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ORIGINAL RESEARCH

Unleashing the Potential of the TQM and Industry 4.0 to Achieve Sustainability Performance in the Context of a Developing Country

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Abstract *Business organizations may be able to improve their Sustainability Performance (SP) by adopting Total Quality Management (TQM) concepts combined with Industry 4.0 (I4.0) technologies. This research has developed a model to investigate the influence of TQM and I4.0 on SP. It also analyzes the mediating role of TQM in the relationship between I4.0 and SP. A survey was conducted among 240 respondents employed in ready-made garment (RMG) industries in Bangladesh. A Structural Equation Modelling (SEM) technique was used to analyze the collected data. Research findings show that both TQM and I4.0 technologies have a significant impact on the sustainable growth of the Bangladeshi RMG sector. Moreover, it is observed that TQM mediates the relationship between I4.0 and SP. The findings show that TQM helps to explain the relationship between I4.0 and sustainable performance. This study will provide a guideline for industrial executives on securing sustainability through the adoption of TQM concepts and I4.0 technologies. We are not aware of any additional studies that look at the possible link between TQM, I4.0, and SP, as well as the mediating role of TQM between I4.0 and SP.*

Keywords Industry 4.0 · Structural equation modelling · Sustainability performance · Total quality management

Introduction

Globally, we are confronting key sustainability challenges in social, economic, and environmental arenas (Sarker et al., 2021). For example, over one billion people are living in extreme poverty (Raj et al., 2020), and The World Bank (2021) stresses that economic disparity and social inequality continue to prevail. Economic and environmental sustainability problems are compounded further as the linear economy module, with a ’take-make-waste’ approach to manufacturing and consumption, does not complement environmentally responsible agendas, ultimately threatening life on Earth (Industrial Development Report, 2018). A rising global population coupled with a linear economy model creates greater ecological damage. Under the current approaches, there is still too high a reliance upon the use of non-renewable raw materials and a consumer approach of waste through non-sustainable consumption, along with excessive manufacturing emissions and pollution via improper disposal of products (Dubey et al., 2014). It is clear businesses play a crucial role in the pursuit of a sustainable planet, as such, there needs to be a global commitment from all industries to engage in significant sustainable business improvements (Dubey & Bag, 2013). By establishing sustainable practices in all businesses, the negative impact of production, services, and logistics on the ecosystem will be reversed (Jabbour et al., 2018). Numerous scholars have highlighted

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TQM and I4.0 as important techniques to increase the sustainability performance of an organization (Abbas, 2020; AlShehail et al., 2021; Machado et al., 2020; Nara et al., 2021; Tasleem et al., 2019).

While there are clear benefits to society from businesses adopting sustainable practices, there can be challenges for the organizations themselves. Business sustainability refers to the triple bottom-line (TBL) of profit, planet, and people (Slaper & Hall, 2011). By its very definition, therefore, becoming sustainable encompasses transitioning to a whole new business approach and culture (Hermelingmeier & Wirth, 2021). In addition, businesses often experience challenges in knowing what aspect(s) to target first, which involves a process of 'strategic reframing' to help guide the company through the change into sustainable development (Haubensak, 2020). Once organizations do have a plan in place, Slaper and Hall (2011) stresses that *"there is no universal standard method for calculating the TBL"*, as such organizations have difficulty in measuring their individual impact on the planet. As such, while the adoption of sustainable business practices is hailed as the solution to our global sustainability challenges, helping businesses transform is a significant undertaking.

Total quality management (TQM), however, can be a strategy to help businesses obtain long-term sustainability by developing an organization's competitive advantage (Siddiqui et al., 2009). TQM's fundamental principle and goal are to enhance operational activities over time to increase production and sales while also increasing customer and stakeholder satisfaction. The scope of TQM has lately been expanded to include wider aspects, such as social obligation and environmental policies (Tasleem et al., 2019). Furthermore, successful TQM implementation substantially impacts green innovation in businesses, which is a crucial component for successful sustainability (Li et al., 2018). Concurrently, Industry 4.0 technology (the industrial Internet of things) is considered another important dimension through which long-term business sustainability can be achieved (Lucianetti et al., 2018). Although under 30% of manufacturers worldwide have fully adopted I4.0 so far (Wopata, 2020), there are reported benefits for those who have. For example, the employment of I4.0 technologies in manufacturing can result in more effective work scheduling and execution, leading to resource and cost reductions (Yao et al., 2019). The technology company, Siemens, was an early adopter of I4.0 in digitizing its production, which has improved its manufacturing productively while also increasing its product quality (Greenfield, 2016). Essentially, adopting TQM alongside I4.0 results in the organization adopting digital quality control process within which resources are used more effectively, ultimately leading to enhanced sustainability performance. Another real-world illustration of I4.0 implementation is the "Technology Initiative Smart Factory KL," which is an R&D project financed by prominent commercial vendors to construct a factory model that is completely smart and backed by advanced technologies. The factory was developed in a flexible style, with each function autonomous and ensuring minimization in production cost and increased resource availability (Sader et al., 2019). Furthermore, I4.0 approaches like interoperability, dematerialization, and service orientation might contribute to extending the life of machines, thus reducing industrial waste, resulting in better utilization of local resources and available assets and expanding recycling opportunities, along with enabling a quick response to changes in energy supply (Bag & Pretorius, 2020; Carvalho et al., 2018). TQM and Industry 4.0 combined can also enhance the sustainability quotient of organizations.

Even though TQM and I4.0 implementation can enhance business sustainability, industries nevertheless face challenges when adopting these approaches in their organizations (Aamer et al., 2017; Lucianetti et al., 2018). This is the situation for Bangladesh's ready-made garment (RMG) sector, which has grown rapidly in the past 10 years, with Bangladeshi RMG exports standing at $33.1 billion in 2019 (Barua, 2021). The challenge in implementing TQM principles and I4.0 technologies in Bangladesh's RMG sector derives from many major factors. Firstly, top management in the RMG industry can be hesitant to empower employees because of the fear of breaking the chain of command. However, past research indicates that empowering employees aids them in executing their tasks more effectively (Aamer et al., 2017; Cho & Linderman, 2019; Xu et al., 2020). Secondly, around 85% of Bangladesh's RMG sector workers are poorly educated and lack technical skills (BGMEA, 2020). Superiors show very little willingness to improve the practical abilities of the workers due to the hefty expense of teaching (Honarpour et al., 2017). Thirdly, top authorities of the RMG sector are cautious about implementing the I4.0 technologies due to the high initial investment (Belhadi et al., 2021). As such, the implementation of TQM principles and I4.0 technologies in Bangladesh's RMG sector remains a significant challenge.

Bangladesh has indeed risen to the top of global apparel manufacturing and is now "one of the world's largest garment exporters, with the RMG sector accounting for 84% of Bangladesh's exports" (Barua, 2021). But the textile industry of Bangladesh requires much improvement in sustainability performance. The Financial Express (2021) stated that in 2021, Bangladesh generated approximately 1000 tons of cloth waste, possibly valued at a billion dollars if recycled. Besides the lack of recycling opportunities, lack of application of statistical process tools, lack of quality consciousness among sub-suppliers etc., are also hindering the process of improving sustainability performance (Akter et al., 2022; Chiarini, 2020). However, I4.0 technologies can be useful for adopting the digital quality control process, and recycling technologies and TQM principles can be beneficial for quality performance improvement by reducing defects across the supply chain, which ultimately will lead to the enhancement of sustainability performance (Ammar et al., 2021; Broady, 2022; Souza et al., 2022; Tambare et al., 2022). The above discussion points us toward a research gap in the literature that the integrated adoption of TQM and I4.0 to enhance organizational sustainability performance is still to explore. Though researchers have separately provided theoretical frameworks for the impact of TQM and I4.0 technologies on sustainability performance (Abbas, 2020; AlShehail et al., 2021; Bag & Pretorius, 2020; Belhadi et al., 2021; Tasleem et al., 2019; Tseng et al., 2018), no known single study has empirically investigated the combined effects of TQM and I4.0 on SP. So to fill this research gap, the current study will attempt to address the below research questions:

RQ1: To what extent do TQM and I4.0 have distinct impacts of TQM and I4.0 on sustainability performance?
RQ2: Does TQM act as a mediator between I4.0 and sustainability performance?
RQ3: What is the impact of I4.0 technologies in TQM implementation?

This study developed a theoretical framework to answer these research questions. For this purpose, this research formulates research hypotheses which are then tested with survey data collected from garment industries located in Bangladesh, using the partial least square-structural equation modeling (PLS-SEM) technique.

The remainder of this work is structured in the following way. A brief review of the theoretical background is presented in the very next section. After that, the establishment of the theoretical model is outlined. Then, the following two sections present research procedures and data evaluation, respectively. After that, the findings of this empirical research are presented. Finally, theoretical and practical implications of this study, limitations, and future scopes are presented.

Literature Review

This section reviews the (TQM) concepts and research in Industry 4.0 (I4.0) and how these technologies can facilitate organizational sustainability performance.

Total Quality Management

In the mid-1950s, the TQM philosophy began in Japan. The term "TQM" has arisen from the idea of Total Quality Control (TQC) (Maganga & Taifa, 2022). Perhaps the fundamental explanation for the conception of TQM is the argument that quality is more than simply a subject of control; it must also be managed (Elibal & Özceylan, 2022). As businesses and industries began to emphasize quality, the authority of the US recognized its importance to the country's economic strength. Then the Malcolm Baldrige National Quality Award (MBNQA) was founded in 1987 as a nationwide declaration of purpose to deliver quality excellence (Sharma & Modgil, 2020). From the beginning, many scholars have defined TQM from various perspectives.

According to Yue et al. (2011), TQM is an integrated technique that aims to synergize all operational activities to create a dynamic outcome with the primary aim of increasing product and service quality and customer satisfaction. TQM can be defined by the implementation of quantitative approaches and personnel to improve all internal systems and fulfill the present and future demands of the consumer (Apornak & Hezaveh, 2019). As per ISO 9000, the concept of TQM was created to encourage quality standards or build demand for quality throughout the supply process (Chaturvedi, 2020). A complete management strategy, TQM is increasingly being utilized to improve business capabilities and management systems while concentrating on consumer requirements, employee participation, collaboration, process redesign, operations, environment of the firm and supplier relationships (AlShehail et al., 2021; Baidoun et al., 2018; Oliveira et al., 2019). In their research, Sharma and Modgil (2020) stress that when TQM practices are combined with SCM practices, these together produce maximum operational performance. As such, the potential for TQM to enhance business performance is magnified when employed with other complementary business systems.

While the benefits are clear, the adoption of TQM requires a culture shift including top-level commitment, administrative changes, customer focus, and comprehensive training courses (Dubey & Gunasekaran, 2015; Gomes et al., 2019). To make optimal use of TQM systems in each organization, senior management commitment, employee participation, workforce cooperation, and feedback loops build foundations for personnel to effectively apply TQM techniques (Gómez et al., 2017; Iqbal & Asrar-ul-Haq, 2018). Without such a foundation, the workforce and other resources cannot be effectively used. For example, Oliveira et al. (2019) stated that unfamiliarity of top-level management with the TQM of an organization, results in a lack of innovative techniques, which in turn hinders continual sustainability improvement.

In the globalized environment, businesses are paying very close attention to TQM methodologies, tools, and approaches. As there is no definite consensus on the elements that comprise TQM (Tasleem et al., 2019), various sets of TQM criteria have been proposed and used in various research because of the wide variety of definitions and scope of TQM. Likewise, Kaynak (2003) and Talapatra et al. (2020) used seven factors of TQM practices in their studies which focus on the leadership abilities of top management, relations between employees, supplier and customer relationship, product and process design. Abbas (2020) and Khan et al. (2020) used seven slightly different TQM factors for their research purpose. According to Tasleem et al. (2019), recently, scholars have started to cite the MBNQA criteria as one of the most acceptable TQM standards. This study selects factors for TQM measurement based on the above literature.

A key principle that assures high quality within a business, TQM can be applied through technology since it allows for strong leadership, continual development, and employee participation (De et al., 2020). As such, the connection between TQM and Industry 4.0 is discussed next.

Industry 4.0

A significant progression from earlier innovations, such as the creation of electricity and then wide-spread automation, Industry 4.0 encompasses the next generation of innovations that businesses need to address. Such innovations in technology include Artificial Intelligence (AI), Machine Learning (ML), Virtual Reality (VR) and Augmented Reality (AR) (Maganga & Taifa, 2022). As such, Industry 4.0 (I4.0) now refers to more than 630 Internet of Things (IoT) platforms that are currently used globally for connecting industries and transforming business operating systems, including Cyber-Physical Systems (CPS), visual computing, and digital manufacturing (Horváth & Szabó, 2019; Mickeleit, 2022). I4.0 initially conceived in 2011 and known as forming a portion of the modern manufacturing policy of Germany, includes increasing interconnection among people, machinery, as well as systems via real-time data sharing (Dalenogare et al., 2018). Under this innovative way of operating, I4.0 opens a whole new world of possibilities for the fields of operations management and supply chain management (Bag & Pretorius, 2020; Contador et al., 2020; Kumar et al., 2022).

For successful I4.0 adoption, it is critical for the top management to be involved in appropriate planning, collaboration with external stakeholders, data processing, information protection, and a flexible organizational structure (Hofmann & Rüsch, 2017; Souza et al., 2022).

The I4.0 transformation requires the digitalization of the whole value chain and enables businesses to provide clients with innovative digital offerings, such as internet-based services incorporated in goods (Souza et al., 2022). I4.0 will help businesses to increase consumer satisfaction by enhancing the quality of provided offerings because of intense standard quality assurance activities (Gunasekaran et al., 2019). Additionally, I4.0 technologies can facilitate leadership approaches by improving collaborative relationships among multiple managerial levels, thereby improving the company's capacity to produce distinguishing quality results (Bai et al., 2020; Liu et al., 2022). I4.0 also can serve as a foundation for the continual development of processes and operational and organizational performance. A fully interconnected manufacturing process will increase quality performance and overall process responsiveness (Ghobakhloo, 2020). Furthermore, I4.0 will help to optimize processes, enhance performance, reduce the effort required for quality concerns by employing sensors at each level of production, and give methods to assist quality operations, resulting in less rework and scrapping (Elibal & Özceylan, 2022; Liu et al., 2022). I4.0 also enables organizations to apply digital quality control tools to production processes, resulting in minimizing the quality cost and early detection of defects (Bag & Pretorius, 2020).

However, while the adoption I4.0 technologies in businesses are advantageous, there are challenges with such a transformation. I4.0 alter conventional methods, procedures, and strategic objectives (Oláh et al., 2020), so a whole organizational culture shift is required. The implementation of I4.0 necessitates detailed knowledge, economic ability, skill upgrades, and the creation of an interactive, flexible culture inside the firm. Top management must also be involved in appropriate planning, collaboration with external stakeholders, data processing, information protection, and a flexible organizational structure for I4.0 adoption (Hofmann & Rüsch, 2017; Souza et al., 2022). Finally, there remains inconsistent data in previous studies on the association between I4.0 technologies and organization performance improvements, stimulating more research into the issues. In this regard, I4.0 offers numerous potential for businesses but poses several challenges because of the continuing automating, digitization, interconnection and measurement (Chiarini, 2020).

However, if these challenges can be addressed, I4.0 promotes a decentralized and simpler framework for business operations, focusing on simple, easily interconnected components with lower degrees of sophistication.

Additionally, there are specific concerns within developing countries' organizations and their ability to adopt I4.0 technology, largely because of a shortage of intellectual, administrative, and connection abilities (Barua, 2021; Brixner et al., 2020). According to Durana et al. (2019), data analysis, integrating emerging technologies with current types of machinery and workers, and computing restrictions are the greatest obstacles with I4.0 technologies. Overcoming these obstacles will open doors to more efficiency, adaptability, profitability, and reliability for businesses in developing nations. Regarding economic and technological problems, increasing consumer demands for customization and agility have altered company models, resulting in more unpredictable and diverse marketplaces. These factors have bolstered the formation of strategic partnerships and collaborations across value chains, increasing managerial complexity (Kiel et al., 2020).

Furthermore, the amount of up-front capital investment needed to incorporate I4.0 is relatively high, making it less appealing to emerging-market firms (Apornak & Hezaveh, 2019). To address political and regulatory challenges, authorities must establish constitutional limits for the use of big data, particularly those connected to information privacy. Another cause of concern is the increased flexibility of working, which necessitates the reform of work rules regarding working hours and corporate responsibility. For these, I4.0 technologies adaptation is a more significant challenge for companies in underdeveloping countries given the application (Bag & Pretorius, 2020; Tortorella et al., 2018).

An essential aspect of the I4.0 study is the examination of present modern technologies to provide the basis for an insight into their operating in a data-driven framework. Kamble et al. (2020) used six popular I4.0 technologies in their research to examine the influence of I4.0 approaches on sustainability. Besides, Bibby and Dehe (2018) measured the level of I4.0 technologies implementation in the defense sector, where they used eight I4.0 technologies for their research purpose. In addition, Braccini and Margherita (2019) identified nine different I4.0 pillars of technologies to identify the challenges to implementing I4.0 techniques. Based on the above literature, this study selects factors for I4.0 performance measurement for further analysis.

TQM 4.0: A New Concept

Quality 4.0 is a relatively new concept (Maganga & Taifa, 2022) which refers to the way in which I4.0 technology can be adopted by, and incorporated into, quality management processes to enhance the overall quality of goods alongside improving business efficiencies. From their literature review, Elibal and Özceylan (2022) outlined six key TQM areas in which I4.0 can be mapped onto customer focus, Leadership, Engagement of People, Process Approach, Improvement, Evidence Decision-Making and Relationship Management.

When TQM processes are combined with I4.0, this creates an *"ecosystem capable of uniting technology, quality and people"* (Souza et al., 2022). These three pillars need to come together seamlessly to establish the right environment for success in terms of organizational competitiveness and sustainability performance.

The potential of I4.0 for TQM is still yet to be fully explored, but this is an emerging field with growing interest (Maganga & Taifa, 2022), especially for its benefits to sustainability performance.

Sustainability

In today's global market, organizations are becoming increasingly conscious of the importance of sustainability management (Nguyen et al., 2018). The World Commission for Environment and Development initially presented the idea of sustainability in 1987. The committee defined sustainability that same year as a socioeconomic growth model that enables people to "satisfy the demands of the current population without jeopardizing future generations' potential to fulfill their respective demands" (WCED, 1987). Furthermore, United Nations (UN) members settled on a worldwide vision for sustainability advancement in 2015, which included the 17 objectives for sustainable growth across the UN, known as the sustainable development goals (SDGs). This program brings together both the public and corporate sectors along with community groups and individuals to work toward these common goals, which include everything from setting objectives to implementing and attaining them (Garcia-Torres et al., 2019; UN General Assembly, 2015). Sustainability management, according to Kuei and Lu (2013), is *"advancing the adaptation of effective management concepts, methods, and practices across the operating system, and allowing the environment to achieve sustainability performance."* Although, challenges to sustainable initiatives in value chain flexibility are acknowledged (Dwivedi et al., 2021). Based on Kaplan's Balanced Scorecard, Figge et al. (2002) and Khalfallah et al. (2021) explored three ways to integrate the three elements (economic, social, and environmental) of sustainability into a unified model termed the Sustainability Balanced Scorecard. Edgeman (2013) created a Sustainable Enterprise Excellence model relying on business excellence frameworks and sustainability performance factors. Sustainability performance is generally seen as a crucial aim for companies because it influences long-term competitiveness (Banihashemi et al., 2019; Lee & Lam, 2012). Hubbard (2009) mentioned that over 75% of major global firms should be required to think seriously about their sustainability and develop performance measurements not based on the usual financial or economic gains. From a Tripple Bottom Line (TBL) perspective, sustainability is defined as a combination of environmental, financial, and cultural objectives that creates equilibrium across these dimensions (Carter & Rogers, 2008; Gunasekaran & Spalanzani, 2012). As such, businesses are encouraged to factor in more environmental and cultural performance measures alongside the more long-standing financial metrics.

The TBL's environmental aspect is focused on the viability of natural resource usage and renewal trends. In terms of organizations, this dimension manifests itself in a culture of using only natural resources reproducible from nature and generating only discharge which could be digested organically by the current ecological system. This can be achieved by resource recycling and regeneration, redesigning manufacturing processes to reduce resource use, replacing all non-renewable resources with renewable ones, and the application of a circular economy approach (Braccini & Margherita, 2019; Kamble et al., 2018).

An organization's economic performance primarily concerns its productivity and profitability (Banihashemi et al., 2019). Daugherty et al. (2005) argued that the economic strength of a business might be assessed using metrics like product returning cost, quality control, cost management, inventory cost minimization, and increased employee effectiveness. Diabat et al. (2013) classified economic policies that positively or negatively impact economic success. The authors characterized advantages gained by sustainable manufacturing techniques as positive economic contributions, like purchasing cost minimization, waste disposal, as well as a reduction in accidents associated with the environment. On the other hand, they characterized expenses associated with sustainable manufacturing techniques as negative economic consequences, such as the cost of acquiring eco-friendly products and operating and retraining costs.

To generate value, the social dimension focuses on an organization's approach toward developing social responsibilities, including human rights, child labor, quality management, and health and safety issues within the communities in which it functions (Banihashemi et al., 2019; Wood, 1991). Sarkis et al. (2010) looked at inner people management, outer population, stakeholder involvement, and macro societal concerns as social parameters. Gold et al. (2010) and Sushil (2011) suggested that the social element of sustainability is understudied and deserves more research.

These three pillars of sustainability overlap with one another and sometimes clash. For example, adhering to environmental sustainability agendas may harm the economic plan, given the additional expenditures required for cleaner manufacturing processes. However, to pursue all of the three pillars, companies must operate holistically, meaning that treating the whole, not just a part of something. Each dimension indicates a required but insufficient prerequisite for attaining sustainability: organizations must support all three dimensions to act suitably (Braccini & Margherita, 2019; Evans et al., 2017; Sassanelli & Terzi, 2022). This study considers all of the three dimensions for measuring sustainability performance.

Model Development and Hypothesis

The theoretical foundation was designed on the link between TQM, I4.0, and sustainability performance acknowledged in the literature. Along the value chain, unsustainable products negatively impact quality, reliability, ecology, and health (Jørgensen, 2008). To gain a competitive advantage, the resource-based view (RBV) of the firm acknowledges that the internal runnings of a business affect organizational sustainability performance. Therefore, the RBV view argues that the valuable internal assets of the company (such as skilled employees, internal processes and systems and technological capabilities) can be utilized to create value and a competitive edge in different ways (Al-Dhaafri et al., 2016; Collis, 1994). TQM and industry 4.0 might be viewed as impalpable internal resources which lead an organization to gain competitive advantages (Abbas, 2020; Nara et al., 2021).

TQM and Sustainability Performance

TQM philosophy proposes systematic strategies to increase the operational efficiency of an organization. TQM philosophy and practices are based on ethical principles (Zairi & Peters, 2002). Ethical principles are more than a humanitarian issue; comradeship and corporations are founded in a society based on these principles. The corporate social responsibility (CSR) notion is linked to quality management ethical principles. The TQM concept is compatible with both the instrumental and moral features of sustainability performance (Tasleem et al., 2019). Over the past few years, scholars have begun incorporating Business Excellence models for an interdisciplinary approach with TQM frameworks (Gómez et al., 2017; Saha & Alam, 2022). "Business Excellence" is a multi-dimensional and expanded definition of quality, which indicates that it addresses not just product quality but also operational quality and the workplace environment (Yusuf et al., 2007).

Based on connections between the TQM principles and excellence frameworks, Zink (2007) recommended that

TQM can be combined with the excellence model's frameworks to link up with the philosophy of sustainability performance of a firm. According to Khalfallah et al. (2021), sustainability may be included in enterprise applications through the use of TQM frameworks, which provide a comprehensive perspective of all activities of a company. The author also suggests that TQM approaches increase the sustainability of an organization in a significant way.

A few theoretical studies exist in the literature that examined the impact of TQM on sustainability performance, although many studies focused on TQM and operational performance (AlShehail et al., 2021). However, while many pieces of research had discovered a favorable relationship between TQM and organizational performance (Dahlgaard-Park et al., 2018; Gomes et al., 2019; Hussain et al., 2020; Khan et al., 2020), other investigations did not discover any such relationship (Berman, 2015; Khalfallah et al., 2021; Wynen et al., 2016). Additionally, the studies which focused on the link between TQM and sustainability performance; most established a positive relationship between them (Abbas, 2020; AlShehail et al., 2021; Soltani et al., 2006; Tasleem et al., 2019). According to Androwis et al. (2018), TQM procedures can be considered a promising approach to enhancing organizational effectiveness across different competitive directions, including development, delivery and lead time, cost, and pricing. As a result of these improved competitive advantages, optimal sustainability performance may be obtained. Meanwhile, Tasleem et al. (2019) suggested that implementing TQM helps an organization improve every aspect of sustainability performance (economic, social, and environmental), through which competitive business advantages can be gained. Though having some varying findings on the influence of TQM's major enabling elements on operational performance and a shortage of empirical research on TQM and sustainability performance, available theoretical works suggest that TQM factors can positively affect sustainability performance (Abbas, 2020). Now, based on the above arguments, the first hypothesis can be proposed as:

H1: TQM positively impacts sustainability performance.

Industry 4.0 and Sustainability Performance

Sustainability approaches coupled with I4.0 practices are gaining in popularity among a variety of organizations. The reason for this involves an organization's need to attain and sustain global competitiveness and sustainability, as such, cleaner technology must be used in several ways (Braccini & Margherita, 2019; Luthra & Mangla, 2018). As per the World Commission, sustainability can be described as the smart and ethical utilization of assets to satisfy current wants without risking future generations' needs (WCED, 1987). At the same time, I4.0 applications aspire to solve present-day challenges, such as global competitiveness, unpredictable economy, increasing personalization via connectivity, knowledge, technology, and faster innovation and throughput times (Müller et al., 2018). The promise of the I4.0 approaches holds the prospect of considerable advances to socially sustainable growth (Stock & Seliger, 2016). From an economic viewpoint, I4.0 adaptation can contribute to effective problem solving, shorter lead times, lower overhead costs, improved flexibility in production, increased efficiency, and higher competitiveness (Dalenogare et al., 2018). With regards to the ecological dimensions, I4.0 technology may minimize resource and energy consumption by assessing data throughout the production process and logistics actions (Sarkis & Zhu, 2018). From the social sustainability perspective, digital technologies and smart manufacturing systems may aid the health and safety of employees by automating routine and tedious operations, resulting in increased job satisfaction and performance of employees (Müller et al., 2018). Still, I4.0 techniques can also pose numerous problems. Increased unemployment, digital security concerns, data complexity, e-waste, and low quality are just a few examples of the challenges with adopting I4.0 processes (Bai et al., 2020).

However, a growing area of research is now emerging that focuses on the relationship between I4.0 application and sustainability performance surrounding social, economic, and environmental perspectives (Machado et al., 2020; Tseng et al., 2018). Most of these studies provide information about the effect I4.0 techniques have on the sustainability performance of any organization (Bag & Pretorius, 2020; Beier et al., 2020; Ghobakhloo, 2020; Müller et al., 2018; Nara et al., 2021; Sartal et al., 2020). Other studies have focused on the particular sustainability challenges faced by an organization in recent times (Jabbour et al., 2018; Tseng et al., 2018). In addition, some emphasize the relevance of sociotechnical factors for technology deployment to improve organizational sustainability (Kiel et al., 2020; Oláh et al., 2020). In summary, these researchers are trying to display the theoretical approach to the potential positive influence of I4.0 implementation on an organization's sustainability performance (Bai et al., 2020; Kamble et al., 2020). Machado et al. (2020) indicated that environmental sustainability might be promoted by integrating the I4.0 technologies and sustainability performance goals that ensure excellent environmental performance with a greater positive effect. Haseeb et al. (2019) suggested that I4.0 techniques act as a critical ingredient to the continuous growth of sustainability in manufacturing industries. In addition, Kamble et al. (2020) established that I4.0 has the potential to directly prevail over organizations' sustainability, affecting all the economic, environmental, and social pillars. However, several studies bring significant concerns about the possible negative impacts of I4.0 implementation on each of the sustainability pillars (Bai et al., 2020; Ghobakhloo, 2020; Nara et al., 2021). Some experts, for example, have raised concerns about the effect of I4.0 adoption on social factors such as employment availability and work health and safety of employees (Ghobakhloo, 2020; Talapatra et al., 2020; Yadav et al., 2020). Overall, despite some anomalies, I4.0 technologies are likely to substantially impact on the sustainability performance of an organization (Jabbour et al., 2018; Kamble et al., 2018). Now, based on those as mentioned above, the following hypothesis can be stated:

H2: I4.0 positively impacts sustainability performance.

Industry 4.0 in TQM Implementation

The introduction of TQM along with I4.0 has resulted in improvements in business that are happening at an accelerated speed. Most of the changes in business organizations at that introductory phase have been generated by the technologies that are being introduced to this situation. As a result, the way quality is managed within the organization must also adjust and adapt to the changes required to optimize the quality and to keep the TQM approach aligned with I4.0 (Souza et al., 2022).

The characteristics of I4.0 offer a solid foundation for supporting business success; interconnectivity boosts the capacity of businesses to function more effectively by employing network technology. The complete value chain of manufacturing has become networked, and devices are interconnected. Production processes may try to adjust to the best production situation even when an immediate breakdown happens, proactive maintenance warnings are quicker to forecast storing, and assets are distributed efficiently and effectively (Chiarini, 2020; Sader et al., 2019).

Regarding Quality Assurance (QA), I4.0 will lift personnel roles from routine tasks to a greater degree of authority and inspection for the production process, depending on context-sensitive situational objectives. Furthermore, I4.0 will enable real-time process tracking to verify that quality requirements are fulfilled during the manufacturing process. That real-time control technique helps improve quality control actions and offers an early warning of product quality changes (Tortorella et al., 2018; Zonnenshain & Kenett, 2020).

I4.0 can affect the best practices for applying Total Quality Management (TQM) concepts. Asif (2020) suggested that to have a successful TQM principles implementation, a business organization should focus on developing the integration of working personnel with I4.0 and using real-time control techniques. Illés et al. (2017) emphasized how, thanks to I4.0 applications, data acquisition has now become crucial for quality throughout an organization. According to the authors, the difficulty is determining where, how, and what to gather and how to evaluate the resulting large amount of data. Durana et al. (2019) examined how traditional TQM principles must adapt to I4.0 developments and challenges. According to the authors, implementing I4.0 and quality management can greatly assist in establishing a robust quality culture instead of a purely technological aspect.

Along with highlighting the opportunities provided by I4.0, they highlighted the contexts where the purpose of the TQM principles cannot be completely served by I4.0 adaptation for various challenges and complications of I4.0. In summary, despite a paucity of studies on the influence of I4.0 on TQM implementation and having some challenges in I4.0 implementation, I4.0 plays a significant role in a successful TQM implementation (Sader et al., 2019; Tortorella et al., 2018). Now, based on the above discussions, the next hypothesis can be stated as follows:

H3: I4.0 has a positive impact on TQM implementation.

Integration Between TQM, Industry 4.0, and Sustainability Performance

Previous researchers have discovered a potential positive link between TQM and sustainability performance. For instance, Abbas (2020) argued that TQM is key to developing sustainable performance for all-sized business organizations. Besides, Tasleem et al. (2019) showed that TQM within the Securities and Exchange Commission registered industries can greatly affect sustainability performance in all aspects. Additionally, Alharbi et al. (2016) suggested that implementing TQM principles can improve the corporate actions related to sustainability in the hotel industry.

The literature on I4.0 and sustainability performance appears to be a generally favorable tone for the I4.0 and sustainability performance relationship. Also, this study supports the notion that TQM principles might provide significant potential to achieve greater sustainability with the presence of existing I4.0 technologies. Based on these considerations, the final hypothesis is stated as follows:

H4: TQM positively mediates the relationship between I4.0 and sustainability performance.

The above four hypotheses in respect of TQM, sustainability performance, and I4.0 are shown in Fig. 1.

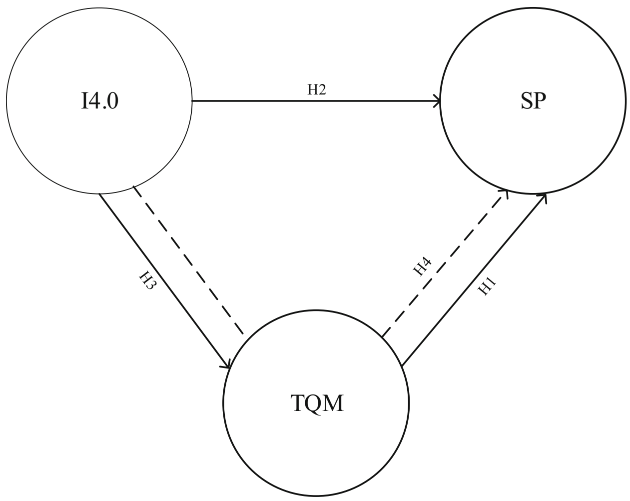

Fig. 1 The proposed research framework

Research Design

Survey Questionnaires Design

This empirical study was conducted with a questionnaire data collection tool. Four main sections were included in the questionnaire; general demographic and employment information, the application of I4.0 technologies in the garment industry, the TQM practices in use in the firm and the current status of the industry's sustainability performance. All of the questions required a Likert scale response, in that respondents were required to rate their level of agreement to statements, on a scale of one to five, where 1 = strongly disagreed and 5 = strongly agreed.

Measures

Measurements of different variables were adapted from various previous research studies. TQM measurement items were adapted from Abbas (2020), Androwis et al. (2018), Kaynak (2003), Machado et al. (2020) and Talapatra et al. (2020). I4.0 measurement items were adapted from Bibby and Dehe (2018), Imran et al. (2018) and Machado et al. (2020). Ten items were used as sustainability performance indicators regarding social, economic, and environmental performance. These are adapted from Abbas (2020), Chardine and Botta (2014) and Tasleem et al. (2019). A list of a total of 28 measured items was set for this study, as shown in Table 8 in the appendix.

Sampling Design

The Bangladeshi Ready-Made Garments (RMG) industry is the total population for this empirical study. Bangladesh has around 5000 export-oriented garments companies (BGMEA, 2020). The maximum sample size for this investigation was calculated using Yamane's (1967) formula. Yamane (1967) projected that any sample size should be greater than 355 to obtain a 95% confidence level. In more recent studies, however, a sampling size of 150 is considered sufficient for obtaining that confidence interval (Aamer et al., 2017; Baidoun et al., 2018; Dubey et al., 2014).

Survey Method and Data Gathering

The data was collected using random sampling techniques from various RMG organizations across Bangladesh. Due to the Covid pandemic, only e-communications were employed to acquire the required data. The data was obtained via e-mail and google forms. Dillman's (2011) method was used during the data collection process. Data was collected by sending out electronic questionnaires to 650 employees within 150 firms who work in different departments of RMG industries across Bangladesh, including production planning and control, human resource management, and the marketing department. After 2 months, 240 employees had completed the questionnaire, and legible responses were selected for further study with a 36.92% response rate; hence, the response rate is acceptable and akin to previous research (Baidoun et al., 2018; Dubey et al., 2014). Therefore, the gathered responses can readily be used to test the hypothesis of this research. The statistical characteristics of the respondents and each category's response rate are shown in Table 1.

Non-response Bias

Every respondent's reply was sorted by receipt date and separated into first and later response groups. Then a *t* -test was performed to investigate the significant variance between first and delayed replies to check whether there was a non-response bias (Armstrong & Overton, 1977; Dubey et al., 2014). On two sets of samples, a *t*-test was used to compare them. The test findings revealed no significant variations in the identification of TQM measures, I4.0 measures, and sustainability performance measures between early and late replies. So the final data set used for the model testing was comprised by merging the early and late responses together.

Data Analysis

Numerous statistical techniques are available to confirm the association between different latent variables, including SEM, factor analysis, and analytic network process (Talapatra et al., 2020). Regarding SEM, two types of

Table 1 Company profile of the respondents

Criteria	Genre	Reply (%)
Gender	Male	66.40
	Female	33.60
Age	25–35 years	32.03
	35–55 years	67.97
Administration	Top	21.88
	Middle	46.88
	Bottom	31.24
Company size	Small (< 60 personnel)	25.40
	Medium (60–400 personnel)	74.60

techniques are available: variance-based SEM and covariance-based SEM. The Partial Least Squares (PLS) method is used in variance-based SEM. This study selects the PLS-SEM technique for analyzing collected data because of the succeeding reasons (Dubey et al., 2015; Gupta et al., 2019; Talapatra et al., 2020):

(1) This method can simultaneously manage a large set of variables
(2) It's a successful technique to investigate and validate the link between the components in a complicated model.
(3) It can effectively manage non-normalized as well as incomplete data.
(4) This can produce superior outcomes regardless of sample size.

Haseeb et al. (2019) have effectively applied the PLS-SEM technique to investigate how I4.0 technologies contribute to information technology implementation. Dubey et al. (2015) have also used this application to investigate the contribution of I4.0 techniques like big data for enhancing organizational sustainability performance. Both scholars have preferred WarpPLS software for their research. This study also uses WarpPLS 7.0 software for analyzing data.

Measurement Model Assessment

Before analyzing, the collected dataset had been normalized. Missing values were not found, and no data with a variance of zero. Likewise, the data also excluded rank-related issues. Moreover, to evaluate the feasibility of the collected data for SEM analysis, this research checked multicollinearity in the data set (Abbas, 2020). This research applied the variance inflation factors (VIF) to analyze the multicollinearity element. The result, illustrated in Table 4, shows that all the VIF values fully meet the maximum requirement of 10 (Hair et al., 2017).

This study utilized three indices as per Hair et al. (2012) and Kock (2022) to determine if the present measurement model had fitted with collected data: average block VIF (AVIF), average path coefficient (APC), and average R-squared (ARS). These variables were also used to assess the model's ability to explain the most significant variance. Table 2 shows that every one of these parameters' values are substantially within the allowable range. From the result, it can be said that the measurement model shows an excellent fit for collected data. It also reflects the capacity of the model to retrieve variance better.

Causality assessment was used as another way to verify the model's correctness. Three parameters were used in this research to check the model's correctness, which is consistent with Chin (2010). These are Simpson's paradox ratio (SPR), *R*-squared contribution ratio (RSCR), and statistical suppression ratio (SSR). Table 3 illustrates the readings of these parameters, and it is shown that all values fall within the allowable range.

Moreover, for validating the reliability and consistency of the measurement scale, Cronbach's alpha (α) values were applied (Nunnally, 1978). Table 4 illustrates the Cronbach's alpha values for each latent variable, and as can be observed, all alpha (α) values considerably exceed the critical limit of 0.6, proposed by Molina et al. (2007). The result shows that the variables have high internal consistency for the specified dimension. This research applied factor loadings to test the construct validity, as Gupta et al. (2019) suggested. Table 9 shows the loadings and cross-loadings of each variable. All factors show the minimum required value of 0.4, as Nunnally (1978) suggested. This confirms the proposed model's content validity.

Then, to confirm the integrity of the assessment model, convergent and discriminant validity tests were performed (Abbas, 2020). This research conducted the convergent validity test to inspect whether the observed variables were heavily loaded in their latent parent constructs. According to Talapatra et al. (2020), to obtain convergent validity, the average variance extracted (AVE) and scale composite reliability (SCR) coefficient values for each variable should not be less than 0.5 and 0.7, respectively. All the AVE and SCR readings are shown in Table 4, and it shows that all the values are in an allowable range.

Again, the discriminant validity analysis was used in this study to verify if the latent constructs are distinctive and unrelated to one another. The discriminant validity test matrix is illustrated in Table 5. From this table, it is shown that no values in any column of the matrix beneath the diagonal element are higher than the diagonal value, and it demonstrates the discriminant validity of the model (Fornell & Larcker, 1981).

Table 2 Measures of the fitness of the model

Criteria	Measures	Allowable limit
APC value	0.169, $p < 0.001$	$p < 0.001$
ARS value	0.246, $p < 0.001$	$p < 0.001$
AVIF value	2.482	Allowable if $3.3 \leq$ measure ≤ 5.0

Table 3 Causality assessment

Indices	Estimate	Allowable range
SPR	1.000	Allowable if ≥ 0.7, best = 1
RSCR	1.000	Allowable if ≥ 0.9, best = 1
SSR	0.962	Allowable if ≥ 0.70

Table 4 Latent construct coefficients

	TQM	I4.0	SP
R^2 coefficients	0.251		0.367
Adjusted R^2 coefficients	0.217		0.339
SCR value	0.873	0.791	0.943
Cronbach's α	0.832	0.761	0.891
AVE	0.743	0.621	0.847
VIF	4.632	7.458	5.832

Structural Model Assessment

The variance-based SEM approach was applied to test the structural model and proposed hypotheses because of its ability to describe the maximum variance of latent variables (Gupta et al., 2019). Table 6 illustrates the outcomes of the SEM path analysis. The results indicate that all four hypotheses are accepted statistically. The bootstrapping approach, also known as resampling, was employed to examine the mediation role of TQM since it has been demonstrated to be more capable of reducing type-1 error at the time of evaluating direct and indirect correlations (Kamble et al., 2020). The bootstrapping method generates many observations, ensuring that the chosen examples are equal across all random samples. The bootstrapping approach is thought to be more efficient than other types of classical mediation analysis that need a lot of assumptions (Cheung & Lau, 2008). This study applied an SEM technique with bootstrapping (1500 resamples) and a 0.95 confidence interval to investigate the mediating role. The findings of direct and indirect impacts to analyze the mediating role are shown in Table 7.

Table 5 Discriminant validity test

	TQM	I4.0	SP
TQM	*0.862*		
I4.0	0.334	*0.788*	
SP	0.562	0.492	*0.920*

The diagonal numbers represent, $\sqrt{\text{AVE}}$, whereas the remaining values represent the interrelation among the two different constructs

Discussion and Concluding Summary

This research investigated the influence of TQM and I4.0 on sustainability performance along with the mediating effect of TQM in I4.0 and sustainability performance in the garment industry in Bangladesh. As reported in the results section, at a 0.01 significance level, it is shown that the very first hypothesis is statistically significant, having a β coefficient of 0.576 ($p < 0.01$). The result implies that TQM implementation substantially contributes to enhancing an organization's sustainability performance. TQM principles help an organization increase customer satisfaction, reduce errors and improve operational performance, which directly contributes to organizational sustainability. This finding confirms earlier research (Abbas, 2020; AlShehail et al., 2021; Tasleem et al., 2019).

In terms of the second hypothesis, it is found that the hypothesis is statistically significant, having a β coefficient of 0.329 ($p < 0.01$), suggesting that I4.0 technologies implementation can positively impact organizational sustainability performance. This result also implies that the practice of I4.0 encourages any organization to advance the operational processes, reduce energy consumption, and reduce waste and pollution. Besides, the application of I4.0 technologies promotes reducing safety incidents and increasing employee morale, which all are directly related to the organization's sustainable performance. This result also is confirmed by earlier studies (Haseeb et al., 2019; Kamble et al., 2020; Machado et al., 2020; Oláh et al., 2020).

The result shows that the third hypothesis is also proved as statistically significant, having a β coefficient of 0.393 ($p < 0.01$). This hypothesis recommends that I4.0 techniques adaptation positively impacts TQM implementation. Under an interconnected I4.0-TQM regimen, customer requirements and marketplace analysis would be directly transmitted to the manufacturing systems, and the quality of the product would be monitored and ensured utilizing advanced sensors and failure investigations analysis. Besides, I4.0 might act as a base for the constant growth of a firm at both the technological and operational stages, which all are directly related to a successful TQM implementation. This study's outcome is also compatible with earlier studies (Durana et al., 2019; Sader et al., 2019; Souza et al., 2022; Tortorella et al., 2018).

Table 6 Results of hypotheses evaluation

Hypothesis for evaluation	Estimate	p value	Outcomes of assessment
H1: TQM positively impacts sustainability performance	$\beta = 0.576$	0.001	Accepted
H2: I4.0 positively impacts sustainability performance	$\beta = 0.329$	0.002	Accepted
H3: I4.0 has a positive impact on TQM implementation	$\beta = 0.393$	0.003	Accepted
H4: TQM positively mediates the Relationship between I4.0 and SP	$\beta = 0.387$	0.002	Accepted

Regarding the fourth hypothesis, the role of TQM as a mediator between I4.0 and sustainability performance is analyzed according to the findings of the PLS algorithm. The analysis revealed positive and significant results that conclude that I4.0 directly and indirectly (through TQM) impacts sustainability performance. The direct effect and indirect effect are shown in Table 7. Thus, this study found the fourth hypothesis supported at the significance level of 0.01.

Theoretical Implications

This work, like others, contains numerous theoretical insights which might be considered. This work contributes to organizations by exploring the influence of I4.0 technologies on TQM implementation that has not yet received adequate observation from scholars. This impact has been validated, and this study may call for future research in the respective field. Furthermore, this work explores the gap in the analysis of the mediator role of TQM in previous literature, which also makes a theoretical contribution to this research field. To put it another way, this work aimed to explore the combined effects of TQM and I4.0 on organizational sustainability performance. The results indicate that I4.0 technology adoption might significantly enhance sustainability in the RMG sector in the presence of TQM principles. As a result, in addition to directly contributing to sustainability performance, TQM practices also serve as a beneficial mediator between I4.0 and sustainability. This result demonstrates the inherent resilience of I4.0 since its advantages can only be realized if its technologies are actively adapted to the context of the industry and seek to complement the existing management strategies and routines, like TQM. Thus, as another significant theoretical addition, this research also adds to the current knowledge of how I4.0 impacts sustainability performance and explains how I4.0 may stimulate TQM implementation.

Table 7 The mediation role of TQM in the link between I4.0 and SP

	Direct effect	Indirect effect	Full effect
Estimate	0.329	0.387	0.716
p value	0.002	0.002	0.002

Practical Implications

The outcomes indicate that the adoption of TQM practices and I4.0 applications can greatly impact organizational sustainability in Bangladesh's RMG industry. Practically, a better knowledge of the combined impacts of TQM and I4.0 technologies on sustainability performance can assist practitioners, administrators, and policymakers, particularly in developing countries, like Bangladesh, in establishing appropriate expectations during the implementation process. Simply said, TQM practices and I4.0 technologies can assist the business organization in obtaining a competitive advantage that distinguishes them from their competitors and improves their market presence. Besides, RMG firms would be benefited from increased investment in social and environmental practices in respect of every TPL dimension. This might be accomplished by putting their sustainability practices into action. For instance, connecting social and environmental practices with the regional neighborhood might help to boost performance. Furthermore, the recognition of the synergistic linkage with mediating effects assists executives in anticipating organizational sustainability improvement difficulties, avoiding wasted decisions and ineffective expenditures. More importantly, the findings suggest that executives who promote TQM approaches throughout the improvement process may obtain a greater degree of organizational sustainability while using I4.0 technology than those who ignore the relevance of TQM. This research also reveals that the positive impacts of TQM and I4.0 are not restricted to developed countries-based organizations; if organizations in developing countries effectively use their methods, similar outcomes may be obtained.

Limitations and Future Scope

This study contains certain shortcomings. Firstly, the sample for this research was confined to 240 participants from the RMG sector in Bangladesh. Even though the sample size was enough for assessment, a higher sample size might be beneficial to confirm the generalizability of this study. Secondly, all the respondents in the data sample were from Bangladeshi RMG sectors, which limits the generalizability of this research to other countries. Adding respondents from different sectors or countries to the data collection would enrich the sample both quantitatively and qualitatively. Thirdly, the responses were gathered from various departments, which may have vastly different perspectives on the questionnaires. Furthermore, the responses were collected from only small and medium-sized organizations, which can be extended for future research. Finally, the degree of dimensions of the constructed variables used here could be added to the current measurement model for future study. In addition, researchers may methodologically examine; (a) RMG industries of Bangladesh need to determine in which area their employees need the training to adopt I4.0 and TQM successfully and (b) RMG industries of Bangladesh need to assess their capabilities (financial and technical) for digitization.

Appendix

See Tables 8 and 9.

Table 8 Items of the measurement construct

Latent constructs	Indication	Description of the observed variable
Total quality management (TQM)	TQM1	Senior managers actively drive change and develop a culture of trust, engagement, and dedication in order to achieve 'Best Practice
	TQM2	Senior managers held similar perspectives about the company's future in your organization
	TQM3	Your company consistently maintains a good relationship with its customers and makes it easy for them to contact
	TQM4	Your organization strives to understand the needs of your external clients in regards to size and product specifications
	TQM5	In your company, all employee clearly understands the perception of internal customers
	TQM6	Your firm measures the satisfaction of all of the employees regularly and properly
	TQM7	All of the employees understand the process instructions since they are clear, consistent, and detailed
	TQM8	Your firm focuses on building long-term partnerships with key suppliers
	TQM9	Your organization always revises a new product design thoroughly before production starts
	TQM10	Manpower from the different working areas (i.e., purchasing, marketing) are involved in a new product design team
Industry 4.0 (I4.0)	Ind1	Your firm can access information smartly from machines, equipment, facilities, and system
	Ind2	All information of your organization are stored within a cloud network
	Ind3	Your firm tries to enhance the processing competency and local storage through CPS
	Ind4	In your organization, advanced connectivity technology is used between machines, products, and human resources
	Ind5	In your firm, Additive Manufacturing makes it possible to do small batch production of customized products, lowering transport costs
	Ind6	Your organization has a high level of automation within the production area
	Ind7	The smart factory makes it possible to avoid working downtime and other challenges related to productivity
	Ind8	Augmented reality has been implemented to progress maintenance measures and encourages cybernetic training
Sustainability performance (SP)	SP1	The performance of your product is comparable to or better than that of competitors and other organization's equivalent product offerings
	SP2	Your organization regularly makes a financial contribution to the development of regional infrastructures
	SP3	Your firm has enhanced its market share during the past few years
	SP4	There is a reduction in energy consumption in carrying out the organizational processes
	SP5	There is a reduction in non-renewable resources usage throughout your firm
	SP6	There is improvement in the use and efficiency of materials, water, and other resources
	SP7	Your firm has a less noisy environment both inside and outside of the workplace
	SP8	Your firm has enhanced its relationship building with customers and will, most likely, continue to do so
	SP9	There is a reduction in the health and safety risks linked with the workforce and community
	SP10	Your firm has enhanced supplier relationship building during the past few years

Table 9 Loadings and cross-loadings of the factors

Item	TQM	Ind	SP
TQM1	**0.674**	− 0.038	− 0.021
TQM2	**0.749**	0.028	− 0.019
TQM3	**0.538**	− 0.076	− 0.054
TQM4	**0.911**	− 0.050	0.162
TQM5	**0.728**	0.036	0.112
TQM6	**0.573**	− 0.048	− 0.039
TQM7	**0.774**	0.288	− 0.002
TQM8	**0.881**	− 0.198	− 0.089
TQM9	**0.838**	− 0.001	0.311
TQM10	**0.719**	− 0.069	− 0.322
Ind1	− 0.189	**0.649**	− 0.276
Ind2	0.087	**0.721**	− 0.005
Ind3	− 0.299	**0.587**	− 0.178
Ind4	− 0.067	**0.811**	0.002
Ind5	− 0.204	**0.578**	− 0.045
Ind6	0.059	**0.634**	0.037
Ind7	0.132	**0.772**	− 0.031
Ind8	0.179	**0.715**	− 0.026
SP1	0.278	− 0.096	**0.892**
SP2	− 0.087	0.075	**0.588**
SP3	− 0.055	− 0.139	**0.679**
SP4	0.287	− 0.017	**0.748**
SP5	− 0.347	− 0.051	**0.723**
SP6	− 0.189	0.002	**0.788**
SP7	− 0.099	− 0.288	**0.847**
SP8	− 0.134	− 0.175	**0.891**
SP9	0.022	− 0.098	**0.690**
SP10	− 0.345	− 0.021	**0.760**

The bold numbers represent item loadings that are greater than the suggested value of 0.4; the loadings on an item's own variable are greater than the cross-loadings with other variables

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Declarations

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References

Aamer, A. M., Al-Awlaqi, M. A., & Alkibsi, S. M. (2017). TQM implementation in a least developed country: An exploratory study of Yemen. *The TQM Journal, 29*(3), 467–487. https://doi.org/10.1108/TQM-11-2015-0141

Abbas, J. (2020). Impact of total quality management on corporate sustainability through the mediating effect of knowledge management. *Journal of Cleaner Production, 244*, 118806. https://doi.org/10.1016/j.jclepro.2019.118806

Akter, M. M. K., Haq, U. N., Islam, M., & Uddin, M. A. (2022). Textile-apparel manufacturing and material waste management in the circular economy: A conceptual model to achieve sustainable development goal (SDG) 12 for Bangladesh. *Cleaner Environmental Systems, 04*, 100070. https://doi.org/10.1016/j.cesys.2022.100070

Al-Dhaafri, H. S., Al-Swidi, A. K., & Yusoff, R. Z. B. (2016). The mediating role of total quality management between the entrepreneurial orientation and the organizational performance. *The TQM Journal, 28*(1), 89–111. https://doi.org/10.1108/TQM-03-2014-0033

Alharbi, K., Al-Matari, E. M., & Yusoff, Z. R. (2016). The impact of total quality management (TQM) on organizational sustainability: The case of the hotel industry in Saudi Arabia: Empirical Study. *The Social Sciences, 11*(4), 3468–3473. https://doi.org/10.3923/sscience.2016.3468.3473

AlShehail, A. O., Khan, M., & Ajmal, M. (2021). Total quality management and sustainability in the public service sector: The mediating effect of service innovation. *Benchmarking: An International Journal, 29*(2), 382–410. https://doi.org/10.1108/BIJ-08-2020-0449

Ammar, M., Haleem, A., Javaid, M., Walia, R., & Bahl, S. (2021). Improving material quality management and manufacturing organizations system through Industry 4.0 technologies. *Materials Today: Proceedings, 45*(6), 5089–5096. https://doi.org/10.1016/j.matpr.2021.01.585

Androwis, N., Sweis, R. J., Tarhini, A., Moarefi, A., & Amiri, M. H. (2018). Total quality management practices and organizational performance in the construction chemicals companies in Jordan. *Benchmarking: An International Journal, 25*(8), 3180–3205. https://doi.org/10.1108/BIJ-05-2017-0094

Apornak, A., & Hezaveh, M. A. (2019). Extension of the model of manufacturing supply chain quality management: An empirical study. *International Journal of Productivity and Quality Management, 28*(4), 417–437. https://doi.org/10.1504/IJPQM.2019.103686

Armstrong, J. S., & Overton, T. S. (1977). Estimating non-response bias in mail surveys. *Journal of Marketing Research, 14*(3), 396–402. https://doi.org/10.1177/002224377701400320

Asif, M. (2020). Are QM models aligned with Industry 4.0? A perspective on current practices. *Journal of Cleaner Production, 258*, 120820. https://doi.org/10.1016/j.jclepro.2020.120820

Bag, S., & Pretorius, J. H. (2020). Relationships between industry 4.0, sustainable manufacturing and circular economy: Proposal of a research framework. *International Journal of Organizational Analysis, 30*(4), 864–898. https://doi.org/10.1108/IJOA-04-2020-2120

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective.

International Journal of Production Economics, 229, 107776. https://doi.org/10.1016/j.ijpe.2020.107776
Baidoun, S. D., Salem, M. Z., & Omran, O. A. (2018). Assessment of TQM implementation level in Palestinian healthcare organizations. *The TQM Journal, 30*(2), 98–115. https://doi.org/10.1108/TQM-03-2017-0034
Banihashemi, T. A., Fei, J., & Chen, P. S. (2019). Exploring the relationship between reverse logistics and sustainability performance: A literature review. *Modern Supply Chain Research and Applications, 1*(1), 2–27. https://doi.org/10.1108/MSCRA-03-2019-0009
Barua, B. (2021). Impact of total quality management factors on knowledge creation in the organizations of Bangladesh. *The TQM Journal, 33*(6), 1516–1543. https://doi.org/10.1108/TQM-06-2020-0145
Beier, G., Ullrich, A., Niehoff, S., Reißig, M., & Habich, M. (2020). Industry 4.0: How it is defined from a sociotechnical perspective and how much sustainability it includes–A literature review. *Journal of Cleaner Production, 259*, 120856. https://doi.org/10.1016/j.jclepro.2020.120856
Belhadi, A., Kamble, S., Gunasekaran, A., & Mani, V. (2021). Analyzing the mediating role of organizational ambidexterity and digital business transformation on industry 4.0 capabilities and sustainable supply chain performance. *Supply Chain Management: An International Journal*. https://doi.org/10.1108/SCM-04-2021-0152
Berman, M. E. (2015). *Performance and productivity in public and nonprofit organizations*. Routledge Books.
BGMEA. (2020). *About Garment Industry of Bangladesh.* Retrieved January 25, 2022, from https://www.bgmea.com.bd/page/AboutGarmentsIndustry.
Bibby, L., & Dehe, B. (2018). Defining and assessing industry 4.0 maturity levels—Case of the defence sector. *Production Planning & Control, 29*(12), 1030–1043. https://doi.org/10.1080/09537287.2018.1503355
Braccini, A. M., & Margherita, E. G. (2019). Exploring organizational sustainability of industry 4.0 under the triple bottom line: The case of a manufacturing company. *Sustainability, 11*(1), 36. https://doi.org/10.3390/su11010036
Brixner, C., Isaak, P., Mochi, S., Ozono, M., Suárez, D., & Yoguel, G. (2020). Back to the future. Is industry 4.0 a new tecno-organizational paradigm? Implications for Latin American countries. *Economics of Innovation and New Technology, 29*(7), 705–719. https://doi.org/10.1080/10438599.2020.1719642
Broday, E. E. (2022). The evolution of quality: From inspection to quality 4.0. *International Journal of Quality and Service Sciences, 14*(3), 368–382. https://doi.org/10.1108/IJQSS-09-2021-0121
Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: Moving toward new theory. *International Journal of Physical Distribution & Logistics Management, 38*(5), 360–387. https://doi.org/10.1108/09600030810882816
Carvalho, N., Chaim, O., Cazarini, E., & Gerolamo, M. (2018). Manufacturing in the fourth industrial revolution: A positive prospect in Sustainable Manufacturing. *Procedia Manufacturing, 21*, 671–678. https://doi.org/10.1016/j.promfg.2018.02.170
Chardine, B. E., & Botta, G. V. (2014). A framework for sustainable performance assessment of supply chain management practices. *Computers & Industrial Engineering, 76*, 138–147. https://doi.org/10.1016/j.cie.2014.07.029
Chaturvedi, A. (2020). *Implementation of TQM in commercial banks: employees perception.* Retrieved January 12, 2022, from https://ssrn.com/abstract=3619738.
Cheung, G. W., & Lau, R. S. (2008). Testing mediation and suppression effects of latent variables: Bootstrapping with structural equation models. *Organizational Research Methods, 11*(2), 296–325. https://doi.org/10.1177/1094428107300343
Chiarini, A. (2020). Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research. *The TQM Journal, 32*(4), 603–616. https://doi.org/10.1108/TQM-04-2020-0082
Chin, W. W. (2010). How to write up and report PLS analyses. In E. V. Vinzi, W. Chin, J. Henseler, & H. Wang (Eds.), *Handbook of partial least squares: Springer handbooks of computational statistics* (2nd ed., pp. 655–690). Springer.
Cho, Y. S., & Linderman, K. (2019). Metacognition-based process improvement practices. *International Journal of Production Economics, 211*, 132–144. https://doi.org/10.1016/j.ijpe.2019.01.030
Collis, D. J. (1994). Research note: How valuable are organizational capabilities? *Strategic Management Journal, 15*(1), 143–152. https://doi.org/10.1002/smj.4250150910
Contador, J. C., Satyro, W. C., Contador, J. L., & Spinola, M. D. M. (2020). Flexibility in the Brazilian industry 4.0: Challenges and opportunities. *Global Journal of Flexible Systems Management, 21*(1), 15–31. https://doi.org/10.1007/s40171-020-00240-y
Dahlgaard-Park, S. M., Reyes, L., & Chen, C. K. (2018). The evolution and convergence of total quality management and management theories. *Total Quality Management & Business Excellence, 29*(9–10), 1108–1128. https://doi.org/10.1080/14783363.2018.1486556
Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics, 204*, 383–394. https://doi.org/10.1016/jijpe.2018.08.019
Daugherty, P. J., Richey, R. G., Genchev, S. E., & Chen, H. (2005). Reverse logistics: Superior performance through focused resource commitments to information technology. *Transportation Research Part e: Logistics and Transportation Review, 41*(2), 77–92. https://doi.org/10.1016/j.tre.2004.04.002
De, D., Chowdhury, S., Dey, P. K., & Ghosh, S. K. (2020). Impact of lean and sustainability oriented innovation on sustainability performance of small and medium sized enterprises: A data envelopment analysis-based framework. *International Journal of Production Economics, 219*(1), 416–430. https://doi.org/10.1016/j.ijpe.2018.07.003
Diabat, A., Khodaverdi, R., & Olfat, L. (2013). An exploration of green supply chain practices and performances in an automotive industry. *The International Journal of Advanced Manufacturing Technology, 68*(1), 949–961. https://doi.org/10.1007/s00170-013-4955-4
Dillman, D. A. (2011). *Mail and Internet surveys: The tailored design method–2007 Update with new Internet, visual, and mixed-mode guide*. Wiley.
Dubey, R., & Bag, S. (2013). Exploring the dimensions of sustainable practices: An empirical study on Indian manufacturing firms. *International Journal of Operations and Quantitative Management, 19*(2), 123–146.
Dubey, R., Bag, S., & Ali, S. S. (2014). Green supply chain practices and its impact on organizational performance: An insight from Indian rubber industry. *International Journal of Logistics Systems and Management, 19*(1), 20–42.
Dubey, R., & Gunasekaran, A. (2015). Exploring soft TQM dimensions and their impact on firm performance: Some exploratory empirical results. *International Journal of Production Research, 53*(2), 371–382. https://doi.org/10.1080/00207543.2014.933909
Dubey, R., Gunasekaran, A., & Ali, S. S. (2015). Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: A framework

for green supply chain. *International Journal of Production Economics, 160*, 120–132. https://doi.org/10.1016/j.ijpe.2014.10.001

Durana, P., Kral, P., Stehel, V., Lazaroiu, G., & Sroka, W. (2019). Quality culture of manufacturing enterprises: A possible way to adaptation to Industry 4.0. *Social Sciences, 8*(4), 124. https://doi.org/10.3390/socsci8040124

Dwivedi, A., Agrawal, D., Jha, A., Gastaldi, M., Paul, S. K., & D'Adamo, I. (2021). Addressing the challenges to sustainable initiatives in value chain flexibility: Implications for Sustainable Development Goals. *Global Journal of Flexible Systems Management, 22*(2), 179–197. https://doi.org/10.1007/s40171-021-00288-4

Edgeman, R. (2013). Sustainable enterprise excellence: Towards a framework for holistic data- analytics. *Corporate Governance, 13*(5), 527–540. https://doi.org/10.1108/CG-06-2013-0073

Elibal, K., & Özceylan, E. (2022). Comparing industry 4.0 maturity models in the perspective of TQM principles using Fuzzy MCDM methods. *Technological Forecasting and Social Change, 175*, 121379. https://doi.org/10.1016/j.techfore.2021.121379

Evans, S., Vladimirova, D., Holgado, M., Van Fossen, K., Yang, M., Silva, E. A., & Barlow, C. Y. (2017). Business model innovation for sustainability: Towards a unified perspective for creation of sustainable business models. *Business Strategy and the Environment, 26*(5), 597–608. https://doi.org/10.1002/bse.1939

Figge, F., Hahn, T., Schaltegger, S., & Wagner, M. (2002). The sustainability balanced scorecard–linking sustainability management to business strategy. *Business Strategy and the Environment, 11*(5), 269–284. https://doi.org/10.1002/bse.339

Financial Express. (2021). *Economy*. Retrieved January 22, 2022, from https://thefinancialexpress.com.bd/page/economy/bangladesh.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50. https://doi.org/10.1177/002224378101800104

Garcia-Torres, S., Albareda, L., Rey-Garcia, M., & Seuring, S. (2019). Traceability for sustainability–literature review and conceptual framework. *Supply Chain Management: An International Journal, 24*(1), 85–106. https://doi.org/10.1108/SCM-04-2018-0152

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production, 252*, 119869. https://doi.org/10.1016/j.jclepro.2019.119869

Gold, S., Seuring, S., & Beske, P. (2010). The constructs of sustainable supply chain management—A content analysis based on published case studies. *Progress in Industrial Ecology, an International Journal, 7*(2), 114–137.

Gomes, C. F., Small, M. H., & Yasin, M. M. (2019). Towards excellence in managing the public-sector project cycle: A TQM context. *International Journal of Public Sector Management, 32*(2), 207–228. https://doi.org/10.1108/IJPSM-11-2017-0315

Gómez, J. G., Martinez, C. M., & Martinez, L. A. R. (2017). EFQM Excellence Model and TQM: An empirical comparison. *Total Quality Management & Business Excellence, 28*(1–2), 88–103. https://doi.org/10.1080/14783363.2015.1050167

Greenfield, D. (2016). *Siemens positions itself as an Industry 4.0 example*. Retrieved March 03, 2022, from https://www.automationworld.com/products/control/blog/13315384/siemens-positions-itself-as-an-industry-40-example.

Gunasekaran, A., & Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics, 140*(1), 35–47. https://doi.org/10.1016/j.ijpe.2011.05.011

Gunasekaran, A., Subramanian, N., & Ngai, W. T. E. (2019). Quality management in the 21st century enterprises: Research pathway towards Industry 4.0. *International Journal of Production Economics, 207*, 125–129. https://doi.org/10.1016/j.ijpe.2018.09.005

Gupta, S., Drave, V. A., Bag, S., & Luo, Z. (2019). Leveraging smart supply chain and information system agility for supply chain flexibility. *Information Systems Frontiers, 21*(3), 547–564. https://doi.org/10.1007/s10796-019-09901-5

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage Publications Inc.

Hair, J. F., Sarstedt, M., Ringle, C. M., & Mena, J. A. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *Journal of the Academy Marketing Science, 40*, 414–433. https://doi.org/10.1007/s11747-011-0261-6

Haseeb, M., Hussain, H. I., Ślusarczyk, B., & Jermsittiparsert, K. (2019). Industry 4.0: A solution towards technology challenges of sustainable business performance. *Social Sciences, 8*(5), 154. https://doi.org/10.3390/socsci8050154

Haubensak, J. (2020). *Three key business challenges to increasing sustainabiliy*. Retrieved January 17, 2022, from https://ramboll.com/ingenuity/3-key-challenges-for-business-to-turn-more-sustainable.

Hermelingmeier, V., & Wirth, V. T. (2021). The nexus of business sustainability and organizational learning: A systematic literature review to identify key learning principles for business transformation. *Business Strategy and the Environment, 30*(4), 1839–1851. https://doi.org/10.1002/bse.2719

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry, 89*, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Honarpour, A., Jusoh, A., & Long, C. S. (2017). Knowledge management and total quality management: A reciprocal relationship. *International Journal of Quality & Reliability Management, 34*(1), 91–102. https://doi.org/10.1108/IJQRM-03-2014-0040

Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change, 146*, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

Hubbard, G. (2009). Measuring organizational performance: Beyond the triple bottom line. *Business Strategy and the Environment, 18*(3), 177–191. https://doi.org/10.1002/bse.564

Hussain, M., Khan, M., Ajmal, M., & Khan, B. A. (2020). Supply chain quality management and organizational performance. *Benchmarking: An International Journal, 27*(1), 232–249. https://doi.org/10.1108/BIJ-07-2018-0196

Illés, B., Tamás, P., Dobos, P., & Skapinyecz, R. (2017). New challenges for quality assurance of manufacturing processes in industry 4.0. *Solid State Phenomena, 261*, 481–486. https://doi.org/10.4029/www.scientific.net/SSP.261.481

Imran, M., Hameed, W., & Haque, A. (2018). Influence of Industry 4.0 on the production and service sectors in Pakistan: Evidence from textile and logistics industries. *Social Sciences, 7*(12), 246. https://doi.org/10.3390/socsci7120246

Industrial Development Report. (2018). *Driving inclusive and sustainable industrial development*. Retrieved February 22, 2022, from https://www.unido.org/resources-publications-flagship-publications-industrialdevelopment-report-series/industrial-development-report-2018.

Iqbal, A., & Asrar-ul-Haq, M. (2018). Establishing relationship between TQM practices and employee performance: The mediating role of change readiness. *International Journal of*

Production Economics, 203, 62–68. https://doi.org/10.1016/j.ijpe.2018.05.034

Jabbour, A. B. L., Jabbour, C. J., Foropon, C., & Godinho, F. M. (2018). When titans meet—Can industry 4.0 revolutionize the environmentally-sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change, 132*, 18–25. https://doi.org/10.1016/j.techfore.2018.01.017

Jørgensen, T. H. (2008). Towards more sustainable management systems: Through life cycle management and integration. *Journal of Cleaner Production, 16*(10), 1071–1080. https://doi.org/10.1016/j.jclepro.2007.06.006

Kamble, S., Gunasekaran, A., & Dhone, N. C. (2020). Industry 4.0 and lean manufacturing practices for sustainable organizational performance in Indian manufacturing companies. *International Journal of Production Research, 58*(5), 1319–1337. https://doi.org/10.1080/00207543.2019.1630772

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection, 117*, 408–425. https://doi.org/10.1016/j.psep.2018.05.009

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management, 21*(4), 405–435. https://doi.org/10.1016/S0272-6963(03)00004-4

Khalfallah, M., Salem, A. B., Zorgati, H., & Lakhal, L. (2021). Innovation mediating relationship between TQM and performance: Cases of industrial certified companies. *The TQM Journal, 34*(3), 552–575. https://doi.org/10.1108/TQM-01-2021-0019

Khan, R. A., Mirza, A., & Khushnood, M. (2020). The role of total quality management practices on operational performance of the service industry. *International Journal for Quality Research, 14*(2), 439–454. https://doi.org/10.24874/IJQR14.02-07

Kiel, D., Müller, J. M., Arnold, C., & Voigt, K. I. (2020). Sustainable industrial value creation: Benefits and challenges of industry 4.0. *International Journal of Innovation Management, 21*(8), 1–34. https://doi.org/10.1142/9781786347602_0009

Kock, N. (2022). *WarpPLS user manual: Version 8.0*. ScriptWarp Systems Books.

Kuei, C. H., & Lu, M. H. (2013). Integrating quality management principles into sustainability management. *Total Quality Management & Business Excellence, 24*(1–2), 62–78. https://doi.org/10.1080/14783363.2012.669536

Kumar, V., Vrat, P., & Shankar, R. (2022). Factors influencing the implementation of industry 4.0 for sustainability in manufacturing. *Global Journal of Flexible Systems Management*. https://doi.org/10.1007/s40171-022-00312-1.

Lee, C. K., & Lam, J. S. (2012). Managing reverse logistics to enhance sustainability of industrial marketing. *Industrial Marketing Management, 41*(4), 589–598. https://doi.org/10.1016/j.indmarman.2012.04.006

Li, D., Zhao, Y., Zhang, L., Chen, X., & Cao, C. (2018). Impact of quality management on green innovation. *Journal of Cleaner Production, 170*, 462–470. https://doi.org/10.1016/j.jclepro.2017.09.158

Liu, Q., Trevisan, A. H., Yang, M., & Mascarenhas, J. (2022). A framework of digital technologies for the circular economy: Digital functions and mechanisms. *Business Strategy and the Environment, 31*(5), 2171–2192. https://doi.org/10.1002/bse.3015

Lucianetti, L., Chiappetta, J. C. J., Gunasekaran, A., & Latan, H. (2018). Contingency factors and complementary effects of adopting advanced manufacturing tools and managerial practices: Effects on organizational measurement systems and firms' performance. *International Journal of Production Economics, 200*, 318–328. https://doi.org/10.1016/j.ijpe.2018.04.005

Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection, 117*, 168–179. https://doi.org/10.1016/j.psep.2018.04.018

Machado, C. G., Winroth, M. P., & da Silva, R. E. H. (2020). Sustainable manufacturing in Industry 4.0: An emerging research agenda. *International Journal of Production Research, 58*(5), 1462–1484. https://doi.org/10.1080/00207543.2019.1652777

Maganga, D. P., & Taifa, I. W. R. (2022). Quality 4.0 conceptualization: An emerging quality management concept for manufacturing industries. Quality management report. *The TQM Journal*. https://doi.org/10.1108/TQM-11-2021-0328

Mickeleit, M. (2022). *Navigating through the buzzword jungle*. Retrieved May 29, 2022, from https://www.hannovermesse.de/en/news/news-articles/navigating-through-the-buzzword-jungle.

Molina, L. M., Lloréns-Montes, J., & Ruiz-Moreno, A. (2007). Relationship between quality management practices and knowledge transfer. *Journal of Operations Management, 25*(3), 682–701. https://doi.org/10.1016/j.jom.2006.04.007

Müller, J. M., Kiel, D., & Voigt, K. I. (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability, 10*(1), 247. https://doi.org/10.3390/su10010247

Nara, E. O., da Costa, M. B., Baierle, I. C., Schaefer, J. L., Benitez, G. B., do Santos, L. M., & Benitez, L. B. (2021). Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry. *Sustainable Production and Consumption, 25*, 102–122. https://doi.org/10.1016/j.spc.2020.07.018

Nguyen, M. H., Phan, A. C., & Matsui, Y. (2018). Contribution of quality management practices to sustainability performance of vietnamese firms. *Sustainability, 10*(2), 375. https://doi.org/10.3390/su10020375

Nunnally, J. C. (1978). *Psychometric theory*. McGraw-Hill Books.

Oláh, J., Aburumman, N., Popp, J., Khan, M. A., Haddad, H., & Kitukutha, N. (2020). Impact of Industry 4.0 on environmental sustainability. *Sustainability, 12*(11), 4674. https://doi.org/10.3390/su12114674

Oliveira, G., Corrêa, J., Balestrassi, P., Martins, R., & Turrioni, J. (2019). Investigation of TQM implementation: Empirical study in Brazilian ISO 9001-registered SMEs. *Total Quality Management & Business Excellence, 30*(5–6), 641–659. https://doi.org/10.1080/14783363.2017.1328273

Raj, M. D., Homi, K., & Selen, O. (2020). *Over 1 billion people live in poverty hotspots*. Retrieved January 07, 2022, from https://www.brookings.edu/blog/future-development/2020/12/02/over-1-billion-people-live-in-poverty-hotspots.

Sader, S., Husti, I., & Daróczi, M. (2019). Industry 4.0 as a key enabler toward the successful implementation of total quality management practices. *Periodica Polytechnica Social and Management Sciences, 27*(2), 131–140. https://doi.org/10.3311/PPso.12675

Saha, P., & Alam, A. (2022). Smart management scheme for the efficient control of industrial inventory. *American Journal of Industrial and Business Management, 12*, 519–530. https://doi.org/10.4236/ajibm.2022.124028

Sarker, M., Moktadir, M., & Santibanez-Gonzalez, E. D. (2021). Social sustainability challenges towards flexible supply chain management: Post-COVID-19 perspective. *Global Journal of Flexible Systems Management, 22*(2), 199–218. https://doi.org/10.1007/s40171-021-00289-3

Sarkis, J., Helms, M. M., & Hervani, A. A. (2010). Reverse logistics and social sustainability. *Corporate Social Responsibility and*

Environmental Management, 17(6), 337–354. https://doi.org/10.1002/csr.220
Sarkis, J., & Zhu, Q. (2018). Environmental sustainability and production: Taking the road less travelled. *International Journal of Production Research, 56*(1–2), 743–759. https://doi.org/10.1080/00207543.2017.1365182
Sartal, A., Bellas, R., Mejías, A. M., & García-Collado, A. (2020). The sustainable manufacturing concept, evolution and opportunities within Industry 4.0: A literature review. *Advances in Mechanical Engineering*. https://doi.org/10.1177/1687814020925232
Sassanelli, C., & Terzi, S. (2022). The D-BEST reference model: A flexible and sustainable support for the digital transformation of small and medium enterprises. *Global Journal of Flexible Systems Management, 23*(3), 345–370.
Sharma, S., & Modgil, S. (2020). TQM, SCM and operational performance: An empirical study of Indian pharmaceutical industry. *Business Process Management Journal, 26*(1), 331–370. https://doi.org/10.1108/BPMJ-01-2018-0005
Siddiqui, F., Haleem, A., & Wadhwa, S. (2009). Role of supply chain management in context of total quality management in flexible systems: A state-of the-art literature review. *Global Journal of Flexible Systems Management, 10*(3), 1–14. https://doi.org/10.1007/BF03396562
Slaper, T. F., & Hall, T. J. (2011). The triple bottom line: What is it and how does it work? *Indiana Business Review, 86*(1), 4–8.
Soltani, E., van der Meer, R., Williams, T. M., & Lai, P. C. (2006). The compatibility of performance appraisal systems with TQM principles—Evidence from current practice. *International Journal of Operations & Production Management, 26*(1), 92–112. https://doi.org/10.1108/01443570610637030
Souza, F. F., Corsi, A., Pagani, R. N., Balbinotti, G., & Kovaleski, J. L. (2022). Total quality management 4.0: Adapting quality management to Industry 4.0. *The TQM Journal, 34*(4), 749–769. https://doi.org/10.1108/TQM-10-2020-0238
Stock, T., & Seliger, G. (2016). Opportunities of sustainable manufacturing in industry 4.0. *Procedia CIRP, 40*, 536–541. https://doi.org/10.1016/j.procir.2016.01.129
Sushil. (2011). Flexibility, vitality and sustainability. *Global Journal of Flexible System Management, 12*(1&2), iii. https://doi.org/10.1007/BF03396594
Talapatra, S., Uddin, M. K., Antony, J., Gupta, S., & Cudney, E. A. (2020). An empirical study to investigate the effects of critical factors on TQM implementation in the garment industry in Bangladesh. *International Journal of Quality & Reliability Management, 37*(9/10), 1209–1232. https://doi.org/10.1108/IJQRM-06-218-0145
Tambare, P., Meshram, C., Lee, C. C., Ramteke, R. J., & Imoize, A. L. (2022). Performance measurement system and quality management in data-driven Industry 4.0: A review. *Sensors, 22*(1), 224. https://doi.org/10.3390/s22010224
Tasleem, M., Khan, N., & Nisar, A. (2019). Impact of technology management on corporate sustainability performance. *International Journal of Quality & Reliability Management, 36*(9), 1574–1599. https://doi.org/10.1108/IJQRM-0102018-0017
Tortorella, G. L., Silva, E., & Vargas, D. (2018). An empirical analysis of total quality management and total productive maintenance in industry 4.0. In *Proceedings of the international conference on industrial engineering and operations management (IEOM)* (pp. 742–753).
Tseng, M. L., Tan, R. R., Chiu, A. S., Chien, C. F., & Kuo, T. C. (2018). Circular economy meets industry 4.0: Can big data drive industrial symbiosis? *Resources, Conservation and Recycling, 131*, 146–147. https://doi.org/10.1016/j.reconrec.2017.12.028
UN General Assembly. (2015). *Sustainable Development*. Retrieved January 07, 2022, from https://www.google.com/search?q=un+general+assembly+2015&oq=UN+General+Assembly+2015&aqs=chrome.0.0i512l3j0i22i30l3.6960j0j4&sourceid=chrome&ie=UTF-8
WCED. (1987). *Brundtland report*. Retrieved January 07, 2022, from https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html.
Wood, D. J. (1991). Corporate social performance revisited. *Academy of Management Review, 16*(4), 691–718. https://doi.org/10.5465/amr.1991.4279616
World Bank. (2021). *Supporting countries' crisis response and recovery*. Retrieved January 07, 2022, from worldbank.org/en/about/annual-report/supporting-countries-crisis-response
Wopata, M. (2020). *Industry 4.0 adoption 2020—Who is ahead?* Retrieved January 15, 2022, from: https://iot-analytics.com/industry-4-0-adoption-2020-who-is-ahead/.
Wynen, J., Verhoest, K., & Demuzere, S. (2016). Quality management in public-sector organizations: Evidence from six EU countries. *International Journal of Public Administration, 39*(2), 122–134. https://doi.org/10.1080/01900692.2014.1003268
Xu, L., Peng, X., Pavur, R., & Prybutok, V. (2020). Quality management theory development via meta-analysis. *International Journal of Production Economics, 229*, 107759. https://doi.org/10.1016/j.ijpe.2020.107759
Yadav, G., Luthra, S., Jakhar, S. K., Mangla, S. K., & Rai, D. P. (2020). A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: An automotive case. *Journal of Cleaner Production, 254*, 120112. https://doi.org/10.1016/j.jclepro.2020.120112
Yamane. (1967). *Statistics: An introductory analysis*. Harper & Row and John Weatherhill Books.
Yao, X., Zhou, J., Lin, Y., Li, Y., Yu, H., & Liu, Y. (2019). Smart manufacturing based on cyber-physical systems and beyond. *Journal of Intelligent Manufacturing, 30*(8), 2805–2817. https://doi.org/10.1007/s10845-017-1384-5
Yue, J. W., Ooi, K. B., & Keong, C. C. (2011). The relationship between people-related total quality management (TQM) practices, job satisfaction and turnover intention: A literature review and proposed conceptual model. *African Journal of Business Management, 5*(15), 6632–6639. https://doi.org/10.5897/AJBM10.435
Yusuf, Y., Angappa, A., Ãã, G., & Dan, G. (2007). Implementation of TQM in China and organisation performance: An empirical investigation. *Total Quality Management & Business Excellence, 18*(5), 509–530. https://doi.org/10.1080/14783360701239982
Zairi, M., & Peters, J. (2002). The impact of social responsibility on business performance. *Managerial Auditing Journal, 17*(4), 174–178. https://doi.org/10.1108/02686900210424312
Zink, K. J. (2007). From total quality management to corporate sustainability based on a stakeholder management. *Journal of Management History, 13*(4), 394–401. https://doi.org/10.1108/17511340719819615
Zonnenshain, A., & Kenett, R. S. (2020). Quality 4.0—The challenging future of quality engineering. *Quality Engineering, 32*(4), 614–626. https://doi.org/10.1080/08982112.2019.1706744

Key Questions

Key Questions Reflecting Applicability in Real Life

1. Is there any direct relationship between Total Quality Management and Sustainability Performance?
2. Is there any direct relationship between Industry 4.0 and Sustainability Performance?
3. Does Industry 4.0 influence Sustainability Performance more in an organization through an indirect association (via the mediation of Total Quality Management)?

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