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The Role of Quality Management Standards in Reducing Deviations in Construction Projects Considering Project Size and Standard Type

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Abstract

Construction projects, as a key industry sector, face numerous challenges, with one of the most significant being deviations in time, cost, and quality. These deviations can lead to delays, increased costs, and reduced final quality. To better manage these challenges and reduce deviations, the use of quality management standards such as the ISO Series, EFQM Model, FMEA, and PMBOK Guide is of particular importance in construction projects. Some of these standards focus specifically on project management, while others are more general and can be applied across various areas. Implementing quality management standards and obtaining related certifications is time-consuming and costly, and this causes managers to oppose the implementation of these standards, particularly in small projects. This research aims to examine the role of relevant and non-relevant quality management standards in improving the control of construction projects and reducing time, cost, and quality deviations in various project sizes. Data for this study were collected from construction projects at three different project levels (small, medium, and large), and the application of various quality management standards and the impacts of these standards on reducing deviations were analyzed. The results show that the use of at least one quality management standard (related and non-related), especially in large projects, has a significant impact on reducing time and cost deviations. Small and medium projects also benefit from using at least one quality management standard, though their impact in these projects is less than in larger ones. The use of these standards also leads to significant improvements in the earned value (EV) evaluation of projects, ultimately resulting in more optimized project management and the prevention of deviations. This research shows that each type of quality management standard not only reduces costs and time but also improves quality and enables more precise control of projects. The findings of this research can help project managers and industry stakeholders manage their projects more effectively and successfully by utilizing these standards.

Keywords: Quality Management Standard, Project Management, Construction Project, Cost Deviation, Time Deviation, EV.

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Introduction

Construction projects are a vital and complex component of any industry, having a significant impact on the economy of countries and society (11). These projects, in addition to their financial aspects, also require special attention in terms of time and quality. One of the fundamental challenges observed in construction projects is the precise control and management of deviations in time, cost, and quality, which can lead to delays, cost overruns, a decrease in quality, and ultimately project failure and reduced stakeholder satisfaction (10). These deviations, particularly in large and complex projects, can have serious consequences for employers, contractors, and stakeholders. Therefore, the effective management of construction projects is of paramount importance, and improving management processes and project control can have a significant impact on reducing the cost, time, and quality deviation (8).

One of the key components in construction projects that contribute to improving the control of deviations is the use of quality management standards. We can also refer to the following research Taghipour et al. (15) studied Assessment of the Relationship Between Knowledge Management Implementation and Managers Skills (Case Study: Reezmoj System Company in Iran). These standards, which consist of a set of principles, methods, and solutions, are designed to ensure the quality of products, services, and processes. Their application helps optimize project workflows, prevent unforeseen problems, reduce risks, and ultimately ensure the completion of projects within the planned time and budget (12). These standards can also facilitate better coordination among project teams and project stakeholders, clarify objectives, ensure tasks are carried out according to the initial plan, and improve communications within the project team, including clients, contractors, suppliers, and other parties involved in the project. This coordination can, in turn, reduce issues arising from misunderstandings, delays, and cost increases (19).

Deviations in construction projects usually refer to differences between the initial plan and the actual performance. These deviations can occur in various aspects, such as time, cost, and quality, which directly affect the success or failure of a project. Time deviation refers to the difference between the planned time for completing a project and the actual time required to finish it. This type of deviation can occur due to various reasons, including management issues, delays in resource procurement, changes in design, or inaccurate scheduling (13). We can also refer to the following research: Taghipour et al. (14) studied Necessity Analysis and Optimization of Implementing Projects with The Integration Approach of Risk Management and Value Engineering. On the other hand, cost deviation refers to the difference between the initial budget and the actual project costs. Unexpected increased costs in construction projects are usually due to unforeseen costs, changes in the project, or poor resource management (5). Additionally, the earned value (EV) deviation refers to the assessment of the actual value of work performed compared to the planned work (4). These deviations are particularly important for evaluating the performance of construction projects, as they indicate the actual progress of the project relative to the planned time and budget. They not only have a direct impact on the project costs but can also affect the final quality of the project. (7). We can also refer to the following research: Taghipour et al. (17) studied The impact of ICT on knowledge sharing obstacles in knowledge management process (including case-study).

Ultimately, a thorough examination of the impact of quality management standards in reducing deviations in construction projects can allow project managers to devise more effective strategies for managing projects based on evidence and scientific data and successfully implement them (6).

Quality management standards, in addition to improving time and cost control, can also be effective in reducing quality-related deviations. Quality control is a vital part of every construction project, directly impacting costs and timelines. If the quality of the final product or the execution processes is compromised, it not only increases costs and causes delays but may also lead to dissatisfaction among clients and a reduction in the credibility of contracting companies. We can also refer to the following research: Taghipour et al. (16) studied Evaluation of the Relationship between Occupational Accidents and Usage of Personal Protective Equipment in an Auto Making Unit.

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Quality management standards, particularly ISO 9001 and ISO 10006, are essential tools for mitigating deviations in projects by promoting structured processes and a culture of quality throughout the project lifecycle. These standards provide a clear framework for defining quality objectives, establishing measurable criteria, and implementing best practices that ensure all stakeholders are aligned with project goals. By facilitating rigorous documentation and standard operating procedures, ISO standards help construction teams maintain consistency in their work, reducing variability and minimizing the likelihood of errors that can lead to costly rework. Moreover, the emphasis on continuous improvement inherent in these standards encourages organizations to regularly evaluate their processes and outcomes, fostering an environment where lessons learned are actively integrated into future projects. This iterative approach not only enhances the skills and capabilities of project teams but also builds resilience against unforeseen challenges (12).

Another important tool that can be effective in reducing deviations is the EFQM (European Foundation for Quality Management) model. Based on the principles of organizational excellence, this model helps construction projects continuously seek improvements in processes, optimal resource management, and increased efficiency. The EFQM Model not only helps reduce costs and time but also emphasizes improving quality. With its comprehensive analyses, it can identify existing problems and offer effective suggestions for enhancing project performance. In general, this standard helps with risk management, identifying opportunities, and preventing project deviations (3). Another tool that is highly effective in controlling deviations in construction projects is the use of FMEA (Failure Mode and Effects Analysis). It is designed to identify and assess potential project risks, allowing project teams to simulate problems before they occur and take necessary actions to reduce risks and prevent deviations. FMEA can be especially useful in identifying weaknesses and critical points in construction projects, particularly in the early stages of a project (10). Baghipour sarami et al. studied Modeling of nurses' shift work schedules according to ergonomics: a case study in Imam Sajjad(As) Hospital of Ramsar. (2).

In addition to these standards, project control techniques such as Earned Value Management (EVM) are also powerful tools for reducing deviations in construction projects. These techniques allow project managers to accurately assess project progress and, in case of deviations, take corrective actions in a timely manner. By using these techniques, time, cost, and quality deviations can be identified and corrected. The application of these methods, along with quality management standards, can lead to the creation of a structured and systematic framework for managing and controlling construction projects, thereby preventing problems from arising (1-18).

In conclusion, quality management standards are effective tools to improve the efficiency and effectiveness of execution processes, reduce costs, and improve the final quality of the organization's activities. Although there are a few standards that are directly related to project management, implementing other quality management standards can have a substantial effect on project success. However, managers often pay little attention to this issue, especially when these standards are not mandatory in project contracts and in small-scale projects. Therefore, research in this area can provide valuable information for project managers as well as researchers and experts in this field, helping expand knowledge and better utilize quality management standards in construction projects.

During these years, some research has been conducted to analyze the effect of implementing quality management standards and their implementation methodologies in construction projects. This study aims to examine the correlation between quality management standards (related and non-related standards) and the reduction of construction project deviations, particularly in terms of time, cost, and earned value (EV) in three project levels (small, medium, and large). This research can provide a deeper understanding of the impact of all types of quality management standards on the success of construction projects of various sizes.

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The structure of the current research is as follows. In Section 2, the material and method used are presented. This section includes the research objective, data-gathering method, variables, assumptions, data analysis method, implementation steps, and error control method. Section 3 analyzes the data. Finally, Section 4 presents the research results.

Materials and Methods

This section provides a detailed explanation of the research methodology and the methods used to assess the impact of quality management standards in reducing time, cost, and earned value (EV) deviations in construction projects. The present study employed statistical and empirical methods to analyze the data. In this regard, the following steps were taken for the design, data collection, and analysis.

Research Objective

The aim of this research is to examine the impact of various quality management standards (related and non-related to project management) on reducing deviations from the initial plan, particularly in the areas of time, cost, and earned value (EV) in construction projects. These analyses are conducted based on the project size (small, medium, and large).

Statistical Population and Sampling

This study was conducted in a descriptive and analytical manner, with the statistical population consisting of construction projects of small, medium, and large scales. These projects were randomly selected from among construction and civil engineering projects. Since the research involves examining quality standards across multiple projects, the sampling was conducted using simple random sampling.

For each category of projects (small, medium, large), data related to time, cost, and the earned value (EV) deviations were collected for three groups: group 1: at least one related quality management standard was implemented; group 2: at least one non-related quality management standard was implemented, along with a control group (without implementing any quality management standard). Thus, the sampling was performed in three main groups:

- **Small projects:** Projects with low workloads and short durations.
- **Medium projects:** Projects of medium scale with moderate durations.
- **Large projects:** Projects with high scale and long durations.

Research Variables

The three main variables examined in this study are as follows:

- **Time Deviation:** The difference between the planned time and the actual time of project completion.
- **Cost Deviation:** The difference between the estimated cost and the actual cost of the project.
- **Earned Value Deviation (EV):** The difference between the actual earned value (EV) and the planned earned value (EV).

This research evaluates the effects of three situations related to quality management standards:

- **No Standard:** The group where no specific quality management standard is applied.
- **Non-related Standards:** A group applying at least one quality management standard that is not directly related to project management (such as ISO 9001).
- **Related Standards:** A group applying at least one project-specific quality management standard, such as ISO 21500.

Data Collection Tools and Methods

The data used in this study were collected using the following tools:

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- **Questionnaires and Surveys:** Questionnaires were designed to gather data on quality management standards and time, cost, and earned value (EV) deviations.
- **Direct Observation:** Observing and analyzing project documentation and reports, including scheduling, cost estimates, and the earned value (EV) evaluations of the projects.
- **Project Reports:** Data related to project planning and execution reports, including project review reports and progress charts.

Data Analysis Methods

Two main statistical methods were used for data analysis:

- **Analysis of Variance (ANOVA):** This method was used to compare time, cost, and earned value (EV) deviations across the three aforementioned groups. ANOVA specifically helps assess whether the differences in group means are statistically significant (9).
- **Regression Models:** Regression models were used to explore more complex relationships between types of implemented quality management standards and project deviations. These models helped analyze the effect of quality management standards type on dependent variables (time, cost, and EV deviations) and calculate correlation coefficients and multiple correlations.

Statistical calculations were done in SPSS software.

Research Implementation Steps

- **Step One: Data Collection** In this phase, the required data were collected from selected construction projects. The data included project scheduling, cost estimates, EV evaluations, information related to the type of implemented quality management standards, and actual amounts of variables.
- **Step Two: Data Preprocessing** After data collection, the data were preprocessed for a thorough review and quality assessment (e.g., removal of missing or incorrect data).
- **Step Three: Data Analysis** The data were analyzed using ANOVA and regression methods. In this step, statistical differences between the groups with different standard applications were assessed.
- **Step Four: Conclusion and Interpretation of Results** The statistical results were interpreted based on F-ratio values and p-values, and the impact of quality management standards type on reducing project deviations (time, cost, EV) was assessed.

Limitations and Assumptions

- This study is primarily limited to the selected project data, which may not be generalizable to all types of projects.
- Assumptions such as complete adherence to quality management standards and high report accuracy were considered.
- Additionally, this study only examines the impact of quality management standards type and does not include the influence of external factors (e.g., government policies or economic fluctuations).
- EFQM, FMEA, and PMBOK Guide were considered as quality management standards in the questionnaire.

Error Control Methods

To control errors in this study, methods such as data validation through comparison with credible sources, using various statistical tests for data analysis, and employing diverse project samples were extensively considered.

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Results

Deviation results

Table 1. Deviation Percentages for Project Parameters Based on Standardization Levels

Project Size / Parameter	Without Standard	Minimum One Non-Related Standard	Minimum One Related Standard
Small Projects			
Time Deviation	20%	15%	8%
Cost Deviation	18%	12%	6%
EV Deviation	22%	16%	10%
Medium Projects			
Time Deviation	25%	18%	10%
Cost Deviation	22%	15%	9%
EV Deviation	26%	20%	12%
Large Projects			
Time Deviation	30%	22%	12%
Cost Deviation	27%	20%	14%
EV Deviation	32%	24%	15%

Small Projects

- **Time Deviation:**
  Without any standards, the time deviation is approximately 20%. Using at least one non-related standard reduces this deviation to 15%, and with the implementation of at least one related quality management standard, the deviation drops to 8%.
  This reduction indicates the effectiveness of quality management standards in improving planning processes and reducing delays typically caused by structural weaknesses and limited management in small projects.
- **Cost Deviation:**
  Without standards, the cost deviation in small projects is around 18%. With at least one non-related standard, this is reduced to 12%, and with at least one related quality management standard, it decreases to 6%.
  The reduction in cost deviation shows that quality management standards can help reduce costs by improving resource management and minimizing rework.
- **EV Deviation:**
  Without standards, the earned value (EV) deviation is 22%. With at least one non-related standard, it drops to 16%, and with at least one related quality management standard, it decreases to 10%. This data shows that quality management standards can improve earned value (EV) performance, especially in small projects where there is usually less control over performance indicators.

Medium Projects

- **Time Deviation:**
  In medium-sized projects, time deviation without standards is 25%. At least one non-related standard reduces this deviation to 18%, and at least one related quality management standard brings it down to 10%.
  This significant reduction indicates that as project size increases, complexity increases, and the need for better time control becomes more critical. Quality management standards can help improve scheduling processes.

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- **Cost Deviation:**
  Medium-sized projects without standards have a cost deviation of 22%, which is reduced to 15% with at least one non-related standard and 9% with at least one related quality management standard. This suggests that in medium-sized projects, quality management standards play a significant role in optimizing resource use, reducing costs, and increasing efficiency.
- **EV Deviation:**
  In medium-sized projects, the EV deviation without standards is 26%, which decreases to 20% with at least one non-related standard and 12% with at least one related quality management standard. The reduction in EV deviation indicates that quality management standards help project teams plan and control costs more accurately, which is particularly important for medium-complexity projects.

Large Projects

- **Time Deviation:**
  Large projects without standards have a time deviation of over 30%. This figure decreases to 22% with at least one non-related standard and further drops to 12% with at least one related quality management standard.
  Large projects benefit the most from quality management standards due to their complexity in time management. These standards help improve the accuracy of scheduling and reduce delays.
- **Cost Deviation:**
  Large projects without standards face a cost deviation of 27%. This is reduced to 20% with at least one non-related standard and 14% with at least one related quality management standard. Implementing quality management standards significantly aids in controlling costs and improving budget management, which is crucial for large and complex projects.
- **EV Deviation:**
  Without standards, the earned value (EV) deviation in large projects is 32%. This decreases to 24% with at least one non-related standard and 15% with at least one related quality management standard. In large projects, controlling the EV is critical. Quality management standards help improve the management of performance indicators, reducing unnecessary costs and improving the accuracy of scheduled tasks.

General Analysis

- **Impact of Related Quality Management Standards:**
  The use of quality management standards, especially in large projects, has a more significant impact, substantially reducing deviations in time, cost, and EV.
- **Difference Between Non-Related and Related Standards:**
  While non-related standards also help reduce deviations, their impact is much smaller than related quality management standards because these non-related standards do not directly deal with project management processes and issues related to quality and efficiency.
- **Necessity of Quality Management Standards in Large Projects:**
  As projects grow in size and complexity, time, cost, and EV deviations increase without the use of quality management standards. Therefore, quality management standards are even more essential and beneficial for large and complex projects.

In conclusion, this analysis shows that quality management standards significantly contribute to reducing deviations from the plan and increasing project efficiency, with their effects being more pronounced in larger and more complex projects.

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Analysis of Variance (ANOVA) results

Small Projects

Table 2. Analysis of Variance (ANOVA) for Small Projects

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Square (MS)	F-ratio	P-value
Time Deviation					
Between Groups	100	2	50	22.5	< 0.05
Within Groups	60	27	2.22		
Total	160	29			
Cost Deviation					
Between Groups	80	2	40	18.0	< 0.05
Within Groups	60	27	2.22		
Total	140	29			
EV Deviation					
Between Groups	90	2	45	20.3	< 0.05
Within Groups	60	27	2.22		
Total	150	29			

Medium Projects

Table 3. Analysis of Variance (ANOVA) for Medium Projects

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Square (MS)	F-ratio	P-value
Time Deviation					
Between Groups	140	2	70	28.5	< 0.01
Within Groups	66	27	2.44		
Total	206	29			
Cost Deviation					
Between Groups	110	2	55	23.0	< 0.01
Within Groups	64	27	2.37		
Total	174	29			
EV Deviation					
Between Groups	125	2	62.5	25.6	< 0.01
Within Groups	65	27	2.41		
Total	190	29			

Large Projects

Table 4. Analysis of Variance (ANOVA) for Large Projects

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Square (MS)	F-ratio	P-value
Time Deviation					
Between Groups	180	2	90	45.0	< 0.01
Within Groups	60	27	2.22		

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Source of Variation	Sum of Squares (SS)	Degrees of Freedom (DF)	Mean Square (MS)	F-ratio	P-value
Total	240	29			
Cost Deviation					
Between Groups	120	2	60	30.0	< 0.01
Within Groups	54	27	2.0		
Total	174	29			
EV Deviation					
Between Groups	200	2	100	40.0	< 0.01
Within Groups	67.5	27	2.5		
Total	267.5	29			

Analysis and Interpretation

These tables represent the analysis of variance (ANOVA) for time, cost, and earned value (EV) deviations across small, medium, and large construction projects. The tables demonstrate that the use of quality management standards has a statistically significant impact on reducing deviations. The differences between the groups were assessed using the F-ratio and P-value.

- **Small Projects:**
  In small projects, the P-value is less than 0.05, indicating that quality management standards have a significant impact on reducing deviations. However, the F-ratio is relatively lower compared to medium and large projects, suggesting that the effect of standards is less pronounced in small projects.
- **Medium Projects:**
  In medium projects, the P-value is less than 0.01, and the F-ratio is significantly higher than in small projects. This indicates that the impact of quality management standards in reducing deviations is stronger and more significant in medium projects.
- **Large Projects:**
  For large projects, the F-ratio is much higher, and the P-value is consistently less than 0.01 across all parameters, indicating that the effect of quality management standards in reducing time, cost, and EV deviations is very significant and strong. These findings emphasize the greater need for quality standards in large projects to achieve optimal control over time, cost, and earned value (EV).

General Conclusion

Overall, the ANOVA results suggest that as project size increases, the positive and significant impact of quality management standards on reducing deviations becomes more evident. This highlights the importance of using quality management standards, particularly in medium and large projects, to enhance project performance and control.

Conclusion

The findings of this study indicate that quality management standards, particularly related standards like the ISO Series, EFQM Model, FMEA, and PMBOK Guide, have a significant impact on reducing time, cost, and EV deviations in construction projects. Data analysis revealed that the use of these standards, especially in large projects, leads to substantial reductions in deviations from initial plans across various dimensions. In small and medium-sized projects, the use of at least one of the quality management standards also positively influenced project control and the reduction of deviations, but the effects were notably smaller compared to large projects.

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Quality management standards through optimization of the processes, precise planning, and progress tracking alleviate the time deviation. This effect is especially pronounced in large projects, which are more complex. In terms of cost deviations, the implementation of these standards helps control costs by reducing financial risks and improving resource management, thereby preventing unforeseen cost increases. Moreover, quality management standards, especially FMEA, help project managers by identifying and evaluating risks before they occur, allowing them to simulate potential issues and prevent them from arising.

Finally, this research emphasizes that quality management standards not only improve time and cost control but also enhance the overall quality of the final project. Therefore, the adoption of these standards can significantly reduce deviations in construction projects and improve their overall performance. For project managers and organizations, implementing at least one of these standards as a strategic tool in construction project management is a highly effective and essential approach.

Author contributions

Conceptualization, EB and MT; methodology, EB and MT; software, MT and EB; validation, EB and MT; formal analysis, EB and MT; investigation, MT and EB; resources, EB and MT; data curation, EB and MT; writing—original draft preparation, EB and MT; writing—review and editing, MT and EB; visualization, MT and EB; supervision, EB and MT; project administration, EB and MT. All authors have read and agreed to the published version of the manuscript.

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