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Research Article

Mitigating Time and Cost Overruns in Construction Projects: A Questionnaire Study on Integrating Earned Value Management and Risk Management

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Abstract

One of the persistent challenges in the construction industry is accurately estimating time and costs for civil engineering projects. Inadequate planning in these areas can lead to unexpected expenses and delays. The main goal of this study is to evaluate the impact of Earned Value Management (EVM) and risk management on factors such as project schedule, project costs, and design defects. For this research, a questionnaire was designed and disseminated to subject matter experts in Iran. Geographically, the participation rates were 38.49% in East Azerbaijan, 31.65% in West Azerbaijan, and 26.86% in the Tehran Province. Data was analyzed using SPSS and AMOS software. Structural equation modeling results indicate that both risk management and Earned Value Management (EVM) have a positive influence on project time (0.53) and cost (0.60). The analysis suggests that the EVM system and risk management directly and positively affect project time management. Moreover, the information phase of the Evam system notably impacts project time and cost management, whereas the performance phase contributes to reducing design defects and enhancing project quality.

1. Introduction

Numerous countries worldwide, particularly during economic development, prioritize infrastructure growth as a key component of their development strategies. This infrastructure is vital for societal progress and is the foundation for economic growth [1]. However, construction projects frequently face delays, with many exceeding their original timelines by more than 50%, resulting in substantial costs and prolonged project durations [2]. These delays lead to lost business opportunities in various sectors and make projects unsustainable because of changing technological, environmental, and social factors [3].

Development projects spearheaded by governments, notable for their vast scale, often face significant construction delays. These delays deeply affect the country's economic landscape and societal cohesion. The underlying reasons for these delays range from inefficient management and insufficient legal safeguards to financing problems and logistical obstacles. Such interruptions highlight fundamental planning difficulties and threaten the nation's overall resurgence and economic progress. Promptly addressing even minor project setbacks is essential for improving productivity, efficiency, and cost-efficiency, ensuring projects stay within budget [4]. Previous research indicates that the reasons for schedule delays and cost overruns are interconnected. Delays adversely affect production planning and control, particularly in construction projects, irrespective of a country's socioeconomic status [5].

Successful project completion relies on thorough planning and scheduling, incorporating construction methods, materials, and practices. Risk management about project tasks is crucial, underlining the importance of precise risk identification and mitigation [6]. Considering the numerous uncertainties, risk management is vital for the smooth functioning of construction supply chains [7]. Enhanced risk management can mitigate the significant impacts of identified risk factors on time and cost efficiency. The preparation and identification of risk factors directly and indirectly influence risk management [8]. On-time project completion is a crucial requirement in the construction industry, where factors causing delays frequently overlap with time and cost challenges [9]. Efficient coordination and wise resource distribution are essential in reducing stakeholder conflicts and guaranteeing smooth project execution. Delays can also arise from design hurdles, complexities in materials acquisition, and issues related to suppliers [10].

To improve project control and forecasting accuracy, it is crucial to leverage the capabilities of earned value management (EVM) and earned duration management (EDM) [11]. Properly addressing major risks in infrastructure projects requires using a quantitative risk measurement approach, which provides essential insights for effective risk management tactics [12]. Additionally, understanding the significance of organizational critical success factors (CSFs) and integrating them with ethical practices is paramount for construction business owners and senior management [13]. However, using limited resources such as materials, funds, and labor effectively should be driven by identifying critical success factors (CSFs) [14]. Ultimately, emphasizing risk management is crucial for enhancing different aspects of construction projects [15]. The primary objective of this study was to improve the cost and timeline of construction projects. To achieve this, the research examined risk management and earned value management using an online questionnaire for factor analysis and assessment.

2. Materials and Methods

2.1. Questionnaire

2.1.1. Study Site and Participants

A structured data collection method, using a questionnaire survey, was executed in specific regions of Iran: East Azerbaijan, West Azerbaijan, and Tehran province, between October 5 and November 10, 2022, as shown in Figure 1. The survey's primary objective was to investigate various facets of project management, emphasizing risk management, cost evaluation, and time management in construction projects. The comprehensive survey included twenty questions centered on the nuances of risk management, five questions addressing cost-related issues, and another five questions focused on time management topics. Through these inquiries, the study aimed to glean insights, data, and feedback from project managers and expert engineers in Iran, facilitating in-depth analysis and evaluation of these pivotal areas of project management in the mentioned regions.

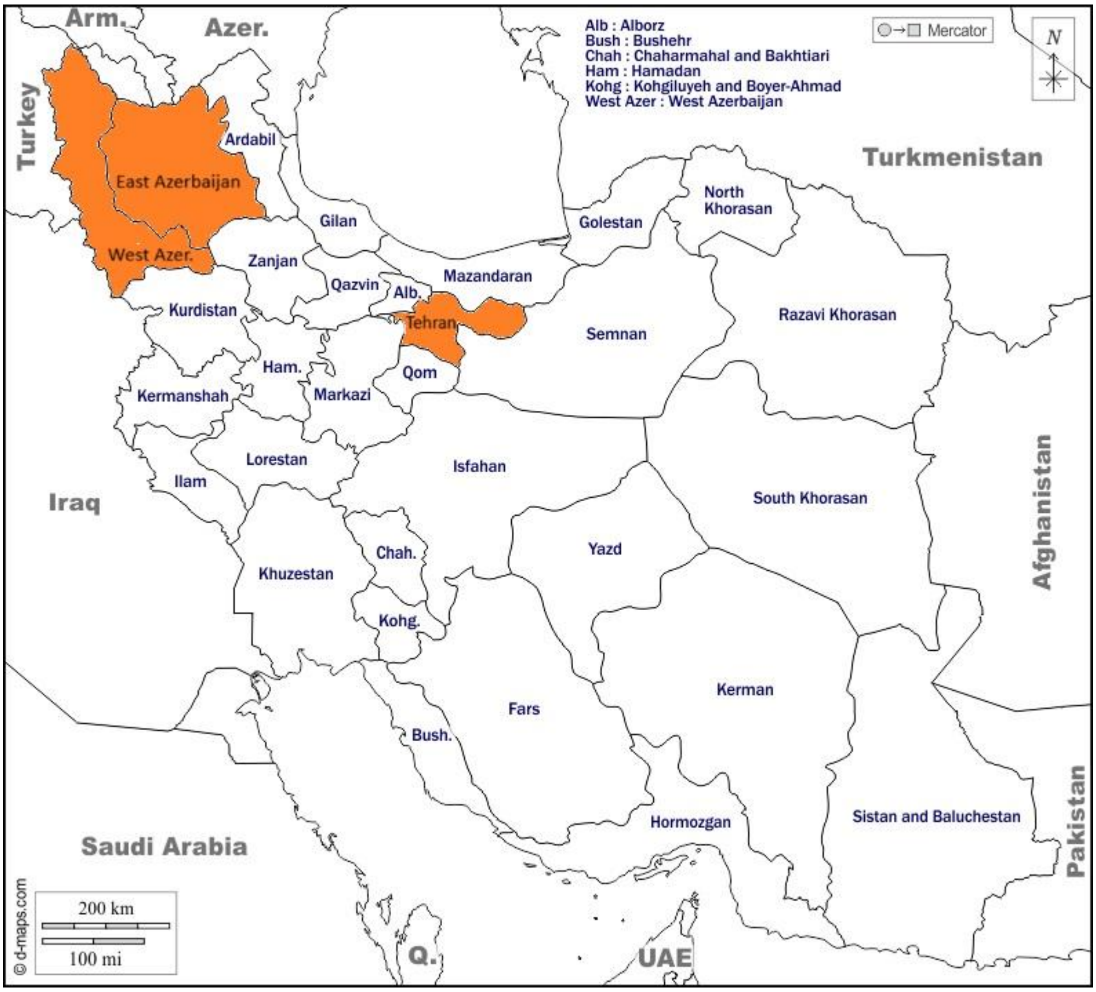

Figure 1. Map of Islamic Republic Iran. (d-maps.com)

2.1.2. Procedure and Instrument

The questionnaire was designed using Google Forms, a free electronic tool provided by Google for voluntarily gathering information via the structured survey. In compliance with the General Data Protection Regulation (GDPR), no personal information, such as first and last names, phone numbers, or emails, was requested or stored [16]. The questionnaires were segmented into three main sections. The first section focused on demographics, encompassing gender, age, and education. The second section addressed risk management; the third delved into earned value management.

2.1.3. Determination of Sample Size

When the population size is unknown, the population proportion is also undetermined. In such cases, it is appropriate to calculate the necessary sample size for this study using Chochlan's formula, as presented below [17].

$$\mathrm{n} = \frac{z^2}{4e^2}$$

n= sample size, p= the population proportions, e=acceptable sampling error(e=0.05) z= value at reliability level or significance level. Reliability level 95% or significance level 0.05; z= 1.96

$$\mathrm{n} = \frac{(1.96)^2}{4(0.05)^2} = 384.16$$

After completing the questionnaire and removing the restricted questionnaires, 278 questionnaires were analyzed.

2.2. Earned value management

EVM has been applied consistently since its introduction by the American Department of Defense in 1967. EVM is grounded in three primary metrics: earned value (EV), which denotes the planned cost for completed tasks; planned value (PV), representing the budgeted cost for scheduled tasks; and actual cost (AC), which indicates the expense of work that has been done [18]. The metrics outlined in Table 1 below can be used to evaluate a project's performance in terms of its schedule and costs at a specific project stage, usually during a designated tracking period. Specifically, a schedule variance (SV) or SV(t) (>0) and a schedule performance index (SPI) or SPI(t) (>1) indicate if the project is lagging or progressing ahead of the planned schedule. Similarly, cost metrics, such as cost variance (CV) > 0 (>0) and cost performance index (CPI) (>1), show whether the project is over or under its allocated budget. If a project's schedule and cost variances are zero, it signifies that the project is on track and within the budget [19].

Table 1. Definitions of EVM key criteria [20].

Metric	Definitions/formula
PD	Planned duration, the planned total duration of the project
BAC	Budget at completion, the budgeted total cost of the project
AT	Actual time
PV	Planned value, the value that was planned to be earned at AT
EV	Earned value, is the value that has been earned at AT
AC	Actual cost, the costs that have been incurred at AT
ES	Earned schedule, the time at which the EV should have been earned according to plan, ES= t + (EV−PVt/PVt+1−PVt) with t the (integer) point in time (i.e., tracking period) for which EV≥PVt and EV<PVt+1

EAC(t)	Estimated duration at completion, the prediction of RD made at AT
EAC ($)	Estimated cost at completion, the prediction of RC made at AT
RD	Real duration, the actual total duration of the project
RC	The real cost, the actual total cost of the project
SV	Schedule variance, SV=EV−PV
SPI	Schedule performance index, SPI= EV/PV
SV(t)	Schedule variance (time), SV(t)=ES−AT
SPI(t)	Schedule performance index (time), SPI(t)=ES/AT
CV	Cost variance, CV=EV−AC
CPI	Cost performance index, CPI=EV/AC
SCI	Schedule cost index, SCI=SPI*CPI
SCI(t)	Schedule cost index (time), SCI(t)=SPI(t)*CPI

2.3. Information gathering tools

This study comprehensively explored the challenges of implementing the earned value management methodology and suggested practical solutions to address these challenges for effective methodology use. The reliability of the questionnaire was validated with a Cronbach's alpha coefficient of 0.82, and its face and content validity were established. Chapter four presents the results of a confirmatory factor analysis undertaken to verify the construct validity of the questionnaire—the research questionnaire comprised thirty items rated on a 7-point Likert scale. Expert feedback was incorporated in the development of the questionnaire to ensure its relevance, with the scoring system detailed in Table 2.

Table 2. Reliability of the research questionnaire using Cronbach's alpha

Variables	Number of questions	Cronbach's alpha	Scoring method
Risk Management	20	0.81	1 to 7
Project time	5	0.82	1 to 7
Project cost	5	0.82	1 to 7

From the table presented above, it is clear that the questionnaire exhibits high reliability since all the values surpass the preferred threshold of 0.7.

2.4. Data Analysis

After collecting data to address the research questions and hypotheses, the researcher needs to use suitable statistical methods for analysis, aiming primarily to harness the data effectively to tackle research issues. This study's results were analyzed using both descriptive and inferential statistics. In the descriptive phase, multiple elements were evaluated, including frequency distribution, score distribution graphs, data skewness, and kurtosis. Central tendency measures like mean and standard deviation were also considered. The structural equation modeling (SEM) technique was used to examine the research hypotheses. The analysis employed both AMOS and SPSS 27 software. The process unfolded: initially, expertise in using MSP software and the earned value approach was assessed through interviews with senior managers, supervisors, and selected experts—those demonstrating exceptional expertise advanced to the development and validation phase of the study questionnaire. The questionnaire was then administered to those qualified interviewees, with a group of up to eight individuals selected as the study's statistical sample. Finally, SPSS and AMOS software were used to analyze the gathered data.

Structural equation modeling (SEM) is a robust statistical method designed to test hypotheses about relationships between observed and dependent variables. Also termed causal modeling, structural analysis of covariance, or simply SEM, it commonly employs the AMOS software for model evaluation and exploring intricate relationships. SEM encompasses two types of variables: latent (unseen) and observed (manifest). The observed variables serve as measures for the latent ones. Like other research types, the model's variables are classified into exogenous (independent) and endogenous (dependent) categories. SEM integrates two models: the structural model, delineating causal links between latent variables, and the measurement model, a facet of confirmatory factor analysis that leverages observable variables to gauge latent ones. The goodness-of-fit indices offered by AMOS assess the model's compatibility with the observed data. The root mean square error is one of various goodness-of-fit tests, with values under 0.05 regarded as excellent, values between 0.05 and 0.08 as moderately acceptable, those between 0.08 and 0.1 as relatively poor, and above 0.1 as weak. Models with a root mean squared error of approximation over 0.10 are deemed notable. Overall, SEM is instrumental in enabling researchers to evaluate intricate models and relationships across diverse data sets.

2.4.1. Stages of the structural equation modeling

Covariance structure analysis follows a systematic procedure that progresses sequentially. This methodological approach consists of several essential stages, each integral to the complete analysis. The process begins with the formulation of a sample statement. Then, the model estimation phase takes place. After that, the model's fit or accuracy is evaluated. Depending on the assessment outcomes, the model might be tailored or refined to match the gathered data more closely. Once an optimal model is discerned, the next stage is interpreting its results, extracting significant insights from the determined parameters and relationships. The culmination of the process is consolidating the outcomes and interpretations into a comprehensive research report.

3. Results and Discussion

3.1. Descriptive statistics

For the data analysis, we begin by presenting the descriptive statistics for the demographic variables of the study, which include gender, age, and education level. The presentation of the analytical statistics follows this.

3.1.1. Gender

The descriptive statistics in Table 3, detailing the frequency distribution for gender, indicate that of the study's respondents, 4% were women, while 96% were men.

Table 3. Frequency distribution of gender variable

Gender	Frequency	Frequency Percentage
Woman	12	4
Man	266	96
Total	**278**	**100**

3.1.2. Work experience

Descriptive statistics related to the work experience variables are given in Table 4.

Table 4. Variable frequency table of work experience

Work Experience	Frequency	Frequency Percentage
Less than 5 years	11	4
5 to 10 years	48	17.2
10 to 15 years	122	43.9
15 to 20 years	97	34.9
Total	**278**	**100**

Based on Table 4, only 4% of respondents have less than five years of experience. Those with experience ranging from 5 to 10 years account for 17.2%. A significant 43.9% have experience spanning 10 to 15 years, and 34.9% have experience between 15 to 20 years.

3.1.3. Education

Descriptive statistics related to the education level variable are given in Table 5.

Table 5. Education level variable

Level of Education	Frequency	Frequency Percentage
Bachelor's degree	116	41.7
Master's degree	162	58.3
Total	**278**	**100**

Regarding the level of education, the results show that 58.3% of the respondents have a master's degree, which is the most frequent among those with a bachelor's degree, which is 41.7%.

3.1.4. Descriptive statistics of research variables

Table 6 presents the descriptive statistics for each research variable, including the mean and standard deviation.

Table 6. Descriptive statistics of research variables

Research variables	Average or mean	Standard deviation
Technical-safety risks	32.6511	13.14281
Management-functional risks	16.1763	6.59678
Internal risks	16.3453	6.65576
External risks	15.7014	6.63766
Time	20.1043	8.08037
Cost	**19.8165**	**8.20092**

3.2. Inferential statistics

3.2.1. Checking the adequacy of the sample

In inferential statistics, assessing the research data's adequacy is vital before undertaking factor analysis. This assessment determines if data can be distilled into a few underlying factors. For this evaluation, two tests are utilized: the Kaiser-Meyer-Olkin (KMO) index and Bartlett's test.

The KMO index gauges the degree of partial correlation between variables. It highlights how much the shared variance of certain latent factors influences the variance of research variables. This index ranges between 0 to 1. Values nearing 1 indicate that the sample size is suitable for factor analysis. Based on the KMO value.

- Values below 0.49 suggest avoiding factor analysis.
- Values between 0.50 and 0.69 mean factor analysis is feasible, but data adjustments are advised.
- Values of 0.70 or above advocate for factor analysis without hesitations.

Bartlett's test evaluates if the correlation matrix is an identity matrix. A significance level for Bartlett's test below 5% denotes the aptness of factor analysis to determine the factor model, rejecting the unity assumption of the correlation matrix. This means significant interrelations exist between variables, enabling the extraction of inherent structures from the data.

Table 7 lists the KMO value, Bartlett's statistic, degrees of freedom, and Bartlett's test significance. The risk management questionnaire has a KMO index of 0.96, while the EVM questionnaire stands at 0.92. Both surpass the 0.7 threshold, signifying the sample size is apt for factor and path analysis using the structural equation model. Additionally, Bartlett's test has a significance value under 5%, confirming a meaningful interrelation between variables, making factor analysis fitting for deducing the structural model from the data.

Table 7. KMO index and Bartlett's test to check sample adequacy

Variables	The amount of KMO	Bartlett test statistic	Degrees of freedom	The significance level
Risk management	0.969	3310.16	190	0.001
EVM	0.926	1111.556	45	0.001

3.2.2. Confirmatory factor analysis

Confirmatory factor analysis of risk management questionnaire**:** In Figures 2 and 3, confirmatory factor analysis is presented in two standard and non-standard formats.

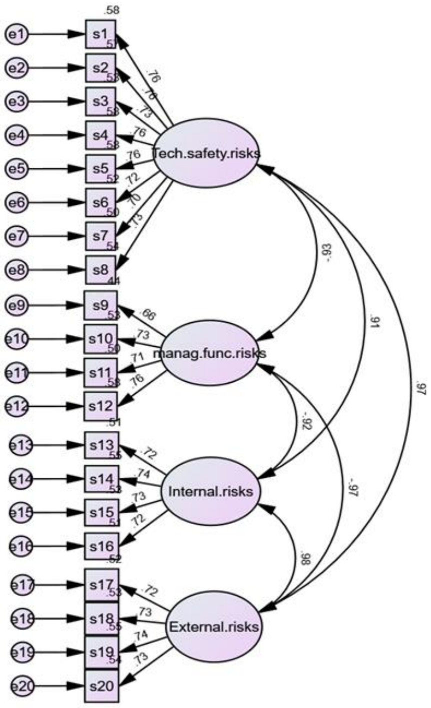

Figure 2. Confirmatory factor analysis of risk management questionnaire in standard mode

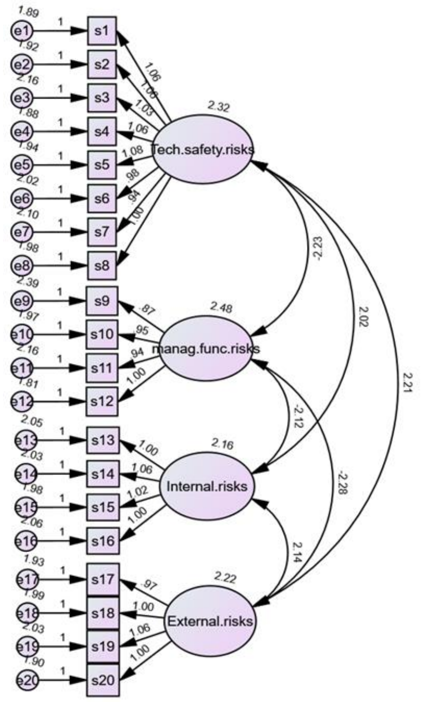

Figure 3. Confirmatory factor analysis of the risk management questionnaire in a non-standard mode

Table 8 displays the fit indices for the research model.

Table 8. Indicators of the risk management model of construction projects

Model fit indices	χ^2	*df*	χ^2/df	GFI	AGFI	IFI	TLI	CFI	NFI	RMSEA
Risk management	226.10	164	1.37	0.93	0.91	0.98	0.97	0.98	0.93	0.037

Based on the results shown in Table 8, all fit indices align with the adequacy benchmarks, reflecting a satisfactory and reasonably acceptable alignment of the structural model. The RMSEA index, under 0.08, confirms an acceptable fit for the research model. Comparative fit indices, such as CFI, NFI, GFI, TLI, and IFI, underscore the model's acceptability. Values above 0.90 in these indices suggest a favorable model fit. Furthermore, the root means square error of estimation (RMSEA) index, which gauges the model's fit, has a value of 0.37, reaffirming the model's fitting aptness. The data aligns within acceptable bounds, and the constructed model has been validated as apt for the study.

Confirmation factor analysis of earned value management questionnaire: In Figures 4 and 5, confirmatory factor analysis is presented in two standard and non-standard formats.

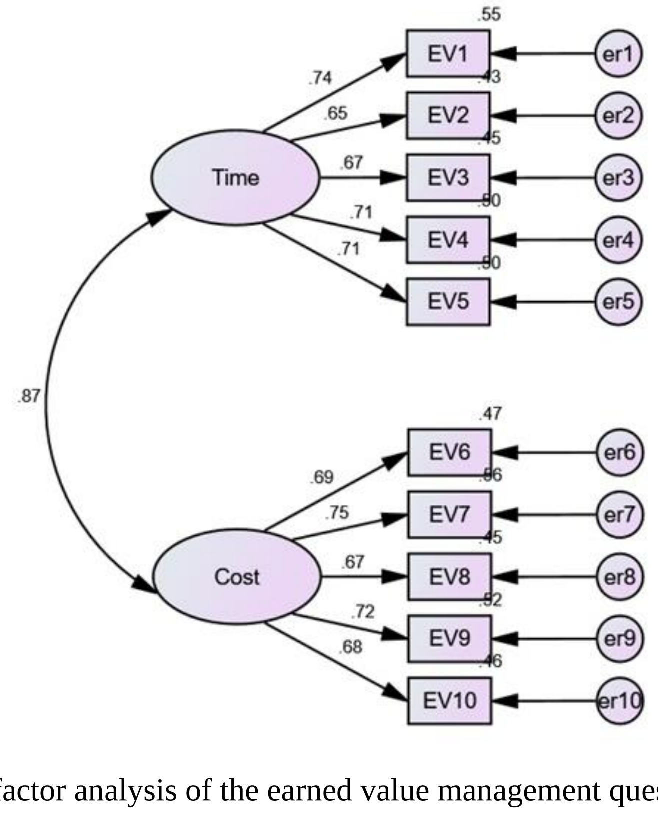

Figure 4. Confirmatory factor analysis of the earned value management questionnaire in standard mode

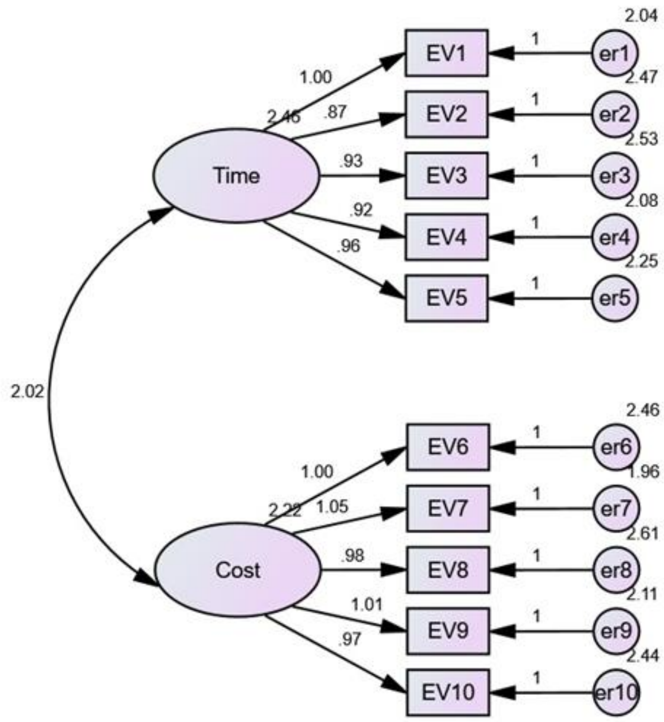

Figure 5. Confirmatory factor analysis of a non-standard earned value management questionnaire

Table 9 displays the fit indices for the research model.

Table 9. Fitness indicators of the performance model of construction projects

Model fit indices	χ^2	***df***	χ^2/df	**GFI**	**AGFI**	**IFI**	**TLI**	**CFI**	**NFI**	**RMSEA**
Earned value management	40.82	34	1.2	0.974	0.958	0.99	0.99	0.99	0.96	0.027

According to the data in Table 9, the fit indices closely align with the adequacy benchmarks, suggesting a satisfactory and reasonably acceptable alignment of the structural model. The RMSEA index, registering below 0.08, attests to the research model's acceptable fit. The comparative fit indices—CFI, NFI, GFI, TLI, and IFI—all validate the model's acceptability, with scores surpassing 0.90, signaling a desirable fit. Additionally, the root means square error of estimation (RMSEA) index, a gauge for the model's fit, posts a value of 0.027, further endorsing the model's aptness. In sum, the gathered data aligns with the acceptable parameters, confirming the model's appropriateness for the study.

Examining the final research models: In Figures 6 and 7, the final models of the project are presented in standard and non-standard formats.

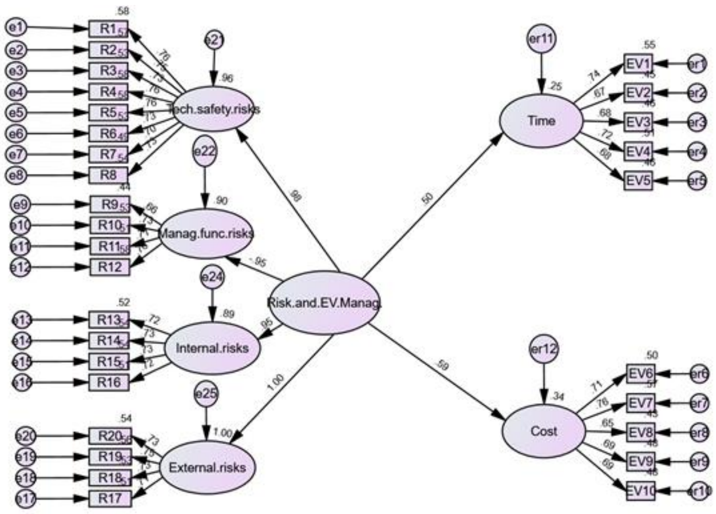

Figure 6. The final model in standard mode

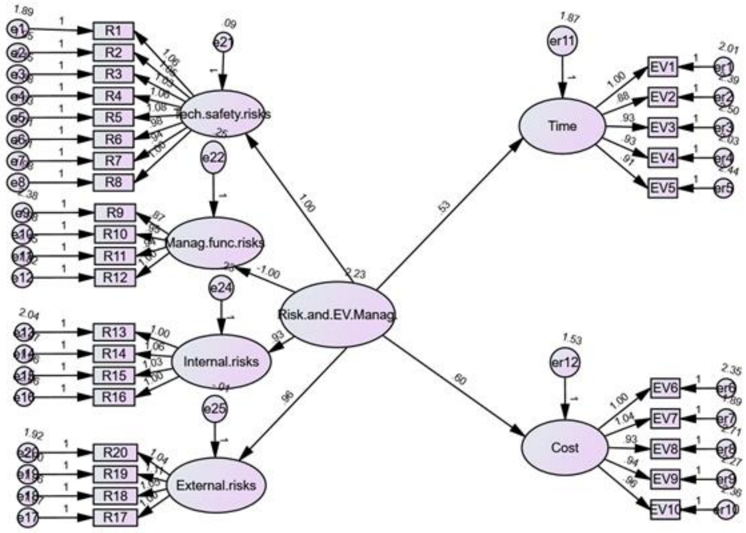

Figure 7. The final model in non-standard mode

Table 10. displays the fit indices for the research model.

Table 10. Fit indices of the final research models

Model fit indices	**χ^2**	***df***	**χ^2/df**	**IFI**	**TLI**	**CFI**	**RMSEA**
Final model	714.67	399	1.79	0.93	0.92	0.929	0.053

From the data in Table 9, all fit indices align closely with the benchmarks for adequacy, suggesting both a satisfactory and a reasonably acceptable alignment of the structural model. The RMSEA index, below 0.08, attests to an acceptable fit for the research model. Comparative fit indices such as CFI, TLI, and IFI validate the model's suitability, with scores surpassing 0.90, marking a desirable fit. Additionally, the root means square error of estimation (RMSEA) index, a gauge for the model's fit, registers a value of

0.053 for the final model, further underscoring its fitting aptness. The gathered data sits within the acceptable parameters, and the constructed model has been affirmed apt for the study. These findings solidify the adequacy and validity of the suggested model, cementing its value for probing the interrelation between risk management, earned value management, and assorted performance metrics in civil engineering ventures.

3.3. Examining research assumptions

In order to evaluate the hypothesis that the integration of earned value management with risk management techniques significantly impacts the reduction of project time, Table 11 presents the path coefficients (or regression weights) of the variables in the research model along with their respective probability values.

Table 11. examination of the first hypothesis of the research

Exogenous variable	Endogenous variable	Standard value	Critical value	A significant amount	The result of the hypothesis
Earned Value and risk management	Time	0.53	6.86	0.001	confirmed

From the information in the preceding table, both earned value management and risk management positively influence construction project duration, showing a significant effect of 0.53 and an error level below 0.05. This confirms the research hypothesis that integrating earned value and risk management significantly reduces project time.

To evaluate the hypothesis that the combination of earned value management with risk management techniques notably impacts project cost reduction, Table 12 offers the path coefficients (or regression weights) of the variables in the research model, along with their respective probability values.

Table 12. examination of the second hypothesis of the research

Exogenous variable	Endogenous variable	Standard value	Critical value	A significant amount	The result of the hypothesis
Earned Value and risk management	Cost	0.60	7.69	0.001	confirmed

From the information provided in the preceding table, it is apparent that earned value management and risk management exert a positive and significant influence on construction project costs, represented by a value of 0.60, with an error level below 0.05. This data corroborates and confirms the research hypothesis: integrating earned value and risk management significantly curtails project expenses.

4. Conclusion

The research study presented in this paper has explored and confirmed various findings that offer significant benefits in improving time and cost efficiencies in construction projects. The study examined a research model comprising Earned Value Management and Risk Management, finding it relatively acceptable and satisfactory for construction projects. This structural model is recommended for its ability to predict project performance, encompassing time, cost, and scope.

Further analysis of the data reveals that Earned Value Management, when used in conjunction with Risk Management, positively influences the timing of construction projects. This effect was quantified at a rate of 0.53, and the error level was less than 0.05. This significant finding supports the hypothesis tested in the research, highlighting the importance of integrating Earned Value Management and Risk Management to reduce the duration of construction projects.

Additionally, the study indicates that the cost of construction projects can be significantly reduced by applying this model. This conclusion was supported by employing regression weights and probability values. The impact of the model on project cost reduction was notable, with a rate of 0.60 and an error level of less than 0.05. The positive effect of Earned Value Management and Risk Management on reducing costs and improving project performance in the construction industry is thus emphasized, suggesting their effective application in future projects.

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

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