

The impact of digitalization on quality management challenges: A field study in a sample of Algerian industrial companies

أثر التحول الرقمي على تحديات إدارة الجودة:
دراسة ميدانية في عينة من الشركات الصناعية الجزائرية

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Abstract:

Digitalization has become a pivotal element in enhancing production processes and boosting competitiveness. However, this transformation imposes new challenges on quality management, necessitating an examination of its impact on industrial companies. This study aims to identify the effect of digitalization on the challenges faced by quality management in a sample of Algerian industrial companies. The study used convenience sampling to distribute a questionnaire to 43 industrial companies in western Algeria during the first three months of 2024. Data coding and descriptive statistical analysis were conducted using SPSS software. Subsequently, Structural Equation Modeling (SEM) was employed using the Partial Least Squares (PLS-SEM) approach via SmartPLS 4. The results revealed that digitalization positively influences more than 78% of the challenges faced by quality management in these companies, prompting the development of adaptive quality management strategies aligned with the evolving digital environment. Based on these findings, it is recommended that quality management personnel in these companies enhance their skills and continuously update their working mechanisms to keep pace with ongoing digitalization, thereby ensuring the achievement of quality standards amid rapid technological advancements.

Keywords: Digitization, Digitalization, quality management, industrial companies, Partial Least Squares Structural Equation Modeling

ملخص:

أصبحت الرقمنة عنصراً محورياً في تحسين عمليات الإنتاج وتعزيز القدرة التنافسية. ومع ذلك، تفرض هذه التحولات تحديات جديدة على إدارة الجودة، مما يستدعي دراسة تأثيرها على الشركات الصناعية. تهدف هذه الدراسة إلى تحديد أثر الرقمنة على التحديات التي تواجه إدارة الجودة في عينة من الشركات الصناعية الجزائرية. استخدمت الدراسة أسلوب العينة المريحة لتوزيع الاستبيان على 43 شركة صناعية في غرب الجزائر خلال الأشهر الثلاثة الأولى من 2024. تم ترميز البيانات وإجراء الإحصاءات الوصفية باستخدام برنامج SPSS 26 بعد ذلك، تم استخدام نمذجة المعادلات الهيكلية (SEM) باستخدام طريقة المربعات الصغرى الجزئية (PLS-SEM) بالاعتماد على برنامج SmartPLS 4، أظهرت النتائج أن الرقمنة تؤثر إيجابياً على أكثر من 78% من التحديات التي تواجه إدارة الجودة في هذه الشركات، مما دفع إلى تطوير استراتيجيات إدارة الجودة التي تتكيف مع البيئة الرقمية المتغيرة. بناءً على هذه النتائج، يُوصى بأن يقوم موظفو إدارة الجودة في هذه الشركات بتعزيز مهاراتهم وتحديث آليات عملهم باستمرار لمواكبة الرقمنة المستمرة، مما يضمن تحقيق معايير الجودة في ظل التطورات التكنولوجية السريعة.

الكلمات المفتاحية: الرقمنة، التحول الرقمي، إدارة الجودة، الشركات الصناعية، نمذجة المعادلات الهيكلية PLS-SEM

JEL codes : M15, L15, D2, C39.

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1. Introduction:

Digitalization and digital transformation are among the most significant shifts reshaping quality management practices within organizations. A multi-case study involving four large Swedish organizations, with employee counts ranging from 15,000 to 100,000, indicated that digitalization has impacted process quality through initiatives such as automation, digital communication, and real-time data analytics (Mattias et al., 2021). Although these initiatives contributed to improved internal efficiency, the role of quality management often remained supportive rather than leading, especially in strategic initiatives or those related to customer interaction (Elg et al., 2021). The study also revealed challenges related to weak integration between quality departments and information technology and a lack of digital skills among quality practitioners, which limits their effective contribution to value creation within customer interaction cycles (Elg et al., 2021). Therefore, quality management must realign its roles to include exploratory and innovative practices that keep pace with the evolving digital environment (Elg et al., 2021).

In the context of Algeria, digital transformation is a fundamental component of the national strategy "Digital Algeria 2030," aimed at promoting digitalization across various economic sectors. According to the 2024 Network Readiness Index, Algeria ranked 100rd out of 133 countries with a score of 39.24 (Portulans institute, 2025). In the business environment pillar, Algeria ranked 42nd with a score of 41.42, achieving 45nd place in the annual investment in telecommunication services with a score of 57.01. These results related to digitalization and digital transformation trends may improve quality management practices in Algerian companies by enabling integration between information technology and operations management. However, these transformations may also create new challenges, such as updating digital skills among quality practitioners in the industrial sector and weak coordination between quality and technology departments.

1.1. Research Problem

With rapid changes in the industrial environment, digitalization has become a crucial factor in improving production processes and enhancing corporate competitiveness. On the other hand, industrial companies face numerous challenges in quality management, particularly with the transition to digital models, which necessitates restructuring control and quality mechanisms to ensure sustainable performance and customer satisfaction.

In Algeria, many industrial companies still struggle to adopt digitalization due to insufficient technological infrastructure, resistance to change, or difficulties in adapting to new quality standards imposed by the digital era. Accordingly, this study raises the following research question:

What is the impact of digitalization on quality management challenges in Algerian industrial companies?

1.2. Research Hypothesis

Based on previous literature and theories related to digitalization and quality management, this study hypothesizes that:

H1: Digitalization has a positive impact on quality management challenges in Algerian industrial companies.

In other words, the more efficient Algerian industrial companies are in adopting digitalization strategies, the greater the challenges associated with quality management, which contributes to improving overall performance and compliance with modern standards.

1.3.The importance of the Study

The importance of this study lies in its contribution to understanding the impact of digitalization on quality management in industrial companies. It provides scientific insights, empirical evidence, and practical recommendations to enhance competitiveness and efficiency in the digital era.

Its importance is represented in the following points:

- Highlighting the relationship between digitalization and quality management challenges in industrial companies, contributing to a better scientific understanding of this field.
- Providing empirical evidence based on primary data on the impact of adopting digital technologies on quality management.
- Offering practical solutions and strategies to help Algerian industrial companies address quality challenges through digitalization.
- Assisting decision-makers and industry practitioners in adopting effective digitalization strategies to improve quality and competitiveness.
- Contributing to the development of academic research on digitalization in the industrial business environment, enriching the scientific literature in this field.

1.4.Objectives of the Study

This study aims to:

- Analyze the role of digitalization in addressing quality management challenges in Algerian industrial companies.
- Assess the level of digitalization adoption in industrial companies and its impact on quality management.
- Test the relationship between digitalization and quality management using structural equation modeling.
- Provide practical recommendations for companies on how to enhance digitalization strategies to address quality challenges.
- Contribute to the development of academic research related to digitalization and quality management, particularly in Algerian industrial companies.

2.Literature Review and Theoretical framework of the study

2.1. Literature Review

2.1.1. The study by: Boutaleb and Senoussi (2025) titled: "The role of digitization in improving the services provided by the economic institution: a case study of Sonelgaz."

This study examines the role of digitization as a comprehensive approach to enhancing the services provided by Sonelgaz. It aims to achieve digital autonomy, strengthen internal collaboration, improve operational performance and human capital, while reducing costs. The findings highlight the importance of digitization in enriching the institution's knowledge base, protecting its assets, increasing profitability, and achieving customer satisfaction through improved service quality. The study also demonstrates that the implementation of digitization contributed to reducing the cost of meter data reading due to technological vigilance. It recommends adopting a comprehensive digitization system, expanding its use across all departments, training staff, and updating software to keep pace with technological advancements, ensuring the continuous improvement of services and their quality. (Boutaleb & Snouci, 2025).

2.1.2. The study by Ntobongwana and Telukdarie (2024) titled: A critical review of global best practices elements in digital technologies: Advancing a theoretical architecture for quality engineering

This study examines global best practices in digital transformation technologies and their impact on quality engineering, proposing a comprehensive theoretical framework to enhance quality management in digital environments. Through a systematic review of scholarly literature published between 2012 and 2022, the study identifies key factors influencing the adoption of digital technologies in quality assurance, such as digital strategy, leadership commitment, big data management, and organizational integration. The research is grounded in the Resource-Based View (RBV), Dynamic Capabilities, and the Technology Acceptance Model, developing a novel theoretical model that integrates quality management, operational sustainability, and digital technologies. The findings highlight that adapting to digital transformation in both service and manufacturing sectors is crucial for improving organizational competitiveness and performance. The study further emphasizes the need for effective policies and strategic initiatives to ensure seamless integration between technology, quality, and organizational management, facilitating the transition to digital quality management environments (Ntobongwana & Telukdarie, 2024)

2.1.3. The study by Tiganasu and Lupu (2023) titled: Institutional quality and digitalization: Drivers in accessing European funds at regional level?

This study examines the impact of institutional quality and digitalization on the absorption of European funding across 56 regions in Central and Eastern European (CEE) countries from 2007 to 2018. The findings indicate that strong governance and advanced digital infrastructure enhance regions' ability to attract and utilize European funds, including CF, ERDF, and ESF. The results show that regions with higher levels of digitalization and effective governance achieve greater absorption rates, contributing to reducing developmental gaps and fostering regional economic growth. The study also highlights significant regional disparities in digitalization and governance, which affect access to European funding. Consequently, the research underscores the necessity of improving institutional quality and accelerating digital transformation to ensure the sustainable utilization of European resources and promote regional development (Tiganasu & Lupu, 2023)

2.1.4. The study by Mattias et al (2021) titled: Digitalization and quality management: problems and prospects

This study examines the relationship between digitalization and quality management by analyzing the roles of quality management practitioners in digital initiatives and the associated challenges. The research is based on a multiple-case analysis of four major Swedish organizations. The findings reveal that digitalization impacts quality management processes in both exploration and exploitation. Six key roles of quality management practitioners were identified in this context. Additionally, the study highlighted the challenges faced in digitalization at the organizational process level and the value chain level, providing empirical evidence to enhance the current understanding of this topic (Mattias, Andrea, Ida, Jason, & Ulf, 2021).

2.1.5. The study by Robertson & Lapina (2021) titled: Digital transformation and the changing shape of quality management practices (Robertson & Lapina, 2021).

This study explores how digital transformation is reshaping quality management practices within organizations, emphasizing the role of digital technologies in modifying quality strategies,

corporate culture, customer interactions, and continuous improvement processes. By analyzing existing literature and examining three logistics companies, the study highlights that digital transformation is more than just implementing new technologies—it drives significant changes in leadership, organizational culture, operational processes, and decision-making frameworks. Additionally, the study underscores the importance of innovation and digital tools in advancing quality management, suggesting that digital transformation may become a fundamental aspect of quality management in the future (Robertson & Lapiņa, 2021).

2.1.6. The study by Cots (2018) titled: Digital transformation of quality management

This study discusses digital transformation in quality management, emphasizing that digital advancements have significantly impacted various fields, including quality management. It highlights that digital transformation goes beyond mere digitisation; it is not just about improving efficiency but about reshaping processes and business models by adopting technologies such as artificial intelligence, big data analytics, and the Internet of Things (IoT). The study also presents seven recommendations for quality managers on how to leverage these transformations to stay competitive in the future (Cots, 2018).

2.2. Theoretical framework of the study

2.2.1. Definition of digitalization and its elements

2.2.1.1. Definition of digitisation and digitalization and digital transformation

Digitisation primarily involves converting analog processes or practices into digital forms without altering their essence or changing the roles involved. In other words, digitisation replaces traditional tools with digital ones without affecting the mechanism of work or its organizational structure (Mattias, Andrea, Ida, Jason, & Ulf, 2021).

Unlike digitisation, digitalization extends beyond simple digital conversion by incorporating workflow restructuring, embracing technology-driven models, and leveraging digital tools to optimize efficiency and enhance overall organizational performance (Robertson & Lapiņa, 2021).

Building upon both digitisation and digitalization, digital transformation represents a fundamental shift, involving a complete redesign of core organizational processes and business models. It is not merely about adopting technology to improve efficiency; rather, it entails a fundamental shift in how tasks are performed, products and services are managed, and markets operate. Digital transformation relies on advanced technologies such as artificial intelligence and big data analytics, making it far more impactful than digitisation or traditional digitalization. The key difference is that digitalization adapts traditional processes to technology, while digital transformation completely rebuilds the work environment to align with the digital world (Cots, 2018).

From the above, we conclude that digital transformation represents an advanced stage that surpasses mere digitisation, which focuses on converting traditional processes into digital formats without fundamental changes, and digitalization, which aims to integrate digital technology to enhance efficiency and restructure certain operations. In contrast, digital transformation entails a complete redesign of business models, leveraging cutting-edge technologies such as artificial intelligence and big data to enable businesses to adapt to the evolving digital environment and enhance their competitiveness. Therefore, digitisation can be considered a technical step, digitalization a gradual development process, while digital transformation represents a fundamental

strategic shift that reshapes the work environment to ensure sustainability and innovation in the digital age.

2.2.1.2.Elements of Digitalization

Many researchers propose four main levels where Digitalization affects organizations: (Mattias, Andrea, Ida, Jason, & Ulf, 2021)

- Process Level: Involves applying digital tools or converting manual activities into digital ones.
- Organisation Level: Focuses on delivering new offerings and reshaping existing services using digital tools.
- Business Domain Level: Entails reshaping roles and value chains.
- Society Level: Alters the nature of work, required skills, and the infrastructure needed for digital transformation.

Building on these elements, digitalization impacts organizations on four interconnected levels: it starts with improving operational processes through automation, then extends to reshaping services and organizational models, leading to transformations in value chains and sectoral roles. At the societal level, Digitalization changes the nature of work and the skills required, necessitating adaptive policies to ensure sustainable economic and social benefits.

2.2.2.Definition of Quality Management

According to Cots (2018), Quality management encompasses a series of methodologies and procedures designed to improve organizational efficiency by overseeing processes, setting performance benchmarks, and maintaining customer satisfaction through ongoing enhancements. This approach incorporates various tools, including statistical analysis, internationally recognized quality standards such as ISO 9001, and comprehensive frameworks like Total Quality Management (TQM) (Cots, 2018).

Moreover, according to Mattias et al (2021),Quality management is a set of principles and practices aimed at improving the performance of processes, products, and services by applying concepts such as process improvement, risk management, and a focus on customer satisfaction. Quality management plays a crucial role in implementing digital transformation strategies within organizations (Mattias, Andrea, Ida, Jason, & Ulf, 2021).

Furthermore, Robertson and Lapiņa (2021) describe quality management as a structured methodology aimed at enhancing organizational effectiveness and ensuring customer satisfaction by implementing industry-recognized standards such as ISO 9001 and employing analytical tools for performance monitoring and evaluation. (Robertson & Lapiņa, 2021).

From these three definitions, it can be concluded that quality management is a structured and systematic approach that focuses on enhancing organizational efficiency, optimizing processes, and ensuring customer satisfaction. It integrates internationally recognized standards such as ISO 9001, employs analytical tools for performance monitoring, and incorporates principles like process improvement and risk management. Additionally, quality management is not only essential for maintaining high standards in products and services but also plays a crucial role in facilitating digital transformation within organizations by aligning processes with technological advancements and strategic objectives.

2.2.3.The Influence of Digital Transformation on Quality Management

The integration of digital transformation into quality management has introduced cutting-edge technologies that enhance accuracy, streamline efficiency, and refine decision-making processes.

By embracing digital tools, organizations can optimize workflows, strengthen customer interactions, and establish a more adaptive and data-driven approach to quality assurance. Some of the key advantages of digital transformation in quality management include: (Robertson & Lapina, 2021)

- Enhancing accuracy and efficiency by minimizing human errors and optimizing processes.
- Leveraging big data and artificial intelligence to support informed decision-making and boost operational effectiveness.
- Improving customer engagement by enabling personalized services and real-time digital interactions.
- Serving as a strategic enabler in modern quality management by integrating technology throughout all stages of production and quality control.

Based on the above, Digital transformation has become an essential component of contemporary quality management. By utilizing advanced technological solutions, businesses can achieve higher efficiency, improve customer experiences, and sustain their competitive advantage in an increasingly digital landscape.

2.2.4.Challenges in Implementing Digital Transformation in Quality Management

Although digital transformation offers significant advantages for quality management, it also presents challenges that organizations must effectively navigate. The adoption of digital tools, the evolution of business models, and the growing dependence on data analytics require quality managers to develop adaptive strategies. Some of the primary challenges include:

- Integrating Digital Tools: Overcoming difficulties in merging digital technologies with traditional quality management practices.
- Redefining Customer Interactions: Adjusting approaches to managing customer relationships in a digitally evolving landscape.
- Ensuring Cross-Departmental Integration: Addressing coordination challenges between quality management, IT, and other key departments.
- Managing Large-Scale Data: Developing strategies for handling and analyzing big data to enhance quality and enable data-driven decision-making.
- Aligning with Evolving Business Models: Adapting quality management practices to fit the framework of digital business models.
- Encouraging an Innovation-Oriented Culture: Fostering an organizational mindset that prioritizes innovation within quality management.

Building on these challenges, Effectively adopting digital transformation in quality management demands overcoming these obstacles through well-structured strategies, technological investments, and cultivating a culture of continuous learning and innovation. Organizations that proactively address these challenges will be better equipped to maximize the benefits of digital transformation and drive long-term success.

3.Methodology

This study relies on the descriptive analytical approach and the structural equation modeling method to study the impact of digitalization on quality management challenges in a sample of Algerian industrial companies, which included the following:

3.1. Sample and Sampling Technique

Given the challenges faced in distributing and collecting questionnaires from the industrial companies in the study sample, due to their wide and scattered distribution, as well as instances of some companies refusing to receive and fill out the questionnaire due to fears of information leakage and espionage by competitors despite the provided clarifications and assurances, a convenient sampling method was employed. The questionnaires were distributed to industrial companies that offered help and support in filling them out. The study included 43 industrial companies in western Algeria, specifically in the cities of Mascara and Mostaganem. The questionnaires were distributed during the first three months of 2024.

This research employed convenience sampling, a method similarly adopted by other studies. For example, (Robert & Dwight, 2014) used this approach to study university students. (Park, Velez, Kannan, & Chorpita, 2020) also utilized convenience sampling to explore individuals' experiences and coping strategies related to the COVID-19 pandemic. Additionally, (Leiner, 2014) applied convenience sampling to collect opinions from voluntary participants, including undergraduate and doctoral students, through the SoSci panel, a well-known platform in Germany for creating questionnaires since 2011. Convenience sampling is one of the techniques detailed by (Saunders, Lewis, & Thornhill, 2012).

3.2. The study Tool

This study relied on a questionnaire designed based on the theoretical literature available on the subject, particularly the study by (Mattias, Andrea, Ida, Jason, & Ulf, 2021). The questionnaire was constructed to include 10 items to measure the variable of digitalization and 4 items to measure the variable of quality management challenges, in addition to one question related to the company size. The aim of this questionnaire is to collect accurate data that contribute to systematically and scientifically analyzing the relationship between the two variables.

Based on previous studies and the current study's methodology. Responses are measured on a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

3.3. Measurement Instruments

To evaluate the reliability and validity of the study model according to Structural Equation Modeling (SEM), a variety of statistical tools were employed. These tools include factor loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE). Additionally, discriminant validity was assessed using the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. The explanatory power of the model was measured using the coefficient of determination (R^2) and effect size (F^2). To evaluate the model fit, indicators such as the Standardized Root Mean Square Residual (SRMR) and Chi-square (χ^2) test were utilized. Finally, path coefficients were analyzed to determine the strength and direction of the effect between independent and dependent variables using T-values and P-values.

This study relied on the SPSS version 26 program to extract descriptive statistics related to the sizes of industrial companies (study sample), in addition to calculating the arithmetic mean and standard deviation, while the rest of the statistical tests relied on the Smart PLS 4 program.

4. Result & discussion

4.1.Results

4.1.1.descriptive statistics

Table 1 presents descriptive statistics for the study sample of industrial companies, categorized based on the number of employees. The data indicate that the most represented category in the sample consists of companies with 10–49 employees, accounting for 37.2% of the total sample, followed by companies with 50–250 employees, which constitute 32.6%. Very small companies with fewer than 10 employees represent 25.6%, while large companies with more than 250 employees make up the smallest proportion, at only 4.7%. These findings highlight the dominance of small and medium-sized enterprises (SMEs) within the sample, which may reflect the nature of the industrial sector under study, where such enterprises constitute the majority compared to large firms.

Table 1. Descriptive statistics for industrial companies (study sample)

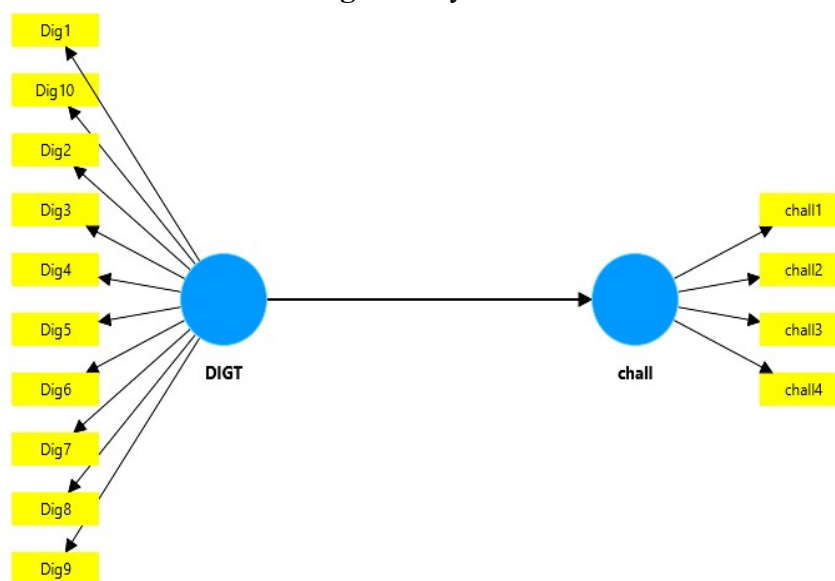
Characteristics	Frequency	Percent
Less than 10	11	25,6
10-49 workers	16	37,2
50-250 workers	14	32,6
More than 250 workers	2	4,7
Total	43	100,0

Source: achieved by author based on SPSS 26 output.

4.1.2.Reliability and Validity Assessment

Table 2 presents the reliability and validity evaluation for the two variables: Digitalization (DIGT) and Quality Management Challenges (CHALL). The assessment is based on factor loadings (λ), Cronbach's alpha (α), composite reliability (CR), average variance extracted (AVE), along with the mean, standard deviation, and variance inflation factor (VIF).

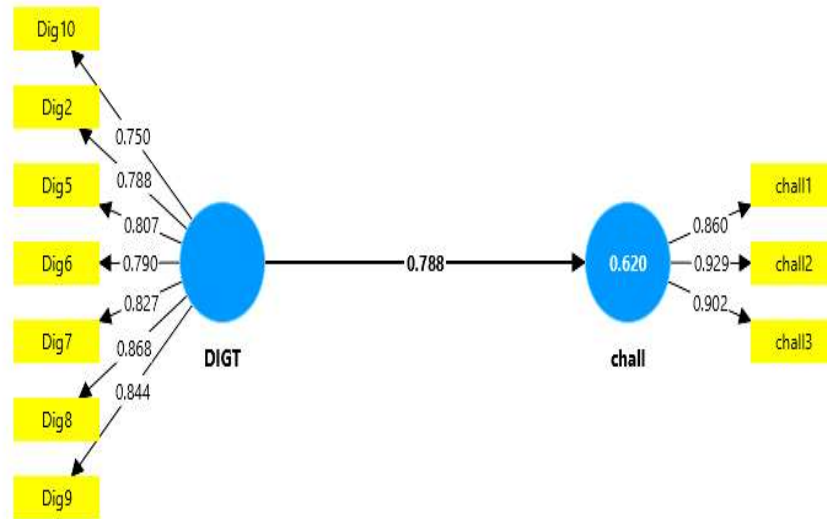
Fig.1. study model



Source: achieved by author based on Smart PLS 4 output.

To ensure the model's robustness, multiple iterations were conducted, evaluating factor loading values for each variable's items and analyzing their relationships until the optimal model was achieved. Figure 1 presents the initial version of the model, while Figure 2 illustrates the final version, which demonstrates validity and reliability.

Fig.2. The result of structural model



Source: achieved by author based on Smart PLS 4 output.

4.1.2.1. Factor Loadings (λ)

Factor loadings (λ) indicate the correlation between each item and the latent variable it measures. According to several references, a factor loading is considered acceptable if it is ≥ 0.50 (Hair, Black, Babin, & Anderson, 2010), while a value ≥ 0.70 (Fornell & Larcker, 1981) or ≥ 0.708 (Hair, Risher, Sarstedt, & Ringle, 2019) is preferred to ensure convergent validity.

In Table 2, the factor loadings for the digitalization variable range between 0.750 and 0.868, indicating a good level of validity. Similarly, for the quality management challenges variable, the factor loadings range between 0.860 and 0.929, demonstrating a strong correlation between the items and the latent construct.

Table 2. Measurement model.

ITEMS	λ	α	CR	AVE	Mean	SD	VIF
Digitalization (DIGT)		0.913	0.920	0.658			
Dig2	0.788				4,0465	0,93356	2.258
Dig5	0.807				3,5581	0,95641	2.653
Dig6	0.790				3,8837	0,91257	2.341
Dig7	0.827				3,9767	0,83328	2.488
Dig8	0.868				3,8605	0,96907	3.443
Dig9	0.844				3,6744	0,92162	3.003
Dig10	0.750				3,7674	0,79867	1.913
Quality management challenges (chall)		0.879	0.879	0.806			
chall1	0.860				3,8837	0,90526	1.961
chall2	0.929				3,8239	0,76794	3.503
chall3	0.902				3,9380	0,77751	2.953

Note. CR=Composite reliability, α = Cronbach's alpha, AVE = Average variance extracted, λ = loading, SD=Standard deviation, Dig2, Dig3, Dig6, Dig7, Dig8, Dig9, Dig10, Dig11 are items of Digitalization, chall1, chall2, chall3 are items of quality management challenges

Source: achieved by author based on SPSS 26 output (mean and SD), Smart PLS 4 (λ , α , CR, AVE).

4.1.2.2.Cronbach's Alpha (α)

Cronbach's alpha is used to assess the internal reliability of the measurement. Values above 0.70 indicate an acceptable level of reliability (Nunnally & Bernstein, 1994), while values ≥ 0.80 are considered good, and ≥ 0.90 indicate excellent reliability (George & Mallery, 2003). In Table 2, Cronbach's alpha for the digitalization variable was 0.913, while for the quality management challenges variable, it was 0.879, indicating a high level of internal consistency.

4.1.2.3.Composite Reliability (CR)

Composite reliability (CR) is used as an alternative to Cronbach's alpha to assess internal consistency and is considered more accurate in confirmatory factor analysis models. According to Fornell and Larcker (1981), a CR value should be ≥ 0.70 to ensure good reliability. In Table 2, the CR value for the digitalization variable was 0.920, while for the quality management challenges variable, it was 0.879, indicating a high level of reliability.

4.1.2.4.Average Variance Extracted (AVE)

AVE measures the amount of variance explained by the latent construct compared to random variance. According to Fornell and Larcker (1981), AVE should be ≥ 0.50 to ensure convergent validity. In Table 2, the AVE value for the digitalization variable was 0.658, while for the quality management challenges variable, it was 0.806, indicating that both variables explain a substantial proportion of variance in their respective data.

Based on the previous explanation, the results indicate high reliability and validity of the measurement instruments used in this study, as all statistical criteria were met according to established academic references. Therefore, these measures can be reliably employed for statistical analysis and deriving meaningful conclusions.

4.1.3.Evaluation of Model Validity and Structural Relationships

This section aims to assess discriminant validity, explanatory power, effect size, and path coefficients of the research model. These evaluations were conducted using Smart PLS 4 and based on widely accepted criteria in Structural Equation Modeling (SEM).

4.1.3.1.Discriminant Analysis Using the Fornell-Larcker Criterion

The Fornell-Larcker criterion is one of the most commonly used methods for testing discriminant validity in structural equation modeling. It is based on comparing the square root of the Average Variance Extracted (AVE) for each variable with the correlation coefficients between the other variables. Discriminant validity is established when the square root of AVE for each variable is greater than its correlation coefficients with other variables in the model (Fornell & Larcker, 1981).

Table 3. Discriminant validity using Fornell-Larcker Criterion

	Digitalization	Quality management challenges
Digitalization	0.811	
Quality management challenges	0.788	0.898

Source: achieved by author based on Smart PLS 4 output.

As shown in Table 3, the square root of AVE for Digitalization is 0.811, which is higher than its correlation coefficient with Quality Management Challenges (0.788), indicating that discriminant validity is achieved. Similarly, for Quality Management Challenges, the square root of AVE is 0.898, which is also greater than its correlation with Digitalization, confirming that each construct measures a distinct concept. This reinforces the reliability of the measurement model used in the study.

4.1.3.2. Discriminant Analysis Using the HTMT Criterion

The Heterotrait-Monotrait Ratio (HTMT) is a more rigorous test of discriminant validity compared to the Fornell-Larcker criterion, as it evaluates the relationship between variables based on the average variance they share. According to (Henseler, Ringle, & Sarstedt, 2015), the HTMT value should be less than 0.90 to confirm discriminant validity, while values exceeding this threshold indicate potential construct overlap, suggesting weak discriminant validity (Henseler, Ringle, & Sarstedt, 2015).

Table 4. Discriminant validity using HTMT.

	Digitalization	Quality management challenges
Digitalization		0.865
Quality management challenges	0.875	

Source: achieved by author based on Smart PLS 4 output.

As shown in Table 4, the HTMT value between Digitalization and Quality Management Challenges is 0.865, which is below the recommended threshold. This confirms that discriminant validity is achieved, ensuring that each variable represents a distinct and independent concept.

4.1.3.3. R² Estimation (Explanatory Power)

The coefficient of determination (R²) is a key indicator for measuring the explanatory power of the model, as it reflects the proportion of variance in the dependent variable that is explained by the independent variables. According to (Chin, 1998), R² values are categorized as follows: values of 0.19 indicate a weak effect, values of 0.33 indicate a moderate effect, and values of 0.67 or higher indicate a strong effect.

Table 5. R² estimation.

	R ²	Category
Quality management challenges	0.620	Moderate

Source: achieved by author based on Smart PLS 4 output.

As presented in Table 5, the R² value for Quality Management Challenges is 0.620. This indicates that Digitalization explains approximately 63.8% of the variance in Quality Management Challenges. Based on Chin's classification, this value falls within the range of a moderate to strong effect. Consequently, these findings suggest that the model possesses a substantial explanatory power in capturing the relationship between the studied variables.

4.1.3.4. F² Estimation (Effect Size)

The effect size (F^2) is an essential indicator for evaluating the strength of causal relationships within the model. It measures the contribution of each independent variable in explaining the variance of the dependent variable. (Cohen, 1988) categorizes F^2 values as follows: values of 0.02 indicate a small effect, values of 0.15 indicate a moderate effect, and values of 0.35 or higher indicate a large effect.

Table 6. F^2 Estimation

	f^2	Category
Digitalization → Quality management challenges	1.633	Large effects

Source: achieved by author based on Smart PLS 4 output.

As reported in Table 6, the effect size for the relationship between Digitalization and Quality Management Challenges is 1.633. This value significantly exceeds the threshold for a large effect, indicating that Digitalization has a substantial and strong impact on Quality Management Challenges. These results confirm the critical role of Digitalization as a key factor influencing quality management challenges in organizations.

4.1.3.5. Model Fit

Evaluating the goodness-of-fit of the structural equation model (SEM) is a fundamental step to ensure the accuracy and reliability of the results. Several statistical indicators are used to assess the extent to which the model aligns with the empirical data. Among these indicators, SRMR reflects a good fit when its value is below 0.08, while lower values for d_ULS and d_G indicate a strong convergence between the proposed model and the ideal model (Henseler, Hubona, & Ray, Using PLS Path Modeling in New Technology Research: Updated Guidelines, 2016),(Dijkstra & Henseler, 2015). The Chi-square (χ^2) test is used to evaluate overall fit but is sensitive to sample size (Hair, Black, Babin, & Anderson, 2010). Meanwhile, NFI demonstrates an acceptable level of fit when it ranges between 0.80 and 0.90 (Bentler & Bonett, 1980).

Table 7. Model Fit

	Saturated Model	Estimated Model
SRMR	0.075	0.075
d_ULS	0.311	0.311
d_G	0.291	0.291
Chi-square	86.741	86.741
NFI	0.806	0.806

Source: achieved by author based on Smart PLS 4 output.

As presented in Table 7, The study results indicate that the estimated goodness-of-fit values support the model's reliability and applicability. The SRMR value of 0.075 suggests a good fit, while $d_ULS = 0.311$ and $d_G = 0.291$ indicate an acceptable level of alignment with the actual data. Additionally, the χ^2 value of 120.948 reflects a reasonable model fit, while the NFI value of 0.806 suggests a moderate yet acceptable fit. These findings reinforce the validity of the model, establishing it as a robust analytical tool for examining relationships between the studied variables.

4.1.3.6. Path Coefficient Analysis

Path coefficients (β) are fundamental in structural equation modeling, as they quantify the strength and direction of the effect exerted by independent variables on dependent variables. The statistical significance of these coefficients is assessed using T-values and P-values. According to Hair et al. (2010), a T-value greater than 1.96 indicates statistical significance at $p < 0.05$, whereas a T-value greater than 2.58 indicates statistical significance at $p < 0.01$.

Table 8. Path coefficient

Paths	B	SD	T values	P values	confidence intervals		Decision
					2.5%	97.5%	
					Direct effect		
Digitalization → Quality management challenges	0.788	0.046	16.989	0.000	0.703	0.884	H ₁ Accepted

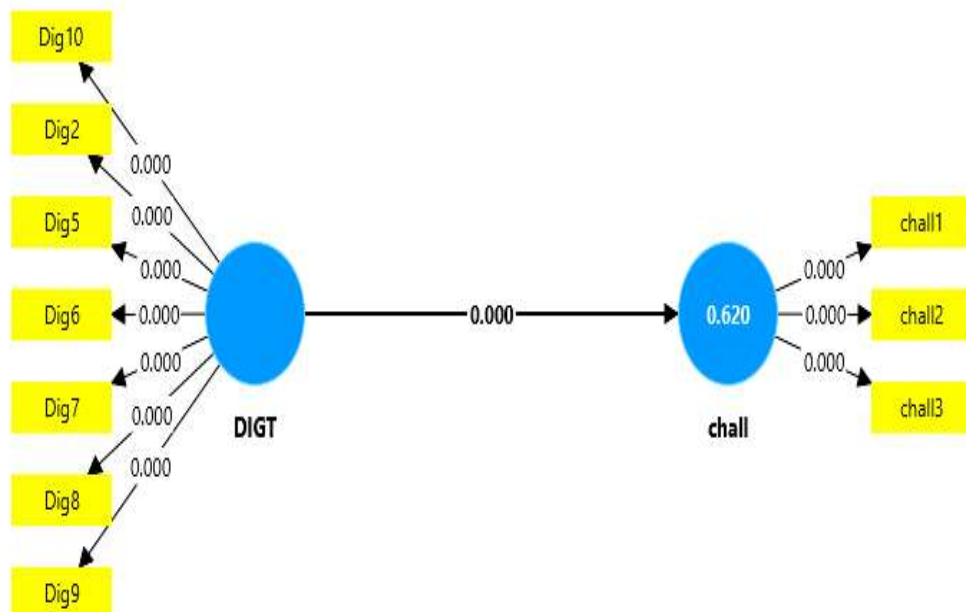
Note. β = Path coefficient, SD= Standard deviation.

Source: achieved by author based on Smart PLS 4 output.

As displayed in Table 8, the path coefficient (β) for the relationship between Digitalization and Quality Management Challenges is 0.788. This result demonstrates a strong positive relationship between the two variables. Moreover, the T-value for this relationship is 16.989, which far exceeds the required threshold for statistical significance. This confirms that the relationship is highly significant at $p < 0.01$. Figure 3 shows this result.

Additionally, the confidence interval for this relationship ranges from 0.703 to 0.884. This indicates a high level of stability in the effect size, reinforcing the robustness of the observed relationship. Based on these findings, Hypothesis H₁, which states that Digitalization positively influences Quality Management Challenges, is supported and accepted.

Fig.3. The result of bootstrapping



Source: achieved by author based on Smart PLS 4 output.

Based on the previous results, it is possible to accept the study's hypothesis, which states that Digitalization has a positive impact on quality management challenges in Algerian industrial companies.

4.2.Discussion

The findings of this study align with previous research on the impact of digitalization on quality management, yet they provide a distinct perspective by focusing on industrial companies in Algeria. A comparison with Mattias et al. (2021) highlights that while their study analyzed the evolving roles of quality management practitioners and the challenges of digital initiatives within Swedish organizations, the current study identifies the direct impact of digitalization on quality management challenges in Algerian industrial firms. Both studies emphasize that digital transformation reshapes quality management practices, requiring organizations to adapt their strategies to a rapidly changing digital landscape.

In relation to Cots (2018), who explored digital transformation from a strategic viewpoint, this study provides a more targeted analysis, specifically addressing how digitalization contributes to the challenges faced by quality management in industrial firms. While Cots (2018) outlined recommendations for quality practitioners to navigate digital change, the present study demonstrates that these transformations create additional complexities for quality management, necessitating new adaptive mechanisms.

A comparison with Robertson & Lapiņa (2021) further underscores the broad impact of digitalization on quality management. While their research investigated the transformation of quality strategies, corporate culture, and customer interactions, the current study shifts the focus toward industrial challenges, highlighting how digitalization alters operational processes and intensifies quality-related issues in production environments.

When juxtaposed with Tiganasu & Lupu (2023), which examined the relationship between digitalization, institutional quality, and access to European funding, the findings reinforce the notion that strong governance and digital infrastructure play a crucial role in facilitating organizational adaptation to digital transformation. While the scope differs—focusing on funding absorption in European regions rather than industrial quality challenges—both studies emphasize the necessity of digital adaptation for long-term sustainability.

Lastly, Ntobongwana & Telukdarie (2024) proposed a theoretical framework integrating quality management, sustainability, and digital technologies, whereas the present study offers empirical evidence supporting the practical implications of digitalization on quality management challenges. By focusing on industrial firms, this study complements theoretical insights with real-world applications, illustrating how digitalization introduces complexities that require new quality management strategies.

Based on these comparisons, it is evident that digitalization significantly influences quality management, not only by reshaping roles and strategies but also by introducing new industrial challenges. While previous research has largely focused on strategic frameworks and theoretical models, the present study contributes an applied perspective, demonstrating how digitalization directly impacts quality management in Algerian industrial companies. These findings reinforce the

necessity of enhancing quality management strategies, upgrading workforce capabilities, and fostering adaptive mechanisms to navigate the evolving digital landscape effectively.

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5. Conclusion

Based on the statistical analyses presented, the study confirms that the measurement model exhibits high discriminant validity according to both the Fornell-Larcker and HTMT criteria, ensuring clear differentiation between the studied constructs.

The R^2 results indicate that Digitalization accounts for a significant proportion of variance in Quality Management Challenges, reinforcing the model's reliability. Additionally, the F^2 analysis highlights a strong effect size, confirming the substantial impact of Digitalization on Quality Management Challenges.

Lastly, the path coefficient analysis supports the strong and statistically significant relationship between the variables, leading to the acceptance of the proposed research hypothesis.

These findings provide robust empirical evidence on the role of Digitalization in shaping Quality Management Challenges within organizations, contributing valuable insights for practical applications in business management.

Based on the findings, the study recommends the following:

-Enhancing Digital Adaptation Strategies

Companies should develop digital adaptation plans for quality management, including upgrading technological infrastructure and fostering a culture of digital innovation to effectively keep pace with digital transformation.

-Investing in Workforce Training

The study recommends implementing specialized training programs for quality management personnel, focusing on the use of digital tools such as artificial intelligence and big data analytics, to enhance operational efficiency and organizational performance.

-Achieving Integration Between Digitalization and Quality Management

Organizations should ensure effective integration between digital transformation and quality management to minimize operational challenges, improve production processes, and enhance institutional efficiency.

-Strengthening Continuous Quality Data Analysis

The adoption of advanced analytical models is recommended to monitor the impact of digitalization on quality processes, enabling data-driven strategic decision-making and fostering continuous improvement in performance.

-Encouraging Further Research on Digitalization and Quality Management.

The study calls for further scientific research to explore the long-term effects of digitalization on quality management, focusing on various industrial and service sectors to ensure broader applicability and maximize benefits.

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Appendices:

Table 1. Latent variables and its items

Latent variables	Items
Digitalization	Your organization enhances internal communication (e.g., digital planning boards and/or digital team collaboration tools). Your organization develops and improves communication tools to increase internal collaboration. Your organization shares errors and countermeasures on social media as a method to find solutions. Your organization establishes a specific digitalization framework that removes all obstacles and constraints. Through digitalization, your organization introduces potential new business models, often focusing on the service aspects of the offering, such as providing a digital service with distinctive programmed features. Your organization increases the use of advanced and integrated technology to detect real-time issues, such as measuring potential production line stoppages. Your organization develops and improves communication tools to enhance internal collaboration. Quality management practitioners in your organization play active roles in adapting existing technologies and developing new digital initiatives. Your organization relies on digital applications that allow customers to modify the settings of the products they use. Your organization assigns responsibility for digitalization initiatives to senior management to ensure long-term results.
Quality management challenges	Your organization creates customer value by developing processes for a better understanding of customer usage and perception of value, such as using software for real-time product monitoring. Your organization improves the quality of previously developed

consumer goods and services, such as enabling new online methods to meet requirements, offering online services, and maintaining digital records of product usage.

Your organization develops new internal processes to enhance value, for example, through cross-functional collaboration with IT or remote collaboration across different locations.

Your organization adapts and aligns with current initiatives, such as new online internal communications and visualization of internal processes.

Source: achieved by author based on some literature