Developing a Systematic and Practical Road Map for Implementing Quality 4.0

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ABSTRACT

Purpose: Various studies have recently focused on Quality 4.0 (Q4.0) or the digitization of quality. However, having a systematic and practical road map for implementing Q4.0 within emerging nations, particularly like Egyptian culture is not researched so far. Hence, this research is intended to address this research gap to create a methodical road map for implementing Q4.0 in the Egyptian service sector.

Methodology/Approach: Empirical research using the questionnaire method is conducted. This study explores and validates the readiness elements with senior quality professionals within Egyptian culture in the service sector to create a methodical road map for implementing Q4.0 in the Egyptian service sector.

Findings: According to the results, the element analytical thinking was the most impacting factor among all other factors. While, the factors of supplier centricity, and scalability are thought to have the least impact.

Research Limitation/Implication: The study was limited by the fact that it solely used a questionnaire to collect data. Additionally, there may not be enough responses to conclude the results of this study. So, future studies should use more than one tool for collecting data.

Originality/Value of paper: Since, research on quality service and its link with digitization is still lacking, particularly in emerging nations like Egypt. This study is a new contribution, as it develops a methodical road map for Q4.0 implementation in the Egyptian service sector.

Category: Research paper

Keywords: quality management; quality 4.0; industry 4.0; Egypt

1 INTRODUCTION

When attempting to implement a strategy that suits the current industrial development in order to adapt to the changes in the business environment brought on by the fourth industrial revolution, quality professionals have encountered major difficulties (Carvalho et al. 2019b; Chiarini, 2020; Carvalho et al., 2020) to achieve challenging goals including higher-quality products, lower production costs, quicker time to market, and environmental performance targets (Christou et al., 2022).

Quality 4.0 (Q4.0) represents the future of corporate excellence and quality inside Industry 4.0 (I4.0) context (ASQ, 2020). Q4.0, businesses will be assisted in attaining organisational excellence by combining quality with I4.0's new capabilities (Carvalho et al., 2021; Sader, Husti and Daroczi, 2022). This will increase and enhance the operational efficiency and performance of the corporate, as well as the factory outputs, and the flexibility of the supply chain (Antony et al., 2020; Cudney, Antony and Sony, 2020; Carvalho et al., 2020; Javaid et al., 2021; Antony, McDermott and Sony, 2022; Escobar et al., 2022; Saihi, Awad and Ben-Daya, 2023). Moreover, it convinces the management that quality should be a corporate priority (Sony, Antony and Douglas, 2020). A new paradigm known as Q4.0 encourages the development of empirical learning, the creation of empirical knowledge, and the generation, collection, and analysis of real-time data to facilitate making intelligent decision (Escobar et al., 2022). The Q4.0 idea has only been adopted and is being used by only 38% of life sciences companies, with the bulk still in the early phases (Singh et al., 2022). Sadly, most firms just focus on maintaining compliance and overly strictly enforce quality certifications as part of their quality management system (Sureshchandar, 2022). As a result, the paradigm change away from the antiquated quality management method must be mirrored in the models and practices of quality used in the I4.0 (Asif, 2020). Theoretical understanding of Q4.0 should be created to conceive the notion, build a complete understanding of it, and appreciate its significance to achieve successfully a transition of Q4.0 (Sony et al., 2021), its importance (Dias, Carvalho and Sampaio, 2022), and senior quality professionals' perceptions of the driving factors (Sony et al., 2021).

Research on Q4.0 in the I4.0 context is still in its infancy with the new quality model (Javaid et al., 2021; Sureshchandar, 2023). The main obstacle is how enterprises, especially those in developing nations, can switch from the traditional approach to modern quality and have a methodical plan for implementing Q4.0 (Maganga and Taifa, 2022). In this context, total quality management (TQM) and I4.0 concerns were reviewed in the literature to produce a bibliographic panorama, focusing on the emerging concept of TQM without going into specifics (i.e., different industrial sectors and different nations' cultures) (De Souza et al., 2022). Furthermore, Schiavone et al. (2022) claim that overall quality management is a solid technique for raising the quality of organizations, although experts dispute how well it applies to the service sector.

The first effort to investigate quality service and its link with digitization is credited to (Schiavone et al., 2022).

To fill this gap, this study explores and validates the readiness elements identified by Cudney, Antony and Sony (2020) with senior quality professionals within Egyptian culture in the service sector to create a methodical road map for implementing Q4.0 in the Egyptian service sector. Then, compare both researchers' results with each other regarding developed and developing countries. Accordingly, this study has couple of questions regarding what the readiness factors of are implementing Q4.0 and whether they are the same as those developed in the developed countries. The following sections discuss the research main components including the literature review, the methodology, the analysis of collected data and its findings, discussion and conclusion, research recommendations, research limitations and future research.

2 LITERATURE REVIEW

Quality has been pursued and used through several tactics to unfulfilled demands and consumer perceptions, as evidenced in the development of quality periods (Carvalho et al., 2019b). Over time, businesses have implemented a variety of quality assurance techniques, including Q0.0, which is represented by minimal or no inspection, and Q1.0, which is the measurement, inspection, and control. Additionally, Q3.0 denotes quality improvement achieved using TQM/TQ Control, Lean, and Six Sigma, while Q2.0 denotes standards-based quality assurance. One last thing, I.4 and digitalization are both considered as parts of Q4.0 (Sony et al., 2021).

According to Broday (2022), some authors claim that quality has stagnated because there hasn't been a new model introduced in the last ten years, losing its status as the organization's driving principle. It is also said that the digitalization of processes is useful since it allows managers to respond to problems more quickly and effectively by communicating information in real-time. Given that quality is evolving, providing quality notions with a conceptual framework within the context of the current digital change that society is experiencing is imperative. To help with quality improvement, the development of a learning organisational culture should be studied, as well as human-computer interaction, education, and training. In addition, traditional quality practices will not be abandoned despite the considerable use of automation and technology required by I4.0; rather, quality must be perceived as having the chance to renew itself. Consequently, to implement Q4.0, it is essential to have a good understanding of traditional quality assurance methodologies. Accordingly, Broday (2022) targeted to confirm the most significant elements related to Q4.0 depending on prior literature, but he failed because there is a lack of research on Q4.0 in the service industry. As well, there is no set structure for implementing Q4.0 that is agreed upon by everyone (Zonnenshain and Kenett, 2020). Thus, Applications for Q4.0 face number of challenges, including manufacturing by enhancing

research and development, methods of product and process quality, procurement, logistics and sales, service and after-sale service, supply chain, and process of decision-making (Sader, Husti and Daroczi, 2022), unstable Internet connectivity, a lack of cyber security, high costs, a lack of skills, training, and knowledge for Q4.0, a lack of leadership support, and resistance to change (Watson, 2019; Chiarini, 2020; Santos et al., 2021). As well, technology and data issues have also been obstacles to Q4.0, delaying the growth of the digital skills gap (Santos et al., 2021). Moreover, strong skill set and set of competences in critical thinking, problem-solving, self-management, managing and communicating activities, technology usage and development, and basic reading are necessary for successfully adopting Q4.0 (World Economic Forum, 2020; Kannan and Garad, 2021).

Since they will aid organizations in improving their business models and organizational performance, TQM digital transformation and its implications for people, processes, and technology are also incorporated into the Q4.0 idea (Jacob, 2017; Silva, Borges and Magano, 2022). Q4.0 additionally emphasises key details, in which reduces the expense of poor quality, and monitors quality outcomes. Several businesses have begun to improve the resolution of their data collection by utilizing sensors and analytics (Narayanamurthy and Tortorella, 2021). It emphasizes the use of I4.0 for quality, such as digitalization and artificial intelligence (Carvalho et al., 2019a; Aini et al., 2020; Nenadal, 2020; Javaid et al., 2021; Singh et al., 2022; Saihi, Awad and Ben-Daya, 2023). Despite the fact that adopting Q4.0 improves the services of the company, the satisfaction of the customer, and product quality (Zonnenshain and Kenett, 2020), it also enhances the supply network's connectivity, either the vertical, horizontal, and end-to-end ones (Chiarini and Kumar, 2021), further makes use of data and other expanded inputs to present feedbacks for decision-making (Stefanović et al., 2019).

Theoretical underpinnings show some essential research on Q4.0, as follows; Jacob (2017) was one of the first authors to recognize the 11 Q4.0 axes, because of the integration of these 11 axes, organizations begin to apply Q4.0, which improves current quality practices. According to Sony, Antony and Douglas (2020), big data storage, improved prescriptive analytics, leveraging quality to create efficient vertical, horizontal, and end-to-end integration, utilizing Q4.0 for strategic advantage, Q4.0 training, Q4.0 leadership, and top management support are the essential success factors for Q4.0 implementation in larger organizations. Chiarini (2020) made deductions about what was lacking from the study at the time in order to examine I4.0 and its relationship with TQM. To evaluate the use of big data and I4.0, Schmidt, Almeida and Luis (2020) carried out a thorough review from the perspective of quality control decision-making. Shrayner and Vladimir (2019) examined the challenges that the QM models in high-tech firms present. Sony, Antony and Douglas (2020) saw that reliable information, using big data to drive quality initiatives, enhancing customer delight and happiness, increasing productivity, and delivering long-term financial and time savings are

the five main reasons for implementing Q4.0 in enterprises. Likewise, the top three implementation challenges were lack of competence implementation, resources, and poor organizational culture (Sony et al., 2021). Moreover, Yadav, Shankar and Singh (2021) considered Twenty different variables for lean sigma success, that comprises of seven parts related to Q4.0 and 13 elements related to the conventional setup.

Thekkoote (2022) also highlighted ten elements that support Q4.0's implementation; APP development, analytics, compliance, connectivity, collaboration, data, scalability, organization culture, leadership, and Q4.0 training are the important components. Later, Antony et al. (2023) discussed the advantages and disadvantages of Q4.0 adoption in organizations, as well as identifying organizational readiness criteria for Q4.0 adoption success. These factors are applied to assess the readiness for Q4.0 adoption. Additionally, Kumar, Ganesh and Rajendran (2022) presented three major themes for Q4.0: drivers of Q4.0 adoption, Q4.0 building blocks, and Q4.0 implementation problems. The creation of a Quality Function Deployment technique for the successful implementation of Q4.0 is presented in the study of Dror (2022). The process turns the desired quality improvement goals into crucial Q4.0 technologies, which are then converted into the most crucial implementation issues that need to be resolved. The main obstacles to installing Q4.0 are worries about cyber security and outdated systems and infrastructure.

One of the earliest scholarly studies to establish the Q4.0 paradigm was Thekkoote (2022). But it needs an execution model that outlines the benefits, drawbacks, and obstacles. Thekkoote (2022) advises more studies to create an organizational cultural readiness self-assessment tool for Q4.0. He added that, big data, software prediction, AI, and solving problem style, appear to be in need of qualified workers. Thus, more knowledge and understanding about the dedication to and capabilities of leadership and management are needed if corporate culture is to be changed. Sony et al. (2021) stated that Q4.0 is a new buzzword among corporations and just a few organisations have successfully applied it. Their study looks at the readiness characteristics and determines their significance with Q4.0. They added that future research should include samples from developing nations to get a more comprehensive view of the incentives and obstacles related to Q4.0. The incentive and obstacle elements in various nations and continents need to be compared in a global study that needs to be conducted. It is also possible to compare readiness variables between industries and it is urgently necessary to do research on how Q4.0 affects corporate success and expansion.

To develop a bibliographic overview of TQM and I4.0 themes, De Souza et al. (2022) released a review of the literature in, focusing on developing TQM4.0 definition without going into specifics. The outcomes show that the QM may be used in conjunction with I4.0 technologies to build an ecosystem that facilitates the fusion of people, quality, and technology in an industrial setting. Also, Antony, McDermott and Sony (2022) aim to examine the organisational motives

and benefits for implementing Q4.0 in the present, as well as to comprehend current Q4.0 projects and the knowledge, abilities, and crucial success aspects needed to implement Q4.0. Gembali, Kumar and Sarma (2023) discussed the advantages and significance of sociotechnical thinking for the integration of I4.0, as well as their subsequent usefulness in analysing value-added activities and related quality issues, and their implications in the Q4.0, product-service systems (PSS), and organisation level/complex systems in the era of I4.0.

Sony et al. (2021) found out what the motivators, barriers, and readiness elements are for implementing Q4.0. The findings referred to top management support to be the most crucial factor for implementing Q4.0, followed by organisational culture and leadership, third-placed Q4.0 vision and strategy, fifth-placed knowledge and awareness, sixth-placed customer-centricity, seventh-placed supplier management, and last-placed training and reward. Therefore, the human element is equally important to Quality 4.0's performance across the company, even though it focuses on leveraging technology to enhance an organization's quality management processes (Johnson, 2019). Also, Antony, McDermott and Sony (2022) examined Q4.0, including its benefits, motivating factors, critical success elements, and the expertise required of high-calibre professionals to apply it successfully. Later, Antony et al. (2023) investigated and analysed the organisational readiness elements for Q4.0 adoption. The findings showed that senior management commitment, leadership, and organisational culture were among the top three preparation criteria for the implementation of Q4.0, and leadership is the most significant preparedness aspect that is critical and heralds the acceptance of Q4.0.

A five-phase process was employed by Zulfiqar et al. (2023) to create a Quality 4.0 readiness self-assessment instrument. Six packaging businesses that were willing to take part in the research were found at this phase. For each of the variables and sub-factors across the collaborating organisations, data analysis and readiness evaluation were used. Top management commitment and support, leadership, organisational culture, staff competency, and the existence of the ISO QMS Standard were among the preparedness criteria identified by the study. Moreover, a system for categorising the participating organisations into five categories of quality preparedness evaluation was devised. This is made possible by sociotechnical systems thinking, which offers a thorough perspective for integrating I4.0 and related quality challenges in logistical and industrial service systems. TQM is a good strategy for enhancing businesses' quality, but experts disagree about how well it applies to the service industry, which has distinct best practices from the manufacturing industry. Additionally, digitalization is a feature of all services, but little is known about the whole quality service standards used by digital-based businesses. The first effort done in discussing the relationship between Total Quality Service (TQS) and digitization is by (Schiavone et al., 2022), with the goal of answering the question: What is the evolution of TQS practices in digitally based service organizations? However, research on quality service and its link with digitization is still lacking,

particularly in emerging nations like Egypt. Hence, this study is intended to address this research gap by exploring the service sector to create a methodical road map for implementing Q4.0 in the Egyptian service sector. Based on previous studies, Tab. 1 shows the readiness factors that concluded and the references for each factor.

Table 1 – Readiness Factors of Q4.0

Factor	**Source**
Top Management Support	Sony et al. (2021)
Leadership	Jacob (2017); Sony et al. (2021); Thekkoote (2022)
Training and Reward for Q4.0	Sony et al. (2021); Antony, McDermott and Sony (2022); Broday (2022)
Knowledge and Awareness	Sony et al. (2021)
Organizational Culture	Shrayner and Vladimir (2019); Sony et al. (2021); Antony, McDermott and Sony (2022); Thekkoote (2022); Broday (2022)
Customer Centricity	Sony et al. (2021)
Supplier Centricity	Sony et al. (2021)
Quality Management System	Jacob (2017); Shrayner and Vladimir (2019)
Metrics and Data-Driven Decision Making	Schmidt, Almeida and Luis (2020)
Competence	Jacob (2017)
Compliance	Jacob (2017)
Analytical Thinking	Jacob (2017)
Data Governance	Thekkoote (2022)
Innovation	Thekkoote (2022)
New-Age Technological Tools	Thekkoote (2022)
Development of APP	Jacob (2017); Thekkoote (2022)
Advanced Analytics	Antony, McDermott and Sony (2022)
Collaboration	Jacob (2017); Thekkoote (2022)
Connectivity	Jacob (2017); Thekkoote (2022)
Scalability	Jacob (2017); Thekkoote (2022)

3 RESEARCH METHODOLOGY

To review the literature review, this study reviewed articles, survey reports, paradigmatic books, and master and doctoral theses from multiple data sources, including Emerald Insight and Science Direct (Tranfield, Denyer and Palminder,

2003). This study can be classed as exploratory and deductive because its goal is to create a methodical road map for implementing Q4.0 in the Egyptian service sector. A quantitative approach through a questionnaire directed to senior quality specialists employed in the Egyptian service sector.

Table 2 – Descriptive Statistics for Respondents Profile

Item	Frequency	Percentage	Total
Gender			
Male	444	65.9%	674
Female	230	34.1%	
Age Group			
Less than 40 years	175	52.7%	674
40 – less than 50 years	201	30.1%	
50 – less than 60 years	1	8%	
60 years or more	62	9.2%	
Sector			
Tourism	136	20.2%	674
Health care	126	18.7%	
Retailing	140	20.8%	
Health insurance	125	18.5%	
Other Services	147	21.8%	
Number of Employees			
Between 0 and 9 Employees	175	26.0%	674
Between 10 and 49 Employees	201	29.8%	
Between 50 and 249 Employees	184	27.3%	
>250 Employees	114	16.9%	
Have you heard of the Quality 4.0 Factors?			
Yes	409	60.7%	674
No	265	39.3%	

The convenient sampling technique was followed as the questionnaire was filled by respondents who are senior quality specialists employed in the Egyptian service sector. The target population is considered an infinite population, where a minimum of 385 respondents should be considered in the analysis. Accordingly, a number of 1,000 questionnaires were distributed, while only 692 questionnaires were collected, with a response rate of 69.2%. A number of 674 respondents were only considered in the analysis after excluding invalid responses. The frequencies for each respondent are shown in Tab. 2. The number of 674 respondents' responses reveal that respondents between the ages of between 40

years and less than 50 are the most prevalent (n = 201). Moreover, Males made up many responders with 444 responses. Additionally, the retailing sector (n = 140) outnumbered other sectors. The 674 respondents' responses reveal that "Between 10 and 49 Employees" is the most prevalent (n = 201).

The questionnaire was used to collect the evaluation of Q4.0 readiness factors from senior quality specialists in the Egyptian service sector, with Likert scale as follows: 1 means not at all, 2 means minimally, 3 means slightly, 4 means significantly, and 5 means extremely. Then, Q4.0 factors were analysed using Interpretive Structural Modelling (ISM) from a point of view of experts. Tab. 3 shows the readiness factors measurement scale.

Table 3 – Research Variables Measurement

Variable	**Statements**	**Source**
Top Management Support	1. My company's top management is dedicated to Quality 4.0. 2. My company's top management supports our effort to advance Quality 4.0. 3. My company's top management emphasizes the significance of Quality 4.0 at all organizational levels. 4. My company's top management allocates the proper personnel, time, and financial resources for quality 4.0. The Firm often consults with outside specialists to assess the overall performance of Quality 4.0.	Sony et al. (2021); Antony et al. (2023)
Leadership	5. To accomplish specific Quality 4.0 targets, leaders foster teamwork and cross-functional problem solving. 6. Leaders support a big data driven decision making culture. 7. Leaders control the speed of change brought on by the adoption of Quality 4.0 8. Leaders in my company continue to place a higher priority on employing Quality 4.0 technology to maintain their positions than on making risky bets to create disruption. 9. Leaders develop the workforce within the company for Quality 4.0 10. Leaders motivate workers in my company to do Quality 4.0 actions. 11. In my company, leaders inspire employees to work towards Quality 4.0	Jacob (2017); Sony et al. (2021); Thekkoote (2022); Antony et al. (2023)
Training and Reward for Q4.0	12. Throughout the company, workers are trained in the ideas, values, and instruments of Quality 4.0. 13. The company evaluates the needs for Quality 4.0 training systematically. 14. Companies develop a system of rewards and recognition at the team level for putting Quality 4.0 projects into practice all throughout the company.	Sony et al. (2021); Antony, McDermott and Sony (2022); Broday (2022); Antony et al. (2023)

Variable	Statements	Source
	15. Employees can participate in incentive programs that use Quality 4.0 to assist processes get better and reduce steps that are unnecessary. 16. Employees who adopt Quality 4.0 to streamline procedures and get rid of pointless stages are eligible for annual bonuses.	
Knowledge and Awareness	17. Workers are aware of the goals and advantages of adopting Quality 4.0. 18. Staff members are aware of the purpose behind Quality 4.0 and the alterations that will be made as part of its introduction and implementation. 19. Workers must be familiar with Quality 4.0 technologies and potential applications. 20. Several Quality 4.0 tasks can be carried out by employees as part of their daily work.	Sony et al. (2021); Antony et al. (2023)
Organizational Culture	21. The culture of the organization encourages open communication among employees on quality 4.0. 22. Organizational culture encourages a data-driven mindset at all levels. 23. Organizational culture encourages the transition to Quality 4.0 and eliminates all impediments and silos that are in the way of this shift. 24. As part of the Quality 4.0 effort, employees are given the authority to enhance their own processes.	Shrayner and Vladimir (2019); Sony et al. (2021); Antony, McDermott and Sony (2022); Thekkoote (2022); Broday (2022)
Customer Centricity	25. With Quality 4.0, customers take part in the earliest design phase. 26. Reputable customers are invited to the facility to offer suggestions on how the business might implement Quality 4.0. 27. customers contribute to Quality 4.0 projects by sharing details about their anticipated future needs. 28. A system is in place for gathering customer complaints utilizing both Quality 4.0 and conventional methods of quality so that future issues can be averted.	Sony et al. (2021); Antony et al. (2023)
Supplier Centricity	29. Suppliers actively participate in product design and development utilizing Quality 4.0 and are aware of product designs. 30. With the use of Quality 4.0, suppliers are routinely checked to ensure that they provide raw materials on time. 31. Suppliers are helpful, dedicated to a long-term partnership with their clients, and assist them in achieving Quality 4.0.	Sony et al. (2021); Antony et al. (2023)

Variable	Statements	Source
Quality Management System	32. Management informs all employees of strategy and objectives of Quality 4.0. 33. Management informs consumers, suppliers, and other well-known external agents of strategy and objectives of Quality 4.0. 34. Employees are involved in creating goals and plans of Quality 4.0.	Jacob (2017); Shrayner and Vladimir (2019)
Metrics and Data-Driven Decision Making	35. A common reason for making the decision to develop a new good or service. 36. Data are used by management to help decision-making. 37. Management has the information necessary for making decisions.	Schmidt, Almeida and Luis (2020)
Competence	38. Employees need to be well-informed across a variety of topics. 39. Using logic to find a course of action. 40. Work productivity is a priority for the company. 41. The will to succeed and the self-assurance to take the lead.	Jacob (2017); Mittal et al. (2022)
Compliance	42. Compliance to the government's internal and external Strategic Goal assessments. 43. Compliance to the evaluations from SME, industry, and enterprise guidelines. 44. Compliance to the conclusions of investors' decisions.	Jacob (2017); Zulqarnain, Wasif and Iqbal (2022)
Analytical Thinking	45. There is analytical thinking to achieve objectives of Quality 4.0.	Jacob (2017)
Data Governance	46. There is Data Governance to achieve objectives of Quality 4.0.	Thekkoote (2022)
Innovation	47. There is Innovation to achieve objectives of Quality 4.0.	Thekkoote (2022)
New-Age Technological Tools	48. Management provides a new Technological Tools to employees.	Thekkoote (2022)
Development of APP	49. For data gathering and reporting, there are portals. 50. The gateway is simple to use.	Jacob (2017); Zulqarnain, Wasif and Iqbal (2022); Thekkoote (2022)
Advanced Analytics	51. Analytics using cloud-based data are available. 52. Analyses based on artificial intelligence or machine learning are used.	Antony, McDermott and Sony (2022); Zulqarnain, Wasif and Iqbal (2022)
Collaboration	53. Outside the formal organizational structure, there is open communication among the employees. 54. Staff members have a history of long-term collaboration and good coordination as a result.	Jacob (2017); Mittal et al. (2022); Thekkoote (2022)

Variable	Statements	Source
Connectivity	55. The IT infrastructure provides the highest connection along with real-time data collection and reporting. 56. highest degree of connectedness between strategic and departmental goals	Jacob (2017); Thekkoote (2022); Zulqarnain, Wasif and Iqbal (2022)
Scalability	57. Processing small- to large-scale data with ease. 58. High processing capacity for small- to large-scale manufacturing.	Jacob (2017); Thekkoote (2022); Zulqarnain, Wasif and Iqbal (2022)

4 RESULTS AND FINDINGS

4.1 Validity and Reliability

The factor loadings for all factors are > 0.4. Additionally, the AVE results were > 50%, so all constructs are considered valid. Moreover, Cronbach's Alpha values are > 0.7, indicating that all constructs are reliable. Sekaran and Bougie (2013) assert that reliability increases as the reliability coefficient approaches 1.0. Reliability coefficients of less than 0.60 are often thought to be poor, those between 0.70 and 0.80 to be acceptable, and those > 0.80 to be excellent. And Average Variance Extracted (AVE) should be > 0.5, and Factor Loading (FL) should be greater than 0.4 for each item.

4.2 Descriptive Analysis for Variables

According to the descriptive analysis of Q4.0 Factors, it was observed that the three factors (Development of APP, Collaboration, Scalability) have a mean value of 2.1261, 2.3071, 2.2196 respectively, which is below the average value. According to the result, the three factors were excluded from the study and analysis.

4.3 Development of Quality 4.0 Factors

Many experts participated in a session to create the structural self-interaction matrix (SSIM) for the Q4.0 factors (Top Management Support (TMS), Leadership (L), Training and Reward (Tr.), Knowledge and Awareness (Kn.), Organizational Culture (Cul.), Customer Centricity (Cus.), Supplier Centricity (Sup.), Quality Management System (QMS), Compliance (Compl.), Competence (Compt.), Analytical Thinking (AT), Metrics and Data-Driven Decision Making (DM), Advanced Analytics (AA), Data Governance (DG), Innovation (Inn.), New-Age Technological Tools (TT), Connectivity (Conn.), Collaboration (Coll.), Development of APP (APP), and Scalability (SC). Then, by developing SSIM for the Q4.0 factors, it could be observed that Advanced Analytics (AA) is always a factor that is influencing all factors. Moreover, the Training and Reward (Tr.), and Connectivity (Conn.) are always influenced by all other factors.

4.4 Development of the Initial Reachability Matrix for Quality 4.0 Factors

To turn the SSIM into the first reachability matrix, the experts' opinions gathered in the previous phase are converted into numbers; 0 or 1 according to the experts' responses in this stage, to reach the initial reachability matrix for Quality 4.0 Factors.

4.5 Quality 4.0 Factors

In this step, the transitivity rule is used to convert the initial reachability matrix (IRij) into the final reachability matrix (FRij). According to this rule, if AA leads to Kn and Kn leads to L, then AA must necessarily lead to L. To calculate a factor's driving power and dependence power, add the values in the rows and columns (Pandey, Litoriya and Pandey, 2018):

- The driving power: the total number of rows in the final reachability matrix for each factor that contain 1s.
- The dependence power: the final reachability matrix's total number of 1s in each factor's column.

The final reachability matrix, as well as the driving and dependent powers, are shown in Tab. 4 for each of these factors. It was evident that some aspects had greater driving power than dependence power, with AA being the most significant of these, while Tr., and Conn. are considered the most influenced factor among these factors as it has the least driving power.

Table 4 – Final Reachability Matrix for Quality 4.0 Factors

Item	TMS	L	Tr	Kn	Cul	Cus	Sup	QMS	Compl	Compt	AT	DM	AA	DG	Inn	TT	Conn	Driving Power
TMS	1	0	1*	0	1	1	1	1*	1	1	1	1	0	1	0	0	1	12
L	1	1	1*	0	1*	1*	1	1	1	1	1	1*	0	1	0	1	1*	14
Tr	0	0	1	0	0	0	0	0	0	0	0	0	0	1*	0	0	1	3
Kn	1*	1	1*	1	1	1*	1	1	1	1*	1	1	0	1	0	1	1*	15
Cul	1*	0	1	0	1	1	1	1*	1*	1	1*	1	0	1	0	0	1	12
Cus	0	0	1	0	0	1	1	1	0	1	0	0	0	1	0	0	1	7
Sup	0	0	1	0	0	1	1	1	0	1	0	0	0	1	0	0	1	7
QMS	0	0	1*	0	0	1	1	1	0	1	0	0	0	1	0	0	1	7
Compl	1	0	1	0	1	1	1	1*	1	1	1	1	0	1*	0	0	1*	12
Compt	0	0	1	0	0	1	1	1	0	1	0	0	0	1	0	0	1	7

Item	TMS	L	Tr	Kn	Cul	Cus	Sup	QMS	Compl	Compt	AT	DM	AA	DG	Inn	TT	Conn	Driving Power
AT	1	0	1*	0	1	1	1	1	1	1	1	1	0	1	0	0	1	12
DM	1*	0	1	0	1	1	1	1	1*	1	1*	1	0	1	0	0	1	12
AA	1*	1	1*	1	1	1*	1	1	1	1*	1	1	1	1	1	1	1*	17
DG	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3
Inn	1	1	1*	1	1	1*	1*	1	1	1	1	1	0	1*	1	1	1	16
TT	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	14
Conn	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Dep.Power	10	5	17	3	10	14	14	14	10	14	10	10	1	16	2	5	17	

Notes: TMS – Top Management Support; L – Leadership; Tr –Training and Reward; Kn –Knowledge and Awareness; Cul – Organizational Culture; Cus – Customer Centricity; Sup – Supplier Centricity; QMS – Quality Management System; Compl – Compliance; Compt – Competence; AT – Analytical Thinking; DM – Metrics and Data-Driven Decision Making; AA – Advanced Analytics; DG – Data Governance; Inn – Innovation; TT – New-Age Technological Tools; Conn – Connectivity; Coll – Collaboration; APP – Development of APP; SC – Scalability; Dep.Power – Dependence Power.

4.6 Level Partition for Quality 4.0 Factors

The final reachability matrix is used to generate the reachability, antecedent, and interaction set for each factor:

- Reachability Set: Include the factor and any additional factors it may have an impact on.
- Antecedent Set: Include the element and any additional elements that could have an impact on it.
- Intersection Set: Include the factors that interact together in the same level.

The process of determining the level of each factor is obtained by developing these sets. The variables whose reachability set is the same as intersection set take the first level of the ISM model. From repeating this process, the levels of all the factors in the model are found from the remaining sets. These levels are used in the construction of both the ISM model and the diagraph (Vinodh et al., 2021).

Tab. 5 shows the level of partition. It could be observed that AA is always considered as an influencing factor on all other factors. On the other hand, the Tr., and Conn. is always dependent on all other factors.

Table 5 – Level Partition for Quality 4.0 Factors

Item	Reachability	Antecedent	Intersection	Level
TMS	TMS, Tr., Cul., Cus., Sup., QMS, Compl., Comp., AT, DM, DG, Conn.	TMS, L, Kn., Cul., Compl., AT, DM, AA Inn., TT	TMS, Cul., Compl., AT, DM	3rd
L	TMS, L, Tr., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, TT, Conn.	L, Kn., AA, Inn., TT	L, TT	4th
Tr	Tr., DG, Conn.	TMS, L, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT DM, AA, DG, Inn., TT, Conn.	Tr., DG, Conn.	1st
Kn	TMS, L, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, TT, Conn.	Kn., AA, Inn.	Kn.	5th
Cul	TMS, TR., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, Conn.	TMS, L, Kn., Cul., Compl., AT, DM, AA, Inn., TT	TMS, Cul., Compl., AT, DM	3rd
Cus	Tr., Cus., Sup., QMS, Compt., DG, Conn.	TMS, L, Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, AA, DG, Inn., TT	Cus., Sup., QMS, Compt.	2nd
Sup	Tr., Cus., Sup., QMS, Compt., DG, Conn.	TMS, L, Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, AA, Inn., TT	Cus., Sup., QMS, Compt.	2nd
QMS	Tr., Cus., Sup., QMS, Compt., DG, Conn.	TMS, L, Kn. Cul., Cus., Sup., QMS, Compl., Compt., AT DM, AA, Inn., Cul.	Cus., Sup., QMS, Compt.	2nd
Compl	TMS, Tr., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, Conn.	TMS, L, Kn., Cul., Compl., AT, DM, AA, Inn., TT	TMS, Cul., Compl., AT, DM	3rd
Compt	Tr., Cus., Sup., QMS, Compt., DG, Conn.	TMS, L, Kn., Cul., Cus., Sup., QMS Compl., Compt., AT, DM, AA, Inn., TT	Cus., Sup., QMS Compt.	2nd
AT	TMS, Tr., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, Conn.	TMS, L, Kn., Cul., Compl., AT, DM, AA, Inn., TT	TMS, Cul., Compl., AT, DM	3rd
DM	TMS, Tr., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, Conn.	TMS, L, Kn., Cul., Compl., AT, DM, AA, Inn., TT	TMS, Cul., Compl., AT, DM	3rd
AA	TMS, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, AA, DG, Inn., TT, Conn.	AA	AA	6th

Item	Reachability	Antecedent	Intersection	Level
DG	Tr., DG, Conn.	TMS, L, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, AA, DG, Inn., TT	Tr., DG	2nd
Inn	TMS, L, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, Inn., TT, Conn.	AA, Inn.	Inn.	5th
TT	TMS, L, Tr., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, DG, TT, Conn.	L, Kn., AA, Inn., TT	L, TT	4th
Conn	Tr., Conn.	TMS, L, Tr., Kn., Cul., Cus., Sup., QMS, Compl., Compt., AT, DM, AA, DG, Inn., TT, Conn.	Tr., Conn.	1st

Notes: TMS – Top Management Support; L – Leadership; Tr –Training and Reward; Kn –Knowledge and Awareness; Cul – Organizational Culture; Cus – Customer Centricity; Sup – Supplier Centricity; QMS – Quality Management System; Compl – Compliance; Compt – Competence; AT – Analytical Thinking; DM – Metrics and Data-Driven Decision Making; AA – Advanced Analytics; DG – Data Governance; Inn – Innovation; TT – New-Age Technological Tools; Conn – Connectivity; Coll – Collaboration; APP – Development of APP; SC – Scalability.

4.7 Development of the Digraph and ISM for Quality 4.0 Factors

At this step, a directed graph is created using the factor inputs' serial numbers. Fig. 1 displays the digraph for the Q4.0 factors after removing the transitive linkages between the components for simplicity. The digraph is used to determine the elements' hierarchical connection. Levels 1 and 2 components go at the top of the digraph, then level 3 and level 4 components, and so on, until all levels have been included.

Table 6 – Ranks of Quality 4.0 Factors

Factors	Rank
Top Management Support	4
Leadership	3
Training and Reward	6
Knowledge and Awareness	2
Organizational Culture	4
Customer Centricity	5
Supplier Centricity	5
Quality Management System	5
Compliance	4

Factors	Rank
Competence	5
Analytical Thinking	4
Metrics and Data-Driven Decision Making	4
Advanced Analytics	1
Data Governance	5
Innovation	2
New-Age Technological Tools	3
Connectivity	6

From the above results, Tab. 6 is designed to show the ranks and the degree of influence of each factor of Q4.0 factor.

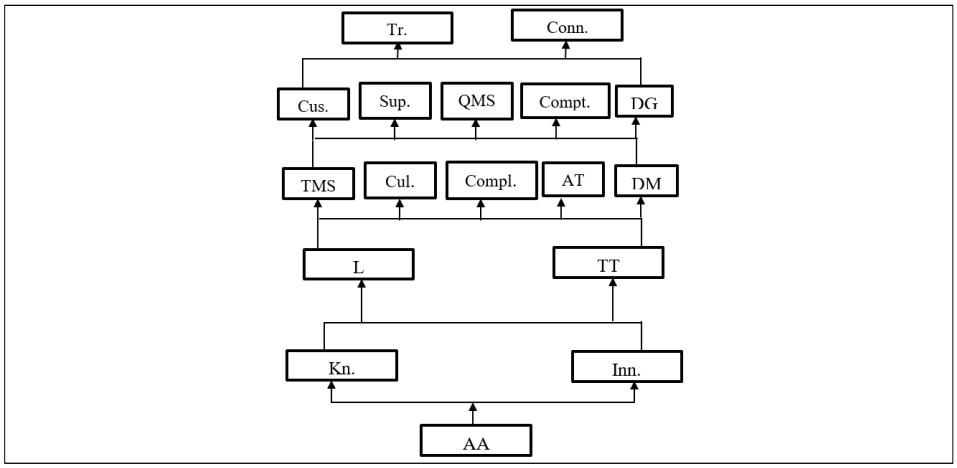

Figure 1 – Digraph for Quality 4.0 Factor

4.8 T-Test and ANOVA Test

These tests are applied to determine whether answers differ based on demographics. The variation in replies by gender is initially investigated using a t-test. According to the results shown from ANOVA Test for Variables, it is proved that gender has an insignificant difference in the implementation of the Q4.0 factors. The findings of an ANOVA test that was performed to assess this association showed that age influenced the research variables. The result showed that older ages had a positive association with the factors. It is also shown that results did not change through different sectors. Additionally, the ANOVA test is used to examine changes that have taken place across several businesses with various employee numbers. According to the research, there was a significant difference with Factors of Q4.0 implementation according to the number of employees.

5 DISSCUSSION AND CONCLUSION

Making the transition from the conventional quality strategy to modern quality and establishing a logical road plan for adopting Q4.0 are significant challenges for businesses, especially those in developing countries. With the help of senior quality specialists, this study looks at and assesses the preparedness standards for the service industry in Egypt to close this gap. It also creates a rigorous and practical road map for Q4.0 implementation in the Egyptian service industry.

The researcher used almost the same factors that Antony, McDermott and Sony (2022) used in their research and added more factors, almost the researcher got the same result of Antony, McDermott and Sony (2022). Antonym McDermott and Sony (2022) used only these factors: top management support, leadership, training and reward, knowledge and awareness, organizational culture, customer readiness, supplier readiness, vision and strategy. The researcher added these factors: quality management system, compliance, competence, analytical thinking, metrics, and data-driven decision making, advanced analytics, data governance, innovation, new-age technological tools, connectivity, collaboration, development of APP, and scalability. According to the result of Antony McDermott and Sony (2022), the most three factors of Q4.0 successful adoption are top management system, leadership, and organizational culture, this is almost near to the result of analysis in this research.

According to the results, the element analytical thinking was the most impacting factor among all other factors, which is shown by its top ranks. This result for the analytical thinking factor was consistent with Thekkote (2022) and Kannan and Garad (2021) results. The factor competence was ranked second, which indicates that it was an additional influencing factor among other factors, however, it may occur because of the analytical thinking factor. This result for the competence factor was consistent with Kannan and Garad (2021) result. Customer centricity, data-driven decision making, and innovation. were the third-ranking elements, which indicates that they were also influential factors, nevertheless, competence and analytical thinking factors also have an effect. The factors top management support and organizational culture are listed in the fourth rank, which indicates that they are additional influencing factors. However, customer centricity, data-driven decision making, inn., competence, and analytical thinking factors may also be in effect. This result for the competence factor was near to the result of Sureshchandar (2022).

The factor leadership was ranked fifth, which indicates that it was an additional influencing factor in addition to the other factors, yet it may occur because of the factors of top management support, organizational culture, customer centricity, data-driven decision making, innovation, competence, and analytical thinking. This result for the Leadership factor was consistent and near to the result of Sureshchandar (2022) and Thekkote (2022). The factor knowledge and awareness of Q4.0 rank sixth, which indicates that it is an additional influencing element in addition to the other factors, although it may also occur because of the

factors of L, TMS, Cul., Cus., DM, Inn., Compt., and AT. The variables advanced analytics and technological tools are listed seventh, which indicates that they are influential factors in addition to other factors. However, Kn., TMS, Cul., Cus., DM, Inn., Compt., and AT factors may also be in effect. This result for the advanced analytics factor was consistent with Sureshchandar (2022).

The factor training and reward for Q4.0 is ranked eighth, which indicates that it is an additional influencing element in addition to other factors, although it may also occur because of the factors of advanced analytics, new-age technological tools, leadership, top management support, organizational culture, customer centricity, data-driven decision making, Inn., Compt., and analytical thinking. The ninth-ranked factor, quality management system, is another one that could influence other factors, but it may also occur as a result of the factors training and reward for Q4.0, advanced analytics, new-age technological tools, leadership, top management support, organizational culture, customer centricity, data-driven decision making, innovation, competence, and analytical thinking, compliance, data governance, and development of APP factors are included in tenth place, which denotes that they are also influential factors. However, quality management systems, training, and reward for Q4.0, advanced analytics, new-age technological tools, leadership, top management support, organizational culture, customer centricity, data-driven decision making, innovation, competence, and analytical thinking factors may also be in effect. This result for the compliance factor was inconsistent with Thekkote's (2022) result.

The factors compliance, data governance, and development of APP, quality management system, training, and reward for Q4.0, advanced analytics, new-age technological tools, leadership, top management support, organizational culture, customer centricity, data-driven decision making, innovation, competence, and analytical thinking all have the potential to influence the factors collaboration, and connectivity, which are ranked eleventh and twelfth respectively. The factors of supplier centricity, and scalability are thought to have the least impact on it and might be avoided if other factors are resolved.

6 RESEARCH RECOMMENDATIONS

Here are some pointers for decision-makers. Focusing on analytical thinking, customer centricity, data-driven decision making, and innovation factors because they were the most influencing factors. By implementing Q4.0, we can advance the baseline and scale up staff skills. Technology should be used to support training and capacity building. Technology could be represented in, social media, mashup software, artificial intelligence, machine learning, virtual reality, and wearables. Technology investments will involve modernizing existing hardware, sensor deployment, AI, ML, and corporate-level platforms for solution expansion.

7 RESEARCH CONCLUSION

The current study aims to close the gap related to methodical road plan for adopting Q4.0 in the developing countries, through investigating and analysing the readiness criteria for the service industry in Egypt with senior quality specialists. The research adopted the quantitative approach through a questionnaire with a final sample of 674 answers. From the structural self-interaction matrix, the study identified ranking of Quality 4.0 factors.

8 RESEARCH LIMITATIONS AND FUTURE RESEARCH

Most of the previous studies discussed implementing Q4.0 in developed countries, that was a limitation that faced the researcher because the researcher discussed implementing Q4.0 in a developing country. The study was limited by the fact that it solely used a questionnaire to collect data. Additionally, there may not be enough responses to conclude the results of this study. So, future studies should use more than one tool for collecting data. Also, using more than one tool to collect data. Assembling many models in the future for more accurate and reliable conclusions. When analysing a company as a longitudinal case study, it would be beneficial to understand its journey toward Q4.0 from its adoption stage to implementation with some instances of projects carried out in various business operations.

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Conceptualization, N.K. and N.G.; Methodology, N.K. and N.G.; Software, N.G.; Validation, N.K. and N.G.; Formal analysis, N.G.; Investigation, N.K.; Resources, N.K.; Data curation, N.G.; Original draft preparation, N.K.; Review and editing, N.K.; Visualization, N.K. and N.G.

CONFLICTS OF INTEREST

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