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QUALITY PAPER

The effect of contract management systems on quality management systems in construction industry: the mediating role of Quality 4.0 technologies

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Abstract

Purpose – This research work aims to investigate the effect of the contract management system (CMS) on the quality management system (QMS) with a focus on the mediating role of Quality 4.0 technologies in the construction industry in Palestine.

Design/methodology/approach – The survey method collected the data of a random sample of 95 questionnaires from top and middle managers who works in Palestinian construction contracting companies. The partial least squares structural equation modeling technique was used for the data analysis.

Findings – The findings contribute to the current literature by displaying a significant association between CMS and Quality 4.0, where each shows a significant effect on QMS in construction companies. Furthermore, the research revealed that CMS has a significant indirect effect on QMS in construction companies, mediated by Quality 4.0.

Originality/value – In Palestine, there is a scarcity of empirical studies that address the relationship between contract and quality management in practices in the construction industry. Such studies become more important because of the unique secularities of construction industry represented, mainly, by a set of economic, political, social, legal, administrative, financial and environmental constraints in the Palestinian construction industry. This study helps decision-makers in the Palestinian construction industry in identifying and assessing the enabling factors to adopt and implement the Quality 4.0 technologies and understand its mediation impact between CMS and QMS to stay competitive in the market and achieve client satisfaction.

Keywords Contract management system, Quality management system, Quality 4.0, Construction industry, SDG 9

Paper type Research paper

1. Introduction

The construction industry (CI) is encountering hurdles in integrating and leveraging emerging technologies and innovations within their operational framework, primarily concerning

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factors like cost, quality and time. Hence, fostering innovation and effectively managing and ensuring quality management system (QMS) emerges as a crucial strategy to enhance productivity and performance in such industry (Alawag *et al.*, 2024). More specifically, the top management commitment to quality specifications is vital to the success of a QMS in CI. However, there are many discrepancies in the way in which contractors manage their construction projects; some of them are bound by contracts to preserve their legal and safety requirements than seeking beyond the best approaches (benchmarks) on quality, other contractors are risk-takers and add value to the quality of work, indeed, this requires a cooperative, partnership and effective contracts (Patel and Pitroda, 2021).

To ensure the success of the project in the construction industry, an effective management system should be coupled with an effective contract management system (CMS). The CMS consists of several contracting parties who, through this contract, should abide by agreed terms and conditions so they achieve the objectives and outputs of the contract (Badi *et al.*, 2021). Effective use of CMS strengthens the team working relationship, as it increases the team spirit within the project framework. The CMS continues for the entire period of project phases until completion and up to the final handover stage (Fatayer *et al.*, 2022). The main goal of the contract system (CS) is to achieve the agreed upon performance of the projects based on specific terms and conditions as presented in the contract. This means CS ensures the greatest possible benefits and lower costs and within the shortest period (Dmaidi *et al.*, 2016).

Industries worldwide are increasingly embracing new digital technologies stemming from the fourth industrial revolution and its digital transformation. While the construction industry is not a leader of this change, it is a complex industry with unique characteristics that do not exempt it from adopting digital innovations (Forcael *et al.*, 2020). The new revolution Industry 4.0 is indeed a reality in developed countries, where several national strategies and supporting policies have been formulated for implementation. However, the availability and adoption of Industry 4.0 technologies pose a challenge to developing nations (Da Silva *et al.*, 2020).

Quality 4.0 represents the future of quality management within the framework of Industry 4.0, emphasizing the digitization of quality in design, conformance and performance through advanced digital technologies (Lekan *et al.*, 2020; Mane and Patil, 2015). The adoption of Industry 4.0 in the CI holds significant potential for enhancing quality processes and achieving project excellence. By integrating digital technologies into quality-related activities, data collection has become more efficient, enabling access to previously unreachable data from critical areas of construction projects (Petrillo *et al.*, 2018). For Quality 4.0 to be sustainable, it requires the development, maintenance and evaluation of a clear strategy, as improvement is impossible without first identifying areas for enhancement. This modern approach to quality must also be grounded in traditional quality principles (Dias *et al.*, 2022). Consequently, research that consolidates and examines the essential components for effective implementation of Quality 4.0 is crucial (Sony *et al.*, 2020).

In Palestine, which is a developing country, there is a lack of empirical studies supporting innovation in construction project management and its practices (Ghaben and Jaaron, 2017). Numerous challenges in the industry lead to rework, time and resource wastage. Establishing systems that use quality control and/or quality assurance approaches is important to meet contractual requirements and manage projects successfully within cost, time and quality constraints. The rationale for this study is based on the growing interest within the Palestinian construction industry in leveraging Quality 4.0 technologies and CMS to enhance the use of quality management systems QMS. Regardless, there is still a notable lack of literature addressing the implementation of Quality 4.0 in this context (Lekan *et al.*, 2022). By expanding knowledge of the proposed constructs, this work could provide a comprehensive understanding of their roles within Palestinian construction contracting companies. As it offers valuable insights for decision-makers and researchers into adopting and implementing Quality 4.0 technologies that would boost competitiveness and improve client satisfaction. Furthermore, the integration of advanced technologies, combined with improvements in contract management practices and partnerships among stakeholders, should basically drive significant positive changes in the industry as a whole.

Accordingly, this study aims to investigate the relationships between CMS, the implementation of Quality 4.0 technologies and QMS in the Palestinian construction industry, while this work also explores the mediating role of Quality 4.0 implementation between CMS and QMS. This study has three contributions: Firstly, analyzing current state of the art literature and examining the combined interactions among the studied variables (CMS, QMS, Quality 4.0), the research broadens the discourse on their integration within the construction industry. Secondly, given the limited focus on adopting Quality 4.0 practices in construction, particularly in developing countries (McNamara and Sepasgozar, 2021; Carvalho *et al.*, 2024; Lekan *et al.*, 2022), this work offers deep insights into the field of construction management (Ghansah and Edwards, 2024). Thirdly, grounded in the resource-based view (RBV) theory, it also delves into the mediating mechanisms of Quality 4.0 implementation, with a focus on the perspectives of senior construction management professionals. Hence, this study focuses on addressing the following research questions:

RQ1. How does CMS affect QMS and Quality 4.0 technologies in Palestinian construction?

RQ2. Does CMS indirectly affect QMS in Palestinian construction industry through Quality 4.0 technologies?

This paper is composed of seven sections. Section one introduces the research subject. Section two presents the pertinent literature review and the hypotheses development. Section three illustrates the research methodology. The fourth section presents the data analysis and presentation of the results while in section five, results are discussed. Section six presents the theoretical and practical contributions of the study. The final section concludes with the study's results.

2. Literature review and hypotheses development

The existing literature highlights a link between CMS, Quality 4.0 and QMS (Emblemsvåg, 2020). According to the resource-based view (RBV) theory, internal organizational factors significantly influence performance and provide competitive advantages (Barney, 1991). Construction companies can achieve a competitive edge by leveraging intangible resources, such as quality management practices (Collis, 1994; Moh'd Abu Raje *et al.*, 2024). Additionally, market-pull theories offer limited insight into the motivations behind firms adopting new technologies like Quality 4.0 in construction (Akmam Syed Zakaria and Amtered El-Abidi, 2021). Leveraging modern Industry 4.0 technologies enables organizations to deliver higher-quality products and services, creating a price-value advantage over competitors (Sony *et al.*, 2020). Studies by Rangone (1999) and Shi *et al.* (2023) demonstrate the effectiveness of applying the RBV framework to understand strategies in subcontractor organizations typical of the construction sector (Goh and Loosemore, 2017). However, the RBV has yet to be employed as a theoretical lens to examine the impact of innovations like Quality 4.0 in construction. This study builds its theoretical foundation on these concepts.

2.1 Quality management system (QMS) and contracting management system (CMS)

The contract system affects the entire project lifecycle, from initiation to the final handover. Its primary objective is to drive construction project performance following the contract terms and conditions. As such, the contract system goal is for high-quality execution that will tend to maximize benefits and in parallel minimize costs and duration (Fayyad *et al.*, 2022). Such systems have evolved into a comprehensive mechanism for ensuring sustainable contractor–customer relationships, that also balance risks and control material prices, also keep enhancing quality performance from implementation to project completion (Dmaidi *et al.*, 2016).

Gunduz and Elsherbeny (2020) developed a comprehensive model for evaluating construction contract management performance. Their model encompasses 11 key constructs affecting construction contract management that have been consolidated into five categories, each with associated indicators: contract administration team management (CAM), performance monitoring, reporting and documentation (PMR), quality and acceptance and changes control (QACC), financial management (FM) and project governance/start-up and close-out (PG). Rashed and Othman (2015) emphasized that the successful adoption of total quality management (TQM) in the construction industry hinges on the effective deployment of QMS. However, it remains uncommon in construction (Öztaş *et al.*, 2007). While challenges inherent to construction projects hinder the successful adoption of these systems, leading to an absence of standardized metrics for evaluating their efficacy in the construction sector. Leong *et al.* (2014) and Neyestani (2016) proposed assessing QMS effectiveness through construction project performance metrics such as scope, cost, client satisfaction, time and safety. Numerous factors drive the adoption and implementation of systems such as ISO9001 in construction. This includes fostering competitive capabilities among construction firms, facilitating training and management programs and integrating computerized systems to optimize resources and performance efficiency. Santos and Millán (2013) argue that such systems enable comprehensive data management, fostering customer and employee satisfaction, promoting quality methodologies, encouraging widespread participation and soliciting feedback for continuous improvement, ultimately leading to project success.

Active involvement of all stakeholders in determining project requirements is crucial for achieving successful outcomes and high-quality results that meet client satisfaction. Continuous evaluation of quality performance is essential in the construction industry (Leong *et al.*, 2014). McNamara and Sepasgozar (2021) found that discrepancies between stakeholders' understanding, and actual practices contributed to executing agencies' struggles in implementing effective contract management systems. They emphasized the negative impact of poor contract management processes, inadequate project monitoring and the employment of unqualified supervisory staff by contractors on work quality and financial losses. Consequently, there is a need for further research into the comprehensive effects of CMSs on QMSs within the construction sector. Five categories to represent the QMS in this study are adopted, namely, scope (SC), client satisfaction (CS), time (Ti), cost (Co) and safety issues (Si). Accordingly, we proposed the following hypothesis:

H1. CMS has a positive and significant impact on QMS.

2.2 CMS and quality 4.0

Construction 4.0 denotes the transformation of the construction industry from the traditional management and practices towards an increased level of digitalization, integrating virtual and real-world data (Craveiro *et al.*, 2019). Soft competencies, particularly communication skills, are crucial in this decade (Kannan and Garad, 2020). You and Feng (2020) showed that Industry 4.0 technologies used in the construction industry are based on an assessment of the industry's features. More specifically, major components of Industry 4.0 technological tools leading to the construction 4.0 era and Quality 4.0 include: Internet of things (IoT), building information modeling (BIM) (Kang *et al.*, 2017), technological devices (Birje *et al.*, 2017) and digital centralized management (Alam *et al.*, 2017; Abdallah Zaky and Nassar, 2021).

The adoption of Industry 4.0 technologies in construction projects is still in its early stages, and the factors that will influence its adoption remain unclear (Ameyaw *et al.*, 2023; Najafzadeh *et al.*, 2024). Therefore, this study aimed to explore the factors influencing the utilization of these technologies in construction. While Industry 4.0's potential to reinvigorate the construction industry has been observed, it has also been urged that Quality 4.0 activities, such as smart technologies and digital ecosystems, cannot be effectively executed without human interaction, as noted by Newman *et al.* (2021), and a well-established management contract system (Boonpheng *et al.*, 2021). According to Zhong *et al.* (2020), the environment for utilizing blockchain in the construction industry has yet to be developed. Thus, the rate of adoption and use of blockchain technology depends on the acceptance and knowledge of this shift in power and control paradigms among management-level workers. Additionally, Elbashbishy *et al.* (2022) argued that CMS activities such as governance, financial management and knowledge of the complex contract administration practices in construction are required to enhance the effectiveness of blockchain applications in construction. Hence, our study proposed that CMS is an antecedent to Quality 4.0 implementation.

Based on the above discussion, we propose the following second hypothesis:

H2. CMS has a positive and significant impact on Quality 4.0 technologies.

2.3 Quality 4.0 and QMS

Quality 4.0 represents a departure from traditional quality practices and is considered an Industry 4.0 approach that emphasizes achieving quality and performance goals by analyzing the interaction between individuals, systems and emerging technologies (Radziwill, 2020). In this paradigm, quality becomes a driving force behind the industry 4.0 transition (Aldag and Eker, 2018; Radziwill, 2018; Zonnenshain and Kenett, 2020). Quality management provides a strong foundation for organizations and, within the context of transformation, can act as a key facilitator of change (Carvalho *et al.*, 2020). More specifically, Carvalho *et al.* (2021) analyzed the association among different quality management practices and new technologies in industry 4.0, which may lead to better quality management. Klinc and Turk (2019) addressed the advantages of adopting digital technologies in the CI, such as saving time and money, improving quality, safety, collaboration and communication, sustainability and improving the image of the company accordingly. Hence, the following hypothesis is proposed:

H3. Quality 4.0 technologies have a positive and significant impact on QMS.

2.4 The mediating role of quality 4.0 implementation

Implementation and adoption of Quality 4.0 may be considered a successful step for all stages of the construction project. Keeping pace with technological developments in control and sensing systems and predictive engineering increases the efficiency of data analysis and evaluation throughout the life of the project within the framework of comprehensive quality standards (Sony *et al.*, 2020). The most important application of Quality 4.0 is predictive quality management, creating a digital simulation of the project before starting execution using BIM technology. According to Khader and Musleh (2018), the awareness level of Palestinian engineers in the construction industry is ranging from high for civil and architectural engineers to moderate for others. Predictive quality improves planning, scheduling and documentation processes which will positively reflect in TQM programs, reduce cost and thus achieving the requirements and satisfaction of all the project parties (Klinc and Turk, 2019; Zonnenshain and Kenett, 2020). Quality is a critical concern in the CI, particularly in the creation of construction products. In today's landscape, quality management parameters are integrated into many of the applications used for the production and marketing of construction products. Modern quality management systems in the CI increasingly rely on expert-based and intelligence-driven applications (De Felice *et al.*, 2016). These applications play a pivotal role in advancing the digitalization of quality management, enabling additive quality manufacturing, intelligent manufacturing, automation of construction processes and the use of robotics (Lekan *et al.*, 2022). Two main categories of Quality 4.0 are considered in the study, namely, smart technologies (ST) and digital ecosystems (DE). Accordingly, the following hypothesis is proposed:

H4. Quality 4.0 technologies mediate the relationship between CMS and QMS.

The proposed conceptual model in Figure 1 consists of three constructs CMS, Quality 4.0 acceptance and implementation and QMS, accompanied with the previously formulated hypotheses. Each construct is supposed to have some indicators. These indicators were developed based on the conducted literature review.

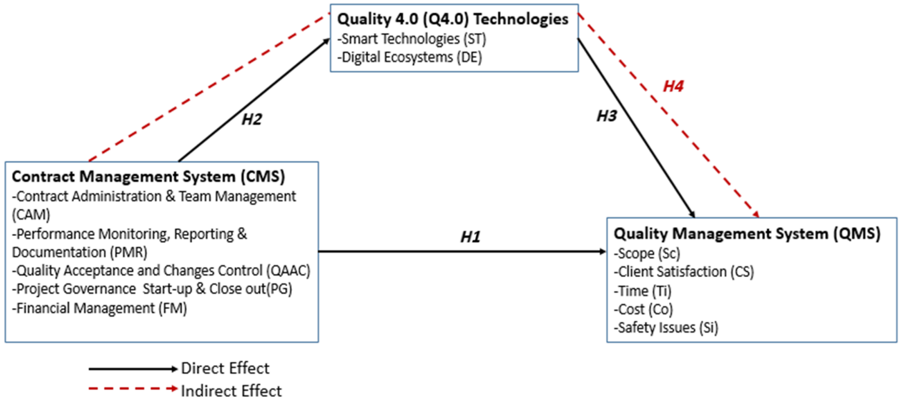

Figure 1. Conceptual model. (*Source:* Authors' own work)

3. Research methodology

3.1 Research methodology flow

The methodology adopted in conducting this research consists of four phases shown in Figure 2.

Phases one is the formulation phases in which the research problem and objectives were defined, and the pertinent literature was reviewed. The outcome of this phase is the development of research hypotheses as well as the conceptual framework. Phase two is the execution phase in which the population was identified which is the legally registered Palestinian building construction contractors. According to Palestinian Contractor Union (PCU) Website, the number of construction contractors legally registered and classified in Palestine is 206 contractors that represent the sampling frame of this study. The study focused on general managers, quality managers and engineers working within construction companies ($N = 206$), as these professionals were considered the most qualified to provide accurate and reliable information about their organizations. Their insights were deemed crucial for understanding the research variables and testing the hypothesized relationships effectively. Also, in this phase a probability-random sample was determined using the Thompson equation as follows:

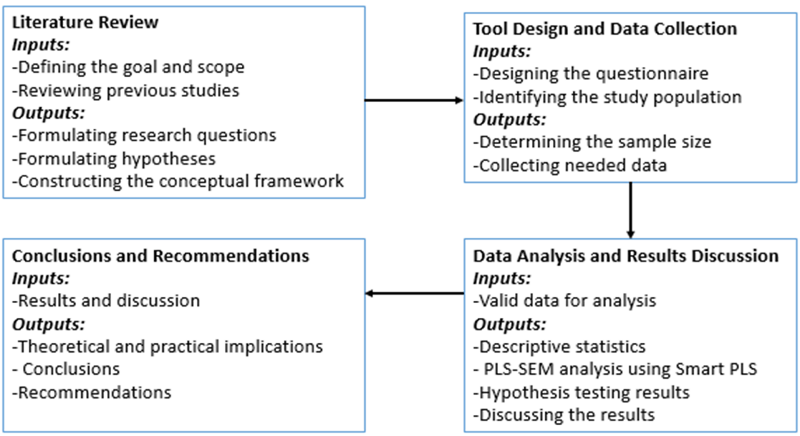

Figure 2. Research methodology flow. (*Source:* Authors' own work)

$$n = \frac{N \times P(1-P)}{\{N - 1 \times \left(d^2 \div z^2\right)\} + P(1-P)}$$

Where, n represents the sample size, N is the population size (with $N = 206$), p is the proportion of property offers and neutral responses ($p = 0.5$), d is the margin of error ($d = 5\%$) and z is the upper$\alpha/2$ of the normal distribution (for a 95% confidence level, $z = 1.95$). By substituting these parameter values into the equation, the sample size is calculated to be $n = 134$.

The data collection process utilized a questionnaire that was carefully designed, validated and distributed to gather the required information. The questionnaire underwent pretesting by industry experts knowledgeable in construction and quality management to ensure clarity and relevance. Based on their feedback, minor adjustments were made to improve the comprehensibility of the items. Additionally, two arbitrators reviewed the questionnaire for simplicity and accuracy, with any typographical errors corrected before distribution.

Phase three is the analytical phase in which data were collected from the sampled contractors and analyzed using the partial least square structural equation modeling (PLS-SEM) approach. Based on the analysis, formulated hypotheses were examined, the final framework was customized, results were discussed and accordingly a set of conclusions are generated. In the last phase, the theoretical and practical implications as well as the conclusions and recommendations are obtained.

3.2 Measurement development and questionnaire design

The questionnaire was designed after specifying the main literature-based constructs in order to obtain accurate results, where 41 questionnaire items were generated. More specifically, to measure CMS, 18 items were selected according to Gunduz and Elsherbeny (2020), constructs are performance monitoring and reporting (PMR) having 4 items, financial management (FM) having 3 items, claims and quality and acceptance and changes control (QACC) having 4 items, project governance/start-up and close-out (PG) having 4 items and contract administration team management (CAM) having 3 items. Additionally, according to Adekunle *et al.* (2024), Karmakar and Delhi (2021) and Zhu *et al.* (2022), Quality 4.0 technologies was formulated through eight items; having the following constructs: smart technologies (ST) and digital ecosystems (DE) with four items each. To evaluate QMS; 15 items were selected from the related literature, specifically Leong *et al.* (2014) and Neyestani (2016) to cover five constructs: scope (Sc), client satisfaction (CS), time (Ti), cost (Co) and safety issues (Si) with three items for each. All items were assessed using a five-point Likert scale, where respondents were asked to indicate their level of agreement with the statements. The response options ranged from (1 = Strongly Disagree) to (5 = Strongly Agree). As mentioned previously, the initial draft of the questionnaire was validated by industry experts. Most of their comments were related mainly to wording and clarity of questions. Since the Arabic language is the mother language in Palestine, an Arabic version of the final validated questionnaire was translated from the English version and used for data collection. An online version of the questionnaire was designed, and its link was sent to the sampled contractors. All items are presented in Table 2.

4. Data analysis and results

4.1 Analysis of survey responses

One-hundred forty (140) responses were received, after screening these responses, only 95 respondents were valid, resulting in a response rate of 68%. The frequency analysis of the respondents conducted using SPSS is summarized in Table 1.

4.2 Assessment of the measurement model (outer model)

The empirical data from the study questionnaire was analyzed using the partial least squares-structural equation modelling (PLS-SEM) approach via Smart-PLS software (Hair *et al.*, 2019)

Table 1. Respondents profile summary

Item	Choices	Percentage
Educational level	Diploma	24.2%
	Bachelor's degree	52.6%
	Higher education	23.2%
	Total	*100.0%*
Company experience	Less than 5 Years	17.9%
	5–15 Years	30.5%
	More than 15 years	51.6%
	Total	*100.0%*
Position of participant	General manager/CEO	32.7%
	Construction engineer	40.0%
	Office engineer	12.6%
	Quality manager	4.2%
	Others	10.5%
	Total	*100.0%*
Company classification	Contracting 1st t	42.1%
	Contracting 2nd	31.6%
	Contracting 3rd	7.4%
	Contracting 4th	11.5%
	Contracting 5th	7.4%
	Total	*100.0%*

Source(s): Authors' own work

to investigate the relationships between research constructs. The study employed the PLS-SEM approach to develop its model. This method was chosen because it is suitable in situations where the assumptions of least squares regression are not met, the sample size is relatively small (as in this study) and issues such as normality, multicollinearity and missing values need to be addressed (Hair *et al*., 2017). Among the various SEM methods, one of the most used is PLS-SEM (Afthanorhan *et al*., 2021). Research by Dash and Paul (2021) comparing these methods for technology forecasting highlights that PLS-SEM offers better variable loading, closer structural relationships, higher discriminant validity and greater composite reliability (CR) compared to other approaches. These findings suggest that PLS-SEM provides better construct validity and reliability. Furthermore, Dash and Paul (2021) concluded that PLS-SEM is better suited for prediction and development. Given the advantages of PLS-SEM it was considered the most appropriate for the present study.

The Smart-PLS analysis consists of two main steps (Hair *et al*., 2017). The first step involves assessing the measurement model (outer model) to examine the correlation between each latent variable and its corresponding indicators. While the second step focuses on the structural model (inner model), which evaluates the relationships between latent variables (paths). Here, it is important to distinguish between two key types of variables: exogenous variables, which function as independent variables in the structural model, and endogenous variables, which are considered as a dependent variable (Hair *et al*., 2019).

The validity and reliability of the constructs are assessed as part of the measurement model. Convergent validity refers to the extent to which a measure correlates positively with other measures of the same construct. There are three tests that are used for evaluating convergent validity in reflective measurement models. As shown in Figure 3 and Table 2, all outer factor loadings exceed 0.6. Composite reliability (CR) results are analyzed to ensure internal consistency and reliability; values range from 0.802 to 0.949, where higher composite reliability values indicate greater reliability. According to Hair *et al*. (2019), composite reliability values should exceed 0.70. As shown in Table 2, all composite reliability values surpass this threshold, confirming the reliability of all constructs. Next, the Average Variance Extracted (AVE) is calculated by averaging the squared outer loadings of the indicators for

Table 2. Cronbach's alpha, composite reliabilities and AVE values

Constructs	Items	Indicators	Factor loadings	Cronbach's alpha (α)	CR	AVE
Contract administration team management (CAM)	Assignment of qualified team and regular performance assessment	CAM-1	0.842	0.841	0.905	0.760
	Roles and responsibilities are clear	CAM-2	0.871			
	Regular training programs	CAM-3	0.900			
Performance monitoring, reporting and documentation (PMR)	Monitoring and reporting systems (KPIs) are developed in the early stages	PMR-1	0.873	0.881	0.918	0.737
	A documentation system is established and maintained	PMR-2	0.881			
	The contractor's care of works is monitored and followed up	PMR-3	0.866			
	Information Technology is utilized for documentation, and stakeholders are provided with relevant statistics	PMR-4	0.812			
Quality and acceptance and changes control (QACC)	The contractor's quality management system (QMS) is audited	QACC -1	0.779	0.880	0.917	0.736
	The quality of work is inspected in a timely manner	QACC -2	0.882			
	Shop drawings and materials are reviewed in a timely manner	QACC -3	0.859			
	The contractor's proposals are evaluated promptly, and change orders are processed in a timely manner	QACC -4	0.908			
Project governance/ start-up and close out (PG)	Project management plans are developed at earlier stages	PG-1	0.882	0.981	0.925	0.755
	Review the contractor's key staff and subcontractor(s) qualifications	PG-2	0.874			
	Document best practices and lessons learned	PG-3	0.874			
	The final account and the review of the closing-out documentation are progressed in a timely manner	PG-4	0.844			
Financial management (FM)	A financial management system is established in the early stages	FM-1	0.905	0.879	0.925	0.805
	The owner is notified about due payments	FM-2	0.900			
	Payment compensations are assessed in a timely manner	FM-3	0.887			

(*continued*)

Table 2. Continued

Constructs	Items	Indicators	Factor loadings	Cronbach's alpha (α)	CR	AVE
Smart technologies (ST)	Our employees have a good understanding of how new technologies and devices can be utilized to support our business	ST-1	0.680	0.701	0.802	0.505
	Applying new technologies in my work environment (e.g. sensors, drones, cameras, RFID, etc.)	ST-2	0.711			
	Our top management takes the risks involved in implementing IoT smart technologies	ST-3	0.673			
	Our top management has sufficient resources to enable the implementation of Industry 4.0 technologies	ST-4	0.773			
Digital ecosystems (DE)	Our company agrees to engage all stakeholders in a digital system to facilitate communication and decision-making	DE-1	0.726	0.782	0.858	0.602
	Our company is ready to handle big data and use artificial intelligence and other supportive digital technologies	DE-2	0.735			
	Our company's strategy focuses on emerging digital technologies, such as BIM, and establishes new supportive policies accordingly	DE-3	0.825			
	Our company is willing to establish a central platform to manage work effectively	DE-4	0.812			
Scope (Sc)	All stakeholders are participating in continuous improvement	Sc-1	0.876	0.856	0.912	0.776
	The quality assurance process and project audits are effective	Sc-2	0.901			
	All employees are aware of quality improvements and understand the quality objectives	Sc-3	0.865			
Client satisfaction (CS)	Increased business benefits	CS-1	0.782	0.849	0.947	0.772
	Reduced customer complaints	CS-2	0.933			
	Increased customer loyalty	CS-3	0.913			

(*continued*)

Table 2. Continued

Constructs	Items	Indicators	Factor loadings	Cronbach's alpha (α)	CR	AVE
Time (Ti)	Effective communication that reduces delays	Ti-1	0.834	0.920	0.946	0.862
	Well-managed supply chain	Ti-2	0.906			
	The project completion corresponds to proposed implementation timeliness	Ti-3	0.863			
Cost (Co)	Efficient process management and resource usage minimize costs	Co-1	0.907	0.876	0.924	0.802
	Business outputs are tracked and measured, which means areas of waste and duplication can be identified and eliminated	Co-2	0.920			
	Realizing the defects earlier and are corrected at a lower cost	Co-3	0.859			
Safety issues (Si)	There is a low number of accidents and injuries during project implementation	Si-1	0.928	0.927	0.949	0.872
	Corrective actions are continuously taken	Si-2	0.940			
	Almost no fatalities occur during the implementation of the project	Si-3	0.933			

Source(s): Authors' own work

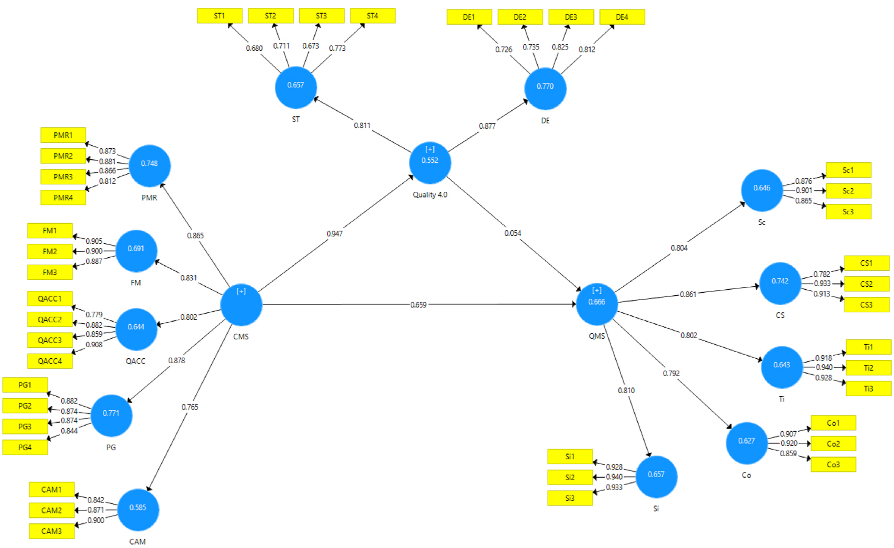

Figure 3. Measurement model. (*Source:* Authors' own work)

each specific construct. The AVE should be greater than 0.50, indicating that the construct explains more than 50% of the variance in its indicators (Hair *et al.*, 2019). In this study, the AVE values presented in Table 2 indicate good convergent validity. Furthermore, a Cronbach's alpha value above 0.7 is recommended as a traditional criterion for evaluating internal consistency, and the results reported in Table 2 demonstrate high internal consistency. The discriminant validity test assesses the uniqueness of a construct in relation to other constructs (Hair *et al.*, 2019).

Table 3 outlines two methods for testing discriminant validity; the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT). According to the Fornell–Larcker criterion, discriminant validity is confirmed when the correlation values of the off-diagonal elements between variables are lower than the on-diagonal values, as outlined by Fornell and Larcker (1981). In contrast, the HTMT method suggests that for discriminant validity to be established, the correlation between variables should be less than 0.90 (Hair *et al.*, 2019). When both methods show that the constructs meet these criteria, it indicates that the model demonstrates good discriminant validity (Henseler *et al.*, 2015).

4.3 Assessment of the structural model (inner model)

The next phase entails examining the structural model and evaluating the significance of path coefficients, along with determination coefficients (R^2), in accordance with Hair *et al.* (2019). R^2 values were calculated, revealing that CMS and Quality 4.0 together elucidate 55.2% of the variability in innovation, a level considered moderate. Quality 4.0 in isolation explains 66.6% of its variability, also falling within the moderate range. Additionally, the f^2 statistic indicates the effect size of each predictor in the model. According to Cohen's (1988) interpretation, f^2 values of 0.02, 0.15 and 0.35 correspond to low, medium and high effects, respectively. In this study, CMS showed a medium effect ($f^2 = 0.158$) on QMS and a medium effect size ($f^2 = 0.593$) on Quality 4.0 technologies. Furthermore, Quality 4.0 technologies were found to have a high effect on QMS, with an f^2 value of 0.365. Table 4 presents the R^2, f^2, Q^2 and variance inflation factor (VIF) values. The VIF helps determine if predictors are collinear, with values below 3 indicating no multicollinearity issues, which is the optimal case. As such, no multicollinearity problem was identified in this study, as the VIF values were below 3. Critical collinearity issues arise when the VIF exceeds 5 (Hair *et al.*, 2019). Finally, the standardized root mean square residuals (SRMR) value was 0.075, which is below the 0.08 threshold suggested by Hu and Bentler (1998), indicating that the structural model fits the collected data well.

4.4 Direct and indirect effects results

Finally, the hypothesized relationships were evaluated using bootstrapping with the PLS algorithm. Path coefficients play a crucial role in PLS, and if they are significant or in line with the expected direction, the hypothesis should not be rejected. The empirical results from the bootstrapping procedure, including the β values, standard deviations, t-values and *p*-values for both direct and indirect relationships, were obtained from 5,000 subsamples. These values provide the necessary evidence to support or refute the proposed hypotheses. As shown in Table 5, the results of the analysis show that three hypotheses are supported. More specifically, the bootstrapping findings show that CMS has a positive and significant effect on QMS ($\beta = 0.659$, $t = 22.859$, $p = 0.000$), which supports H1; CMS positively and significantly affects Quality 4.0 ($\beta = 0.947$, $t = 83.210$, $p = 0.000$), which supports H2. Similarly, the bootstrapping findings show that Quality 4.0 has a positive and significant effect on QMS ($\beta = 0.054$, $t = 2.663$, $p = 0.000$), which also supports H3. On the other hand, the findings of the indirect effect of the mediating variable are also shown in Table 5. The results show that Quality 4.0 mediates the relationship between CMS and QMS ($\beta = 0.207$, $t = 2.663$, $p = 0.000$, LL = 0.052, UL = 0.355) and hence H4 is supported.

Table 3. Discriminant validity

Construct	CAM	CS	Co	DE	FM	PG	PMR	QACC	ST	Sc	Si	Ti
Fornell and Larcker												
CAM	*0.872*											
CS	0.084	*0.878*										
Co	0.316	0.657	*0.896*									
DE	0.305	0.251	0.108	*0.776*								
FM	0.162	0.168	0.532	0.386	*0.897*							
PG	0.303	0.121	0.149	0.175	0.366	*0.869*						
PMR	0.052	0.285	0.601	0.439	0.125	0.652	*0.858*					
QACC	0.022	0.263	0.59	0.476	0.126	0.65	0.114	*0.858*				
ST	0.042	0.126	0.533	0.328	0.091	0.643	0.212	0.537	*0.710*			
Sc	0.335	0.563	0.217	0.599	0.215	0.242	0.08	0.347	0.167	*0.881*		
Si	0.36	0.505	0.309	0.659	0.25	0.231	0.277	0.235	0.258	0.553	*0.934*	
Ti	0.12	0.175	0.398	0.17	0.315	0.244	0.219	0.103	0.193	0.092	0.255	*0.928*
HTMT												
CAM	–											
CS	0.142	–										
Co	0.093	0.252	–									
DE	0.35	0.762	0.365	–								
FM	0.333	0.278	0.122	0.309	–							
PG	0.175	0.196	0.616	0.445	0.116	–						
PMR	0.357	0.178	0.182	0.216	0.443	0.214	–					
QACC	0.065	0.311	0.685	0.496	0.138	0.728	0.125	–				
ST	0.078	0.291	0.679	0.552	0.139	0.733	0.139	0.787	–			
Sc	0.074	0.141	0.615	0.379	0.103	0.726	0.257	0.595	0.682	–		
Si	0.36	0.626	0.242	0.674	0.234	0.265	0.095	0.375	0.35	0.191	–	
Ti	0.403	0.578	0.356	0.77	0.283	0.271	0.344	0.268	0.293	0.294	0.621	–

Source(s): Authors’ own work

Table 4. R^2, f^2, Q^2 and VIF

Construct	R^2	f^2 Q4.0	f^2 CMS	Q^2predict	VIF
QMS	0.666	0.365	0.158	0.479	1.887
Quality 4.0	0.552	–	0.258	0.387	1.566

Source(s): Authors' own work

Table 5. Results of direct and indirect relations

Path	Hypothesis	Original sample (β)	*T*-value	*p*-value	Result
Direct Effects					
CMS → QMS	H1	0.659	22.859	0.000	Supported
CMS → Quality 4.0	H2	0.947	83.210	0.000	Supported
Quality 4.0 → QMS	H3	0.054	4.103	0.000	Supported
Indirect Effects (Mediation)					
CMS → Quality 4.0 → QMS	H4	0.207	2.663	0.000	Supported

Source(s): Authors' own work

5. Discussion of results

The statistical results demonstrate a significant positive relationship between CMS and QMS. The findings align with previous research conducted by Coleman *et al.* (2020) and Nsefu *et al.* (2020), who affirmed that poor contract management results in poor service delivery of an institution that deals with contract management.

This result is not surprising, the contract documents are the core of works' execution in construction industry and technical specifications formulate an essential part of these documents. In these specifications, the quality of the materials, the way of work execution and technical instructions are specified and mutually agreed prior to any commencement of works. Thus, the relationship between CMS and QMS is logically significant, and this result agrees also with those in Gunduz and Elsherbeny (2020) and Emblemsvåg (2020) studies.

Next, the statistical results show a positive and significant relationship between CMS and Quality 4.0. This result can be attributed to the crucial roles CMS play in fulfilling the goals of Quality 4.0 through enhancing the accuracy of data, fostering collaboration, improving compliance, streamlining and standardizing processes and providing data analytics. Accordingly, higher quality standards and better organizational performance could be realized. More specifically, construction firms can effectively align their contract management practices with the principle of Quality 4.0 through leveraging a robust CMS, and thus sustaining continuous quality improvements and competitive advantages could be ensured. The effective use of information technology in contract administration can help minimize time waste associated with document transfer and paperwork, while also helping enable real-time tracking (Gunduz and Elsherbeny, 2020; Najafzadeh *et al.*, 2024). This result has been also shown in the work of Rumane (2017) and is in agreement with those in Wawak *et al.* (2020), Lu *et al.* (2023) and Shen *et al.* (2018).

Further, the statistical results indicated a positive and significant relationship between the acceptance and implementation of Quality 4.0 and QMS. More specifically, the acceptance and adoption of Quality 4.0 technologies can be employed to track real-time work and predict maintenance requirements, thereby avoiding errors and ensuring effective implementation of

QMS. As a result, project quality generally will improve, this will lead to higher employee engagement. This outcome agrees with the findings of Javaid *et al*. (2021).

Finally, in this research work, the proposed mediating effect of Quality 4.0 acceptance and implementation on the relationship between CMS and QMS is supported. Quality 4.0, through advanced digital technologies, accelerates the transformation of quality management practices from traditional into digital systems. Specifically, Quality 4.0 promotes big data analytics and other artificial intelligence (AI) tools to analyze the vast amounts of data generated by CMS. This analysis helps in identifying potential quality issues and making fact-based decisions (Ahmed *et al*., 2017; Wu *et al*., 2019). Additionally, Quality 4.0 technologies, such as blockchain, enhance the compliance of CMS with contractual requirements and construction industry regulations by providing consistent, real-time data on compliance metrics, thereby ensuring the consistency of quality standards throughout the construction project lifecycle (Sajjad *et al*., 2023; Shen *et al*., 2023). Furthermore, Quality 4.0 supports the automation of contract management, which accelerates workflows and reduces manual errors using smart technologies like IoT and robotics, which leads to enhancing overall project efficiency and quality (Wu *et al*., 2019). Also, Shen *et al*. (2023), state that Quality 4.0 enhances collaboration among various stakeholders in the construction industry by utilizing digital tools like cloud-based platforms and virtual reality to facilitate better coordination and real-time communication, which, in turn, improve quality outcomes.

6. Theoretical and practical implications

6.1 Theoretical implications

This work offers several theoretical implications. First, the inclusion of Quality 4.0 technologies such as big data analytics, AI, IoT and robotics into traditional QMS practices in the construction industry represents a significant advancement in integrating technological innovations into quality management theories. This integration necessitates a shift from conventional approaches to data-driven and automated methods for managing quality in this industry (Saihi *et al*., 2023). Secondly, investigating the mediating role of Quality 4.0 between CMS and QMS introduces a new dimension to mediation theory within the construction industry. The results indicate that such mediation enhances the relationship through Quality 4.0 technologies, which act as intermediaries that strengthen the effects of conventional management systems. Thirdly, integrating CMS, QMS and Quality 4.0 into a single conceptual framework emphasizes interdependence and introduce synergy among these constructs. It would also highlight how such integration can lead to comprehensive improvements in quality management within the construction sector. This integration also extends to incorporating advanced technological Quality 4.0 tools in contract management, underscoring the adaptable and dynamic nature of contracts in the digital age (Papantoniou, 2020).

6.2 Practical implications

The results of the research have implications for other stakeholders, such as policymakers and industry associations, who support Quality 4.0 implementation. Recognizing the essential variables allows stakeholders to create a well-designed strategy to help firms overcome adoption issues. Policymakers, for example, must implement CMS activities such as team management, performance monitoring and documentation, project governance and other financial support mechanisms to encourage their enterprises to use Quality 4.0 technologies. Meanwhile, industry groups may help construction companies share knowledge, train employees and collaborate to develop the necessary skills and experience.

In addition, the benefit of integrating CMS, QMS and Quality 4.0 technologies that in effect would lead to significant improvements in the quality of construction projects. In this context, CMS ensures compliance with all contractual requirements, while Quality 4.0 tools such as big data analytics and artificial intelligence facilitate proactive and preventive actions in quality management (Wawak *et al*., 2020). Furthermore, developing CMS can help firms gain a common knowledge of Quality 4.0 adoption, helping them to traverse this complicated landscape more effectively. These initiatives can also assist in reducing the uncertainties and risks connected with quality adoption, promoting more QMS in terms of cost reduction, increased customer satisfaction and safety concerns.

A social perspective is essential for Quality 4.0, which requires upskilling people to adapt to emerging technologies and aligning work with their needs (Gunasekaran *et al.*, 2019; Breque *et al.*, 2021). The transformation also has socio-economic impacts (Radziwill, 2018) and emphasizes human-centered approaches (Dias *et al.*, 2022). As customized production grows, new business models focused on customer experience will become more profitable (Hyun Park *et al.*, 2017). Rethinking business models and work practices is crucial for the digital transition, with customer service and employee integration playing key roles. For sustainable Quality 4.0 adoption, traditional quality principles must form the foundation (Carvalho *et al.*, 2024). The findings of this study raise awareness on the adoption of digital technologies in construction, helping inform policymaking and strategies for aligning with statutory and client requirements, promoting collaboration and enhancing the quality process.

7. Conclusions

This study aims to explore how contract management systems affect the quality management systems of contracting construction companies, with a particular emphasis on the mediating role of Quality 4.0 practices. The research was conducted through surveys, collecting data from contracting construction companies in the West Bank region of Palestine. The data collection procedure involved management personnel at various levels, providing valuable insights into the guidelines and activities of construction firms. These individuals are essential for data exchange and policy enforcement within their companies. Smart PLS 4.0 software was employed for data analysis. Within the Palestinian construction industry context, it has been concluded from the findings that contract management systems have significant positive impacts on both quality management systems and Quality 4.0. Also, adopting and implementing Quality 4.0 technologies have been found to positively affect the success of quality management systems and it proved to play a mediating role between contract management and quality management in the Palestinian construction industry.

This research enables organizations to strategically plan for a gradual transformation to the Quality 4.0 era, aimed at eliminating waste, achieving desired contractual quality, ensuring client satisfaction and ultimately reaching sustainability. Fundamentally, specific dimensions of Quality 4.0, such as BIM technology and digitalized management systems like enterprise resource planning (ERP), are acknowledged as significant contributors to Quality 4.0. Respondents confirm that digital management systems are much more essential than technologies like sensors and IoT. Managers must recognize the value of emerging technologies, such as BIM, in enhancing quality management systems and TQM.

Nevertheless, this study has several limitations. Firstly, the sample size was limited to 95 companies in the construction sector in Palestine. While this sample size was sufficient for analysis, a larger sample would have enhanced the generalizability of the study’s findings. Secondly, since all respondents were from the Palestinian construction sector, the ability to generalize the findings is restricted. More specifically, participants from other developing countries in the region could have quantitatively and qualitatively strengthened the sample and the generalizability of the results. Furthermore, data was collected exclusively from managers, overlooking the perspectives of functional staff, whose insights could have added depth to the findings. It is strongly encouraged to address the previously mentioned limitations in future research.

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