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Essential Ingredients for the implementation of Quality 4.0: A narrative review of literature and future directions for research

Purpose: Quality 4.0 is concerned with managing quality in the Industry 4.0 era. Specifically, its focus is on which digital tools are used to *enhance* an organisation's *ability* to *reliably* give customers *high*-quality products. The purpose of this paper is to investigate the key ingredients for the effective implementation of Quality 4.0.

Approach: A narrative literature review was conducted on the extant works to collate and analyse previous studies in this relatively new field.

Findings: The study revealed **eight** key ingredients for the effective implementation of Quality 4.0 in organisations, namely: (i) handling big data (ii) improving prescriptive analytics (iii) using Quality 4.0 for effective vertical, horizontal and end-to-end integration (iv) using Quality 4.0 for strategic advantage (v) leadership in Quality 4.0 (vi) training in Quality 4.0 (vii) organisational culture for Quality 4.0 and lastly (viii) top management support for Quality 4.0. These findings have provided a steer for the future research agenda of Quality 4.0.

Practical Implication: Organisations can use the eight ingredients to perform a self-assessment on the current state of each element within their own organisation. When implementing Quality 4.0, each ingredient should be effectively analysed, and measures taken so that the implementation of Quality 4.0 is effective.

Originality of Value: The paper makes the first attempt to present the key ingredients an organisation should possess to effectively implement Quality 4.0.

Keywords: Quality 4.0; Industry 4.0; Cyber-Physical Systems, IoT, Quality Management

Introduction

Industry 4.0

In their systematic review of the literature on Industry 4.0, Kamble *et al*., (2018) confirmed that this technology promises a new wave of revolution in manufacturing. This new perspective is focussed on how manufacturing can conjoin advances in digitization to produce maximum output whilst using minimum resources (Kamble *et al.*, 2018) and (Sony and Naik, 2019b).

Initially introduced in Germany to take a pioneering role in industries, Industry 4.0 has symbolized the beginning of the fourth industrial revolution (Alexopoulos, *et al*., 2016; Xu, Xu and Li, 2018). "Industry 4.0" is the current buzzword / phrase; it utilizes technologies such as cyber-physical systems (CPS), the internet of things (IoT) and cloud computing (Kagermann, 2015; Kagermann, *et al*., 2013; Lasi, *et al*., 2014; Lu, 2017).

Industry 4.0 integrates the so-called cyber-world with the physical systems by using embedded systems, semantic machine-to-machine communication, IoT and CPS. This creates a smart factory to deal with the complexities of the modern production system using a cyber-physical environment (Xu *et al*., 2018). It promises production and network connectivity integrated through CPS and IoT thus making Industry 4.0 a reality.

Managing Quality

The digitalization of organisations creates unique opportunities for managing the quality of products and services delivered by the organisation. The challenges faced by traditional quality management practices were that *customer needs are ever-changing and it is difficult to maintain a high level of quality* (Bergman and Klefsjö, 2010). In the *ad et hunc*, many companies are evidently still struggling with quality management given the numerous product recalls from the motor industry (Gunasekaran, *et al*., 2019) and other industries. How far the traditional quality management practices and methods have absorbed changes in product development stages, cycle time compression, and employee effort to match demand and customer expectations is a challenge (Gunasekaran, *ibid*. 2019).

Given the research already undertaken on TQM generally in terms of both the hard and soft skills required (Ershadi, Najafi and Soleimani (2019). It is pertinent that this is managed effectively. Further challenges are the allocation of resources for research and innovation for developing new methods of quality, the *global standardization of quality standards where companies are producing from different locations* (Kline and Hutchins, 2017) and finally, *maintaining quality when customizing products* (Du, *et al*., 2006).

Digitalization creates unique circumstances, wherein the traditional quality methods of quality management will have to incorporate technological advances to arrive at new optimums in operational excellence, performance, and innovation (Gunasekaran *et al*., 2019).

Quality 4.0

The term “Quality 4.0” was framed by Dan Jacob, research director and principal analyst with **LNS research,** a leading manufacturing research and advisory firm (Johnson, 2019). Whilst building on and improving traditional quality methods, Quality 4.0 is closely aligning quality management with Industry 4.0 to enable enterprise efficiencies, performance, innovation and improved business models.

Technologies such as CPS, IoT, cloud computing, are being used to meet requirements in terms of the quality of design, quality of conformance and quality of performance. Thus, there is a need for a study that collates and analyses the key ingredients for effective implementation of Quality 4.0. Therefore, the investigation of these key ingredients for effective implementation of Quality 4.0 was the purpose of this study.

Background Theory

The growth of technologies such as collaborative robots, autonomous vehicles, IoT are important technological factors for implementation of Industry 4.0 (also known as digital production).

Challenges for Industry

Some of the challenges faced by the organisations while implementing Industry 4.0 are the acceptance of new technology and the interoperability of digital subsystems for the effective functioning of the production system (Ferreira, *et al*., 2016). Industry 4.0 thus, describes and incorporates a set of technological changes in the production and also determines the priorities, to preserve global competitiveness of industry (Qin, *et al*., 2016).

The whole value chains within the organisation are digitalised for creating a value chain, which has continual access to information in a form of virtual models to create the fourth industrial revolution (Závadská and Závadský, 2018). Industry 4.0 is the application of CPS, technologies oriented on the internet, and intelligent devices with the interaction of man and machine. This enables communication amongst all the entities in the production system and that too in real-time.

The three forms of integration are (i) horizontal integration which is along the entire value creation chain (ii) vertical integration which is alongside the production systems within the organisation and (iii) end-to-end integration along the product life cycle (Almada-Lobo, 2016; Stock and Seliger, 2016).

Industry 4.0 is a collection of concepts. Some of the fundamental concepts of Industry 4.0 summarised are:

(1) Smart factory. In this environment the manufacturing will be completely equipped with sensors, actors, and autonomous systems;

(2) Cyber Physical Systems are integrations of computation, networking, and physical processes within the organisation;

(3) Self-organisation in manufacturing systems leads to decentralised systems, which brings with it a disintegration of classic production hierarchy and a change towards decentralised self-organisation;

(4) New systems in distribution, procurement and development of products and services which will progressively be individualised;

(5) Adaptation to human needs to create new manufacturing systems that should be designed to follow human needs (Lasi *et al*., 2014; Lucke, *et al*., 2008). Thus, Industry 4.0 will digitalise the entire organisation and along with it, its basic functions.

One of the areas which will significantly impact with digitalisation is quality management. The traditional functions of quality management will have to incorporate these five concepts of Industry 4.0 in order to create high-quality products and services. Quality 4.0 is thus the digitalisation of quality of design, quality of conformance, and quality of performance using modern technologies.

The application of digital technologies can change the quality in various ways, for instance an organisation can monitor processes and extract data from real-time sensors (Sony, 2018). The big data generated from these sensors can be further analysed to predict quality issues and maintenance needs of the organisation (Johnson, 2019). Quality 4.0 as such is so much more than technology. It is a new method by which digital tools can be used so that organisations' ability to consistently deliver high-quality products can be improved. Quality 4.0 will drive improvements across the value chain.

In a recent study by Boston Consulting Group, American Society for Quality and others it was found that manufacturing and R&D will immensely benefit due to the implementation of Quality 4.0 (Küpper, *et al*., 2019). In manufacturing, the perceived importance of value in the shop floor to create the quality of conformance will undergo a sea change with the application

of smart diagnostic tools. The R&D impact of Quality 4.0 will impact the quality of design, as the data pertaining to the usage of the product will be relayed back to the designers through end-to-end integration of Industry 4.0 (Cheng, *et al*., 2016). Therefore, user needs can be better mapped and better products and services will be designed by the manufacturers. Thus, justifying the need for a study that collates and analyses the key ingredients which are essential for the effective implementation of Quality 4.0.

Method

A narrative literature review is a comprehensive, critical and objective analysis of the current knowledge on a topic. Unlike systematic reviews that benefit from guidelines, the narrative literature review does not have any acknowledged guidelines (Ferrari, 2015). The searches for literature were carried out using Scopus, Web of Science, Google Scholar, Ebsco, and ProQuest. Though some scholars have recommended the exclusion of conference proceedings (Scott-Findlay and Estabrooks, 2006) the present study included them to extract insights relating to this emerging research area (Flick, 2015). The keywords used in this study were *Quality 4.0, Quality and Industry 4.0, Fourth Industrial revolution and Quality, Smart Manufacturing* and *Quality, Smart factory* and *Quality, cyber physical system* and *Quality, internet of things* and *quality, industrial internet* and *Quality, Big data* and *Quality, Digitalization* and *Quality.* The references of identified articles were also utilised to expand the selection process. Quantitative studies were included if they were primary research investigating the quality management in a digitalised environment. Likewise, only English language literature was considered. The studies were critically appraised by at least two of the authors to identify methodological limitations and potential biases to assess validity and reliability. Qualitative or conceptual studies that focused on broader questions were included. Qualitative or conceptual studies were assessed in terms of the validity criteria for the paradigm employed in the research, where that was clear in the paper (Say, *et al*., 2006). There were very few articles focussing on Quality 4.0 *per se*, however, articles dealing with quality in the digitalisation process were analysed in an integrative manner to obtain the ingredients for successful implementation of Quality 4.0.

Results

The articles were analysed in-depth to classify the articles into first-order categorization themes. Subsequently, the first order categorised themes were collated into higher-order themes (Sony, *et al*., 2019; Sony and Naik, 2019a). The higher order categories that were unearthed in this study are as follows:

1. Handling big data
2. Improving prescriptive analytics
3. Effective vertical, horizontal and end-to-end integration through Quality 4.0
4. Use Quality 4.0 for strategic advantage
5. Leadership in Quality 4.0
6. Training in Quality 4.0
7. Organisational Culture for Quality 4.0
8. Top Management Support for Quality 4.0.

(1) Handling Big data

The data have been the most important element in quality management (Goetsch and Davis, 2014). The success of quality management programs rests on the process of data collection, analysis and decision making (English, 2009). The recent development of affordable sensors, improved data acquisition systems and fast communication systems in the cyber-physical systems of Industry 4.0, enables a large amount of data to be generated (Lee, *et al*., 2013) which can be used by quality management systems. A single machine by virtue of it being interconnected will generate a large amount of data which primarily revolves around its operating and maintenance conditions. Big data will be generated in terms of volume, variety, velocity of generation of new data and analysis and value of data (Erevelles, *et al*., 2016; Vaidya, *et al*., 2018).

These big data can be used in Quality 4.0 for improved quality of design, quality of conformance and quality of performance of products and services.

Improved quality of design

The quality of design will be achieved by first understanding the customer needs, big data can be used to effectively do so (Chen, *et al*., 2012). The big data will also enable the understanding of customers' needs in a holistic or all-encompassing manner, as almost all customers' needs can be mapped and analysed. In Kano model terms, the threshold / basic attributes, performance attributes and excite/ delight attributes can be accurately analysed using big data. Therefore,

from a design perspective, these attributes will help the organisations to design a better trade-off in design variables, *i.e.* cost and value of the product.

Quality of conformance

Big data can be used in the quality of conformance phase. Manufacturing has evolved from its traditional manual design and become more automated, computerised and complex (MacDougall, 2014). In the recent years, smart manufacturing is an emerging form of production in which the integration of manufacturing assets with sensors, computing platforms, communication technology, control, simulation, data-intensive modelling and predictive engineering (Kusiak, 2018). Consequently, Big data from these smart manufacturing systems can be successful in different phases of quality management. For instance, an organisation can analyse the data of smart products and services throughout its manufacturing phase so that the manufactured product or a service rendered must meet the standards selected in the design phase.

Quality control and performance of quality

Another instance could be the control of quality from the raw material to finished product can be successfully carried out by designing algorithms, in an efficient and self-regulating manner by using modern technologies such as, *inter alia*, CPS, IoT, and cloud computing. The end-to-end integration across the product life cycle is one of the striking features of Industry 4.0. This will result in a large amount of product usage data (Sony, 2018; Stock and Seliger, 2016), which can be used by manufacturers to monitor the quality and reliability of the product. Consequently, the quality of performance can also be effectively monitored by collecting and analysing the product usage data in customer's hands through in an automated manner using artificial intelligence. Moreover, the performance data will also be an important design input to continuously improve the product and services.

Therefore, the successful implementation of Quality 4.0 will, in turn, depend on how well organisations handle this big data for meeting the quality goals.

(2) Using Prescriptive Analytics Algorithms for Quality Metrics

Poor metrics is one of the primary barriers for accomplishing quality objectives, because the current quality metrics, including defect rate, failure rate and so on, primarily describe what happened, why it happened and what might happen next. It seldom describes what actions to be taken in a prescriptive manner (Pedersen, 2017). The recent advances in the area of business

analytics in terms of prescriptive analysis provides organisations with adaptive, automated, and time-dependent courses of actions to take advantage of likely business opportunities (Soltanpoor and Sellis, 2016).

Prescriptive analytics algorithms in quality management can provide two levels of human intervention for decision making (Hagerty, 2017). The first level of intervention is the decision support system. For instance, these algorithms will provide recommendations for quality of design, quality of conformance and quality of performance. The larger solution set from these algorithms will warrant human intervention in an assisted manner to finalise the best options.

The second level of prescriptive analytics will be based on intelligent algorithms which will result in decision automation through machine learning. This type of prescription algorithm will help in implementing the prescribed action in an automated and self-regulating manner.

Prescriptive analysis algorithms in terms of first level will be very beneficial in quality planning and quality improvement, as it will provide large amount of solution options with scenario analyses. However, prescriptive analysis in terms of decision automation will be more helpful for quality control, because decisions such as conformance to specifications can be automated by analysing data from the IoT. Nevertheless, both aspects will play an important role to determine the best solution or outcome among various choices in all three phases of quality planning, quality control and quality improvement.

The prescriptive analytics algorithms will also assist the organisations to maximize their quality goals and at the same time mitigates their likely risks by recommending optimal sequences of actions by considering organisations quality objectives. Therefore, strategically handling prescriptive analytics algorithms will boost the chances of the success of Quality 4.0.

(3) Effective Vertical, Horizontal and End-to-End Integration through Quality 4.0

An organisation has several physical and informational subsystems. Physical subsystems include an actuator and sensor, and control. Informational subsystems include enterprise resource planning (ERP), and Systems Applications and Products (SAP). The physical and informational subsystems are integrated at various levels within the production system to create a flexible and reconfigurable manufacturing system. This will also help the smart machines to form a self-organized system that can be dynamically reconfigured to adapt to different product types; and the massive information is collected and processed to make the production process transparent (Wang, *et al*., 2016). In other words, it is the vertical integration of hierarchical

subsystems such as various departments inside a factory to create a flexible and reconfigurable manufacturing system (Sony, 2018).

In order to, efficiently manufacture products and services, many organisations should form the inter-organisation horizontal integration, which is made up of related corporations, to form an efficient ecosystem. Information, finance, and material can flow smoothly among these organisations (Vaidya *et al*., 2018). Thus, a new value networks, as well as, business models may emerge. In a product-centric value creation process, a chain of activities is involved, such as customer needs, product design and development, production planning, production engineering, production, services, maintenance, and recycle. Integration of all activities which are product-centric value creation is end-to-end integration (Stock and Seliger, 2016).

A quality management system should concentrate on all three types of integration to create an efficient and effective Quality 4.0 program by strategically extracting, analysing and deciding on the data based on all three forms of integration. For instance, a vertical integration Quality 4.0 sub-module will be concerned with all quality planning, quality control and quality improvement activities within the organisation in a self-automated and organized manner. In horizontal integration sub-module, the activities such as quality planning, control and improvement activities focus on all the organisations that cooperate within the value creation process to produce product and service. In end-to-end integration, the quality planning, control and improvement activities are targeted towards various phases of product life cycle more specifically of the usage phase. This also includes the integration of customer usage data back to the manufacturer, which provide Quality 4.0 module with an excellent opportunity for managing the quality of performance.

Thus, Quality 4.0 should include all three forms of integration for the successful implementation.

(4) Use Quality 4.0 for Strategic Advantage

The digital data from the modern organisation can be used in a strategic sense to create a competitive advantage (Porter and Heppelmann, 2014). By using modern technologies of Industry 4.0, an organisation can create better quality products and services and thereby create a price-value advantage over the competitors (Sony and Naik, 2019b). The smart, connected products vividly expand opportunities for product differentiation, moving competition away from price alone. Consequently, the data on how customers use the products enhances a company's ability to segment the customers, customize the products, set prices to better capture

value, and extend value-added services (Porter and Heppelmann, 2014). Quality 4.0 will play a major role not only in delivering such products to the customers but also in monitoring the product usage throughout its life cycle leading to better design of products and services.

Organisations that compete on quality using digital technologies should therefore use an operational strategy that is based on continuous improvement using both digital technologies and big data.

(5) Leadership for Quality 4.0

Leadership is the skill to inspire, motivate, and channelize activities to achieve organisational goals (Waddell, *et al*., 2007). Leaders achieve the desired goals by using an appropriate leadership style as per the situation (Bass, 1985). Quality 4.0 requires a process of innovation and learning because the core concept of Quality 4.0 is about bringing the practice of quality management with the emerging capabilities of Industry 4.0. This is done to help drive organisations toward operational excellence. Thus, Quality 4.0 requires a leadership style that considers innovation and learning. One of the widely used styles in innovation and learning is transformation leadership (Aryee, *et al*., 2012; Birasnav, 2014). Quality 4.0 requires more than a transformation leadership style and it should be specific also to consider the learning and innovation. The transformational leadership style at present is limited to idealized influence, inspirational motivation, intellectual stimulation, and providing vision (Bass, 1985). Quality 4.0 will also require the learning and innovation component. Consequently, it requires a knowledge-oriented leadership style. One such style of knowledge-oriented leadership is a combination of transformational and transactional leadership (Donate and de Pablo, 2015). Knowledge-oriented leadership is more specific to learning and innovation. However, there is still a potential to extend the construct of knowledge-oriented leadership to be used in Quality 4.0 by extending the knowledge-oriented leadership to incorporate adding innovative role modelling, stimulating knowledge diffusion, supportive behaviour, delegation, consulting, and mentoring to the construct of knowledge-oriented leadership (Shamim, *et al*., 2016). Therefore, leadership will play a major role in Quality 4.0

(6) Training for Quality 4.0

Quality 4.0 uses many technologies to improve competency. Smart glasses will be used in non-conformity management, quality control, and change management. Smart gloves will be used in quality control, dispatching and manipulation. RFID (radio frequency identification) technology barcodes, QR codes, drones, autonomous vehicles, 3D printing, simulation by virtual reality, and collaborative robots, amongst other things, will be used in manufacturing

and quality control (Závadská and Závadský, 2018). The outputs from artificial intelligence and machine learning systems can be used to develop new expertise (Varian, 2018). In addition, artificial reality (AR) and virtual reality (VR) systems can be used to improve employee's expertise in quality control and management. Social media tools can be leveraged to share lessons and experiences across organisations, and also in between the organisations (Bretschneider and Parker, 2016). The use of tools in Quality 4.0 will have to be developed for quality planning, quality control and quality improvement and the employees will have to be trained in a strategic manner continuously. The Quality 4.0 skills needed would be technical skills such as install and operate IT, RFID tags, and big data analysis. There would also be a requirement of transformational skills such as adaptability, critical thinking, creativity and social skills such as teamwork, and knowledge transfer (Schallock, *et al*., 2018). Therefore, training will play a major role in the successful implementation of Quality 4.0.

(7) Organisational Culture for Quality 4.0

Organisational culture is a set of the set of norms, beliefs and values shared by members of the organisation (Gimenez-Espin, *et al*., 2013). The organisational culture is somewhat a broad term and therefore it is important to classify it at different levels in terms of values, rules and practices. Organisational culture influences members of the organisation such as influencing their behaviour, performance outcomes, and organisations external environment (De Long and Fahey, 2000). By virtue of connecting data, analytics and processes and thereby improving visibility, connectivity, collaboration and insights, The four types of organisational culture such as clan, adhocratic, hierarchy (Cameron and Quinn, 2011) and market will play an important role in Quality 4.0. The organisation acts like a family, promoting teamwork, commitment and involvement. Quality 4.0 requires the use of technology to support improved quality performance. By investing in technology, the cost of bad quality is avoidable. Technologies that enable increased control of operations and quality monitoring can not only result in higher yields but also give employees better tools to do their jobs. This calls for employees to work as a clan to promote the use of these technologies to attain quality goals. Adhocratic culture fosters flexibility, but its orientation is external. Its objectives include creativity, risk-taking, individuality and initiative. Knowledge in the context of Industry 4.0 will normally be treated as a functional resource, which is representing a 'truth' or at least something instrumentally useful on a subject matter which is directed towards automation and integration. It could also be viewed as a set of principles or techniques for dealing with material or social phenomena. In addition, knowledge also creates a norm as to how things should be (Alvesson, 2001). The

gap between how things should be, and the present state will attract the potential to solve problems in different capacities. Knowledge will be the key resource and the requirements of knowledge workers will be immense to solve complex problems through creativity and innovations. Another point to consider is that in the higher order jobs, the problems are new or ill-defined and depending upon the context of work the frequency of such problems will vary (Frey and Osborne, 2017; Schneider, 2018). Those implementing Quality 4.0 in a modern environment will require employees to exhibit adhocratic culture. Market culture looks for an external perspective through which to differentiate it from competitors. Quality 4.0 is directed to produce a sustainable competitive strategy which is directed to produce a market leader; therefore, market culture is significant. The hierarchical culture is based on stability and control along with an internal focus. The fundamental characteristic of Quality 4.0 is the use of standards for the objective of achieving efficiency in terms of the value creation. Consequently, hierarchical culture is also an important aspect in the implementing of Quality 4.0.

(8) Top Management Support for Quality 4.0

Top management support within an organisation can encourage the practices and behaviours that lead to quality performance throughout the organisation. The role of top management support in quality management implementation is well documented (Flynn, *et al*., 1995). The top management support refers to the degree to which top management understands the importance of the Quality 4.0 and the extent to which top management is willing to support Quality 4.0 implementation within the organisation. The top management support is critical in enhancing the incorporation of Quality 4.0 technology into the business strategy. It will facilitate Quality 4.0 implementation in quality of design, quality of conformance and quality of performance. Top management support in the quality of design phase will result, in sheltering companies from the pressures of rushing a new product in the market, thereby giving enough opportunities for the design team to analyse the big data on customer needs to design a well fit product. In the quality of conformance phase, the top management support will result in providing and suggesting judicious use of resources by stakeholders for building quality in all phases of manufacturing. In the quality of performance, the top management support in designing new and unique services based on the product usage data, product servitization will become a reality if the top management supports the new service products (Baines, *et al*., 2009; Ennis, *et al*., 2018; Vendrell-Herrero, *et al*., 2017).

The most difficult and challenging Quality 4.0 implementation relates to the major changes to be made in organisational structure and business processes. These changes could meet resistance from various stakeholders within the organisation (Todnem By, 2005). If there is commitment from the top management team, these changes can be handled well (Mackness, 1991). Secondly, Quality 4.0 implementation involves a programme of wide-ranging organisational change initiatives and therefore, the top management support will help in implementing the change initiatives. A transparent and visible top management support encourages positive user attitudes towards quality 4.0 system. The top management cannot facilitate the other organisational members within the supply chain to accept using the new technology. The success of Quality 4.0 depends on the user acceptance of the Quality 4.0 with the entire supply chain. A supporting top management will help in the process of technology adoption among the supply chain elements. Therefore, high levels of top management support towards quality 4.0 will lead to perceived usefulness of quality 4.0 and its importance among the other employees. Therefore, top management support is critical for Quality 4.0 success.

Discussion

Quality management is one of the evergreen research areas in the modern century (Gunasekaran *et al*., 2019). The traditional quality management has changed with the advent of digitalisation of all the functions of the organisation through the implementation of Industry 4.0 (Johnson, 2019). In Quality 4.0 companies are adopting new digital tools to improve their operational efficiency and product quality. The research question put forward in this paper was "What are the key ingredients for the effective implementation of Quality 4.0?". Through a narrative analysis of literature, this study proposes eight ingredients for the effective implementation of Quality 4.0. Industry 4.0 signifies that the modern trend of automation technologies in the manufacturing industry, such as the cyber-physical systems (CPS), Internet of Things (IoT) and cloud computing (Xu *et al*., 2018) generates a large amount of data. The effective implementation of Quality 4.0 will be possible if we handle this big data for quality management. The data should be handled strategically in all three areas of quality which includes quality of design, quality of conformance and quality of performance. Quality 4.0 stresses the importance of prescriptive analytics compared to descriptive/ predictive/diagnostic analysis in quality planning, control and improvement. The solutions are adaptive, automated, and time-dependent courses of actions to take advantage of likely quality management opportunities within the organisation to deliver products and services. At a system level, Industry 4.0 implementation includes horizontal, vertical and end-to-end integration (Wan *et*

al., 2016). The effective implementation of Quality 4.0 in terms of quality planning, control and improvement along these three integration mechanisms may result in the delivery of high-quality products and services by the organisations. However, further evidence in terms of empirical study should be conducted. The big data generated in the modern organisation can be used in a strategic sense to create a competitive advantage for the organisation (Porter and Heppelmann, 2014). Moreover, in Quality 4.0 the big data is used for quality of design, conformance and performance for creating products and services for the organisation which will lead to competitive advantage using the high-end technology.

Quality 4.0 requires a process of innovation and learning, and good leadership style will promote the organisation wide culture of learning and innovation. No one leadership style will suit such a situation rather an approach where a combination of leadership styles will benefit the organisation. The use of advanced technology in quality management will result in a need for high-quality training for Quality 4.0 (Závadská and Závadský, 2018). The training required should be specific and up to the point for the effective implementation of Quality 4.0. Effective implementation of Quality 4.0 will require an organisation wide culture which promotes quality by using modern technologies. Organisations will have to strategically inculcate the culture of quality within the organisation, particularly given that changing the organisational culture is a long-term process.

The top management support is also crucial for the success of quality 4.0 not only in terms of allocating resources but also in terms of motivation provided for employees to accept and use the Quality 4.0. Leadership and top management support in tandem will play a major role in Quality 4.0 success. A creative and innovative leader will provide unity of purpose, while also establishing the direction of Quality 4.0 in the organization. Strong leaders will also help in improving the top management support by making other members of top management understand the importance of Quality 4.0 through effective communication. In addition, a strong leader will also help to ensure Quality 4.0 policy and Quality 4.0 objectives are well established and are compatible with context and strategic direction of the organization.

Conclusions

Quality 4.0 is an emerging research area and this study proposes the key ingredients for effective implementation of Quality 4.0. An exploratory qualitative study may be carried out in various organisations to explore any additional key ingredients which are specific to a sector.

Also, a scale to measure the key ingredients of Quality 4.0 should be developed and tested so that organisations can use this scale before the implementation of Quality 4.0. In addition, a self-assessment readiness framework should be developed.

Research should be directed on the use of big data in quality of design, conformance and performance. The existing tools of quality management should be tested on whether it can be used with big data. Likewise, guidelines as regards to its usage of these tools and its integration with big data should also be studied so that the organisation can use these guidelines for effective implementation of Quality 4.0.

The usage of prescriptive analytics in quality planning, control and improvement is in the preliminary stages. The prescriptive solutions in terms of adaptive, automated, and time-dependent solutions need to be investigated longitudinally for its efficacy in Quality 4.0.

The quality management tools and techniques that will be beneficial for the vertical, horizontal and end-to-end integration should be investigated. Such a study will help organisations while implementing Industry 4.0.

The strategic advantage of Quality 4.0 implementation should be studied longitudinally. The impact of Quality 4.0 on customers and other competitors will help to understand their impact on the market. Moreover, the impact of Quality 4.0 on quality costs in different sectors will help to understand the cost implications of Quality 4.0.

The effective implementation of Quality 4.0 in the delivery of high-quality products and services by the organisations should be empirically investigated.

The impact of leadership on Quality 4.0 will also clarify the efficacy of different leadership styles and its impact on Quality 4.0 implementation. Organisational culture impacts quality management practices (Pieter van Donk and Sanders, 1993).

Future studies should explore the impact of organisational culture on the successful implementation of Quality 4.0 in a longitudinal manner. In addition, one should develop a self –assessment organisational cultural readiness instrument for Quality 4.0, especially for small and medium scale organisations. Quality 4.0 implementation will need employees to possess new technical skills. In addition, the transformational skills such as adaptability, critical thinking, creativity and social skills will also be needed. Consequently, future studies should explore how to train employees strategically for the Quality 4.0 implementation in both technical and transformational skills.

Future research could also be directed on the benefits and drawbacks the companies would accrue by embarking on Industry 4.0 and Quality 4.0 via in-depth interviews with CEOs contemplating on embarking on the Quality 4.0 journey and with those companies that play a part in supporting such companies. The challenges, the tools of Quality 4.0 and the success factors of Quality 4.0 for larger organizations and small- and medium-sized organizations will not be the same. These differences will be explored further through an empirical study.

Limitations

This study explored the key ingredients for the effective implementation of Quality 4.0 by narratively examining the extant literature. This study finds eight ingredients for the effective implementation of Quality 4.0. The key ingredients are 1) handling the big data 2) improving prescriptive analytics 3) effective vertical, horizontal and end-to-end integration through Quality 4.0, 4) use Quality 4.0 for strategic advantage 5) leadership for Quality 4.0, 6) training for Quality 4.0, 7) organisational culture for Quality 4.0 and 8) top management commitment for Quality 4.0.

These ingredients should be implemented by the organisations in a methodological manner for successful implementation of Quality 4.0. All the components are equally important for the success; therefore, organisations should implement all the key ingredients. The limitations of this study are the results are limited by the database searched. Second, only English language literature was considered, and other language studies were excluded. The study could further be improved by literature from other languages.

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