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Abstract

Purpose – This study aims to investigate how early and late adopters of Q4.0 differ in terms of organizational performance.

Design/methodology/approach –The authors employed a grounded theory approach for interviewing 15 senior managers from diverse organizational contexts throughout the globe as part of their qualitative research methodology.

Findings – The research's findings were analyzed based on four types of performance: operational, financial, environmental, and social. It was clear that early adopters of Q4.0 were sustaining superior performance in quality over time, even though their investment was significantly higher than that of late adopters. From a financial viewpoint, it was evident that early adopters had a competitive edge over their rivals compared to late adopters. Late adopters have utilized the notion of the circular economy (CE) more effectively than many early adopters in the context of environmental performance in order to establish a green economy and sustainable development.

Research limitations/implications: Although the results of the interview indicate that Q4.0 is having some positive effects on social performance, in the authors' view, it is still least understood from an empirical standpoint.

Originality/value –The study's findings assist organizations in comprehending the performance differences between Q4.0 early adopters and late adopters.

Keywords: Quality 4.0, Industry 4.0, Quality management systems, Organizational performance, Grounded theory approach, Qualitative research methodology, Sustainable development

Paper type – Research paper

1. Introduction

Quality 4.0 (Q4.0) is a new trend in the field of quality management (Antony, McDermott, *et al.*, 2022; Chiarini and Kumar, 2020, 2021; Zulfiqar *et al.*, 2023). In simple terms, Q4.0 is managing quality in the modern era of Industry 4.0 (I4.0) (Antony, Sony, Furterer, *et al.*, 2021a; Sader *et al.*, 2022). Q4.0 is not just about integrating I4.0 technologies into the traditional quality management system. However, it is an integrated "social (human) and technical (technological) system, working in a goal-directed manner to meet the quality objectives of the organization" (Antony, Sony, Furterer, *et al.*, 2021a; Sony and Naik, 2019a, 2020). Thus, while implementing Q4.0, organisations must devote equal attention to human and technological aspects to achieve

new optimums in quality management (Antony, McDermott, *et al.*, 2022). Dan Jacob was one of the first to highlight the concept of Q4.0 as a separate term. He mentioned that Q4.0 should be a company-wide strategy and be fully swung across the entire organization (Sony *et al.*, 2020). As per the American Society for Quality (ASQ), the term Q4.0 ensures that it is the future of quality achieving operational excellence for I4.0 (Radziwill, N.M., 2018). Antony et al. (Antony, Sony, Furterer, *et al.*, 2021a), through a qualitative study, provide a brief definition of Q4.0 "*the use of advanced technologies such as IoT, C.P.S., Cloud computing to design, operate and maintain adaptive, predictive, self-corrective, automated quality systems along with improved human interaction through quality planning, quality assurance, quality control and quality improvement to achieve new optimums in performance, operational excellence, and innovation to meet the vision, mission and goals of an organization".* Organizations that implemented Q4.0 have reaped benefits in terms of increased productivity, customer satisfaction, reduced costs of quality, improved operational efficiency, and enhanced product quality are motivating factors for adopting Q4.0 (Antony, McDermott, *et al.*, 2022). Javaid et al **[11]** explicate that in the manufacturing sector, Q4.0 has the potential for automating inspection, reducing quality cost, dynamic and real-time quality control, increase in product performance, business culture improvement, opportunities for partnership, re-alignment of quality functions, redesigning production systems, automatic detection of defects, and life cycle management of products. They further suggest the impact of Q4.0 on environmental dimensions, such as facilitating the maintenance of environmental quality and green production by assisting operators in monitoring and managing temperature, moisture, air, and water quality. Antony et al. (Antony, Sony, Furterer, *et al.*, 2021a) conducted an integrative literature review and suggested that Q4.0 can impact an organization's financial, operational, social, and environmental performance. One of the limitations of these studies is that they have not considered the timing of the adoption of Q4.0 by the organizations. Rodgers (Rogers, 1962), in the seminal study, classified innovation adoption into five categories "innovators, early adopters, early majority, late majority and laggards". From a practical perspective, it is not easy to classify adopters into these five distinct categories. Therefore, studies have classified the adoption into two categories early and late adoption (Gatignon and Robertson, 1989; Shankar *et al.*, 1999). To cite an instance, organizational performance may vary considerably whether they are early or late adopters of an initiative (Jacobs *et al.*, 2015) (Antony, Sony, McDermott, *et al.*, 2021). Early adopters could benefit from first mover advantage, whereas late adopters might benefit from experience advantage over the early advantage, which might influence organizational performance (Jacobs *et al.*, 2015). Therefore, it is essential to compare organizational performance between Q4.0 early and late adopters. Thus, the primary research question of this study is, "*How do organizational performances vary between early adopters and late adopters of Quality 4.0?*"

The remaining portions of the article are structured as follows: The literature review is outlined in Section 2, the methodology is presented in Section 3, the results and discussion are covered in Section 4, and the theoretical and practical implications of the study are provided in Section 5. Finally, conclusions and recommendations for further research are included in Section 6.

2. Literature Review

2.1. Quality 4.0 implementation and duration

Quality 4.0 has gained increasing attention because of its ability to improve quality management and enhance customer satisfaction via digitalization. Several authors have put forward definitions of Q4.0. According to Dias et al **[17]**, "*Q4.0 delivers superior quality by using modern technology to augment the capabilities of both people and quality tools and methods*". Other definitions include "*Q4.0 is the utilization of latest technologies for improving product quality*" (Antony *et al.*, 2021). As with any technological or strategic implementation, there is no defined implementation duration for Q4.0. Numerous studies have emphasized the significance of a detailed project implementation timeline for Q4.0 in alignment with a strategic roadmap and quality-oriented culture to enable technological transformation (Kupper et al, 2019). To effectively implement Q4.0 in organizations, eight key "ingredients" have been identified, including handling big data, improving analytics capabilities, understanding horizontal, vertical, end-to-end integration, leadership, strategic advantage, organizational culture, Q4.0 training, and support of top management (Sony *et al.*, 2020). Critical success factors (CSFs) have also been identified, such as having positive organizational culture, top management support, a Q4.0 vision aligned with strategy, a supportive leadership, and a training program to meet Q4.0 needs (Antony, McDermott, *et al.*, 2022). Zulfiqar et al (Zulfiqar *et al.*, 2023) proposed a readiness model for Q4.0 measurement based on five weighted factors. This model was tested in six packaging organizations that were beginning to implement Q4.0 and was used to assess their readiness in terms of chaotic, primitive, structured, mature, and proficient stages.

2.2. Quality 4.0 early versus late adopters

The innovation curve model, introduced by (Rogers, 1962; Rogers *et al.*, 2014), which categorizes adopters into innovators, early adopters, early majority, late majority, and laggards, is a classic theory for examining the technology lifecycle and is frequently used to explain how, why, and at what rate people adopt innovations (Ng, 2023). Innovators, who are less risk-averse and represent about 2.5% of adopters [12], are typically the first to adopt new technology. Early adopters, who make their adoption decisions after innovators, represent about 13.5% of adopters (Berliner *et al.*, 2019). The early and late majority adopters, comprising about 34% of adopters, drive the success of the innovation once they embrace it (Ozaki and Sevastyanova, 2011; Rogers *et al.*, 2014). Early majority adopters tend to be pragmatists and process-oriented (Mattila *et al.*, 2003), while late majority adopters are more cautious and skeptical of new technology (Connolly and Kick, 2015). Laggards, who represent about 16% of adopters, are traditionally suspicious of innovations and take longer to adopt them, if at all (Rogers, 1962; Rogers *et al.*, 2014).

Q4.0, which was first coined by Jacob in 2017, aligns quality management with I4.0 to enable innovation, enterprise efficiencies, improved business models, and performances. In this study, we use Rogers's innovation curve to describe how organizations adopt Q4.0 by categorizing adoption into two phases: early and late. We define early adopters as those organizations that implemented Q4.0 before 2019 and late adopters as those who implemented it after.

2.3 Benefits & Barriers for early adopters.

There are many benefits to Q4.0. Sader et al (Sader *et al.*, 2022) have described the benefits of I4.0 technologies as a supporting "incubator" for “quality management practices”. The initial advantages of adopting technology early can be financial benefits and other benefits such as improved customer satisfaction and efficiency. Operationally, implementing Q4.0 can result in several benefits, including improvements in key performance indicators such as quality inspection costs, first-pass yields, rework, defect rates, increased customer satisfaction, reduced warranty claims, product-related complaints, and on-time delivery (Kupper et al, 2019; Radziwill, N.M., 2018; Shin *et al.*, 2018). In addition, studies have shown that a high level of Q4.0 awareness correlates with early adoption of Q4.0 (Maganga and Taifa, 2022).

Early adopters gain what is known as the first-mover advantage (F.M.A.) because of the advantage of novel and increased competencies leading to competitive advantages (Lieberman and Montgomery, 1998). In addition, improved product and service quality will benefit early adopters of digitalization to enable Q4.0.(Sony, Antony, Douglas, *et al.*, 2021) . On the other hand, Q4.0 is the organization's embrace of cutting-edge/modern technology. (Sony *et al.*, 2020); thus, as a result, those that adopt new technologies early will be exposed to larger hazards. Nonetheless, compared to late adopters, early adopters will pay more for technology installation and up-front costs **[16]**. Therefore, although the impact of Q4.0 on financial performance is very positive in the long term, the cost of implementation of Q4.0 is high due to acquiring new technologies, equipment, and processes, but over time the organization will break even (Sony, Antony, Mc Dermott, *et al.*, 2021a).

Early adopters of Q4.0 will face a barrier of a skills gap and having to upskill employees. In addition, quality professionals will have to become more proficient in big data, data analytics, data mining, data imaging and other digitalization techniques (Escobar *et al.*, 2021; Montgomery, 2014) The financial investment for digitalization can be a significant barrier to an early adopter organization than late adopters of Q4.0 as the implementation cost of digitalized technologies was higher during the early stage than the present. In a case study by Foley et al (Foley *et al.*, 2022), the authors described how in one medical device company, decisions over investment and approval of spending for digitalization taking several years led to the company becoming a late adopter rather than an early adopter of digitalization. Yan et al (Yan *et al.*, 2019) reported that fear of new technology is one of the leading barriers which affect Q4.0 implementation in organizations.

2.4. Benefits and barriers of late adopters

Late adopters have more access to information and benchmarking about implementation practices, which can help them develop an informed strategic plan by considering digitalization's political, social, environmental, legal, technological, and economic aspects (Antony, Sony, McDermott, *et al.*, 2021). In addition, late adopters have more access to personnel with Q4.0 implementation experience and can avail of consultants and managers with their deployment

experience. Further, late adopters will have certified professionals well-positioned to deploy Q4.0 technologies and strategies (Escobar *et al.*, 2021).

While early adopters can realize as many benefits, one case study on a late adopter highlighted the following benefits. Foley et al (Foley *et al.*, 2022) found that implementation of digitalization led to the following quality benefits; improved product quality and compliance, recall reduction, reduced person-hour efforts in quality audits, improved time to market, time to market, scrap reduction, and acceleration of improvement programs. Q4.0 investment takes time, money and resources and needs Senior Leadership support and commitment, so thus late adopters can take time to assess their approach to deployment.

The barriers to late adopters of Q4.0 are fewer than early adopters. For example, the lack of readiness factors, critical success factors, maturity models, critical failure factors, and uncertainty for late-adopting organizations would be lower than for early adopters (Sony and Naik, 2019b). In addition, late adopters, particularly in highly regulated industries, can adopt a "wait and see" approach to see whether the new technologies adopted by their competitors or industry partners require validation and regulatory submissions before implementation (Yan *et al.*, 2019). Late adopters, thus, can judge what technology requires the most regulatory effort and decide to implement it accordingly.

2.5. Organizational performance

Studies have demonstrated that Q4.0 and digitalization positively influence organizational performance metrics (Antony, Sony and McDermott, 2021; Foley *et al.*, 2022). Q4.0 is “an opportunity to utilize those I4.0 technologies to realign quality functions with the organizational strategy” (Kupper et al, 2019). Antony et al (Antony, Sony, Furterer, *et al.*, 2021a) have found that Q4.0 may impact internal business processes, customer value proposition, financial, environmental, social, organizational, and learning and growth performance. Early adopters of Q4.0 will benefit from improved quality of products and services (Sony, Antony, Mc Dermott, *et al.*, 2021a). Thus time to market, regulatory compliance, improved quality, and fewer defects can decrease product delivery and cycle times and reduce customer queries. Q4.0 implementation results in technology monitoring processes and product quality in manufacturing (Antony *et al.*, 2021). By having more Q4.0 data, continuous improvement programs can be enabled, and problem-solving can increase(Antony *et al.*, 2021).

Regulatory compliance due to government laws and regulating bodies and standards can improve due to Q4.0. For example, some industries, such as medical device and pharmaceutical manufacturing, where patient safety is involved, are subject to highly mandated legislation, whereas others may have less regulated compliance environments. Using Q4.0 systems and technology will aid compliance and reduce risks of non-compliance and late regulatory submissions (Foley *et al.*, 2022). Digitalization can aid in staying current with new standards and regulatory changes, thus avoiding non-compliance and potential products taken off the market and revenue loss (Maganga and Taifa, 2022). Another benefit of Q4.0 to organizational performance is in terms of systems that will link and communicate with one another (Maganga and Taifa, 2022), such as the Quality Management System (Javaid *et al.*, 2021), Product

Lifecycle Management System (PLMS) (Foley *et al.*, 2022), Enterprise resource planning (Sader *et al.*, 2022), Regulatory Management, Supply Chain Management (S.C.M.) and Engineering Change Systems (E.C.M.) (Foley *et al.*, 2022). Furthermore, to take full advantage of Q4.0, automating digital processes and harmonizing and linking those automated processes improves the overall system and minimizes the time needed for high-value employees and management to implement (Javaid *et al.*, 2021).

2.6. Research gaps

There is a gap in the literature relating to Q4.0 implementation. Most literature is oriented towards I4.0 maturity assessments and discusses maturity models (Nenadál *et al.*, 2022). While there has been increased awareness of Q4.0, it is still an understudied area (Antony, Sony, Furterer, *et al.*, 2021a). Many authors have described Q4.0 as an emerging and nascent area (Antony *et al.*, 2021; Maganga and Taifa, 2022). While there has been a focus on the potential benefits of quality control from Q4.0, there is a lack of studies in terms of understanding the effect of Q4.0 on other quality management tools and methodologies (Martin *et al.*, 2023). There is also a lack of studies demonstrating the impact of Q4.0 on quality costs to aid the justification of investments needed (Saihi *et al.*, 2021). Many studies have focused on the potential benefits of Q4.0, but few studies examine the impact of Q4.0 on financial performance (Saihi *et al.*, 2021).

Further, there is a lack of studies that examine the impact of Q4.0 on organizational performance. Moreover, no studies reported the variation in organizational performance of early and late adopters of Q4.0 in organizations. Thus, this gap motivated authors to perform the present study to fulfil this gap.

3. Methodology

Qualitative studies are used to capture the opinions of people. The experience or viewpoints of the people can be better analyzed through qualitative methods (Hammarberg *et al.*, 2016). The prime objective of the qualitative method is to create meaning in people's viewpoints/opinions(Cruz and Tantia, 2017). The present study seeks to understand the difference in organizational performance between early and late adopters of Q4.0 from the viewpoints of senior managers working in manufacturing and service organizations worldwide with more than 5 years of experience in Q4.0 implementation. Hence, this study used an exploratory qualitative design method to capture the experience of top/senior managers in the relevant field. In qualitative methods, the grounded theory (G.T.) approach sets out to construct or discover a theory from the data and systematically obtain and analyze the data using comparative analysis (Glaser *et al.*, 1968). Instead of deductively obtained methods, it is a theory that is consecutively obtained through “social research” (Unkelos-Shpigel *et al.*, 2015). G.T. has emerged as a widely adopted approach across the social sciences field, allowing researchers to develop, test, and strengthen new theories from their research data (Hussein *et al.*, 2020). Hence, this study applied G.T. to examine the difference in the organizational performance of early and late adopters of Q4.0. To understand this difference, interviews were conducted with a panel of 15 selected senior managers from different organizations implementing Q4.0. The interviewees

involved in this study were from Singapore, United Arab Emirates (U.A.E.), Germany, the United States (U.S.), Helsinki, Pakistan, and Turkey. These top/senior managers belong to different manufacturing and service industries where they have already implemented Q4.0 projects; the detailed information of participants is presented in Table 1.

Table 1: Participant Details

Participants name	Role/Title	Years of experience	Company Type	Status of adoption	Geographical location
P1	Director, Business Excellence	>25	Automotive	Early	Singapore
P2	Senior Business Excellence Manager	>20	Security	Late	U.A.E.
P3	Senior Manager	>15	Consultancy/Marine Systems	Late	Germany
P4	Senior Quality System Manager	>15	Healthcare	Late	Finland
P5	Vice President of Quality	>20	Industrial Production	Early	USA
P6	Senior Quality System Manager	>20	Nuclear Energy	Late	U.A.E.
P7	Senior Quality Manager	>25	Automotive	Late	Turkey
P8	Vice President of Quality	>25	Automotive	Early	USA
P9	Quality Assurance Manager	>15	Packaging	Late	Pakistan
P10	Senior Quality Manager	>25	Packaging	Early	Germany
P11	Integrated Quality Management Systems Manager	>20	Consultancy	Late	Germany
P12	Head of Quality Management and Digitalisation	>20	Consultancy	Early	Germany

P13	Vice president of Quality	>25	Logistics	Late	Germany
P14	Head of Quality Management	>15	Consultancy	Late	Germany
P15	Senior Quality Manager	>15	Healthcare	early	Germany

Our objective was to choose participants from various organizations and countries to include divergent viewpoints about Q4.0 implementation. The professional and trusted networking source (LinkedIn) was used to identify and approach the senior managers for the interview(Unkelos-Shpigel *et al.*, 2015). The study details and questions were shared with those participants who responded to our invitation and agreed to share their knowledge and experience to understand the difference in the performance of early and late adopters of Q4.0. The questions were prepared with utmost care to address our research objectives and were more focused on bringing a smooth conversational flow(Frey and Oishi, 1995). Eight experts cross-checked the developed questions before initiating the interviews, and their feedback was incorporated to improve the consistency of the questions. As 4.0 is a new and emerging technology, very few people and industries have experience with its adoption. Therefore, this study considered the following criteria to select the top/senior managers for interview: (i) the person who has at least 3 years of experience and (ii) he has been involved in the implementation of at least two Q4.0 projects in the concerned or any organization. As discussed earlier, 15 interviewees were shortlisted for the interview. Although unlike quantitative research, a low sample size can be used in qualitative research to perform the analysis, a sample size of more than 10 is acceptable and gives satisfactory results (Marshall, 2005; "Sample Size in Qualitative Interview Studies: Guided by Information Power - Kirsti Malterud, Volkert Dirk Siersma, Ann Dorrit Guassora, 2016", n.d.).

The interview process was organized through Microsoft Teams, and the average time to interview participants was 46.3 minutes. The interview started with general demographic questions, followed by 12 semi-structured open-ended questions relevant to Q4.0 adoption reason, benefits, current implementation status, performance measures, advantages of early adoption, disadvantages of late adoption, Q4.0 implementation early and late adopters impact on various organizational performances themes (i.e., operational, financial, environmental, and social). To reduce the bias in answers gathered through interviews, the authors ensured that the participants' responses would be kept confidential, and there was no comparison of right or wrong answers to asked questions(Pearce and Pearce, 2020). All the recorded information gathered from interviewees was added to the Atlas Ti9 software for analysis purposes("ATLAS.ti | The #1 Software for Qualitative Data Analysis", n.d.; Friese, 2023). For open coding, three different techniques were applied, resulting in a list of themes within the data. Further, axial coding categorise themes, and selective coding is applied to condense data into specific categories (Cascio *et al.*, 2019; Charmaz and Belgrave, 2007). The data analysis process is summarized in Figure 1.

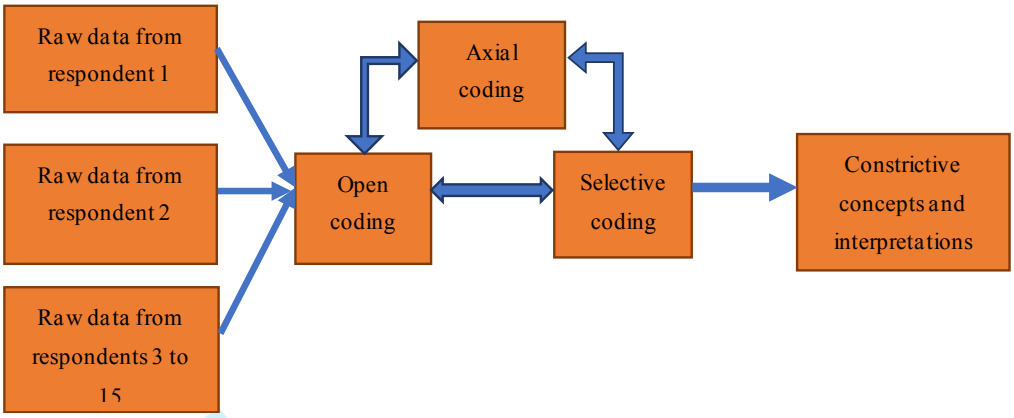

Figure 1. Data analysis process

The interviews were transcribed. The authors checked each transcription to minimize errors. Each interview was denoted a pseudo name (P1, P2 and so on). This helped in the analyses of interviews.

4. Results & Discussion

In this study, we classified the organisations that adopted Q4.0 before 2019 as early adopters, and late adopters were organizations that adopted it after 2019. Organizational performance is a very broad term; hence, to bring in holistic understanding, we use a triple bottom line approach (Antony, Swarnakar, *et al.*, 2022). Therefore, we asked the respondents questions which capture the performance effects of early and late adopters based on four broad emerged themes (i) operational performance, (ii) financial performance, (iii) environmental performance, and (iv) social performance.

4.1. Early and late adopters of Q4.0 impact on operational performance

The operational performance of an organization can be measured through several operational parameters such as effectiveness, efficiency, performance, customer satisfaction index, employee satisfaction index, and productivity, For example, energy usage, cycle time, changeover time, finished product, regulatory compliance, flexibility, waste reduction, etc.(Antony, Sony, Furterer, *et al.*, 2021b; Antony, Swarnakar, *et al.*, 2022). An effective Q4.0 strategy enables organizations to overcome their chronic quality problems and create new businesses. Organizations adopting Q4.0 early will benefit from improved quality and defect-free products/services (Zonnenshain and Kenett, 2020). The successful implementation of Q4.0 can help organizations to strengthen efficiency, effectiveness, performance, and business models to sustain in the competitive market (Sony *et al.*, 2020). Q4.0 adoption resulted in digitalization, creating a new opportunity to incorporate advanced technologies for organizations to arrive at new optimums in quality management (Sony and Naik, 2020). "*Digitalized technologies such as automation and sensors help to detect the problem at the very initial stage and indicate instantly so that the problem can be either handled by skilled staff or robots which results in reduced waste/defect, lead time and improved productivity"* (P5). However, digitalization brings the

smart factory concept that enhances operational performance (Watson, G, 2019). The smart factory of the future will help to reduce quality costs by improving operational efficiency, reducing non-conformance, on-time delivery of products/services, increasing revenue, improving product compliance, increasing flexibility, introducing new quality products, and reducing supplier defect rate (Antony, Sony, Furterer, *et al.*, 2021b; Zonnenshain and Kenett, 2020). Thus, early Q4.0 adopters' organizations will benefit from improved quality, flexibility, productivity, and defect-free product or services. *Q4.0 is not something you can implement and finish; on the contrary, it is an evolving process* (P8). I4.0 technologies such as the Internet of Things (IoT), Industrial Internet of Things (IIoT), Cyber-Physical Systems (C.P.S.), Cloud Computing (CC), Artificial Intelligence (A.I.), Digital twins, Smart manufacturing, Cognitive Computing, etc. have been applied as part of Q4.0 in organizations that result in improved transparency, quality design, quality performance and quality conformance (Park *et al.*, 2017; Zonnenshain and Kenett, 2020). Lean Six Sigma (L.S.S.) tools and techniques must be integrated with Q4.0 techniques for better results (Yadav *et al.*, 2021). The supply chain concept can also be integrated to have a faster, cheaper, and better supply of quality products to the customers. Thus, the Q4.0 implementation in organizations is a time-consuming process that brings opportunities for organizations to learn over time (Sader *et al.*, 2022). As the Q4.0 implementation is still nascent for many organizations, therefore most respondents' organizations are following the "learning by doing" strategy.

The authors asked respondents about early and late adopters of Q4.0 impact on operational performance; the following views are observed from some of the respondents' which can be helpful to organizational managers to understand the impact on it.

"An early adopter organization can enjoy the benefits of process improvement resulting in a better quality product, improved productivity, and increased flexibility. As a result, these organizations will be able to provide better quality products/services than their contenders and stay in the competitive market for the long run. On the other side, they suffer the challenges, but once they learn the trick to sustain, it would be difficult to beat them" (P4).

"Having skilled people on board is very difficult for early adopter organizations as fewer people understand the Q4.0 tools, techniques, strategy, and implementation roadmap. However, skilled people play an important role in improving the organisation's operational performance." (P8).

"The early adopters will be able to understand the quality-related problems at a very early stage and solve those problems earlier than other competitors, whereas the late adopters will have more chances to lose their customers as customers may have moved to competitors who deliver a good quality product" (P13).

It is clarified from the above statements; the early adopters must put more effort and spend money to implement Q4.0 in the organization. In comparison, the late adopters will use the mature model and attain the best quality product/services in the shortest duration with minimum investment and effort. Nearly all the respondents have stated that companies who adopted Q4.0 in the early stage suffered in searching for trainers to get training to employees, whereas trainers

were easily available in the market for late adopters. Further, new benefits were observed: "*The recognition level was low for the organizations who implemented Q4.0 earlier compared to late adopters*" (P9). *"Late adopters do not need to put any investment into the development of software/technology/approaches etc., but in the case of early adopters, it was necessary as the sensors, actuators, etc., not easily available in the market like nowadays"* (P11). Thus, the early adopter organizations might strengthen their position/brand image in the competitive market due to high-quality products and services (Závadská and Závadský, 2020), and late adopters may enter the market with updated business models that target to enhance the quality characteristics of products/services that are not focused on by early adopters.

If we compare the operational performance of early and late adopters' based on the respondents' opinions, we can conclude that the early adopters of Q4.0 organizations may not have the benefit of reduced operational cost. The early adopter can be benefited in terms of different operational performances: *Solve the quality-related problems in a very early stage; hence they will get competitive advantages* (P2), *and they would be able to analyze and improve their operational performance in a very early stage as compared to late adopters* (P6), *the adoption of change management would be very easy for early adopters as compare to late adopters* (P9), *the customer satisfaction rate would be high for early adopters* (P12)*, having strengthened to compete other competitors would be very high in comparison to late adopter of Q4.0 organizations* (P15). These benefits are consistent with Antony et al (Antony, McDermott, *et al.*, 2022); adopting Q4.0 will improve product quality by ensuring traceability, transparency, and reinforcing intelligence. Further, consistent with Santos et al (Santos *et al.*, 2021), it will significantly reduce the cost of poor quality by minimizing quality assurance steps, multiple inspections, and reliability issues with the help of digitalized systems. However, the implementation cost of Q4.0 for early adopters' organizations is higher than those adopted late, as the necessary technologies, tools, techniques, modern systems, training facilities, and skilled people were higher in the infancy stage. We cannot forget that Q4.0 technology is still nascent, and most organizations are still planning for its adoption (Chiarini and Kumar, 2021; Javaid *et al.*, 2021). However, many authors suggested that the successful implementation of Q4.0 with I4.0 tools and techniques can be reduced operational costs by around 10% (Bag *et al.*, 2021; Shin *et al.*, 2018), but the majority of early adopters have not experienced the same outcomes. Respondent 14 pointed out, *"In comparison to early adopters, the late adopters may get benefits related to low implementation cost, improved productivity, and flexibility because the systems, mechanisms, tools, and techniques used in updated models are more powerful and effective than those earlier*". Respondent 12 pointed out "*The benefit of late adopters will also depend on the type of product and the market competition. Sometimes, it would be difficult for late adopters to beat the early adopters if the market type is monopolist*". Thus, it can be concluded that the late adopters may enjoy a strategic cost and operational performance benefit. However, in the case of an oligopoly and monopoly-type market, the early adopters can have a better chance to get sustained in a competitive environment through operational performance.

4.2. Early and late adopters of Q4.0 impact on financial performance

The implementation of Q4.0 technology will impact the organization's financial performance. The 4th industrial revolution provides opportunities for organizations to enhance business using digital supply chain concepts(Santos *et al.*, 2021). Digitalization enables the mass customization of product/services, which result in increased revenue. However, the mass customization process and personalized production help organizations fulfill the increasing customer demand (Park *et al.*, 2017). Based on the voice of participant 2, *"The early adopters of Q4.0 will get benefits related to increased productivity and flexibility; the flexible system will open opportunities for organizations to change the product or service designs/parameters as per the customer demand, which results in expanding of business"*. Thus, the early adopters will be able to fulfill the customer demands earlier than their contenders and expand their business in the competitive market.

Further, automated processes or systems will help to improve the quality of conformance through continuously monitoring product/service flow at all stages of the process. Furthermore, automation will recognize value-added and non-value-added processes; thus, it is easy for organizational managers to minimize the non-value added process and keep only value-added and necessary non-value-added (Rüßmann *et al.*, 2015). In addition, the automated process will verify/confirm whether the product design, specifications, and quality meet or not the customer's needs using big data analytics (Sony *et al.*, 2020). Thus, in this way, organizations can attract more customers. Participant 5 articulated, *"The right product or service with improved quality will increase customer satisfaction and this result in increased revenue and competitive advantages"*. The statement is consistent with Pearce and Pearce (Pearce and Pearce, 2020) that the improved product quality will help to improve customer satisfaction which will ultimately increase the revenue of the concerned organization and enhance competitive advantage. Thus, early adoption of Q4.0 technology in the organization will bring more opportunities to increase the total revenue than late adopters.

Most interviewees clearly stated that the early adopter organizations witnessed a marginal increase in profit. *"The early adopters will be able to reduce the cost of quality by adopting digitized systems such as automation, Artificial Intelligence, Digital Twins, Big Data analytics systems, Robots, etc., that help in quality control and get the product or services at less cost increasing profit and competitive benefits"* (P7, P11). *"With the adoption of Q4.0, the early adopters will benefit from decreased sales and stock price costs due to reduced inventory and material costs. The early adopter organizations will be considered a forward-looking visionary for quality"* (P13). Based on the respondents' voices, it is clear that the early adopters may not get many financial benefits from Q4.0 implementation as the cost of associated tools and techniques needed to adopt in the industry was high initially. Also, organizations have been facing several challenges as the majority of the people have less knowledge about this. One of the challenges includes difficulties in information sharing throughout the supply chain process that causes failure of supply chain strategy. However, supply chain failure caused by either internal operations or external suppliers causes a significant impact on quality and delivery costs. According to Chen et al (Chen *et al.*, 2017, 2010), digital twins can solve the problem related to

information sharing throughout the supply chain process, and big data generated across the supply chain process will enhance resource utilization efficiency. The application of Big data also provides the flexibility to reduce non-value-added activities and enable resource scheduling in the production process (Rüßmann *et al.*, 2015)Sony et al., 2020). Overstocking issues can be solved through automated J.I.T. systems and IoT with algorithms [54,55].

Further, innovations and design challenges can be handled by A.I. machines (Ghoreishi and Happonen, 2020). Participant 8 articulated, "*The early adopter will have more chances to overcome past limitations of highly interactive human inputs into the design process*". Thus, the efficiency of the technical system will be increased due to the adoption of automation in the process, which results in the decreased marginal cost of products/services (Sony, Antony, Douglas, *et al.*, 2021)

Organizations that adopted Quality 4.0 in a very early stage either purchased or developed required systems and technologies at a very high cost as it was very expensive at the nascent stage, but it was somewhat cheaper for the late adopters (Závadská and Závadský, 2020). Therefore, the debt-to-equity ratio and financial leverage will be high for those organizations purchasing the required systems from debt (Antony *et al.*, 2021). Some respondents agreed and observed that nearly all the early adopters have to buy Q4.0 technologies from debt; hence debt-to-equity ratio and financial leverage may be high for them. Participant 2 uttered, "*The early adopters may get additional benefits from a quality perspective as the product/service purchased from debt will go through several quality checks which will improve the quality of conformance and performance. In addition, there will be fewer chances of internal and external failure, which will reduce failure cost*".

Nearly all the participants shared their thoughts about early and late adopters' impact on financial performance. They stated that the financial performance of a company depends on several factors, including "how much money they spent to adopt Q4.0 practices", "where they implement it (i.e., either in one unit or whole organization)", "size of the organization", "type of product or services", "implemented country or continent", "competitor type", "what are the competitive forces", "supplier", "type of market" etc. For example, the financial performance of early adopters of Q4.0 would be better than late adopters in some markets where there is a threat to new organizations due to entry barriers (Bal and Erkan, 2019). In addition, the markets where customer bargaining power is very high (Bal and Erkan, 2019). Therefore, in these cases, the early adopters' impact on financial performance will be higher than late adopters unless they implement completely updated and innovative business models.

4.3. Early and late adopters of Q4.0 impact on environmental performance

The implementation of Q4.0 technology will impact the organization's environmental performance. Q4.0 digitalized system is implemented in the organization to adjust the quality process and optimize signal response. However, the adaptive learning approach enhances self-induced corrective action within a system or process(Kupper *et al.*, 2020). Thus, an organisation's successful implementation of Q4.0 technologies improves resource efficiency. It also helps to reduce defects, rework, and scrap through continuous monitoring of the

manufacturing/production process using digital monitoring systems resulting in good quality products or services and minimum wastes (Kupper et al, 2019). Due to the reduction of waste, minimum environmental impact has been noticed, as waste and rework directly relate to the environmental effect (Li *et al.*, 2019). Participant 3 commented, "*The early adopters of Q4.0 technologies will get benefits related to meeting environmental regulations because the data related to the usage of water, energy, coolant, lubricants, natural resources materials, and emissions of gases and other outputs will be available in the cloud, hence, result in better environmental management*". It is necessary to implement the cloud-based system to take the real benefits of Q4.0 and the smart factory concept. Automation and A.I. machines will help organizations to save energy, reduce emissions, water, lubricants, and raw material wastage, and improve material efficiency (Ghobakhloo and Fathi, 2020). The adoption of Q4.0 technologies encourages organizations to use renewable resources and promote the judicious use of natural resources (Shin *et al.*, 2018). The systematic utilization of resources with the help of Q4.0 digitalized tools will help organizations reduce fuel consumption, water consumption, energy wastage, steam wastage and improve system efficiency (Cort and Esty, 2020). Further, the application of 3D printing in organizations has greater benefits in terms of minimum material wastage, minimum scrap, less pollution, and recyclable materials, hence creating an eco-friendly environment (Khosravani and Reinicke, 2020). Based on the statement of Participant 4, *"Modern technologies such as 3D printing, Additive manufacturing, etc. help to reduce pollution as they are less polluting technologies. Though these technologies are recently nascent, they will benefit organisations adopting them later"*. This statement is consistent with (Niaki *et al.*, 2019), the application of additive manufacturing, HPC-CADM, and A.V.R. in the organization has facilitated an environmentally friendly place.

For better management of environmental regulatory compliance, the organization should focus on the systematic collection and analysis of process parameter data. However, Q4.0 digital technologies provide several facilities such as data acquisition, transparency, sharing, integrating, monitoring, etc. By implementing Q4.0 technologies, the organization will be able to collect and analyze process parameter data which results in better management of environmental regulatory compliance and improved efficiency (Khuntia *et al.*, 2018). Digital transformation in the organization has several benefits, such as reduced pollution, reduced energy, minimum water and coolant usage, reduced natural resources, maximum usage of renewable resources, and reduced wastage (Oláh *et al.*, 2020). Participant 8 mentioned, *"The cloud system will help to secure environmental management related data and application of IoT, and IIoT will help to share real-time data. These digitalized systems will control and correct the data based on the requirement. Hence, this system will improve the image and loyalty of early adopters"*. However, the effective use of horizontal, vertical, and end-to-end Q4.0 technologies enables optimized energy, water, lubricants, coolant, etc., further contributing to environmental performance (Beier *et al.*, 2017; Ford and Despeisse, 2016).

Nearly all the participants stated that Q4.0 technologies positively impact environmental performance. However, some of them commented (Participants 2, 6, 9, 10, 11, 13, and 15), *"Environmental performance of a company majorly depends on two factors: type/nature and size of the organization, the Q4.0 adoption impact on environmental performance can be assessed*

from these two most important parameters". For example: if the factory type/nature is one among these (i.e., fuel and energy, transport, agriculture, food production, fashion, construction, etc.), then it will pollute more than others, or it has a higher impact on the environment (Statista, 2023). Besides, if the size of the industry is large, then it also has a high impact on the environment than S.M.E.s and MSMEs. Thus, it can be concluded that the early adopters of Q4.0 technology may get the advantage of improved environmental performance in real-time monitoring and accounting of environmental-related parameters. In contrast, late adopters will benefit from adopting the circular economy concept.

4.4. Early and late adopters of Q4.0 impact on social performance

The implementation of Q4.0 technology will impact the organization's social performance. Q4.0 technology impacts internal and external stakeholders (Antony, McDermott, *et al.*, 2022). The main objective of organizational managers is to implement Q4.0 to produce high-quality products and services that meet customer expectations (Sony, Antony, Mc Dermott, *et al.*, 2021b). The quality of products and services manufactured/developed using automation and digitalized system is higher than those produced by the traditional process (Zonnenshain and Kenett, 2020). Other advantages of automation and digitized systems are defect-free products, less waste, a low scrap rate, and fewer human accidents (McDermott *et al.*, 2022). The process can be automated using collaborative robots; this robot may be very useful where humans cannot work. Using such robots can help eliminate human efforts, especially where work is dangerous, repetitive, and monotonous, reducing the accident rate (Sony, Antony, Mc Dermott, *et al.*, 2021b). Participant 7 stated, "*The use of robots in industry reduces the cycle time of the process, reduces defects, reduces material, reduces human effort, increases accuracy, increases product quality and improves production and productivity*". Collaborative robots are known to improve safety, reduce ergonomic hazards, improve product quality and reduce absenteeism of employees (Amrani and Vallespir, 2021; Chen *et al.*, 2017). Nowadays, in nearly all smart industries, the hazardous, routine, and monotonous kind of work is performed by collaborative robots, which will improve the employees' work. Thus, we can say that the automation process impacts social performance. *"The early adopter organization place collaborative robots where the work type is either hazardous, routine, or monotonous, thus reducing the chances of workers' accidents. The late adopters may benefit from smarter collaborative robots which can better identify the hazardous areas and assess the risks; therefore, organizations are safer for humans and machines"* (P12).

Participant 9 commented, "*The implementation of Q4.0 will enhance the workers' health and safety and improve the working environment of an organization. In addition, automated systems and processes will help organizations improve product quality and enhance employee satisfaction*". Most organizational managers argue that implementing Q4.0 technologies eats humans' jobs; therefore, this study will clarify their concerns and answer them. Participant 11 illustrated, *"The adoption of automation and digitalized systems in the organization may eliminate the human involvement in low to medium-skilled jobs, but it will create a new job for them in system safety, process engineering, etc."*. This statement is consistent with Ghobakhloo and Fathi(Ghobakhloo and Fathi, 2020); automation may eliminate small jobs resulting in job

loss. However, these job losses can be overcome by creating new jobs by implementing Q4.0 technologies.

Further, Q4.0 technologies help improve the quality of H.R. processes such as employee hiring, selection, training, promotion, retention, etc. H.R. managers can use the application of A.I. and data analytics tools to design personalized carriers' development schemes for employees and prepare learning programs based on skills, behavior, learning patterns, experience, personality, etc. (Lengnick-Hall *et al.*, 2018). One of the interesting benefits observed by the early adopters' respondent's organization was *"after implementing Q4.0 in the H.R. management process; all the human resources-related process was digitalized and transparent. Therefore, there is no impact of favoritism and politics within the organization which generally has in most places" (P15)*.

The major problem observed in the industry is a communication gap between top-level management and employees(A. Mahajan *et al.*, 2012) which can be solved using Q4.0 technologies. The Internet of People (IoP) improves communication among top management, employees and staff; hence, the communication gap among those is reduced (Corral de Zubielqui *et al.*, 2019). Another crucial problem of organizations is employee training time and cost (Dubihlela and Rundora, 2014) which can also be solved using the Q4.0 technology. According to Gavish et al. (Gavish *et al.*, 2015), the use of A.V.R. and simulation will help to provide training to employees at a lower cost, and this training would be easier, quicker, safer, and more effective for employees. Participant 8 uttered, *"The early adopters have some impact on the social performance of internal stakeholders, including a reduction in monotonous, dangerous, and repetitive work. In addition, there are also benefits related to overcoming the H.R., government regulations, training, and communication gap challenges"*. Though the early adopters have challenges, they need to place all the data related to employees and stakeholders in the digital system and develop a plan for retraining, rehabilitation, and redeployment of workers. *In this case, the late adopter will benefit more as they have a knowledge base or experienced H.R.*

The implementation of Q4.0 will greatly impact society because modern technologies will provide quality products and services at a cheaper rate and a healthy environment for people. Participant 14 commented, *"Due to the Q4.0 adoption, people would be able to enjoy products or services beyond their thinking. It will change their lifestyle and improve the living standard of people. In addition, it will increase the digital literacy of the country"*. Thus, we can say that the countries whose socioeconomic status is low due to a lack of industrialization can now use this opportunity by adopting Q4.0 technologies which will change their status. As this technology helps to produce a good quality product at minimum cost, it would be easy for early adopters to sell the product at a lower margin than previously and expand their business, resulting in socioeconomic improvement. But late adopters will benefit society more because they have to provide their product at a lower price than early adopters. The results of the present study are summarized in Table 2.

Table 2. Result summary of early and late adopters' impact on organizational performance

Theme	Early adopters organization	Late adopters organization
Operational Performance	Improved quality, flexibility, productivity, and defect-free product or services	Best quality in a short period of time
	Strength to stay competitive in the long run	More chances to lose their customers
	Embrace the challenges of implementing Quality 4.0 technologies	Benefit from a mature model with minimum investment and effort
	Difficult to get skilled people	Difficult to get skilled people
	Ability to solve quality-related problems earlier than competitors	Higher recognition level
	Implementing Quality 4.0 requires significant effort and investment from the organization	
	Securing qualified trainers to provide employee training may present a challenge for the organization	Trainers will be easily available in the market
	The organization is not widely recognized or known	
	Huge investment into the development of software/technology/approaches	No investment required in the development of software/technology/approaches
	Higher operational and implementation cost	Lower operational and implementation costs
	Change management is easier	
Financial Performance	Facility to change product or service designs/parameters based on customer demand	Ability to get machines, tools, etc., at a cheaper rate than early adopters
	Fulfil customer demands earlier than competitors	Benefit from updated systems and technologies
	Increased revenue and competitive advantages	Compete for market space
	Increased profit and competitive benefits	
	Reduced cost of sales and stock price	
	Reduced inventory and material cost	
	Minimized non-value-added process	
	Decreased marginal cost of products/services	
	Reduced failure cost	
Environmental performance	Improved resource efficiency	Reduced pollution by adopting less polluting technologies
	Minimized environmental impact due to reduced waste, scrap, and rework	Advantage of adopting the circular economy concept
	Meet environmental regulations	
	Reduced consumption of required material and improved system efficiency	
	Secured environmental management-related data and the ability to share real-time data	
	Improved organization image and loyalty	
	Optimized use of resources	
	Real-time data monitoring and accounting of related environmental parameters	
Social performance	Reduced accidents	Smarter collaborative robots that can identify hazardous areas and assess risks
	Enhanced workers' health and safety and improved working environment	Ability to handle uncertain conditions
	New jobs for employees in system safety, process engineering, etc.	Knowledge base or experienced HR
	Digitalized and transparent human resources-related process	Better-managed displaced workers
	Reduced favouritism and politics within the organization	
	Reduced monotonous, dangerous, and repetitive work	
	Reduced H.R., government regulations, training, and communication gap-related challenges	
	Improved living standard of people	
	Increased digital literacy in the country	
	Socioeconomic improvement	

5. Theoretical perspective on early and late adopters of Quality 4.0

The early adopter of innovation usually has the advantage because of novelty and development of capabilities (Lieberman and Montgomery, 1998). This study contributes to this perspective that early adopters of Q4.0 result in improved quality, flexibility, productivity, and defect-free product or services, strength to stay in the competitive market for the long run, have the facility to change the product or service designs/parameters based on customer demand which results in expanding of business, and fulfil the customer demands earlier than their contenders. Further, the institutional theory also explicates early adopters to adopt it for efficiency reasons and not for normative, mimetic, or coercive reasons (Benner and Veloso, 2008; Westphal *et al.*, 1997). This study contributes to this standpoint by suggesting that early adopters of Q4.0 has experienced increased revenue and competitive advantages, increased profit and competitive benefits, decreased cost of sales and stock price, reduced inventory and material cost, minimized the non-value-added process, decreased marginal cost of products/services and reduced failure cost, besides, environmental and social performance of the organization. On the other hand, early adopters face challenges since the knowledge base is limited or nonexistent (Meyer *et al.*, 2009). This study contributes to this outlook by suggesting that Q4.0 early adopters will experience challenges in implementing Q4.0 technologies, difficulty in getting skilled people, putting more effort, and spending a huge amount of money to implement, searching for trainers to get training employees, huge investment into the development of software/technology/approaches, higher operational and implementation cost.

In contrast, the late adopters have fewer uncertainties as knowledge grows from documented decisions and experiences of early adopters (Terlaak and Gong, 2008). This study contributes to this perspective by suggesting that Q4.0 late adopters will achieve the best quality in a short period, benefit from the mature model with minimum investment and effort, trainers will be easily available in the market, and higher recognition level of the organization. In addition, the late adopters can use the knowledge infrastructure of early adopters for better design and implementation of processes, resulting in cost advantage and maximizing positive impacts (Ritchie and Melnyk, 2012). This study contributes to this viewpoint by suggesting that late adopters of Q4.0 will require less investment into the development of software/technology/approaches, get the required machines, tools, etc., at a somewhat cheaper rate than early adopters, and get the benefit of updated systems and technologies, reduced pollution by adopting less polluting technologies, get an advantage by adopting the circular economy concept, smarter collaborative robots which can identify hazardous areas and assess the risks, handle the uncertain condition, have a knowledge base or experienced H.R., and better management of displaced workers. However, some challenges experienced by late adopters are higher competition in the marketplace and less long-run marginal profits.

5.1. Practical Implications

This study offers important implications for senior managers responsible for quality management in their organizations regarding the adoption timing of Q4.0 and its impact on organizational performance. Q4.0 is still in the nascent stage, and many organizations have not implemented it (Chiarini and Kumar, 2021). Therefore, this study will be an eye-opener to organizations

concerning the performance benefits an organization can derive from Q4.0. A key takeaway for managers from this study is the drastic improvement in organizational performance in terms of operational, financial, environmental and social dimensions for both early and late adopters. These findings can be used to devise long-term and short-term strategies for the organization using Q4.0 implementation. Another point managers should consider is that the organizational performance challenges experienced by early and late adopters of Q4.0 differ depending on the adoption timing. Thus, we advise managers to consider these challenges holistically while implementing Q4.0. Also, we recommend that managers consider operational and financial performance while evaluating their Q4.0 initiative in their organizations but also social and environmental performance assessment. This will help managers to realistically judge the organizational performance after implementing Q4.0. Our study has shown that early adopters of Q4.0 has experienced increased revenue and competitive advantages, increased profit and competitive benefits, decreased cost of sales and stock price, reduced inventory and material cost, minimized the non-value-added process, decreased marginal cost of products/services and reduced failure cost. On the other hand, most organizations find Q4.0 implementation costly and time-consuming (Antony, Sony, Furterer, *et al.*, 2021b). Thus, we propose to the managers that the Q4.0 initial cost component is high; however, this cost would be offset by the financial advantages both early and late adopters accrue over a period.

Further, it is time for managers to consider Q4.0 to meet the organisation's environmental targets. Our study finds that organizations have experienced improved resource efficiency, met environmental regulations, secured environmental management-related data and could share real-time data after implementing Q4.0. These results suggest that quality managers, especially those operating under stricter environmental regulations, must consider implementing Q4.0 to achieve new levels of optimum environmental dimensions. Further, managers face social and governance issues termed E.S.G. (Economic, Social and Governance) challenges for managers (Cort and Esty, 2020). Our study finds that Q4.0 implementation results vary from reduced accidents to socioeconomic empowerment and improved transparency in the organization. Thus, Q4.0 can be considered a means for meeting E.S.G. challenges.

6. Conclusion, limitations, and directions for future work

Quality 4.0 as a relatively new concept is gaining unprecedented attention among the quality professionals for the past couple of years at a global level. In this paper, the authors have carried out a qualitative research to understand the differences in organizational performances between early and late adopters of Quality 4.0. The authors have analyzed four types of performance: operational, financial, environmental and social. It was observed that many organisations are integrating one specific type of technology from the tool box of Industry 4.0 and claiming that they have implemented Quality 4.0 successfully in their organization. The authors felt that there have been huge misconceptions around this topic, thus further research is required to remove some of the common myths around Quality 4.0 and reveal the realities of what it can and cannot do for organisations. Although the number of interviews with quality professionals was deemed satisfactory, the authors felt that many companies are at the very early stages of implementing Quality 4.0 in their companies and therefore the information gained from the interviews may not be very accurate. The next phase of the research is to pursue a quantitative survey looking at how Quality 4.0 impacts various business performance metrics (economic, social, operational and environmental) in various types of organisations. Moreover, the role of organizational culture and

leadership should be explored further as mediators in the relationship between Quality 4.0 practices and their impact on performance.

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