The implementation cost of EVM is significant, and it might be challenging at times.	(Lei et al., 2022)
Barrier - 3	The nature of the contract may negatively impact EVM.	(Proaño-Narváez et al., 2022)
Barrier - 4	Obtaining timely information from the site regarding cost and duration is often challenging in the context of EVM	(Aramali et al., 2022)
Barrier - 5	EVM promotes high-value, low-cost activities for a greater Cost Performance Index (CPI).	(Wendell, Lowe and Gordon, 2022)
Barrier - 6	EVM predictions are not effective and suitable in data uncertainty conditions.	(Mahmoudi, Javed and Deng, 2021)
Barrier - 7	Top management failed to understand how the EVM works.	(Martens and Vanhoucke, 2017)
Barrier - 8	Cultural resistance to implement EVM as a control tool.	(Morad and El-Sayegh, 2016)
Barrier - 9	Implementing EVM creates conflicts between the various stakeholders involved.	(Yang and Lai, 2023)
Barrier - 10	Concern over whether managers will make good use of the EVM.	(Wendell, Lowe and Gordon, 2022)

III. METHODOLOGY

This study adopted a four-phase methodology, as in Figure 1. Phase – 1 consists of writing items representing the benefits, critical success factors and barriers of EVM in construction projects from literature study. After collecting the list of benefits of EVM in construction projects, a pilot study was conducted to identify the relevance, clarity and simplicity of the written items in phase – 2. Item – Content Validity Index (I-CVI) and Modified Kappa Statistic (k*) were adopted for testing content validity and inter-rater reliability as part of qualitative analysis.

Phase – 3 consists of collecting primary data by use of a structured questionnaire, which was administered using a five-point Likert scale and has a combination of closed and open-ended items. The survey is targeted at project managers and construction practitioners. Continuous to the collection of responses, the validity of the sample is assessed using the Kaiser-Meyer-Olkin (KMO) test, Bartlett's test of Sphericity and the sample's reliability is assessed using Cronbach's α and McDonald's ω. Phase – 4 involves the analysis of validated and reliable responses by utilizing Mean Weighted Value (MWV) and Relative Importance Index (RII) methods for listing out key benefits of adopting EVM in construction projects.

A. Item Writing and Content Validity

Thirty items representing the benefits, critical success factors and barriers of EVM in construction projects were identified and listed from the literature review as presented in Table 1, Table 2 and Table 3. After listing the items, eight project management experts conducted a pilot survey to judge the content. In the pilot survey, each item was judged in relevance, clarity and simplicity based on a 4-point Likert scale, as given in Table 4.

B. Item Content Validity Index

The item-content validity Index (I-CVI) value indicates the level of consensus among experts about the relevance, clarity and simplicity of the scale items used to measure the theoretical construct. The I-CVI was determined by summing the number of experts who rated each item as relevant (rating 3 or 4) and dividing this sum by the total number of experts, as outlined in the Universal Agreement Method (Polit et al., 2007). As established by (Lynn, 1986), the assessment criteria of the I-CVI range are presented in Table 5. I-CVI of relevance, clarity and simplicity of the pilot study are presented in the Table 6.

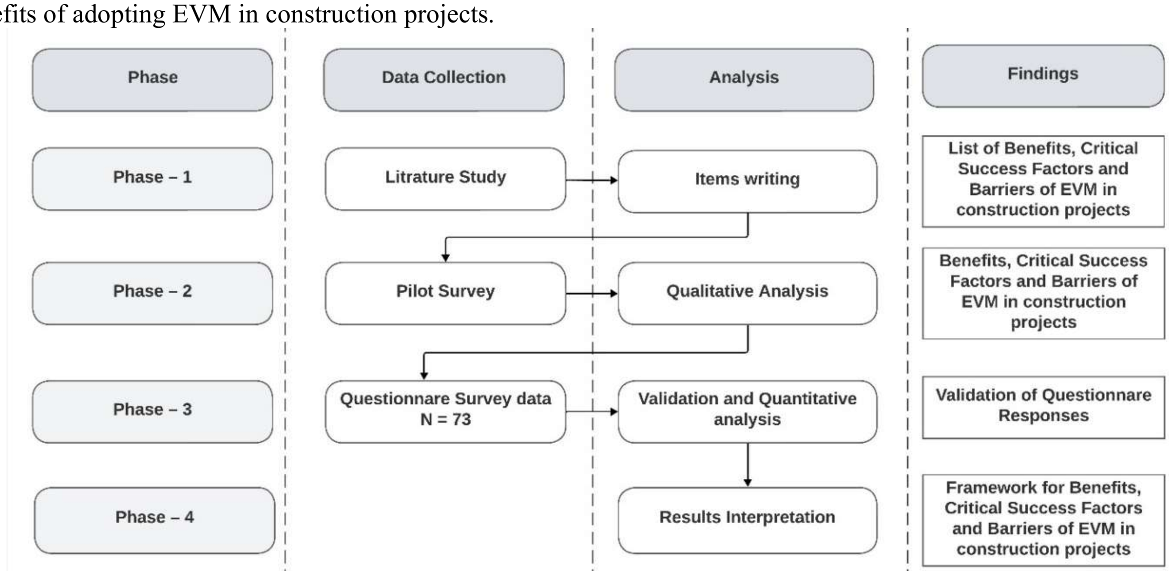

Figure 1. Schematic diagram of four phase study methodology

Table 4. Likert Scale adopted for pilot survey

Relevance		Clarity		Simplicity	
1	Not Relevant	1	Not Clear	1	Not Simple
2	Somewhat Relevant	2	Somewhat Clear	2	Somewhat Simple
3	Quite Relevant	3	Quite Clear	3	Quite Simple
4	Highly Relevant	4	Highly Clear	4	Highly Simple

Table 5. Assessment criteria for Item Content Validity Index (I-CVI) and Modified Kappa Statistic (k*)

I-CVI (Item Content Validity Index)		Modified Kappa Statistic (k*)	
1.00 > I-CVI > 0.80	Relevant	1.00 > k* > 0.75	Excellent
0.79 > I-CVI > 0.70	Needs Revision	0.74 > k* > 0.60	Good
0.69 > I-CVI > 0.00	Eliminated	0.59 > k* > 0.40	Fair

I-CVI, Item Content Validity Index; k*, Modified Kappa Statistic

Table 6. I-CVI and k* of relevance, clarity and simplicity for Benefits, Critical Success Factors and Barriers of EVM in construction projects

Item No.	Relevance		Clarity		Simplicity	
	I-CVIs	k*	I-CVIs	k*	I-CVIs	k*
Benefit-1	0.875	0.871	1.000	1.000	1.000	1.000
Benefit-2	0.625	0.520	0.750	0.719	0.625	0.520
Benefit-3	0.625	0.520	0.875	0.871	0.875	0.871
Benefit-4	0.875	0.871	0.875	0.871	0.750	0.719
Benefit-5	0.875	0.871	0.875	0.871	0.750	0.719
Benefit-6	0.625	0.520	0.875	0.871	0.875	0.871
Benefit-7	0.500	0.312	0.750	0.719	0.750	0.719
Benefit-8	0.625	0.520	0.750	0.719	0.750	0.719
Benefit-9	1.000	1.000	1.000	1.000	1.000	1.000
Benefit-10	0.875	0.871	0.875	0.871	0.875	0.871
CSF - 1	0.625	0.520	0.750	0.719	0.875	0.871
CSF - 2	1.000	1.000	1.000	1.000	0.875	0.871
CSF - 3	0.875	0.871	0.750	0.719	0.750	0.719
CSF - 4	0.875	0.871	0.875	0.871	0.750	0.719
CSF - 5	0.500	0.312	0.875	0.871	0.750	0.719
CSF - 6	0.625	0.520	0.750	0.719	0.750	0.719
CSF - 7	0.875	0.871	0.875	0.871	0.375	0.200
CSF - 8	1.000	1.000	0.750	0.719	0.750	0.719
CSF - 9	0.625	0.520	0.875	0.871	0.875	0.871
CSF - 10	0.500	0.312	0.750	0.719	0.750	0.719
Barrier - 1	0.875	0.871	0.875	0.871	0.875	0.871
Barrier - 2	1.000	1.000	0.750	0.719	1.000	1.000
Barrier - 3	0.625	0.520	0.875	0.871	0.875	0.871
Barrier - 4	0.625	0.520	0.875	0.871	0.750	0.719
Barrier - 5	0.875	0.871	0.750	0.719	1.000	1.000
Barrier - 6	1.000	1.000	0.875	0.871	0.750	0.719
Barrier - 7	0.625	0.520	0.750	0.719	0.625	0.520
Barrier - 8	0.875	0.871	1.000	1.000	0.750	0.719
Barrier - 9	0.625	0.520	0.875	0.871	0.750	0.719
Barrier - 10	0.500	0.312	0.750	0.719	0.875	0.871

I-CVI, Item Content Validity Index; k*, Modified Kappa Statistic

The benefits, critical success factors and barriers that have I-CVI values greater than 0.7 (Benefit - 1, Benefit - 4, Benefit - 5, Benefit - 9, Benefit – 10, CSF – 2, CSF – 3, CSF – 4, CSF – 7, CSF – 8, Barrier - 1, Barrier - 2, Barrier - 5, Barrier – 6 and Barrier - 8) were considered as given in Table 5. I-CVI values less than 0.69 (Benefit - 2, Benefit - 3, Benefit - 6, Benefit - 7, Benefit – 8, CSF – 1, CSF – 5, CSF – 6, CSF – 9, CSF – 10, Barrier - 3, Barrier - 4, Barrier - 7, Barrier – 9 and Barrier - 10) were rejected. The selected barriers, critical success factors and barriers of EVM in construction projects for questionnaire are given in Table 7.

C. Sample and Procedure

Purposive sampling was employed in this investigation. Purposive sampling is a method of selecting individuals or cases for a research study based on specific criteria or characteristics that are relevant to the research objectives. The sample size was determined using the general guideline, S:P ratio, where S is the sample size, and P is the number of parameters; it should be at least 5:1 (Nazam, Husain and Gull, 2022). Here, in this study, we adopted S as 10. The minimal sample size for this investigation was 50. The prototype items were developed and evaluated with construction industry practitioners using an online survey with Google Forms. After eliminating incomplete replies, 73 valid responses were selected for study.

D. Validity

The sample's validity is assessed using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity. The Kaiser-Meyer-Olkin (KMO) test is a statistic used to assess whether factor analysis is acceptable for a particular dataset. The threshold value of KMO more than 0.7 (Shrestha, 2021) suggests a robust indicator of sampling adequacy. Bartlett's Test of Sphericity is a statistical tool used to evaluate the appropriateness of variables for analytical procedures such as factor analysis, which rely on correlations across variables (Williams et al., 2010). Even with weak correlations, larger samples may yield higher KMO values. It uses partial correlations, which are hard to calculate and interpret with many variables (Nazam, Husain and Gull, 2022). KMO sampling adequacy for the sample is 0.773. The Bartlett's Test of Sphericity for the results as $\chi 2 = 69.0$ and $p < .001$.

Table 7. Selected items for the questionnaire

Item No	Item
Benefit-1	EVM aids in meeting project deadlines
Benefit-4	EVM indices are more effective than complex calculations.
Benefit-5	EVM is more effective and efficient in reporting project progress.
Benefit-9	The Cost Performance Index serves as a benchmark.
Benefit-10	Visual graphical reporting of EVM is more effective than other monitoring methods.
CSF - 2	Consistent encouragement from the top management and project managers
CSF - 3	EVM adoption by team members
CSF - 4	EVM implementation requires sufficient organizational resources
CSF - 7	Extensive instruction on using EVM
CSF - 8	Project managers' technical and administrative competencies
Barrier - 1	EVM promotes high-progress, non-critical activities to ensure more Schedule Performance Index (SPI).
Barrier - 2	The implementation cost of EVM is significant, and it might be challenging at times.
Barrier - 5	EVM promotes high-value, low-cost activities for a greater Cost Performance Index (CPI).
Barrier - 6	EVM predictions are not effective and suitable in data uncertainty conditions.
Barrier - 8	Cultural resistance to implement EVM as a control tool

CSF, Critical Success Factor

E. Reliability

The sample's reliability is assessed using Cronbach's α and McDonald's ω. Cronbach's α and McDonald's ω are statistical metrics used to evaluate the reliability and consistency of a collection of questions inside a questionnaire or test designed to gauge a shared underlying concept (Kineber, Uddin and Momena, 2022). The values of Cronbach's α and McDonald's ω greater than 0.7 indicate high internal consistency. Cronbach's α and McDonald's ω assumes that all items on a test have the same true score variance, which is often not the case in real-world data (Nazam, Husain and Gull, 2022). The Cronbach's α and McDonald's ω of the sample are 0.736 and 0.738, respectively.

F. Mean Weighted Value

Mean Weighted Value concisely summarizes responses to a series of survey questions. The process entails allocating varying weights to levels on the Likert scale according to their significance and then computing the weighted average of the responses (Juliana et al., 2023).

A greater MWV indicates that respondents, on average, gave answers that aligned more closely with the upper end of the scale, such as agree or strongly agree. In contrast, a lower MWV indicates that the answers were mostly weighted towards the lower end of the scale, such as disagree or strongly disagree. MWV for any dataset is calculated by using the equation (1).

$$Mean\ Weighted\ Value = \frac{Sum\ of\ Weighted\ Scores}{Number\ of\ Respondents} \quad (1)$$

G. Relative Importance Index

The Relative Importance Index (RII) is a statistical method used to analyze questionnaires to ascertain the relative significance of various items within a survey questionnaire (Dolla, Jain and Kumar, 2023; Gündüz, Nielsen and Özdemir, 2013). RII assesses the relative significance of different aspects based on the views of respondents. RII for each item in the questionnaire is calculated using the equation (2) (Karthik and Kameswara Rao, 2022). Maximum and minimum limits of RII important levels are given in Table 8 (Toyin and Mewomo, 2023).

$$RII = \frac{\text{Mean Score for the Item}}{\text{Maximum Possible Score}} \quad (2)$$

Table 8. Relative Importance Index ranges adopted for questionnaire analysis (Toyin and Mewomo, 2023)

Relative Importance Index (RII)		Important level
Upper Limit	Lower Limit	
1.00	0.81	High (H)
0.80	0.61	High–Medium (H–M)
0.60	0.41	Medium (M)
0.40	0.21	Medium–Low (M–L)
0.20	0.00	Low (L)

RII, Relative Importance Index

IV. RESULTS AND DISCUSSION

This study reports the descriptive information obtained from the survey questionnaire. Table 9 shows the demographic characteristics of the respondents. According to the data from the figure, the highest number of respondents (38%) have 10 to 15 years of experience. 12% of respondents have less than five years of experience, 36% have 5 to 10 years of experience, 8% have 15 to 20 years of experience, and 4% have more than 25 years of experience. Architect/ designers, director/ vice directors, contractor/ builders, structural engineer / geotechnical engineers, QS/planning engineers, construction/project managers, site/residential engineers and academicians made up of 3%, 4%, 5%, 8%, 12%, 14%, 16% and 37%.

Respondents work on an aggregation of residential projects, commercial projects, mixed-use projects, institutional projects, industrial projects, heavy civil projects, NASA projects, IT projects, international development, and research projects. 55% of respondents utilized earned value management (EVM). 12%, 37%, 45%, 29%, 36%, 27%, 32%, 15%, 3%, and 1% of respondents used risk management, performance reviews, key performance indicators (KPIs), change control, stakeholder engagement, quality control, regular progress reporting, milestone tracking, subjective assessments, integrated APPP management respectively.

Table 9. Demographic information of respondents

Category	Classification	Percentage
Respondent's Experience	Less than 5 Years	12%
	5 to 10 Years	36%
	10 to 15 Years	39%
	15 to 25 Years	8%
	More than 25 Years	4%
Respondent's Role	Architect/ Designer	3%
	Director/ Vice Director	4%
	Contractor/ Builder	5%
	Structural Engineer / Geotechnical Engineer	8%
	QS/Planning Engineer	12%
	Construction/Project Manager	14%
	Site/Residential Engineer	16%
	Academician	37%
Project Monitoring and Controlling Techniques	Risk Management	12%
	Performance Reviews	37%
	Key Performance Indicators (KPIs)	45%
	Change Control	29%
	Stakeholder Engagement	36%
	Quality Control	27%
	Regular Progress Reporting	32%
	Earned Value Management (EVM)	55%
	Milestone Tracking	15%
	Subjective assessments	3%
	Integrated APPP Management	1%
Types of Projects	Residential Projects	7%
	Commercial Projects	25%
	Mixed-Use Projects	42%
	Institutional Projects	42%
	Industrial Projects	40%
	Heavy Civil Projects	29%
	NASA Projects	3%
	IT Projects	1%
	International Development	1%
	Research Projects	3%

Table 10. MWV and RII analysis for benefits of EVM in construction projects

Item	Proportion			MWV	RII	Importance Level
	Disagreement (1 or 2)	Neutral (3)	Agreement (4 or 5)			
Benefit-1	8%	19%	73%	4.01	0.80	High (H)
Benefit-4	7%	25%	68%	3.79	0.76	High–Medium (H–M)
Benefit-5	12%	25%	63%	3.82	0.76	High–Medium (H–M)
Benefit-9	8%	12%	80%	4.10	0.82	High (H)
Benefit-10	8%	25%	67%	3.81	0.76	High–Medium (H–M)
CSF - 2	5%	10%	85%	4.19	0.84	High (H)
CSF - 3	18%	14%	68%	3.71	0.74	High–Medium (H–M)
CSF - 4	10%	23%	67%	3.88	0.78	High–Medium (H–M)
CSF - 7	14%	23%	63%	3.73	0.75	High–Medium (H–M)
CSF - 8	11%	18%	71%	4.01	0.80	High (H)
Barrier - 1	7%	16%	77%	4.12	0.82	High (H)
Barrier - 2	14%	19%	67%	3.77	0.75	High–Medium (H–M)
Barrier - 5	16%	22%	62%	3.68	0.74	High–Medium (H–M)
Barrier - 6	10%	14%	77%	4.04	0.81	High (H)
Barrier - 8	19%	8%	73%	3.98	0.79	High–Medium (H–M)

MWV, Mean Weighted Value; RII, Relative Importance Index

It is observed that "EVM aids in meeting project deadlines", "The Cost Performance Index serves as a benchmark" have highest mean weighted value greater than 4 and are the highest benefits with RII more than 0.8 as shown in Table 10.

The critical success factors "Consistent encouragement from the top management and project managers" and "Project managers' technical and administrative competencies" are noted as major critical success factors of EVM in construction projects with highest mean weighted value greater than 4 and are the highest benefits with RII more than 0.8 as shown in Table 10.

"EVM promotes high-progress, non-critical activities to ensure more Schedule Performance Index (SPI)" and "EVM predictions are not effective and suitable in data uncertainty conditions" are identified as major barriers of EVM in construction projects with mean weighted value greater than 4 and are the highest benefits with RII more than 0.8 as shown in Table 10.

CPI is a benchmark for projects from inception to end. It shows the health of the project, ranging from 0 to 1. Near zero indicates terrible or poor health and requires many changes to make the project on budget. Similarly, a CPI near 1 indicates the project is in good health and small changes are required to bring the project back to the planned budget. EVM aids in meeting project deadlines by showing Schedule Performance Index (SPI) value in every stage of the project from the inception to the end of the project.

Top management has a crucial role in establishing the organization's dedication to EVM. Consistent support from them is crucial for creating a culture that prioritises EVM principles, including precise planning, monitoring, and controlling project operations. When senior leadership openly supports EVM, it conveys a strong message to the entire organisation on the significance of following best practices in project management. Project managers with technical abilities can provide input to decision-making, give unique perspectives, and enhance communication with team members who have specialised technical expertise. Effective stakeholder management enhances the synchronisation of project objectives with stakeholder expectations, leading to project success and favourable organisational relationships.

The ultimate objective of the project management is to achieve a higher Schedule Performance Index. The project intends to obtain an SPI larger than one by expediting the completion of non-critical operations, signalling it is ahead of schedule. It is important to balance non-critical and vital tasks to achieve project objectives, milestones, and deadlines. EVM projections may be inadequate in complicated or unpredictable projects, leading to erroneous estimations of future costs and completion dates due to the dynamic nature of the task. Project managers may use scenario planning to explore several potential outcomes stemming from varying degrees of uncertainty, rather than depending on a single set of assumptions. This method provides increased flexibility in adjusting to evolving circumstances.

V. CONCLUSION

The study addressed benefits, critical success factors, and barriers of EVM implementation in construction projects. The study then quantified the relative importance of benefits, critical success factors, and barriers and demonstrated the ranking of the factors. This objective was achieved through the analysis of questionnaire responses. The most and least essential benefits, critical success factors, and barriers were achieved through ranking results.

The identified key benefits of adopting EVM in construction projects are EVM aids in meeting project deadlines and The Cost Performance Index serves as a benchmark. The apprehended key critical success factors of adopting EVM in construction projects are Project managers' technical and administrative competencies and Consistent encouragement from the top management and project managers. The observed key barriers of EVM implementation in construction projects are EVM promotes high-progress, non-critical activities to ensure more Schedule Performance Index (SPI) and EVM predictions are not effective and suitable in data uncertainty conditions.

This research holds the potential to significantly impact the education of present and future project managers and decision-makers, providing valuable insights into effective predesign procedures to enhance the success of their projects. The research sample consisted solely of construction project stakeholders from India. Consequently, research involving additional countries is encouraged.

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