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Insights into quality professionals' adoption of Quality 4.0 in the high-tech industry

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Abstract

Purpose – This paper examines the factors influencing the adoption of Quality 4.0 technologies by quality professionals. The study evaluates perceived usefulness, perceived ease of use, attitude towards use, and intention to use new technologies.

Design/methodology/approach – The research involves a literature review, identification of latent variables derived from the Technology Acceptance Model (TAM), and a survey conducted among 200 quality professionals in the high-tech sector using computer-assisted web interviews.

Findings – The study elucidates the attitudes and intentions of high-tech industry employees towards adopting Quality 4.0 technologies. The primary conclusion drawn is that the predominant factor shaping the attitude of quality professionals towards new technologies is their confidence in their ability to effectively engage with these technologies rather than solely the perceived usefulness of such technologies to themselves or their organization.

Research limitations/implications – This study is subject to certain limitations. Firstly, it focuses on five variables identified in the TAM model, potentially overlooking other pertinent factors that could provide a more comprehensive understanding. Secondly, the analysis of Quality 4.0 technologies is presented in a generalized manner, possibly resulting in nuanced differences if each specific technology were examined individually.

Originality/value – This article fills a gap in the literature by identifying the factors influencing quality professionals' adoption of Quality 4.0 technologies and delineating the relationships between these factors.

Keywords Quality 4.0, Quality professionals, Technologies acceptance, High-tech industries

Paper type Research paper

1. Introduction

Quality management aims to optimize profitability by continuously enhancing every facet of business operations, spanning from enhancing customer satisfaction to refining product quality (Yeşilyurt *et al.*, 2022). Numerous studies have demonstrated the pivotal role of quality management in determining the success or failure of companies (Bhaskar, 2020; Potkany *et al.*, 2022).

In recent times, a novel paradigm termed Quality 4.0 has emerged within the domain of quality management. This approach has arisen in response to the advent of the fourth industrial revolution, characterized by the integration of various physical and digital technologies such as artificial intelligence, cloud computing, adaptive robotics, augmented reality, additive manufacturing, and the Internet of Things (IoT). The primary purpose of the

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revolution is to improve resource efficiency and productivity, thereby bolstering the competitive capabilities of companies (Ustundag and Cevickan, 2018). The latest technological advancements are anticipated to elevate productivity, efficiency, and work quality across multiple industrial sectors. Nevertheless, resistance to adoption can have consequences for both organizations and employees' well-being (Molino *et al.*, 2021).

In light of the disruptive challenges posed by Industry 4.0 across various dimensions such as business models, manufacturing processes, and the economy, it becomes imperative to enhance the human workforce across different facets, including technical, psychological, and social realms, to effectively address these transformations (Edwards and Ramirez, 2016). The workforce of the future will necessitate high levels of adaptability, resourcefulness, resilience, and interdisciplinary skills to foster interaction and collaboration within the industrial market. However, empirical research underscores the existence of significant challenges and risks associated with Industry 4.0, including the identified issues such as the lack of expertise and employee apprehension (Moeuf *et al.*, 2020). Plawgo and Ertman (2021) have illustrated that early-stage companies may not possess a comprehensive understanding of the competency requirements pertaining to Industry 4.0. Furthermore, the competency needs perceived as most crucial, both by managers and other employees, may remain unaddressed in the near future. Consequently, preparing employees to navigate the realities of Industry 4.0 emerges as one of the primary challenges. Identifying the novel skills requisite for the future workforce is paramount (Verma and Venkatesan, 2022). However, it should be taken into account that, as Blayone and VanOostveen (2021) demonstrated, employee attitudes hold equal significance to their skills and knowledge.

Numerous studies have endeavoured to forecast the skills and knowledge requisite for employees responsible for quality management (Burcher *et al.*, 2008; Moczulska and Rogala, 2020). Some of these studies specifically pertain to skills associated with Quality 4.0 (Kannan and Garad, 2020; Santos *et al.*, 2021; Závadská and Závadský, 2020). However, so far, scant attention has been directed towards investigating the attitudes of quality professionals towards Quality 4.0, particularly concerning the novel technologies associated with it. Furthermore, a significant portion of the existing research on the concept of Quality 4.0 relies on literature reviews or analyses of prevailing quality management models and practices. Hence, there exists a gap and a pressing necessity for empirical research aimed at addressing research inquiries pertinent to this concept.

The primary objective of this study is to investigate the factors influencing quality professionals' adoption of Quality 4.0 technologies, including but not limited to cloud computing, Internet communication, robotics, automation, mobile phone applications, big data, and the Internet of Things. The research question guiding this inquiry is as follows:

RQ. What factors impact quality professionals' attitudes and intentions to adopt Quality 4.0 technologies?

The study aims to address this question by leveraging insights obtained from both a comprehensive literature review and a survey conducted among quality professionals employed in high-tech companies. The Technology Acceptance Model (TAM) will serve as the theoretical framework for this investigation, with data collection executed through surveys targeting quality professionals within the High-Tech industries.

This paper is structured as follows. In the next section, a literature review is provided, encompassing discussions on quality professionals, Quality 4.0, and the Technology Acceptance Model. In the "Materials and methods" section, the applied methodology is identified and depicted. Key research stages were described, including:

(1) Selecting the appropriate version of TAM and formulating hypotheses.

(2) Determining observable indicators.

(3) Conducting survey research.

(4) Determining the relationship between indicators and constructs (Quality 4.0 acceptance model evaluation).

Section "Results" encapsulates the findings derived from the survey and the evaluation of the Quality 4.0 Acceptance Model. The results are discussed in detail in the "Discussion" section. The last section presents the main conclusions of the research, highlights the identified limitations, and outlines prospective avenues for future investigation.

2. Literature and theoretical approach

2.1 Quality professionals

In practice, quality management is typically overseen by specialized personnel, commonly referred to as quality professionals. These professionals may operate within dedicated quality management units, hold independent positions within the organizational hierarchy, or be integrated into other departments, such as the production department. These specialists have multiple principals and multiple responsibilities (Seyfried and Reith, 2021). It is generally expected that quality professionals possess the ability to:

(1) Efficiently amalgamate quality management principles with effective quality engineering tools.

(2) Comprehend the various dimensions of quality management across product, process, systems, organizational, and societal levels, and seamlessly navigate between different scales or scopes of quality application in a multidimensional context.

(3) Establish robust connections between quality management and other interconnected domains, thereby assuming responsibility for tasks such as data analysis (including addressing big data challenges), fostering innovation, managing processes, and facilitating product development, among others (Sampaio and Saraiva, 2016).

The existing body of literature on quality professionals is relatively limited, yet the available research highlights that the roles and responsibilities assigned to quality professionals in practice are often narrowly defined. Consequently, enterprises may not fully realize the potential benefits that effective quality management could offer (Elg *et al.*, 2011).

For this reason, there is a growing call for an expansion of the scope of tasks assigned to quality professionals. Contemporary enterprises are increasingly focusing on value creation, and it is suggested that quality professionals of the future should leverage innovation to create and manage value for customers, stakeholders, and the enterprise itself. As such, it is proposed that quality professionals should evolve into multifaceted roles, encompassing responsibilities such as change agents, experts in process excellence, strategists, advocates for customers, and leaders in innovation, among others (Antony, 2013).

Indeed, a consensus exists among the majority of scholars regarding the indispensable role of quality professionals within enterprises, with an acknowledgement that their significance is expected to increase in the future (Antony, 2013; Goetsch and Davis, 2006; Martin *et al.*, 2021; Sampaio and Saraiva, 2016).

Several studies have been devoted to defining the competencies that quality professionals, including quality managers, quality auditors or ISO 9001 management representatives, should possess (Ingason and Jónsdóttir, 2017; Martin *et al.*, 2021; Moczulska and Rogala, 2020).

Recently, there has been a burgeoning interest in publications focusing on quality professionals within the context of Quality 4.0. Santos *et al.* (2021) demonstrated that Quality 4.0 professionals necessitate a diverse skill set, including creative thinking, leadership capabilities, effective communication skills, and proficiency in teamwork. Additionally, proficiency in emerging technologies, particularly cyber-physical production systems, is deemed crucial, along with the integration of these technologies with established quality management practices. Notably, decision-making in this context is increasingly reliant on data analytics derived from Big Data.

On the other hand, Kannan and Garad (2020), drawing upon a literature review, highlighted the technical competencies requisite for quality professionals in the era of Quality 4.0. These competencies encompass the ability to interpret large volumes of process data to inform strategic decision-making, proficiency in utilizing augmented reality tools, and awareness of data security risks. Methodological competencies are also deemed essential for leveraging data to pinpoint the root causes of issues and access reliable learning resources while possessing the aptitude to utilize new tools for efficiently resolving complex problems. Social competencies are emphasized, including effective communication across diverse sites, suppliers, and customers via collaborative virtual platforms. This entails retaining both tacit and explicit knowledge within a decentralized environment, necessitating leadership skills for decision-making. Additionally, personal competencies, such as adaptability to flexible work arrangements and agility in navigating frequent changes, are deemed indispensable. Furthermore, Závadská and Závadský (2020) presented practical research findings outlining the anticipated expectations for quality managers amidst the proliferation of intelligent technologies by 2025. They identified 14 technologies, including smart glasses, 3D printing, and collaborative robots, and estimated their growth potential in the near future.

2.2 Quality 4.0

The notion of Quality 4.0 presents a challenge for contemporary quality management professionals, necessitating the enhancement of personal competencies and proficiency in modern technologies. Concurrently, this concept appears to offer a solution to the issue of overly restrictive delineations of professionals' roles and quality management functions within enterprises, as previously highlighted.

Quality 4.0 is being presented as the new stage of quality development. However, its overlying concept and rationale are still hard to define (Oliveira *et al.*, 2024) owing to a paucity of empirical studies and scholarly discourse on the subject. Nonetheless, a synthesis of extant literature on Quality 4.0 delineates several key themes. Definitions of Quality 4.0, while diverse, consistently underscore the following aspects:

(1) Departure from conventional, manual methodologies of quality management.

(2) Integration of contemporary technologies synonymous with the paradigm of Industry 4.0.

(3) Facilitation of enhanced collaboration across the entirety of the supply chain.

Two trends in defining Quality 4.0 emerge within the scholarly discourse (Sader *et al.*, 2021). The first trend pertains to the integration of modern technologies into established quality management frameworks, such as Total Quality Management (TQM), the EFQM Model, the ISO 9001 quality management system, Lean Management and Six Sigma. Several studies affirm the applicability of these methodologies in elucidating the Quality 4.0 concept (Fonseca *et al.*, 2021; Sader *et al.*, 2019; Saxby *et al.*, 2020; Yadav *et al.*, 2020). Leveraging technology, Quality 4.0 not only aids managers in ongoing process control but also expedites reporting tasks and enhances process transparency, thereby fostering organizational learning and continuous improvement (Emblemsvåg, 2020). This interpretation of Quality 4.0 was presented by, among others, by Aldag and Eker (2018), Allcock (2018) and Jacob, 2020.

A conceptual framework elucidating the model of Quality 4.0 is proposed by Maganga and Taifa (2022), delineating four foundational pillars that encapsulate a contemporary approach to quality management leveraging Industry 4.0 technologies:

(1) TQM principles include leadership, top management commitment, continuous improvement, supplier management, customer focus, and employee involvement.

(2) Industry 4.0 solutions, e.g. Internet of Things, machine learning, virtual reality, autonomous robots, augmented reality.

(3) Real-time quality management: the use of sensors, the use of apps for communication, real-time decision making, interlinks and predictive control, etc.

(4) Big data management: big data analytics, digitalization, automation, IT, etc.

The second trend in conceptualizing Quality 4.0 underscores its evolution within the domain of quality management, highlighting its interconnectedness with established principles and practices such as Total Quality Management (TQM). This perspective accentuates the significance of transformative changes necessitated within specific facets of quality management, driven by the possibilities of using modern technologies (Jacob, 2020).

From this perspective, the conceptualization of Quality 4.0 is articulated through a model developed by LNS Research (www.lnsresearch.com, 2022). In this model, Quality 4.0 is presented in a dynamic perspective, portraying it as an evolution from the conventional quality management paradigm towards Quality 4.0 through the integration of modern technologies. According to the model, the transformation is envisaged to occur across eleven key domains, including management systems, analytics, data, app development, connectivity, scalability, and collaboration.

In summary, effective implementation of the concept of Quality 4.0 requires improvement in two key areas. Sony *et al.* (2020) emphasize the importance of factors such as leadership, training, organizational culture and top management commitment. In addition, they point to the importance of quality professionals' skills related to change management, teamwork, interpersonal communication, and motivation.

However, it is undeniable that modern technologies play a fundamental role in Quality 4.0. Therefore, research endeavours should encompass inquiries into various aspects, including the attitudes of quality managers towards the concept of Quality 4.0, the degree of acceptance of modern technologies among quality managers, and the extent of changes occurring in the competencies of managers and quality employees, organizational culture, collaborative dynamics within the organization, and other facets of employee relations.

2.3 Technology acceptance model (TAM)

The impetus for investigating the acceptance of Quality 4.0 among quality professionals draws inspiration from the Technology Acceptance Model (TAM) theory, which elucidates the reasons behind the adoption of technology solutions and practices by users. The TAM theory was developed by Fred Davis (1985), who assumed that the use of technical systems could be explained and predicted by user motivation, which is directly influenced by external factors such as the functionalities and capabilities of the said technical system (Chuttur, 2009).

The TAM theory was initially formulated to investigate the behaviour and user acceptance of Information Communication Technology (ICT) from a social psychology perspective. In general, the acceptance of technology is a critical factor and necessary condition in the implementation of ICT in everyday life.

An extensive literature survey was conducted utilizing the Scopus scientific database. The Scopus repository encompasses a vast collection of scholarly papers, with 18,639 publications on TAM recorded from 1964 to 2023. Employing the search phrase “Technology Acceptance Model” AND “Literature Review” yielded insights from 828 abstracts, with 265 full-text papers eventually utilized in this study. Unfortunately, abstracts typically provide only a cursory overview of the application of TAM, necessitating a thorough examination of models and variables outlined in the full-text papers for detailed analysis.

Over nearly 4 decades, numerous theoretical models have emerged to comprehend the acceptance and utilization of ICT. Researchers often encounter challenges in selecting the most suitable theoretical model to assess the acceptance and usage of ICT. Recognizing the need for ICT and individuals’ acceptance of it within business organizations typically constitutes the initial stage of any business endeavour. This comprehension can prove instrumental in charting the path for future ICT implementation strategies.

According to Taherdoost (2018), acceptance is defined as “antagonism to the term refusal and means the positive decision to use an innovation”. Over the past forty years, numerous models have been developed to elucidate user adoption of new technologies, incorporating various factors that influence user acceptance. The modelling of ICT acceptance originated from the seminal work of Davis (1985). In his model (see Figure 1), the Design Features represent Alternative Systems, which may impact User Motivation. User Motivation encompasses Cognitive Response and Affective Response. Davis posited that Affective Response, specifically Attitude Toward Using, is a function of two variables: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), with Perceived Ease of Use exerting a causal effect on Perceived Usefulness (PU).

In the original TAM model, Design Features directly impact Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Ultimately, Actual System Use (ACU), representing Behavioural Response, is determined by Affective Response, namely Attitude Toward Using

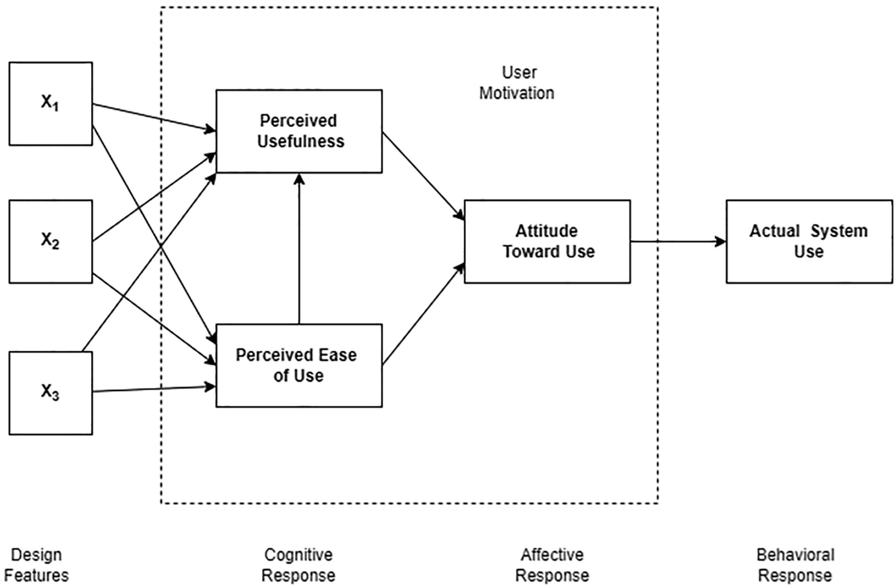


Figure 1.
Davis’s technology acceptance model

Source(s): Davis (1985), p.24

(see Figure 1). Davis defines the PU construct as the extent to which an individual believes that using a particular system would enhance their job performance, while the PEOU construct is conceptualized as the degree to which an individual perceives using a particular system to be devoid of physical and mental effort (Davis, 1985). In his doctoral dissertation (Davis, 1985), Davis introduced two additional models: TAM2 and TAM3. In TAM2, two additional variables were incorporated: Expected Enjoyment and Self-Predicted Use. TAM3, on the other hand, introduced system variables that were treated as determinants of Quality Numeric, Ease of Use Numeric, Quality Non-numeric and Ease of Use Non-numeric. These variables served as exogenous factors for Perceived Usefulness (PU) and Expected Enjoyment (EE). Furthermore, TAM3 integrated Attitude Toward Using and Self-Predicted Use into its framework.

Over the past 3 decades, the research community has been deeply engaged in identifying factors influencing technology acceptance. Predecessors of the Technology Acceptance Model (TAM), such as the Theory of Reasoned Action (TRA) and the Theory of Planned Behaviour (TPB), laid the groundwork for understanding user acceptance of technology (Park and Park, 2020; Marikyan and Papagiannidis, 2021). While Davis initially developed the TAM model and proposed modifications like TAM2 and TAM3, researchers have increasingly turned to the Unified Theory of Acceptance and Use of Technology (UTAUT) model. UTAUT posits that actual technology usage is determined by behavioural intention, which is influenced by four key constructs: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. Additionally, the effects of these variables are moderated by factors such as Age, Gender, Experience, and Voluntariness of Use (Venkatesh *et al.*, 2003).

Recognizing the importance of factors related to costs, benefits, and contextual use, Venkatesh *et al.* (2012) proposed a UTAUT2 model explicitly tailored for examining technology acceptance in organizational settings. UTAUT2 expands upon UTAUT by introducing additional constructs such as Hedonic Motivation, Price Value, and Habit while maintaining the moderation effects of Age, Gender, and Experience. In both UTAUT and UTAU2 models, Behavioural Intention is posited to influence Use Behaviour.

Chukwuere *et al.* (2021) introduced the Revised Technology Acceptance Model (RTAM), which consolidates earlier technology acceptance models and emphasizes the determination of Actual Usage variables and their determinants. The RTAM framework opens avenues for further exploration into latent variables that may impact the actual usage of various Quality 4.0 technologies.

In this study, the TAM model developed by Davis (1985) is the foundational framework for assessing the acceptance of new technologies.

3. Materials and methods

3.1 The conceptual model and hypotheses

The literature review reveals several research publications utilizing the questionnaire method to ascertain the practitioners' perception of the Quality 4.0 technologies (Maganga and Taifa, 2023; Xiang *et al.*, 2023; Roy Ghatak and Garza-Reyes, 2024; Alrabadi *et al.*, 2023). Considering the literature review on latent variables included in the technology acceptance models, it is observable that there is no standardized approach and models are formulated according to researchers' preferences. Consequently, the authors of this paper have opted to concentrate on employing basic constructs from Davis's TAM model while introducing the Intention to Use (ITU) construct.

Although the research community offer various technology acceptance models, scholarly discourse predominantly centres on the specification of constructs (i.e. latent variables), occasionally incorporating moderating variables. However, the authors of this study observe a substantial opportunity within the application of the Technology Acceptance Model (TAM) for researchers to introduce their original approach to item identification (i.e. assigned indicators). Despite the abundance of publications focused on the estimation and analysis of Davis's TAM model, a fundamental question remains unanswered: how do researchers formulate items, and which specific items are considered in various TAM model applications? In addressing this gap, the authors of this study apply the TAM model to the context of Quality 4.0 technologies, presenting their original list of items tailored to the intricacies of the study (Table 1).

Quality 4.0 technologies encompass a highly diverse array of internal solutions, systems, algorithms, and devices. Therefore, querying recipients at High-Tech companies on issues such as security, trust, and support may yield highly equivocal responses, as respondents may encounter difficulty unequivocally interpreting the questions.

The following constructs and hypotheses supported by TAM approach have been identified:

1. Perceived Usefulness (PU), i.e. the degree to which a High-Tech Company Quality Professional believes that the Quality 4.0 technologies and practices will be effective in achieving their intended business objectives. Perceived Usefulness influences the decision of a professional or specialist on whether to accept or reject a particular technology. In accordance with the TAM (Park and Park, 2020), managers' PU influences their Attitude Towards Using (ATT) as well as their Intention to Use (ITU). The PU reveals the extent to which managers believe that using Quality 4.0 technologies improves their work performance. By definition, the PU signifies confidence in the information technology

Latent variables		Items
Perceived usefulness	PU1	Quality 4.0 is useful at my work
	PU2	Quality 4.0 increases my productivity
	PU3	Quality 4.0 reduces my mistakes and flaws
	PU4	Quality 4.0 allows data access anytime and anywhere
Perceived ease of use	PEOU1	Quality 4.0 facilitates my work
	PEOU2	Quality 4.0 permits the usage of user-friendly tools
	PEOU3	Quality 4.0 allows for quality evaluation at each stage of the product/service lifecycle
	PEOU4	Learning to use Quality 4.0 technologies and practices is easy for me
Attitude	ATT1	I have a positive attitude towards Quality 4.0
	ATT2	Quality 4.0 makes my work more interesting
	ATT3	Quality 4.0 makes that my work gives me satisfaction
	ATT4	I will encourage others to implement Quality 4.0
Intention to use	ITU1	I will increase usage of Quality 4.0, if only I have the appropriate financial and technical resources and competences
	ITU2	I will increase usage of Quality 4.0 if only I have knowledge concerning the IT implementation
	ITU3	I will increase the usage of Quality 4.0 if the organizational culture is favourable
	ITU4	I will increase usage of Quality 4.0 if I see that it ensures a competitive advantage for my enterprise
Actual use	ACU1	I am using practices and technologies of Quality 4.0 more than traditional methods of quality management
	ACU2	Application of Quality 4.0 helps me to understand my tasks
	ACU3	I do not meet any constraints in the application of Quality 4.0 practices and technologies

Source(s): Authors own creation

Table 1.
Items in the survey

solutions to improve individual productivity and effectiveness (Chukwuere *et al.*, 2021; Thong *et al.*, 2006; Hsiao *et al.*, 2016).

The proposed hypotheses are as follows:

H1. Perceived Usefulness has a positive impact on the Attitude towards using.

H2. Perceived Usefulness has a positive impact on the Intention to Use.

2. Perceived Ease of Use (PEOU), i.e. the degree to which a High-Tech Company Quality Professional believes that using the Quality 4.0 technologies and practices would be easy and free of effort in aspects such as learning and application. Perceived Ease Of Use (PEOU) is identified with a personal judgment that technology can be utilized in a user-friendly and comfortable way to execute tasks (Chukwuere *et al.*, 2021). Users are inclined towards effortless technology usage, as they often lack time for extensive learning and seek intuitive tools for application (Thong *et al.*, 2006). Bradley (2009) argues that PEOU determines the Actual Usage.

The proposed hypotheses are as follows:

H3. Perceived Ease of Use has a positive impact on Perceived Usefulness.

H4. Perceived Ease of Use has a positive impact on Attitude towards using.

3. Attitude (ATT), i.e. the intention of a High-Tech Company Quality Professional to engage in specific behaviour defined by subjective norms, opinions, and position. The relationship between Attitude and intention to use is a focal point in the TAM theory (Park and Park, 2020). Sharma and Mishra (2014) define Attitude (ATT) as the degree of belief in a particular behaviour. Lai (2017) argues that the Attitude is a personal assessment of objects.

The proposed hypothesis is:

H5. Attitude towards using has a positive impact on the Intention to Use.

4. Actual usage (ACU), i.e. the degree to which a High-Tech Company Quality is actually using the Quality 4.0 technologies and practices without encountering constraints. In Davis's TAM model, the actual usage determines the intention to use (Davis, 1989). According to Chukwuere *et al.* (2021), the ACU denotes the effective application of technology to achieve the desired objectives.

5. Intention to use (ITU), i.e. the degree to which a High-Tech Company Quality Manager intends to use and enhance the usage of Quality 4.0 technologies and practices under favourable circumstances. The ITU is understood as individual behaviour that determines intentions to use it (Fathema *et al.*, 2015). Chukwuere *et al.* (2021) define the ITU as the primary motivation for the adoption of modern technology.

The proposed hypotheses are:

H6. Intention to Use has a positive impact on the Actual Usage.

H7. Attitude has a positive impact on the Actual Usage.

Hence, Figure 2 encapsulates the conceptual and theoretical model elucidating the actual usage of Quality 4.0 by Quality Professionals within High-Tech companies. Arrows within the figure delineate the relationships between constructs (i.e. latent variables), as well as between constructs and their associated indicators (i.e. items or observable variables).

3.2 Observable indicators for the Q4.0 acceptance model

In recent years, information technologies (ICT) have assumed a pivotal role across various facets of modern society, profoundly influencing socioeconomic development across multiple sectors, including education, administration, business, healthcare, and agriculture. The benefits of technologies in quality management can be appreciated only if Quality 4.0 professionals use them. In order to evaluate the adoption of these new technologies, the technology acceptance model can be a valuable aid. Technology acceptance by managers has emerged as a prominent research area within the domain of Human Resources Management (Menant *et al.*, 2021). The discourse surrounding TAM engenders a discussion on the potential avenues for the future development of Human-Machine-Organization relations.

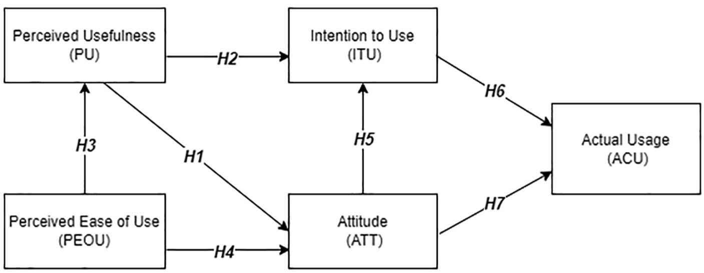
The literature review on TAM and UTAUT models reveals a predominant focus on the identification of latent variables. However, it is imperative also to consider the specification of observable items (i.e. indicators) in research endeavours. In this paper, authors have opted to examine five latent variables, necessitating a meticulous selection of questions tailored to recipients at High-Tech companies.

Considering the literature review and proposals from other researchers regarding observable variables, the authors in this study have provided their specification of indicators for the Quality 4.0 acceptance model in Table 2. The implementation of Quality 4.0 within High-Tech companies involves numerous intricate projects influenced by factors extending beyond technical considerations alone. According to the TAM theory, psychological factors and general perceptions about technologies and associated practices play pivotal roles in the selection of the Quality 4.0 solution (Park and Park, 2020). Therefore, Table 1 includes indicators such as organizational culture, knowledge concerning the technologies, financial and technical resources, and human competencies. These factors are incorporated into the indicators of Intention to use (ITU) in Table 1, encompassing certain conditional opinion requests. This approach exhibits a degree of uniqueness compared to those delineated in the existing literature (Table 1).

3.3 Data collection

The study is based on the results of a survey conducted in 2022 using the CAWI (computer-assisted web interview) technique (see Kagerbauer *et al.*, 2013). The research questionnaire was disseminated to quality professionals within the High technology (high tech) industries. These industries were chosen due to their prominence as leaders in the implementation of Quality 4.0.

The questionnaire contained the statements presented in Table 1. Respondents were prompted to evaluate the extent to which they concurred with each statement. The assessment was conducted on a scale ranging from 1 to 7, where: 1- means "I strongly



Source(s): Authors own creation

Figure 2.
Conceptual model showing the factors that influence the Quality 4.0 Actual Usage

Construct	Cronbach's alpha	rho_A	Composite reliability	AVE	Item	Outer loadings
ACU	0.798	0.799	0.881	0.713	ACU1	0.880
					ACU2	0.797
					ACU3	0.854
ATT	0.827	0.828	0.885	0.659	ATT1	0.784
					ATT2	0.838
					ATT3	0.842
					ATT4	0.781
ITU	0.894	0.896	0.927	0.759	ITU1	0.837
					ITU2	0.871
					ITU3	0.907
					ITU4	0.870
PEOU	0.803	0.809	0.871	0.629	PEOU1	0.838
					PEOU2	0.801
					PEOU3	0.803
					PEOU4	0.725
PU	0.803	0.803	0.871	0.629	PU1	0.826
					PU2	0.812
					PU3	0.756
					PU4	0.775

Source(s): Authors own creation

Table 2. Construct reliability and validity – preliminary model

disagree", 2 – "I disagree", 3 – "I somewhat disagree", 4 – "I neither agree nor agree", 5 – "I somewhat agree", 6 – "I agree", 7 – "I strongly agree".

In general, TAM models are commonly estimated through Structural Equation Modelling (SEM), an approach designed for testing hypotheses concerning the relationships among observable and latent variables (Sabi *et al.*, 2016).

In this study, structural equation modelling is conducted using Partial Least Square –Structural Equation Modelling (PLS_SEM), which is a composite-based SEM method (Hair *et al.*, 2017; Ringle *et al.*, 2014).

4. Results

4.1 Sample

The survey was conducted among 200 representatives of companies operating within the High-Tech in Poland, specifically targeting employees engaged in quality management roles.

The majority of respondents fell within the 5–10 years of experience bracket in positions related to quality management, comprising 44.5% of the total respondents. Similarly, a substantial portion, accounting for 40.0% of respondents, possessed 11–20 years of experience. Individuals with less than 5 years of work experience constituted 6% of the respondents, while those with over 21 years of experience comprised 9.5% of the sample.

The distribution of respondents according to industry sector reveals that the largest percentage (42.5%) were representatives of companies operating within the electronics industry. A smaller proportion of respondents hailed from companies in the biotechnology and computer industries, accounting for 15.0 and 13.0% of respondents, respectively. The remaining respondents (29.5% of the total) represented companies spanning various industries, including pharmaceutical, optical, aerospace, machinery, automotive, medical, chemical and defence.

In terms of enterprise size, the majority of respondents (66.5%) were employees of small enterprises. Medium and large enterprises accounted for 15.0 and 18.5% of respondents, respectively.

Furthermore, the survey revealed that a significant majority of quality professionals surveyed (65.0% of respondents) held independent positions within their respective organizations.

When asked about the scope of responsibilities in the area of quality management, the respondents highlighted the following tasks:

(1) maintaining relations with suppliers and customers concerning quality assurance (83.5%),

(2) maintaining compliance with standards (ISO and other standards) and auditing (82.5%),

(3) product quality control (error detection) and supervision of production processes (69.0%),

(4) quality planning in production processes (50.0%),

(5) products design (39.5%).

There were no significant differences in responsibilities among respondents from different industries who participated in the survey. Similarly, the breakdown of indicated areas of responsibility did not exhibit significant variance among respondents from companies of varying sizes.

4.2 Quality 4.0 acceptance model evaluation

The presented conceptual model (see Figure 2) comprises items interconnected with variables. SmartPLS4.1.0.1 was employed for model calculation. Initially, the model was computed using the standard PLS algorithm. Subsequently, the model underwent calculation utilizing the Bootstrap algorithm, wherein the number of samples was configured to 5,000 for the full version incorporating bias-corrected and accelerated in two-tailed distribution. The significance level was set at 0.05.

The dataset was constructed to assess quality and facilitate estimation. The reliability of the variables was tested using Cronbach's Alpha and Composite Reliability (CR). Table 2 presents the results for reliability and validity for the entire sample. It is recommended that all Cronbach's Alpha and CR values exceed 0.700 (Hair *et al.*, 2017). Additionally, Average Variance Extracted (AVE) and Composite Reliability (CR) values should be higher or in close proximity to 0.500 and 0.700, respectively, to affirm convergent validity. According to Hair *et al.* (2017), CR > 0.7 and <0.9 is a satisfactory measure of internal consistency; however, CR > 0.6 indicates a lack of internal consistency, and CR > 0.95 is deemed undesirable. A higher value of Cronbach's Alpha signifies better reliability.

Table 3 shows that each of the model scales representing the model constructs is reliable, as evidenced by Cronbach's Alpha exceeding 0.70. An AVE below 0.5 is considered insufficient, as it suggests that error variance outweighs indicator variance (Gotz *et al.*, 2010).

Table 3. Fornell-Larcker criterion

	ACU	ATT	ITU	PEOU	PU
ACU	0.844				
ATT	0.861	0.812			
ITU	0.824	0.828	0.871		
PEOU	0.763	0.837	0.752	0.793	
PU	0.718	0.803	0.668	0.863	0.793

Source(s): Authors own creation

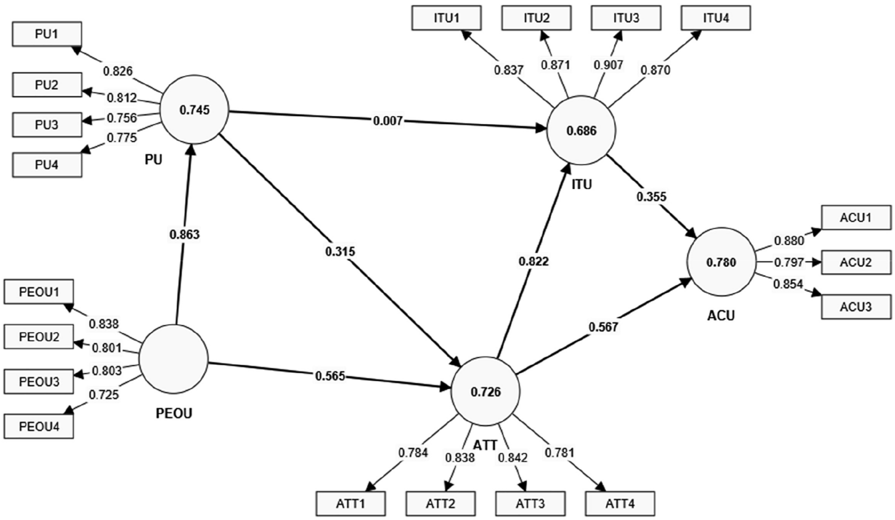
Hair *et al.* (2017) argue that Average Variance Extracted (AVE) serves as a standard measure to establish convergent validity. AVE values of 0.5 or higher indicate that the construct explains more than half of the variance of its indicators.

Beyond the verification of Construct Reliability and Validity, Discriminant Validity is examined through the Fornell-Larcker Criterion, as presented in Table 3. This criterion illustrates that all the constructs exhibit significant differences.

According to Hair *et al.* (2017), indicators (i.e. observable variables) with outer loadings falling within the range of 0.40–0.70 "should be considered for removal from the scale only when deleting the indicator leads to an increase in the composite reliability above the suggested threshold value". Indicators with outer loadings exceeding 0.7 should be retained.

Figure 3 presents the PLS Algorithm estimated model, while Table 4 provides Path Coefficients and R^2 values for the constructs.

The goodness of the model is determined by the strength of each structural path determined by the R^2 value for the dependent variable, which should be equal to or exceed 0.1 (Falk and Miller, 1992). The results in Table 5 show that all R^2 values surpass the threshold of 0.1. The R^2 values of 0.75, 0.50 or 0.25 for endogenous latent variables can be described as substantial, moderate or weak, respectively (Ringle and Sarstedt, 2011).



Source(s): Authors own creation

Figure 3. The PLS-SEM model with estimated path coefficients

	R^2	ACU	ATT	ITU	PEOU	PU
ACU	0.780					
ATT	0.726	0.567		0.822		
ITU	0.686	0.355				
PEOU			0.565			0.863
PU	0.745		0.315	0.007		

Source(s): Authors own creation

Table 4. PLS algorithm R^2 and path coefficients

The R^2 values for latent variables indicate a moderate to strong fit of the model. The R^2 value of 0.745 for the variable PU signifies that the model elucidates 74.5% of the variance in the variable. Consequently, the model's predictive capability is established.

R-square (R^2) signifies the strength of the least-squares fit to the training set activities. A value of 0.745 implies that the model accounts for 74.5% of the variance in the observed activities for the training set. As more PLS factors are incorporated into the fit, the R^2 value approaches 1 (100%). R-square values range from 0 to 1, where a value of 0 suggests that the exogenous variable cannot explain the endogenous variable, while a value of 1 indicates that the endogenous variable can be perfectly explained without error by the exogenous variable.

The R^2 value denotes the proportion of variance in endogenous variables explained by the exogenous variables (Xiang *et al.*, 2023). Thus, a higher R^2 value increases the predictive ability of the structural model.

In this study, it is observed that 78% of the variation in ACU is explained by the constructs ATT, ITU, PU, and PEOU. Additionally, 74.5% of the variation in PU is explained by PEOU, 72.6% of the variation in ATT is explained by PEOU and PU, and 68.6% of the variation in ITU is explained by the constructs PU, PEOU, and ATT, as indicated in Table 4.

In this analysis, the SmartPLS algorithm function is used to obtain the R^2 values, while the SmartPLS bootstrapping function is used to generate the t-statistics values.

The SEM model has been successfully verified using SmartPLS4.1.0.1. The results of the tests indicate that the proposed constructs exert a significant and tangible influence on the intention to use Quality 4.0. Particular attention should be paid to two latent variables: Perceived Ease of Use (PEOU) and Attitude Towards Using (ATT). These two variables have a strong, direct, and positive impact on Perceived Usefulness (0.863) and Intention to Use (0.822), respectively (Table 5). Perceived Usefulness demonstrates a weak positive impact on quality professionals' attitudes (0.315). Intention to Use (ITU) among quality professionals exhibits a weak impact on their Actual Use of the Quality 4.0 technologies (0.355). The perceived Ease of Use (PEOU) has a moderate impact on quality managers' Attitude (ATT) towards Quality 4.0 (0.565). Finally, the ATU has a moderate impact on the ACU latent variable (0.567).

If a p value falls below a certain threshold, typically 0.05 (Kock, 2014), the corresponding hypothesis is assumed to be supported. In this research, hypotheses H1 and H3–H6 are supported, while hypothesis H2 is rejected.

This study allowed for the verification of seven hypotheses. The conceptual model formulated by the authors elucidates the behaviour of Quality 4.0 Professionals, as determined by the perceived technology usefulness, ease of use and user attitude. Nearly all tested hypotheses have been accepted. Hence, the authors conclude that the proposed model strongly aligns with the theoretical framework proposed by Davis (1985) and subsequently modified by Chukwuere *et al.* (2021).

Hypothesis	Hypothesis (direction)	Original sample	Sample mean	Standard deviation	T-statistics	p values	Decision
H1	PU → ATT	0.315	0.311	0.089	3.552	0.000	Yes
H2	PU → ITU	0.007	0.009	0.071	0.105	*0.917*	*No*
H3	PEOU → PU	0.863	0.864	0.018	46.801	0.000	Yes
H4	PEOU → ATT	0.565	0.569	0.086	6.551	0.000	Yes
H5	ATT → ITU	0.822	0.822	0.060	13.675	0.000	Yes
H6	ITU → ACU	0.355	0.356	0.070	5.042	0.000	Yes
H7	ATT → ACU	0.567	0.566	0.064	8.873	0.000	Yes

Source(s): Authors own creation

Table 5. Bootstrapping Path Coefficients for the final model

5. Discussion

It is evident that technologies associated with Industry 4.0 have already had a considerable impact on quality management and are poised to have an even more significant influence (Závadská and Závadský, 2020). This study aimed to investigate the determinants influencing quality professionals' acceptance of Quality 4.0 technologies.

The analysis proved that the quality professionals' Attitude Towards Quality 4.0 technologies is predominantly influenced by Perceived Ease of Use (H4) and, to a lesser extent, by Perceived Usefulness (H1). Notably, the impact of the latter factor is comparatively less significant. The Perceived Usefulness of Quality 4.0 affects quality professionals' attitudes only to a moderate extent and does not affect Intention to Use (H2). It can be concluded that either quality professionals do not highly evaluate the usefulness of modern technologies (though this scenario seems improbable), or, despite recognizing their high utility, they may have reasons such as resistance to change or apprehension about complications, which deter them from considering it a sufficient incentive to adopt these technologies. Conversely, Perceived Ease of Use significantly influences Quality Professionals' attitudes and, concurrently, has a substantial impact on the Perceived Usefulness of Quality 4.0 (H3).

This problem has been previously highlighted by Antony *et al.* (2023), who suggested that the adoption of Quality 4.0 might pose a challenge for the ageing workforce, as older workers may require assistance in adapting to new technologies.

The higher importance of Perceived Ease of Use than Perceived Usefulness may seem unconventional. Many analyses using TAM indicate that Perceived Usefulness has a more significant effect on people's attitudes than Perceived Ease of Use (see Wu *et al.*, 2022; Yang and Yoo, 2004, Chau and Hu, 2002, Brandon-Jones and Kauppi, 2018). However, for quality professionals, the opposite appears to hold true. This situation can be interpreted using the research results by Burcher *et al.* (2008), who illustrated a lack of innovatory drive among quality professionals who seem to prioritize maintaining standards over embracing dynamic changes. The integration of modern technologies necessitates acquiring new skills, which quality professionals may be hesitant to engage in or apprehensive about their ability to meet the challenge.

To address these challenges, organizations can take several proactive measures. Firstly, it is essential to foster genuine interest among quality professionals in Quality 4.0 technologies rather than imposing them forcefully. Secondly, providing comprehensive support, such as access to consultants or experts, can significantly facilitate the introduction of new technologies. Additionally, organizations should emphasize the importance of continuous learning and development by encouraging quality professionals to enhance their competencies through training programs. Participation in professional associations and scientific conferences can also broaden their knowledge and perspective (Waddell and Stewart, 2004).

The challenges encountered by quality professionals in implementing Quality 4.0 must not be underestimated. Existing research highlights various obstacles, including inadequate organizational resources and a lack of supportive organizational culture (Sony *et al.*, 2021). It is reasonable to infer that quality professionals are cognizant of these barriers, which may lead them to perceive the implementation of Quality 4.0 as a challenging endeavour. Furthermore, findings from Seyfried and Reith (2021) suggest that quality managers tend to prioritize their self-interest. Consequently, it can be deduced that the effective implementation of new technologies hinges upon receiving substantial support from company management.

The research also demonstrated the critical role of Attitude Towards Using in influencing the Intention to Use Quality 4.0. Although some previous studies showed the relatively low significance of Attitude for the acceptance of technologies (e.g. Davis *et al.* (1989) stated that the influence of Attitude on technology use is, at best, modest), the findings of this study suggest otherwise for quality professionals. In their case, Attitude plays a crucial role in determining intention to use, which directly translates into actual usage of Quality 4.0 technologies (H6).

The research has important implications.

Firstly, it provided further evidence supporting the validity of the Technology Acceptance Model. Out of the six hypotheses tested, five were supported, with only one hypothesis being rejected. The model successfully explains 68% of the variance in actual Quality 4.0 usage ($R^2 = 0.680$).

Secondly, the obtained results enable a better understanding of the behaviours of quality professionals related to the implementation of Quality 4.0. Unlike earlier studies on implementing Quality 4.0, the study pays more attention to the "human factor" by exploring the concerns, expectations and attitudes of people who have to use new technologies at work.

Third, the findings also hold immediate practical implications. They offer guidance on how enterprises can navigate the transition to Industry 4.0 more successfully. The results indicate the need to provide quality professionals with appropriate support to facilitate their adaptation to new technologies. On the other hand, they suggest that efforts need not be focused on persuading quality professionals of the functionality of Quality 4.0, as this factor exerts little influence on their behaviour. These insights can be instrumental in addressing a persistent challenge highlighted in the literature (Rana and Daultani, 2022), which concerns businesses' underutilization of the potential offered by emerging technologies such as machine learning and artificial intelligence.

6. Conclusions

6.1 Key findings

The paper delineates the determinants influencing quality professionals' acceptance of Quality 4.0 technologies, employing the Technology Acceptance Model (TAM). It elucidates that both perceived usefulness and perceived ease of use significantly influence the attitude of quality professionals toward Quality 4.0 technologies. Subsequently, this attitude directly impacts both the intention to use and the actual utilization of these technologies.

The research offers valuable insights applicable to enhancing the implementation process of Quality 4.0 and comprehending the attitudes, behaviours, and intentions of quality managers. The main conclusion from the research is the need to provide support for quality professionals in introducing Quality 4.0 because Perceived Ease of Use is a factor strongly influencing their attitudes toward Quality 4.0. This support may include, among others: (1) training programs tailored to specific technologies, emphasizing the development of practical skills and fostering confidence among participants in their ability to navigate new technologies effectively, (2) access to consulting services, either through external experts or internal specialists, who can offer guidance throughout the implementation process and provide ongoing support to address any challenges that may arise. These advisors may be external consultants or specialists from a given organization, e.g. from the IT department. Establishing such support mechanisms can bolster the confidence of quality professionals in their ability to manage new technologies, thereby increasing their likelihood of adoption and utilization.

This study explores the factors influencing the acceptance of Quality 4.0 technologies among quality professionals in the high-tech industry. The authors found that professionals tended to accept Quality 4.0 technologies with ease even before their formal introduction while also identifying key challenges that must be addressed when integrating these technologies into high-tech companies. Notably, the study revealed that when quality professionals perceive Quality 4.0 technologies as easy to use, they exhibit spontaneous attitudes and behavioural intentions to adopt them. Consequently, high-tech companies should prioritize providing comprehensive education on Quality 4.0 technologies to foster professionals' interest and knowledge in their usage. Thus, it is imperative to ensure that the utilization of Quality 4.0 technologies is clearly explained and supported by accessible education to enhance the willingness of quality professionals to embrace these advancements effectively.

Many authors (e.g. Kannan and Garad, 2020; Santos *et al.*, 2021) have already pointed out the need to raise qualifications by quality professionals. However, to date, no study has demonstrated a direct relationship between these capacity-building activities and the attitude and willingness of quality professionals to adopt Quality 4.0 technologies.

6.2 Limitations

The study has some limitations. Firstly, it focused solely on five variables identified in the TAM model. Consequently, while it was found that Perceived Usefulness and Perceived Ease of Use did influence the attitudes of quality professionals, the modest strength of this influence suggests that the model may not have accounted for all variables shaping their attitudes.

Future research could benefit from exploring the impact of additional factors, such as Experience, Individual Innovativeness, or Self-Efficacy, as utilized in modified TAM versions. It might also be helpful in further research to consider research results related to employee resistance to technological change (see, e.g. Shulzhenko, Holmgren, 2020). While continuing the research, it would also be worthwhile to examine how demographic characteristics of respondents (e.g. age, gender, education, job responsibilities, industry type) influence the acceptance of Quality 4.0 because, as shown in previous studies, the deployment of technologies is determined by many different factors, such as, e.g. (1) the branch of industry, (2) the number of pre-manufacturing, manufacturing, post-manufacturing and cross-manufacturing processes, (3) the scope of individual processes (Závadská and Závadský, 2020). Such factors may significantly impact technology acceptance, as indicated in the literature (see, e.g. Howcroft and Taylor, 2022). Secondly, the study provided a broad overview of Quality 4.0 technologies without delving into specific technologies individually. It is plausible that the analysis results would differ if each technology were examined separately.

6.3 Future studies

Future studies may examine the additional and external variables that reflect the characteristics of Quality 4.0 technology adopters in the high-tech business environment. This deeper insight can facilitate the systematic and rational introduction of Quality 4.0 technologies in high-tech industries. In their further studies, authors should also identify specific Quality 4.0 technologies, which have the value for quality management.

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