Humanities & Social Sciences Reviews
eISSN: 2395-6518, Vol 8, No 4, 2020, pp 483-495
https://doi.org/10.18510/hssr.2020.8447

THE PERSPECTIVE OF QUALITY MANAGEMENT SYSTEM DEVELOPMENT IN THE ERA OF INDUSTRY 4.0

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Article History: Received on 27th July 2020, Revised on 15th August 2020, Published on 17th August 2020

Abstract

Purpose of the study: This study tried to examine the level of awareness and vision of prospects for the development of quality management and its corresponding systems in the era of transition to the technologies and principles of Industry 4.0 among quality management professionals of Russian companies.

Methodology: The study is based on the survey conducted in April - May 2019 among the expert community in the field of quality management. A total of 50 experts from Russian industrial and service companies participated in the survey. The survey was organized in accordance with the stages of 'the Deming Plan-Do-Check-Act cycle. The data analyzed by using the Spearman correlation to determine the relationship between the understanding of current priority and anticipation of future changes in quality management concepts, principles, and tools in the era of Industry 4.0.

Main Findings: The survey results show how innovative quality management methods can be applied practically with relevance to 4th industrial revolution technologies. The authors conclude that the changes in the core concepts of quality management are necessary for the Industry 4.0 era and offer a 4.0 quality definition through the revision of quality management principles.

Applications of the study: The finding of this study is useful for the development of a digital transformation strategy of the business companies by showing the correlation between quality management principles awareness and implementation of digital tools. The study shows the necessity to offer interdisciplinary training for quality management professional and IT specialists on the digital transformation of quality management.

Novelty/Originality of the study: The originality is in the design of the survey that covered issues that haven't been studied in correlation with each other before the influence of Industry 4.0 tools and key provisions on quality management and development strategy of the company. In the survey, the perception of new quality management principles was investigated for the first time.

Keywords*: Industry 4.0, Quality Management, Business Model, Industrial Revolution, Digital Transformation.*

INTRODUCTION

The radical and dynamic technological changes that take place in day-to-day life impact every person, enterprise, and organization resulting in the emergence of new business models and strategies. According to the President of World Economic Forum (WEF) Schwab (2017), 'the nature of such changes is fundamental, which has not yet known in world history — now we are witnessing the era of both great opportunities and potential dangers'. Artificial Intelligence, Internet of Things (IoT), robotics, autonomous vehicles, simulation and augmented reality, cloud technologies, bioengineering and new materials, big data analytics, unlimited internet access and information technologies testify the onset and transition to fourth industrial revolution i.e., 'Industry 4.0' and the digital transformation of socio-economic processes (Batkovskiy et al., 2019; Raharja et al., 2019). The fourth industrial revolution connects the material world with the virtual resulting in the origin of novel cyber-physical complexes that form a digital ecosystem. Moore (2011) opined that with the advent of the Internet, various sectors such as retail, communications, music, entertainment, and the news got revolutionized. Health, education, public administration, transport and communications industries are experiencing disruptive technologies that transform the characteristics of goods and services, organizational processes, management practices, consumer expectations and business models, which require to their review their approaches so as to ensure the competitiveness and sustainable development of modern organizations (Hilkevics & Semakina, 2019; Tyapukhin, 2013; Malitskaya, 2014; Mahrinasari, 2019). Before the WEF-2018 report, several reports were published stating the unjustified expectations of the economic impact of 'Industry 4.0' ("The backstage of Davos," 2018). For example, direct measurements of the multifactor productivity in both the United States and the United Kingdom have shown that the productivity has grown only a 0.3 % while the previous technological revolutions increased the productivity by 2% per year. It infers that the new technologies do not provide a sufficient level of value for goods and services both in terms of consumption as well as cost.

The World Bank introduced the concept of digital business to create new business models by bridging the gap between digital and physical worlds by bringing people, businesses and things together ("The backstage of Davos," 2018). At the same time, organizations which rely on data captured by them are transformed into organizations which are guided by their own data. According to Scalabre (n.d.), chief partner and managing director of Boston Consulting Group (BCG), the fourth industrial revolution is a transformation that allows the collection and analysis of machine data which results in providing speed, flexibility and efficiency to the high-quality products at lower costs. This industrial revolution is set to create conditions for increasing labor productivity, serve as a stimulus for economic growth, change the economy and the profile of the labor force, and increase the competitiveness of companies and regions (Scalabre, n.d.; Vitik et al., 2016; Brinza et al., 2015). Despite this, the governmental programs and strategies for the development and promotion of digitalization of national economies and industrial sectors have already been developed and implemented in dozens of countries across the globe. According to the official data published by the European Commission in the year 2017, there were more than 30 national and regional initiatives on industrial digitalization only in the European Union. For example, Germany, back in 2011, officially presented her national strategy called 'Industrie 4.0' as well as several other strategies and initiatives of a similar profile and focus (Xu et al., 2018). In Russia, the program' Digital Economy of the Russian Federation' was approved by the government order No. 1632-R by the Russian Federation dated July 28, 2017. The fourth industrial revolution, although it is yet to have a significant impact on labor productivity on an international scale, it still radically changed the nature of products and services, which no longer reflects the diversity of intangible value propositions offered to the customer. As a result of the cumulative impact of the advanced Industry 4.0 technologies, there are various servitization processes in progress with a change in value creation models. The WEF reports (World Economic Forum, 2016, n.d.) suggest to use the concepts such as 'solution economy' and 'experience economy' which shift the focus from the consumer properties of products and services to their ability in generating the benefits for the consumer, solve their problems, offer a cognitive and emotional experience not only in the consumer market but also in the B2B interactions too (World Economic Forum, 2016, n.d.).

'Industry 4.0' changes the content and correlation of various entities such as consumption, expectations, value, quality, and consumer experience, which require the transformation of traditional views and approaches to quality management (Akhmetova et al., 2019). Thus, in studying the socio-economic impacts of the fourth industrial revolution, one can observe a combination of two trends: the emergence of a digital type of consumption and a digital type of production. As shown in the literature (Alpackaya & Alpackiy, 2018; Novikova et al., 2016), these two trends are relevant to two main approaches in the digital transformation on a national scale while the first is market approach, when businesses offer consumers new digital products and services, thereby transforming their expectations whereas the second one is planned approach, when the state stimulates and regulates the digital transformation of industries to increase the competitiveness in both digital as well as traditional markets.

The purpose of the survey is to identify the level of awareness and vision of prospects for the development of quality management and its corresponding systems, in the context of the transition of enterprises or organizations to the technologies of Industry 4.0.

LITERATURE REVIEW AND RESEARCH HYPOTHESIS

The fourth industrial revolution is gradually taking over all spheres of life, so the "opportunities and dangers", according to Schwab (2017), caused by the entry into this new era, are only now beginning to manifest. Before the WEF-2018, several published reports stated the unjustified expectations of the economic impact of "Industry 4.0" ("The backstage of Davos," 2018). For example, direct measurements of multifactor productivity in the United States and the United Kingdom have shown that while previous technological revolutions increased productivity by 2% per year, at this stage, productivity is seeing only a 0.3% growth. This means that new technologies do not provide a sufficient level of value for goods and services in terms of consumption and costs. Nevertheless, governmental programs and strategies for the development and promotion of digitalization of national economies and industrial sectors have already been created and implemented in dozens of countries worldwide. Only the European Union, according to the official data from the European Commission in 2017, has seen more than 30 national and regional initiatives on industrial digitalization. For example, Germany officially presented a national strategy called Industrie 4.0, as well as several other strategies and initiatives of a similar profile and focused back in 2011 (Xu et al., 2018). In Russia, the "Digital Economy of the Russian Federation" program was approved by the order of the government of the Russian Federation with No. 1632-R on July 28, 2017.

The fourth industrial revolution, although it has not yet had a significant impact on labor productivity on an international scale, has radically changed the nature of products and services and no longer reflects the diversity of intangible value propositions offered to the customer. As a result of the cumulative impact of advanced Industry 4.0 technologies, servitization processes and a change in value creation models have been observed. The WEF reports (World Economic Forum, 2016, n.d.) allude to the concepts of "solution economy" and "experience economy," which shift the focus from the consumer properties of products and services to their ability to generate benefits for the consumer, solve the consumer's problems, and offer a cognitive and emotional experience—not only in the consumer market but also in B2B interactions (World Economic Forum, 2016, n.d.). Thus, studying the fourth industrial revolution's socio-economic impacts, we can observe a combination of two trends: the emergence of the digital form of consumption and a digital form

of production. As shown in work by Alpackaya and Alpackiy (2018), these two trends are relevant to two main approaches to the digital transformation on the national scale: the market approach, when businesses offer consumers new digital products and services, thereby transforming their expectations, and the planned approach, when the state stimulates and regulates the digital transformation of industries to increase competitiveness in both digital and traditional markets. The following features of the digital form of consumption are considered in works (Krubasik et al., n.d.; Ryynänen & Hyyryläinen, 2018; Belk, 2013):

- The transition from the concept of "product ownership" to the concept of "access to products on demand." The essence of the concept is the value of the product or service, unique for each individual consumer as a result of his or her experience. Based on the research presented in work (Vargo & Lusch, 2004), it can be argued that an organization does not have the opportunity to create such an experience and customer value in advance; it can only offer customers the conditions for creating it and the subsequent formation of a value proposition.

- The Diffusion of shared and multi-homing consumption, with the simultaneous use of products from several competitors. Digital products and digital solutions have a network effect: their value increases with the increasing number of users.

- Hyper personalization of products. This means creating value together with the consumer at the time of a product's use, in conjunction with other services and solutions, which leads to a new phenomenon: mass customization, based on a combination of previously incongruous types of production (mass and individual).

- They were changing consumer properties of digital products and services, usually associated with the generation and circulation of information, data, and knowledge, which lead to the transfer of qualitative and quantitative properties of information to products and services. Diffusion of expectations. Across various sectors, so modern organizations compete not only within one industry but also with leading digital service providers, forming consumer expectations about the quality of life in general.

As part of the review of digital production trends in the era of the fourth industrial revolution, we study its distinctive characteristics, the degree to which "Industry 4.0" technologies have penetrated different types of production and different stages of the life cycle of products and services, as well as their impact on the production system (Xu et al., 2018; Westerman et al., 2014; Yin et al., 2018; Shin et al., 2018; Závadská & Závadský, 2018; Kiel et al., 2017; Tishina et al., 2017; Vlasov et al., 2018). Currently, information on the degree of integration of "Industry 4.0" technologies in industry and services is being accumulated, and attempts to predict the further transformation of production and management systems are being made. The concept of cyber-physical systems is being developed, as well (Xu et al., 2018). A model was proposed by (Tarassov, 2019) to assess the digital maturity of the business on the basis of nine elements, which were identified by a survey of 157 CEOs of companies with a turnover of at least $ 1 billion. They are grouped into three transformation groups: consumer experience, operational processes, and business models (Westerman et al., 2014). Akberdina et al. (2018) propose a model of the industry digitization process which consists of five stages—how and for what the data are used. The five stages are as follows: primary information and communication digitization; electronic data exchange with external partners; use of specialized software; production of information and communication technologies and equipment; use of robots and sensors.

"Industry 4.0" changes the content and correlation of categories of consumption, expectations, value, quality, and consumer experience, which requires the transformation of traditional views and approaches to quality management. The paper (Krubasik et al., n.d.) presents the results of a survey of 50 leading experts in the field of quality and managers of large industrial companies, in which 40 % of respondents noted that the standard methods of quality management significantly reduced their efficiency. At the same time, 48 % of respondents indicated the increased importance of quality management problems over the past 10 years.

Amid the transition to the technologies of "Industry 4.0," prospects for the development of quality management systems (and quality management in general) are the subject of research by scientists and specialists representing various fields of study. The analysis of these works showed that opportunities and challenges for quality management—which carries the fourth industrial revolution—have already been identified (Kiel et al., 2017; Zaidin et al., 2018; Foidl & Felderer, 2016). New conceptual approaches to the definition of quality have also been offered (LNS Research, 2017; Park et al., 2017), and discussion surrounding the content of quality management principles in the digital age is underway (Park et al., 2017; Sader et al., 2017). The transition from understanding total quality management as a functional area of management to the recognition of quality management as a management paradigm—a basis of business strategy—has been completed (Anupama, 2018; Dahlgaard-Park et al., 2018). In the papers (Zaidin et al., 2018; Foidl & Felderer, 2016), the opportunities brought by Industry 4.0 are divided into three groups: strategy, operations, and environment, and people. Quality improvement is part of operation management.

Rethinking the key concepts of quality management led to the fact that in 2017, B. Pederson introduced the concept of "quality 4.0" (LNS Research, 2017), and Park et al. (2017) introduced the concept of "open quality". In the international standard ISO 9000: 2015 "Quality management Systems. Fundamentals and Vocabulary," the concept of quality is related

to the satisfaction of the needs of stakeholders and is defined as the "degree to which a set of inherent characteristics of an object fulfills requirements" (International Organization for Standardization, 2015). It should be stated that the stakeholders theory, sustainable development and the quality management concept orients organization to identify its stakeholders, understand their needs and manage the relevant relationships (Salimova, et al.2014). Quality 4.0 includes the digitalization of quality management systems and conformity assessment, focusing not only on the application of technology in the organization, but also on improving culture, collaboration, and leadership through the use of technology.

The content of the term "open quality" is associated with the implementation of a new quality strategy, when all quality of any product or service is created, produced, promoted, and implemented on the basis of an open and transparent approach for different stakeholder groups (Park et al., 2017; Eddelani et al., 2019; Yakhneeva et al., 2020). The definitions of quality 4.0 and open quality reflect the development of two trends: digitalization of production and digitalization of consumption. Integrating these interrelated phenomena, we propose to define quality 4.0 as the adaptive ability of an object at all stages of the life cycle to meet the needs of a particular consumer on the basis of partnership with stakeholders and digital management of the value chain (data-driven value chain management). At the same time, the object is understood as a broad result of activity, including products, services, projects, and digital solutions. Adaptability is regarded as a set of customized characteristics of the object, open to change in accordance with the requirements of a particular consumer. In the context of mass customization, characteristics of products, services, and digital solutions must be adaptive, not standard. "Embedded" quality is transformed into "customizable."

Considering the need for a radical change of management paradigm, instant response to changes in the business environment, consumer demands, risks of destruction of traditional organization structures and value chains, as well as the blurring of boundaries between traditional industries and other challenges of the fourth industrial revolution, the concept of quality 4.0 reflects the total digitalization of all components of the organization's quality management system (organizational management structure, processes, and documented information, resource management, etc.).

The research hypothesis is that the quality 4.0 concept focuses on the transition to a new quality level of management and organizational activities through the introduction of technology. To test the hypothesis, we use the theoretical ideas about the essence and principles of the Quality 4.0 concept and further verify it through an expert survey.

Park et al. (2017) presented the analysis of changes in the goals and strategies of quality management in the transition to the fourth industrial revolution, which in 2018 was supplemented in the work of Salimova and Vatolkina (2018) with analysis of changes in the definitions of quality and approaches to management (Table 1).

Table 1: Transformation of approaches to quality management

Industrial Revolution	Operation Strategy	Quality Concept	Quality Management Goal	Approach to Management	Quality Management Strategy
4.0	Mass customization and personalized production system	The ability to anticipate and meet the needs of customers, taking into account the interests of other stakeholders	The anticipation of expectations of customers and other stakeholders	Responsible quality management	Partnership shared values, accountability
3.0	Lean production	Quality as requirement conformity	Customer satisfaction with the cost-efficiency	Quality Management	Innovation, efficiency
2.0	Mass production	Quality as a set of product properties	Minimization of defects	Quality assurance	Audit, standardizatio n
1.0	Factory production	Quality as synonymous of excellence	Sorting of products	Quality control	Inspection

In the paper (Salimova & Vatolkina, 2018), quality 4.0 is based on eliminating the gap between the requirements of consumers and the properties of products, which arises due to the need to adapt mass products to the individual needs of a person or organization. The introduction of innovative methods of quality management should be accompanied by a radical transformation in its paradigm and principles regarding the enterprise or organization. Since the 1990s, new approaches in management have been emerging: talent management, value-based management, and sustainable

Humanities & Social Sciences Reviews
eISSN: 2395-6518, Vol 8, No 4, 2020, pp 483-495
https://doi.org/10.18510/hssr.2020.8447

development management. However, they are still disintegrated, which makes it difficult to form a new management paradigm that meets the challenges of the fourth industrial revolution. These challenges create prerequisites for rethinking the principles of quality management (International Organization for Standardization, 2015). The paper (Sader et al., 2017) summarizes the contributions of Industry 4.0 in the implementation of quality management principles, such as improved responsiveness, high coordination among all levels of the organization, effective evaluation for results, active dynamic interaction with market needs, instant re-configuration of production processes, rich information and analytics dashboards, etc. Based on the literature review, we offer the transformation of quality management principles as fundamental rules of doing business today (Table 2).

Table 2: Transformation of the principles of quality management in the transition to the technologies of Industry 4.0

Name	Characteristics
Shared Leadership	The transition from individual to team leadership, when the responsibility for quality is distributed among all team members on the basis of voluntary involvement
Talent Management	Use and development of talent in order to create value for all stakeholders, which are the main object in personnel management (serves as the basis for identifying and developing leaders and implementing the principle of shared leadership)
Customers' Engagement in Value Creation	Attracting consumers to actively participate in creating value as a full member of the production system
Project management & networking	Moving from a value chain to a value network
Management of Data & Innovation	Real-time management decisions, flexibility, and adaptability of all data-driven organization structures focus on continuous improvement
Capacity Building Through Partnerships with Stakeholders	Organizational capacity building based on attracting value to an open network of partners and stakeholders
Value-Based Management	The use of key values for the organization of universal values
Responsibility for a Sustainable Future	Focus on sustainable development: economic, environmental and social responsibility for the consequences of activities

METHODOLOGY

The importance and complexity of the problems with regards to the transformation of Quality Management Systems (QMS) among Russian enterprises and organizations in the digital era prompted a survey to be conducted in April - May 2019 among the expert community in the field of quality management as a part of the current study. A total of 50 experts participated in the survey representing enterprises and organizations of various industrial sectors (Table 3): heads of quality services in Russian enterprises and organizations; experts in the field of QMS; heads of departments who create and implement the organizational strategies. The regional sample of respondents included the representatives of the cities of Moscow and St. Petersburg along with the constituent entities of the Russian Federation: the Republic of Mari-El, the Republic of Mordovia, the Republic of Tatarstan, the Chuvash Republic, Krasnodar Territory, Izhevsk, Nizhny Novgorod, Penza, Samara, Tver, and Ulyanovsk Regions.

Table 3: Distribution of the respondents by the scope of activity, %

Scope of Activity of	Total	%
Electrical Engineering	6	12
Food Industry	8	16
Agriculture	2	4
Construction	2	4
Military Industry	2	4

Automation of Industrial Enterprise	4	8
Cargo Transportation	3	6
Banking	8	16
Higher Education and Research	9	18
Consulting	6	12
Total	50	100

Source: Elaborated by Authors

The survey was conducted using the Google docs service. Big Large business was represented by 26% of experts followed by medium business - 54% and 20% small business experts. The survey was organized in accordance with the stages of 'the Deming Plan-Do-Check-Act cycle' which was chosen based on its versatility and the possibility of application in various industries and fields of activity including the conduct of this study (Deming, 1986). This allowed the authors to clearly structure the goals and objectives of the study, plan and organize the study, monitor its implementation, and also suggest recommendations from on the results obtained (Figure 1).

PLAN Setting goals and objectives of the study; preparation of a research program; expert selection and communication	DO Conducting an online survey of experts; expert advice
ACT Bringing the results of the study to the attention of experts for their use in practice	CHECK Generalization and analysis of research results; drawing conclusions

Figure 1: Stages of a study based on the Deming cycle

In the planning stage (PLAN), a goal was determined and specific tasks were formulated to assess the prospects for the development of QMS in Industry 4.0 conditions. Based on the goals and objectives, a research program was conducted with a questionnaire for respondents. Next, a group of experts was selected to participate in the survey, and negotiations were held with them. When selecting the representatives of the expert community, one should be guided by the presence of a QMS in place at the enterprise or organization, as well as the willingness of enterprises and organizations to make changes that will cause the transition to the Industry 4.0 technologies. The developed questionnaire included 15 questions that were conditionally divided into the following groups:

- Focus on the implementation of key provisions of Industry 4.0 in the current development strategy;
- The importance of quality management in implementing the development strategy,
- Practical application of innovative Quality Management Methods specific to the fourth industrial revolution;
- Transformation of the QMS, methods, and principles of quality management in the context of the transition to Industry 4.0 technologies;
- The impact of ongoing changes on organizational culture.

At the stage of the study (DO), the questionnaire was sent to the experts and consulted on how to fill it up. The information was collected directly from the areas of the study. At the stage of analysis (CHECK), the results of the questionnaire were summarized, systematized according to the selected groups of questions and individual questions, and the obtained data were evaluated. In conclusion (ACT), the results of the questionnaire were brought to the attention of experts in order to develop recommendations for their use in the transformation processes related to QMS and the activities of the organization as a whole. It was supposed to receive feedback from the experts about how the results can be used in the practical activities of enterprises and organizations that participated in the study.

RESULTS AND DISCUSSION

In the course of the study, the respondents were asked to characterize the degree of reflection in the current development strategy of organizations that focus on key priorities of 'Industry 4.0'. 52% of respondents noted that the strategy implemented in their organization is based on existing experience and technological structure and is not focused on new

technological challenges. A total of 44% respondents indicated that the key priorities of Industry 4.0 are reflected in the current strategy whereas only 4% of the experts, representing military-industrial complex and banking sector enterprises, noted that the strategy of their enterprises and organizations is based on the priorities and technologies of Industry 4.0. The high importance of quality management as a key priority of the implemented development strategy was noted by 82% of the respondents though 46% of them indicated that the provisions of quality management, despite the great importance in ensuring competitiveness and sustainable development, are not reflected in the strategies implemented in their organization. 32% of the respondents intend to step up activities in the field of quality management in a five-year perspective, including the forthcoming challenges of the fourth industrial revolution. According to 26% of the experts, the organizations that they represent are constantly enhancing the approaches in quality management. A majority of the respondents (64%) agreed that, in the context of the transition to Industry 4.0 technologies, there is a growing importance to solve the quality management problems. Though 20% of the representatives of organizations agreed with this statement, they emphasized that they did not expect significant changes in quality management processes. The interviewed experts identified the most significant trends (no more than three) that impact the practice of quality management in enterprises or organizations (Table 4).

Table 4: The most significant trends affecting the quality management practice identified by the respondents

Trend	Respondents, %
Globalization of economy	64
Digitalization of the economy, increasing transparency of economic processes	54
The growing complexity of products/services	50
Focus on innovation	48
Shortening the life cycle of products on the market	32
The increasing importance of environmental issues	24

As can be seen from Table 4, the key trends that have a significant impact on the practice of quality management, according to the interviewed experts, are globalization and digitalization of the economy, increasing transparency of economic processes, the complexity of products and services, and focus on innovation. The composition of respondents in terms of the level of formation of management systems remained interesting. Close to 46% of the enterprises and organizations that participated in the survey implemented and certified QMS according to the requirements of the ISO 9001 standard of 2015 whereas 12% organizations had a certified integrated management system (mainly enterprises that represent the food industry) whereas 6% were certified according to the requirements of the national standard GOST RV 15.002–2012, 'System for the development and production of products for the production of military equipment. Quality Management Systems. General requirements'. In the rest, 16% were developing QMS while 18% do not have a formalized QMS and 2% of the enterprises and organizations that participated in the survey comply with the provisions of the international standard ISO 18295-1: 2017 'Customer contact centers - Part 1: Requirements for customer contact centers'.

The data presented confirm that the formation of QMS according to ISO 9001 standard remained the most popular and attractive approach used by enterprises and organizations worldwide. According to the ISO survey 2017 (International Organization for Standardization, 2017), the number of certified QMS in 2017 exceeded one million. The representatives of the majority of organizations surveyed (62%) believe that the role played by QMS in fourth industrial revolution conditions will increase, since the system is a mechanism to ensure total transparency and integration of processes, including the processes of interaction with consumers and other groups of stakeholders on quality issues. The invariable role played by QMS was indicated by 20% of respondents who believed that the system fulfills its role to the full whereas 12% noted that in fourth industrial revolution conditions, the development of QMS is not a priority and finally 6% of the participants found it difficult to answer.

During the study, the participants were asked to provide their opinion in identifying the systems that make up quality management and are fundamentally transformed in the first place according to the digitalization challenges. At the same time, the expert was able to note down several such components (Table 5).

Table 5: Elements of a Quality Management System that will fundamentally transform in the conditions of Industry 4.0 in the first place, distribution of answers, % (the respondents could choose several items)

Element	Respondents, %
Stakeholder Engagement	50
Planning, including risk management	48
Quality management of product and service life cycle processes	40
Leadership at all levels of organization management	38
Exchange and management of quality data	36
Means and methods of quality assurance	24
Organization Performance Assessment	14
Improvement	10

Humanities & Social Sciences Reviews
eISSN: 2395-6518, Vol 8, No 4, 2020, pp 483-495
https://doi.org/10.18510/hssr.2020.8447

As can be seen from Table 5, the respondents predominantly expected functional changes associated with the transformation of approaches and models of interaction from both external as well as internal environments. These changes mandate the usage of innovative quality management methods based on the technologies of the fourth industrial revolution. A list of the most significant methods and technologies that can be used for quality management in the transition to 'Industry 4.0' was also determined. The respondents were asked to indicate the innovative methods of quality management that are already applied to the enterprise or organization and are planned for use in the next 3-5 years (Table 6).

Table 6: Distribution of answers on the application of innovative methods of quality management (the respondents could choose several answers)

Answer	**Apply, %**	**Plan to apply, %**
Real-time customer feedback	40	55.1
Big Data Analysis of Quality	18	36.7
"Open quality", when all quality characteristics of any product are created, produced, promoted and implemented on the basis of an open and transparent approach for various stakeholders	26	30.6
Remote technologies (diagnostics, maintenance, training, communications)	38	26.5
The use of 3D modeling to improve the quality of processes of design, production, installation, and maintenance of products	10	14.3
Blockchain	8	14.3
Internet of Things, IoT	8	14.3
Virtual Supply Chain Quality Management	2	12.2
Integration of all quality management functions through artificial intelligence	6	10.2
Systems engineering based on integrated design of technical systems and software according to customer requirements	12	8.2
Autonomous robots	2	—

An analysis of the responses showed that almost one-third of the organizations (28%) currently do not use innovative methods of quality management. In organizations that use these methods, the most popular was real-time feedback from consumers and remote technologies, which confirms the priority of changes in interaction with stakeholders. These methods are leading in the survey results conducted among 50 leaders of European industrial companies as given in the literature (Krubasik et al., n.d.). When these two methods are used, it can bring the greatest benefit to the organization. So, 88% of the respondents representing European companies expect to receive benefits from the activation of consumer feedback in real-time and 86% from the introduction of remote technologies. At the same time, only a small number of representatives belonging to Russian organizations who participated in the study used 3D modeling, blockchain technology, and artificial intelligence, the Internet of things, autonomous robots and virtual quality management tools. Despite the high diffusion rate of these technologies, not more than 15% of organizations plan to use it for the next 3-5 years.

The most important condition for an effective transformation of QMS in the digital age is the organizational culture, which ensures the harmonization of personnel actions and the application of technologies (Akhmetshin et al., 2018). Therefore, the respondents were asked about the role played by organizational culture in the conditions of the fourth industrial revolution. A total of 78% of respondents assured that the role played by organizational culture is set to increase whereas 18% of respondents believed no impact in this regard and only 4% noted a decrease in the culture of the enterprise or organization. The growing importance of organizational culture is associated with a change in the principles of quality management. In the literature (Salimova & Vatolkina, 2018), the necessity to transform the principles of quality management based on the challenges of the fourth industrial revolution was mentioned. The study revealed an expert opinion on this transformation (Figure 2). The respondents could choose several principles. Figure 2 shows the answers of the experts as a percentage. The experts consider the key principles of the organization to be the attraction and retention of talents, the transition to the project and network approaches to management (the transition from the value chain to the value network) and partnership with stakeholders. The significant importance, according to the respondents, will be the involvement of consumers in value creation, shared leadership, value-based management, as well as responsibility for the future. It was shown in the literature (Kuei & Lu, 2013) that all the principles of Total Quality Management are related to Sustainable Development and the term 'quality-driven sustainable development' is introduced. The current study also showed that six of the eight principles, reflect the responsible behavior of the organization in relation to its employees,

Humanities & Social Sciences Reviews
eISSN: 2395-6518, Vol 8, No 4, 2020, pp 483-495
https://doi.org/10.18510/hssr.2020.8447

consumers, partners, and society as a whole, which should aim for modern enterprises and organizations to create responsible quality management. Thus, it is possible to define responsible quality management as a coordinated partnership of various groups of stakeholders to create products and services. This should meet the open quality (quality 4.0) standards-based on shared responsibility for management decisions in the interests of ensuring sustainable development.

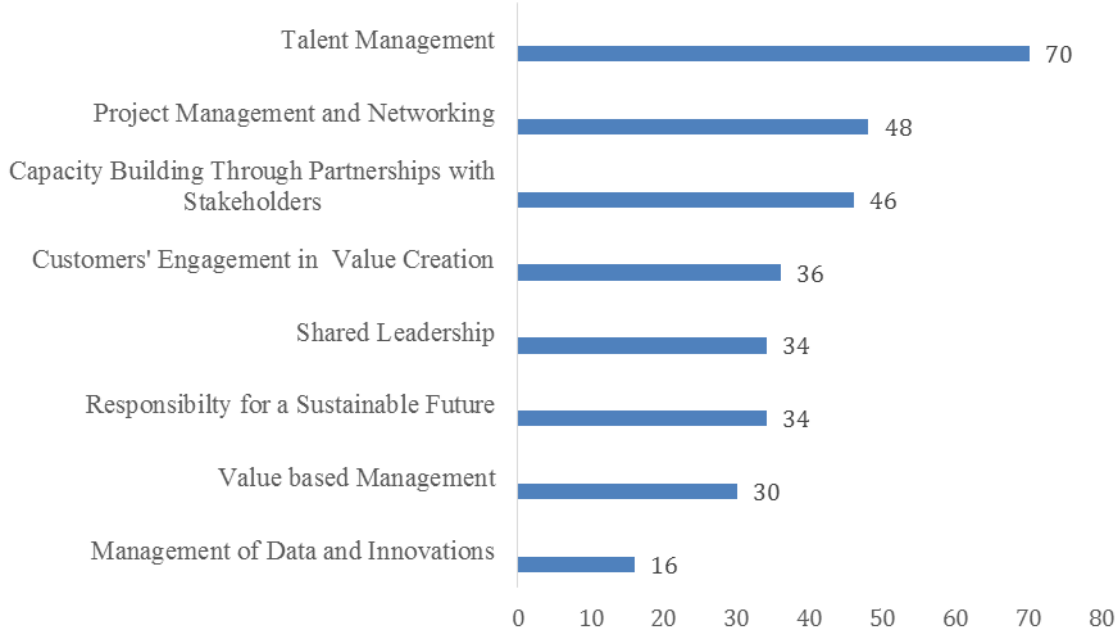

Figure 2: Distribution of answers about the most significant principles of Quality Management for organizations in the 3-5 years perspective, % (the respondents could choose several answers)

Source: Elaborated by Authors

We performed the analysis of correlation according to the criterion of consent χ2 Pearson on key aspects of the study. This criterion is used to assess the significance of the differences between the actual (revealed as a result of the study) number of outcomes or qualitative characteristics of the sample falling into each category, and the theoretical number that can be expected in the study groups with the validity of the null hypothesis (Grzhibovsky, 2008).

The value of the criterion χ2 was calculated using the formula:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{ij}-E_{ij})^2}{E_{ij}}, \quad (1)$$

where i is the row number (row, from 1 to r), j is the column number (from 1 to c), Oij is the actual number of observations in cell ij, Eij – expected number of observations in cell ij of the contingency tables.

The Cramer V criterion is used to estimate the tightness of the relationship between nominal variables:

$$V = \sqrt{\frac{\chi^2}{n(r-1)(c-1)}} \quad (2)$$

Research on the relationship between respondents 'responses to the following questions: "Is quality management a priority in Your organization at the moment?" and "Whether, in Your opinion, the role of the QMS will change in the conditions of the Fourth industrial revolution" assumes the construction of the conjugacy table (Table 7) and the table of expected quantities of observations (Table 8).

Table 7: Conjugacy table

	A1*	A2	A3	Total
B1	13	16	2	31
B2	4	4	2	10

B3	0	3	3	6
B4	1	0	2	3
Total	18	23	9	50

*A1 –«Yes, quality management is a key priority of our organization's strategy»

A2- «In general, yes, but quality management is not formalized as the strategy»

A3 – «No»

B1 – «The importance of the QMS will increase, since it is a mechanism for ensuring total transparency and integration of processes, including processes of interaction with consumers and other groups of stakeholders on quality issues»

B2 – «It will not change, since the QMS is already fulfilling its role»

B3 – «It will decrease because in the conditions of the fourth industrial revolution, the development of QMS is not a priority»

B4 – «Other»

Table 8: Expected quantities of observations

	A1	A2	A3
B1	11.16	14.26	5.58
B2	3.6	4.6	1.8
B3	2.16	2.76	1.08
B4	1.08	1.38	0.54

The found value of the criterion $\chi 2 = 13.885$ exceeds the critical value (12.6), therefore, based on the application of the criterion $\chi 2$ Pearson null hypothesis about the absence of a statistical relationship between the studied features can be rejected at a significance level of 5%. The calculated Kramer criterion V (V = 0.215) shows the average strength of the relationship. 70% of the companies surveyed, for whom quality management is a priority in the organization's strategy, believe that the role of the QMS in the Fourth industrial revolution will increase, since the QMS is a mechanism for ensuring total transparency and integration of processes, including processes of interaction with consumers and other groups of stakeholders on quality issues.

When identifying the relationship between the answers to the questions "Is quality management a priority in your organization at the moment?" and "Will the role of quality culture change in the fourth industrial revolution?" we also obtained a significant (average) strength of the relationship ($\chi 2 = 19.566$, $\chi 2kr = 12.6$, V = 0.255).

Organizations for which quality management is a key priority of the strategy believe that the role of quality culture in the conditions of the fourth industrial revolution will increase.

We see an interesting result when comparing the answers to the questions "Does your organization plan to increase the focus on the development of quality management in the next 3-5 years?" and "Do you agree with the statement that in the transition to the Fourth industrial revolution, the importance of quality management problems increases?". Although the relationship is lower than average ($\chi 2 = 22.316$, $\chi 2kr = 16.9$, V = 0.161), we see that 76% of organizations that are constantly improving approaches and methods of quality management, and plan to significantly strengthen the work in the field of quality management absolutely agree that in the transition to the Fourth industrial revolution, the importance of quality management issues increases and this is due to the transformation and integration of the processes of creating products and services.

The study revealed that the digital transformation of modern organizations and QMS are inevitable objective processes that should be reflected in the organizational development strategy as well as in the implemented approaches to quality management, elements, and processes of QMS resulting in the transformation of quality concept. The concept of 'open quality' or 'quality 4.0' is defined as the adaptive ability of products or services, at all stages of the life cycle, to satisfy the needs of a specific consumer through partnerships with stakeholders and digital management of the value chain. Quality 4.0 is based on bridging the gap between consumer requirements and product properties which arises due to the need to adapt mass products to meet the individual needs of a person or organization, on the transition to mass customization, as shown in the literature (Ceylan et al., 2018), and reducing the customer sacrifice (Porterfield & Ferguson, 2012).

The following principles of quality management may become key areas in the new conditions: shared leadership; attracting and retaining talent; involving consumers in value creation; transition to project and network management approaches; organization capacity building through partnerships with stakeholders; value-based management and responsibility for a sustainable future. Simultaneously, QMS, as an instrument of the global market, is called upon to become a driver that integrates digital technologies and the principles of the new management paradigm. The empirical

study results based on the survey of managers and specialists in the field of quality management showed that the development strategies of most of the surveyed enterprises and organizations were not yet focused on the changes that are taking place. A significant section of the respondents confirmed that the importance of solving quality management problems is increasing. At the same time, more than half of the respondents indicated that the globalization of the economy, digitalization, growing transparency of the processes that take place in the society, and the growing complexity of the products or services are the most significant trends that affect the practice of quality management. The representatives, from the majority of the enterprises surveyed, confirmed the hypothesis that the role of the Quality Management System in the conditions of Industry 4.0 is increasing as a mechanism to ensure transparency and integrated processes. There is a significant correlation between the current role of the QMS in the organization and the perception of its importance in the future. Hence, 76% of organizations that are constantly improving approaches and methods of quality management, and plan to significantly strengthen the work in the field of quality management absolutely agree that in the transition to the Fourth industrial revolution, the importance of quality management issues increases and this is due to the transformation and integration of the processes of creating products and services. The respondents identified talent attraction and retention as a key principle of quality management.

CONCLUSION

This study aims to examine the level of awareness and vision of prospects for the development of quality management and its corresponding systems in the era of transition to the technologies and principles of Industry 4.0 among quality management professionals of Russian companies. The results of the study found that despite the confirmation about the importance of using innovative methods of quality management and digital technologies, it has been revealed that this process involves above all, the transformation of managerial thinking itself. All transformational processes are focused on human beings as the core element of production and consumption systems. It means that transition to Quality 4.0 calls for the new understanding of stakeholders relationships and responsibilities, the transformation of core principles underlying decision-making in companies, and not only implementation of Industry 4.0 technologies for quality improvement.

LIMITATIONS AND STUDY FORWARD

The limitation of this study lies in the small scope of the research location, which only sees the case of a limited number of Russian companies and does not cover all types of industries.

As a direction for further research, it is planned to hold focus groups with experts in the field of quality with various objectives such as to study the development directions of a systematic approach to quality management in the era of the introduction of Industry 4.0 technologies, to develop recommendations for the implementation of Quality Management Systems in enterprises and organizations that use these technologies and the cascading tasks to integrate the proposed principles of quality management with existing integrated management systems. The authors of this paper plan to conduct an additional expanded survey with an increase in the number and composition of study participants, as well as to develop tactics for disseminating its results. Back in the mid-1970s, the American writer and thinker Pirsig (2006) noted that "the quality that creates the world arises as a relationship between a person and his experience".

ACKNOWLEDGEMENT

The reported study was funded by RFBR, project number 19-010-00968 «Methodology and tools of digitalization of quality management of the education system, and ensuring sustainable development of economic agents».

CO-AUTHORS CONTRIBUTION

The first author is the leader of the research project. She contributed with the formulation of the research hypothesis and conceptualization of the paper, prepared research methodology, participated in survey design and discussion of survey results, made final review and editing of the paper.

The second author contributed with the literature review and participated in the writing of a paper draft. She participated in the discussion of survey results.

The third author contributed to survey design, data collection, and formal analysis, discussion, and visualization of survey results.

The fourth author contributed with correlation analysis, discussion of survey results, and final conclusions of the research paper.

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