International Journal for Quality Research 18(4) 1199–1210
ISSN 1800-6450

Miladin Stefanovic
Slawomir Wawak
Elena Popkova
Milan Eric
Slobodan Mitrovic
Aleksandar Djordjevic[1]
Marija Zahar Djordjevic

Article info:
Received 09.09.2023.
Accepted 22.02.2024.

UDC – 005.336.3
DOI – 10.24874/IJQR18.04-18

FROM QUALITY 4.0 TO QUALITY 5.0 - THE TRANSITION ROADMAP

Abstract: *Numerous authors and researchers state that the transition from Industry 4.0 to Industry 5.0 is practically a transformation from digital manufacturing to a digital society with the convergence of science and technologies in Society 5.0, moving from technology to society. Changes are noticeable in the field of quality, and it is realistic to expect a transition from Quality 4.0 to Quality 5.0, which involves a significant shift in focus and approach. This research aims to answer several questions: 1) to clearly understand the current situation and learn lessons from the implementation, successes, and drawbacks of Quality 4.0; 2) to discuss the vision, mission, trends, and challenges in transitioning to Quality 5.0; 3) to define models for the development, implementation, and integration of Quality 5.0, covering important variables such as development strategy, digitalization strategy, level of investment, level of business excellence, competitiveness level, and knowledge level. In this manuscript, we will provide an analysis and insights from a literature review of published manuscripts in this field, insights from industry solutions, as well as results from recent research.*

Keywords: *Quality 4.0, Quality 5.0, Industry 4.0, Society 5.0, business strategy, trends, challenges*

1. Introduction

Advances in technology that form the foundation for Industry 4.0 have transformed production: isolated, optimized cells are coming together to form a fully integrated, automated, and optimized production flow. This leads to greater efficiencies and changes traditional production relationships among suppliers, producers, customers, as well as between humans and machines (Rüßmann et al., 2015).

Given that many authors consider Industry 4.0 to be a technological revolution, it is clear that this revolution targets society as a whole. In other words, new technologies have a profound and deep impact on all areas of human life and activity.

These new technologies that form the main pillars of Industry 4.0 are (Rüßmann et al., 2015; Lee et al., 2015; Brettel et al., 2014): Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cybersecurity, The Cloud, Additive Manufacturing, and Augmented Reality. They have provided an impact in various industrial and business fields, as well as society at large.

Industry 4.0 has a significant impact on various areas, leading to the development of concepts such as Quality 4.0 (Gunasekaran

[1] Corresponding author: Aleksandar Djordjevic
Email: adjordjevic@kg.ac.rs

et al., 2019), Maintenance 4.0 (Franciosi et al., 2018; Scurati et al., 2018), Safety 4.0 (Badri et al., 2018), Cybersecurity 4.0 (Lezzi et al., 2018), Operator 4.0 (Peruzzini et al., 2018), and Logistics 4.0 (Barreto et al., 2017). It also influences and connects with SCM and Lean (Sanders et al., 2014). Some authors have stated that Quality Management and the ISO 9001 standard have a great impact on three key aspects of Industry 4.0: vertical, horizontal, and end-to-end engineering integration (Foidl & Felderer, 2015). Given that the quality concept is based on three components: people, process, and technology, it is clear that changes in one of these components have a significant influence on the other two. This means that changes in technology will influence changes in processes as well as in people. The technological changes that brought us Industry 4.0 and consequently Quality 4.0 will further affect the way we conduct business and our lives.

Quality 4.0 refers to the current state of quality and organizational excellence in the context of Industry 4.0, addressing its needs and performance expectations.

Quality 5.0 signifies that prevailing theories and approaches to successfully running businesses are being challenged on several fronts (Arsovski 2023, Arsovski, Arsovski & Stefanovic 2023, Jovicic et al, 2023).

The field of quality management is undergoing noticeable changes, with a realistic transition from Quality 4.0 to Quality 5.0 on the horizon (Arsovski S., 2023b). This shift entails a significant change in focus and approach. This research aims to address several key questions:

1. Understanding the current situation and extracting lessons from the implementation, successes, and drawbacks of Quality 4.0.
2. Discussing the vision, mission, trends, and challenges associated with the transition to Quality 5.0.
3. Defining models for the development, implementation, and integration of Quality 5.0, considering essential variables such as development strategy, digitalization strategy, investment level, business excellence, competitiveness, and knowledge.

The manuscript will offer analysis and insights derived from a literature review of published works in this field, input from industry solutions, and recent research findings.

2. Literature review

Digitalization and new technologies are rapidly spreading throughout the world, specifically in business, industrial, and societal infrastructures (Basulo-Ribeiro et al., 2023; Williams, 2021). This digital transformation has reached every corner of the globe, often under different names, but profoundly changing all aspects of business and life, becoming a pillar of industrial policy. It is known in Europe as "Industry 4.0," in China as "Made in China 2025" (Bilgen, 2021), in Asia as "Smart Cities," and in North America as "Industrial Internet" (Khalil et al., 2021; Zengin et al., 2021).

Today, the landscape of Quality and Quality Management is heavily influenced by the implementation of digital technologies, following the roadmap of Industry 4.0. Concepts such as Quality 4.0 and QMS 4.0 are now prevalent (Chiarini, 2020; Butt, 2020; Zonnenshain & Kenett, 2020; Ammar et al., 2021). It is evident that fundamental principles of quality management have been significantly enhanced through the adoption of new technologies such as AI, big data analytics, and cloud computing. These advancements improve evidence-based decision-making and enhance quality control and management, alongside facilitating horizontal and vertical system integration (Asif, 2020; Sader, Husti & Daroczi, 2022; Saihi, Awad & Ben-Daya, 2023).

What are the biggest challenges in implementation of the Industry 4.0 or

underlying concepts?

Industry and Academia have similar answers (Bajic et al. 2020, Da Silva, et al. 2020, Sony & Naik 2020, Veile et al. 2020, Rajput & Singh 2021): Standardization and Reference Architecture, Managing Complex Systems, Delivering a Comprehensive Broadband Infrastructure, Safety and Security, Work Organization and Design, Training and Continuing Professional Development (CPD), Regulatory Framework and Resource Productivity and Efficiency (Kipper et al. 2020, Pang, Lee & Murshed 2023).

It can be concluded that Industry 4.0 represents a philosophical transformation of society, while Quality 4.0 advocates for the adoption of advanced ICT to enhance quality efficiency and competency (Hernandez-de-Menendez et al., 2020). Currently, the two biggest challenges are understanding and knowledge.

The world is becoming increasingly dynamic, with rapid and continuous changes. The transition from Industry 4.0 to Industry 5.0 signifies a shift from digital manufacturing to a digital society (Zizic et al., 2022), integrating science and technology in Society 5.0, moving from a focus on technology to one centered around society (Carayannis & Morawska-Jancelewicz, 2022).

Quality 5.0 is embedded in the concept with fundamental goals: Leave no person behind; Empower users through robust digital identities; Ensure business benefits society; Ensure safety and security for all; Establish new rules for a transformed environment; and Break through data barriers. The transition from Quality 4.0 to Quality 5.0 involves a significant shift in focus and approach (Arsovski S., 2023b). Key changes required include a human-centric focus, societal value, sustainability, collaboration with advanced technology, and a broadened scope.

In other words, the concept of Quality 5.0 within Society 5.0 is closely linked to sustainability, sustainable digital innovation, digital culture, social innovations, and the overall quality of life (Tavares, Azevedo & Marques, 2022).

Regarding everything mentioned above, we need to determine the nature of the changes occurring in the field of quality, who will be affected, how they will be affected, and whether there are possible suggestions and directions for navigating this path.

3. From Quality 4.0 to Quality 5.0

Quality 5.0 represents a significant shift in how quality is managed and achieved in manufacturing and industrial production.

Quality professionals can play a vital role in leading their organizations to apply proven quality disciplines to new, digital, and disruptive technologies.

It integrates advanced technologies with human-centered approaches to create a more proactive, collaborative, and efficient quality control system, benefiting both manufacturers and customers.

Customer demands are increasing, while we observe a decline in employee engagement and satisfaction.

In order to make identification and to find out about directions that authors World-wide notice we started with analysis of manuscripts that have been submitted to International Journal for Quality Research Scopus Q2 journal ESCI IF 1.2. We covered 6012 manuscripts covered from 75 different countries with following distribution: Afghanistan 2, Albania 18, Algeria 10, American Samoa 3, Australia 4, Austria 1, Azerbaijan 3, Bahrain 5, Bangladesh 20, Barbados 1, Belarus 1, Belgium 1, Bhutan 1, Bosnia and Herzegovina10, Brazil 38, Bulgaria 7, Cameroon 1, Canada 4, China 26, Colombia 11, Cook Islands 1, Croatia 15, Czech Republic 13, Denmark 1, Ecuador 1, Egypt 24, Eritrea 1, Estonia 1, Ethiopia 106, Finland 2, France 4, Gambia 1, Georgia 2, Germany 14, Ghana 9, Greece 2, Hong Kong 1, Hungary 2, India 1055, Indonesia 326, Iran 49, Iraq 60, Israel 4, Italy 4, Japan 3,

Jordan 59, Kazakhstan 12, Kenya 1, Kuwait 2, Lebanon 2, Libya 3, Macedonia 2, Malaysia 122, Mexico 4, Morocco 45, Myanmar (Burma) 3, Nepal 2, Netherlands 2, Nigeria 99, Niue 1, Norway 1, Oman 23, Pakistan 59, Palestine 4, Papua New Guinea 2, Peru 8, Philippines 19, Poland 77, Portugal 11, Romania 4, Russia 66, Saudi Arabia 72, Serbia 27, Slovakia 13, Slovenia 5, Somalia 1, South Africa 18, South Korea 2, Spain 8, Sri Lanka 7, Sudan 2, Sweden 1, Syria 1, Taiwan 4, Tanzania 5, Thailand 21, Trinidad and Tobago 1, Tunisia 12, Turkey 44, Ukraine 30, United Arab Emirates 25, United Kingdom 6, United States 11, Uzbekistan 19, Vietnam 59, Yemen 2, Zambia 7, and Zimbabwe 2.

Starting from the sample listed above in the first step we tried to find out which topic are the most frequent and what kind of shift has been going on in the period of last 6 years.

According to Figure 1 it is clear that most manuscripts are in the field of Performance measurement and management (925), Quality management (902), Process management and improvement (816), Quality of life (812), Management Systems (649).

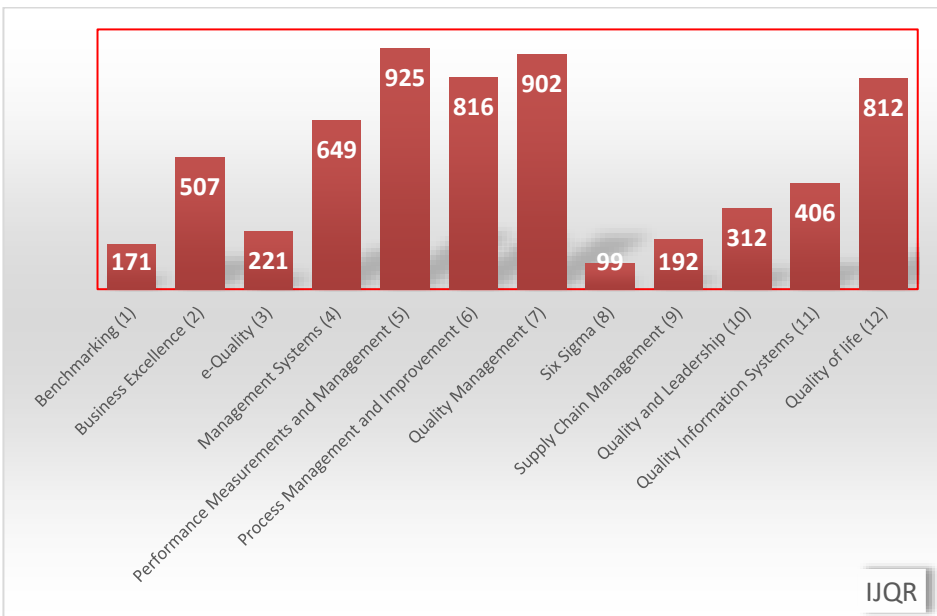

Figure 1. Distribution of most common topics in the sample (Sample: 75 countries / 6012 submissions)

It is important to emphasize that in the last 6 years topics Performance measurement and management and Process management and improvement have stabile share among total number of papers, the topic Quality of Life has increases share as well as e-Quality. Performance measurement, key performance indicators, process monitoring and improvement gain importance and get in the focus with increased implementation of technologies from Industry 4.0 tool box. When it comes to quality of life it has become in the focus of number of researches starting from the very broad definition of quality of human life in the concept of Society 4.0, and Society 5.0 to the concept of improving quality of working environment and life (having in mind that quality of life and working condition are extremely important for both traditional environment as

well as modern environment where humans interact with highly automatized and robotized platforms, AI and modern decision making systems. Exploring dimensions, indicators and concepts of quality of life in Industry 4.0 has becoming very interesting research topic.

Topics such Benchmarking, Quality and Leadership, Quality Information Sustems, and Business Excelence dicrease in number of submissions in last years. Mostly because some of these concpets emerges with other topics.

In the second step, we analyzed key words and terms that have been recurring, as well as indicators (increasing or decreasing), over the last six years in a sample of 6012 manuscripts from 75 different countries.

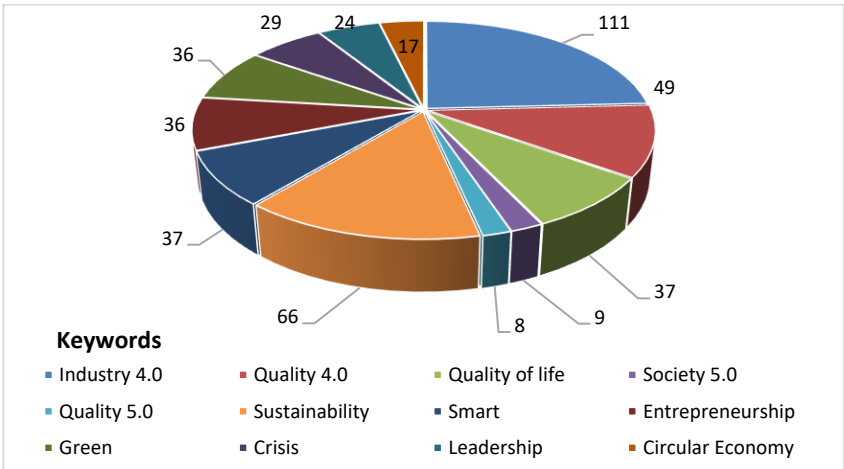

Figure 2. Emerging key words in analyzed mansucripts

According to Figure 2 distribution is as following: Industry 4.0 – 111; Quality 4.0 – 49; Quality of life – 37; Society 5.0 – 9; Quality 5.0 – 8; Sustainability – 66; Smart – 37; Entrepreneurship – 36; Green – 36; Crisis – 29; Leadership – 24; Circular Economy – 17.

Going back to the beginning of the analyzed period, the keyword "Industry 4.0" started to appear. As the concept developed, the term "Industry 4.0" increasingly appeared in various research studies. Initially, manuscripts focused on general concepts and the development of the idea. Over time, this evolved into analyses of the impacts of Industry 4.0 in different areas such as Quality 4.0, Maintenance 4.0, Safety 4.0, Cybersecurity 4.0, Logistics 4.0, as well as its influences and connections with SCM and Lean methodologies.

This concept was followed by the emergence of Quality 4.0 and an increased interest in Quality of Life. In the last couple of years, two more emerging concepts have arisen: Quality 5.0 and Society 5.0. In some cases, these concepts intersect.

During the COVID-19 period, there was an increase in the number of manuscripts dealing with concepts of crisis and crisis management. Consequently, some concepts evolved towards analyzing VUCA (volatility, uncertainty, complexity, ambiguity). Generally, VUCA provides the foundation for effective management and leadership, thereby bringing new value to more classical approaches in quality management and leadership, which are fundamental principles of quality management.

Concepts of sustainability and the green approach are steadily gaining presence

across different fields. Sustainability can be viewed as a domain of quality, and over time, they have developed and evolved alongside each other. In many cases, they intersect with other contemporary concepts and ideas.

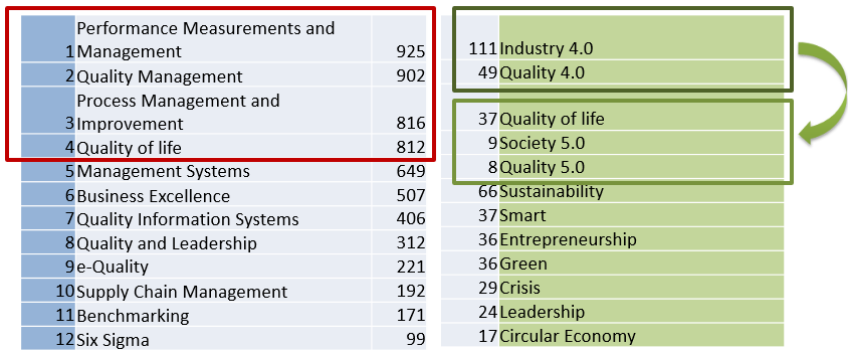

Figure 3. Major concepts addressed in IJQR manuscripts

Although Industry 4.0 is commonly used to describe the fourth industrial revolution, academics still face challenges in defining it precisely. However, there is general agreement that this concept encompasses Cyber-Physical Systems, Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cybersecurity, The Cloud, Additive Manufacturing, and Augmented Reality. From manuscripts presented in the International Journal for Quality Research, it is evident that Industry 4.0 has reached a more mature phase of development and significantly impacts (often extensively) all underlying and interconnected fields. Therefore, it is not surprising that the concept of Quality 4.0 has emerged alongside it.

There are different approaches and even definitions of Quality 4.0 but questions arise about how quality management processes and quality as while could benefit and adapt in the era of digital technologies. Quality 4.0 is an extended approach to quality management, where recent technologies are being integrated with traditional quality practices (QC, QA, TQM) to expand the quality management scope and to improve quality activities (Sader, Husti, & Daroczi 2022). Quality 4.0, is characterized by automation, machine learning, computer vision, big data analytics, intelligent systems, virtualization, AI, and the Internet of Things. According to analyzed manuscripts the first mansucript tackling Quality 4.0 started with attempt to make proper definition, features, to list technologies, possible applications, and challenges. The first manuscripts were general, then second grup of anuscripts started with possbility of implementatin of listed technologies and possible benefits of quality using advanced and digital technologies. The first mansucripts deal with digitalization of the process, some of them find good and proper use of computr vision in quality control and non-conformity detection. The first reseraches generally put focus on software side based on computers for image procesing since in last years proces of technology dicrease, ther are musch more example of usage of cameras with embeded IA modules. Genneraly, we are witnesing the decrease of prices of equipment so compelx system robotics, sensors etc are much ore affordable. A large part of the manuscripts deal with the implementation of various technologies from the Industry 4.0 toolbox into daily activities in quality control and management. This

includes leveraging advanced communication capabilities, mobile devices, and data warehouses for storing large amounts of process data.

But in the recent period we have one more key word emerging Quality 5.0. Also we have witness that concept Society 5.0 emerges as well as increased attention to Quality of life.

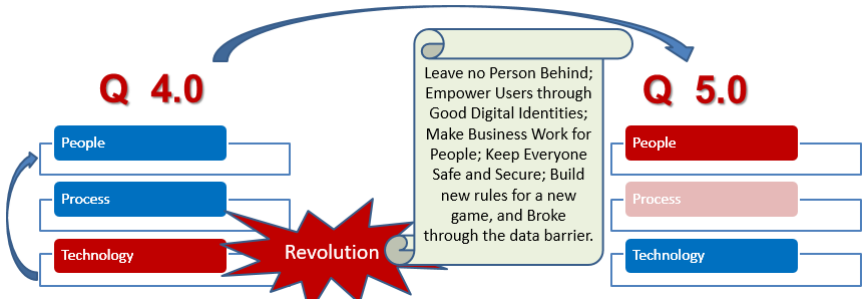

Figure 4. Transition from concept Quality 4.0 to Quality 5.0

We can notice one thing the shift from the concept Quality 4.0 to Quality 5.0 is happening according to the submissions that we have analyzed (Considering topics, key words, papers) (Figure 3).

We can say according to previous experience that research community have ability to predict shifts, at least according to published researches.

Now we need to make analysis of the shifts that is going on, character to identify possible fields that will be affected as well as to generate some recommendation how to deal with this transition.

As we know Quality deals with three major components that interact in many different ways: people, processes and technology. We have witnessed that changes in one affect and drive changes in other two (Figure 4). Starting from idea, definitions, experiences and practices of Industry 4.0 we can state that this revolution, technological was driven by digitalization. This revolution also affects and concept of Quality 4.0 emerged mostly driven by technological revolution of Industry 4.0 and its impact on other fields (such it was stated in the text above). Technology has profoundly influenced and impacted the basic principles of quality management, including customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management. With each technological advancement, there has been a significant impact on both individuals and processes. Recent research indicates that following the technological revolution that introduced Quality 4.0, we are poised to witness further changes that will enhance approaches to process management and further benefit individuals involved.

In this transition we need to take care about important principles: Leave no person behind; Empower users through good digital identities; Make business work for people; Keep everyone safe and secure; Build new rules for a new game and Broke through the data barrier.

The pressing question is: Are we witnessing another change that we will label as Quality 5.0, and what are the main characteristics of this new transition? Alternatively, is this change simply an extension of the Quality 4.0 transformation? Regardless of whether we categorize this new change as Quality 5.0 or not, several trends are becoming apparent: Quality 5.0 places a greater emphasis on sustainability, resilience, social values, and broader perspectives (such as green and smart initiatives).

Considering the keywords, topics, and concepts presented in manuscripts submitted to the International Journal for Quality Research, some insights become clearer. The ongoing change will primarily focus on human resources and improved approaches to process management. In the analyzed manuscripts, there is a noticeable positive correlation among the topics of Quality 5.0, Society 5.0, and Quality of Life. Currently, while we may not have a large sample of manuscripts specifically addressing the concept of Quality 5.0, all of them address improvements and changes in human resources, enhancements in competencies and knowledge, and better collaboration between humans and advanced technologies.

Additional demands that will drive Quality 5.0 include enhanced human collaboration with advanced technology. Quality 5.0 envisions humans working alongside AI-powered robots and advanced technologies to optimize workplace processes.

The key issue is the necessity for new and improved knowledge, skills, and attitudes among all workers, particularly those involved in quality management. We require a "Quality Manager 5.0" who possesses updated competencies and capabilities to effectively navigate and lead in the evolving landscape of Quality 5.0:

- Quality professionals in the future, must have skills such as, creative thinking, be leaders, know how to communicate, and work as a team and capable of complex problem-solving with emotional intelligence.
- Besides that, they must have knowledge of new technologies, that is cyber-physical production systems and combine that with the best quality management practices, where their decisions will be based on Big Data.

We are going to face number of important questions connected with Training and Continuing Professional Development (CPD).

There are numerous research studies, such as Santos et al. (2021), which provide frameworks for the new essential quality management skills required for Quality Managers 4.0. This raises important questions, particularly regarding the significant changes anticipated in human resources scope, new knowledge, skills, and evolving roles of professionals in the field of quality management, both in Industry 4.0 and future concepts.

Besides the ongoing and future focus on human resources and social values, the new concept clearly demonstrates increased interest in sustainability, the green agenda, and broader perspectives. Analyzing the keywords from Figure 2, we observe that concepts of Quality 4.0 and 5.0 are frequently associated with: Sustainability (66 mentions), Smart (37 mentions), Entrepreneurship (36 mentions), Green (36 mentions), Crisis (29 mentions), Leadership (24 mentions), and Circular Economy (17 mentions).

It can be predicted that these changes will indeed affect people, and it raises questions about what will happen with the third component, processes. We believe that this field opens up a wide area for research and future improvements.

As observed, the first revolution occurred in the field of technology, and now developments and changes in human resources are set to take place. However, several other factors will also be necessary to fully implement and evolve the concept, whether it's Quality 4.0 advancing to a new level or transitioning into the concept of Quality 5.0.

Currently, we are in a technology revolution that has introduced numerous technical solutions and equipment. The primary demand now is towards standardization and interoperability of these systems. Another critical issue is the management of complex systems, as well as work organization and design. Addressing these issues is crucial to unlocking the full potential of the industrial

revolution known as Industry 4.0.

Standardization and reference architecture, along with process specification and modeling languages, represent crucial areas for future development. Process specification and generation based on the model-driven paradigm aim to enhance factory flexibility and address challenges more efficiently in the era of Industry 4.0.

There is a growing demand for modeling languages that produce machine-readable models. These models should be independent of any specific production or business system, allowing for automatic transformation into various target environments. Additionally, there is a need for generators that can automatically convert production process models into different types of manufacturing documents (such as those for manufacturing, maintenance, and quality).

4. DISCUSION AND CONCLUSION

We are witnessing the major changes in technology and change that we defined as industrial revolution or Industry 4.0. This concept has been with as for a while and we have number of theoretical and practical researches that depict different aspects of Industry 4.0. The concept of Industry 4.0 affected all aspects of business and industry so number of X.4,0 concepts appeared. The Quality 4.0 is one of the examples. The changes in technology affected the Quality bringing the new opportunities as well as challenges in concept of Quality. Also new possibilities brought new values in core principles of quality and quality management. It affected mission and vision of achieving quality and managing quality in the new era and new environment.

In this manuscript we tend to make analysis of current change and transformation in the field of quality by analyzing submissions and researched to International Journal for Quality Research. According to analysis we can detect the further change, the first one appear in the field of usage of digitalization and technology in the field of quality, consequently the other to concepts were affected people and processes. Authors are stating that new change could be entitled as Quality 5.0, right now we can't provide full evidence is it the ne revolutionary change or is it adjustment of the system for the change that appeared in technology. Many historical examples teach us that industrial revolutions are often followed by significant social and political changes (as evidenced by the effects seen after previous industrial revolutions). This is why the concept of Society 5.0 has emerged, linking to previous concepts and indicating where the next changes will likely occur. One thing is clear: Quality 5.0 places a strong emphasis on sustainability, resilience, social values, and broader perspectives (including green and smart initiatives).

Considering all factors, the most significant changes will occur in the domain of human resources, focusing on new roles, management responsibilities, collaboration environments, and the development of necessary knowledge and skills. Additionally, there will be changes in the development of new modeling languages and models aimed at enabling interoperability and maximizing the utilization of new technologies across complex and diverse platforms, both digital and traditional.

To effectively advance, we must adopt new models for developing and integrating key components within the concept of Quality X. This includes strategies for further digitalization accompanied by increased levels of investment in business excellence and competitiveness. Achieving this requires heightened investment in human resources to ensure individuals can effectively navigate and maximize the technological changes occurring.

Additionally, technological advancements must undergo a mature phase characterized by increased standardization and the

development of reference architectures. This approach is essential for establishing cohesive and interoperable systems that can fully leverage the benefits of evolving technologies.

References:

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*, 5089-5096.

Arsovski S. (2023). Quality 5.0: from challenges to reality. *Journal of Innovations in Business and Industry, 1*(1), 13-21. https://doi.org/10.61552/JIBI.2023.01.002

Arsovski S. (2023b). The sustainability transition from quality 4.0 to quality 5.0. A role of sustainable spiritual and intelligent leadership in the creation of intangible capital for future. *Journal of Innovations in Business and Industry*, *2*(1), 53-64. doi: 10.61552/JIBI.2023.02.001

Asif, M. (2020). Are QM models aligned with Industry 4.0? A perspective on current practices. *Journal of Cleaner Production*, 258, 120820.

Badri, A., Boudreau-Trudel, B., & Souissi, A. S. (2018).Occupational health and safety in the industry 4.0 era: A cause for major concern?. *Safety Science*, *109*, 403-411. https://doi.org/10.1016/j.ssci.2018.06.012.

Bajic, B., Rikalovic, A., Suzic, N., & Piuri, V. (2020). Industry 4.0 implementation challenges and opportunities: A managerial perspective. *IEEE Systems Journal*, *15*(1), 546-559.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing*, *13*, 1245-1252. https://doi.org/10.1016/j.promfg.2017.09.045.

Basulo-Ribeiro, J., Amorim, M., & Teixeira, L. (2023). How to accelerate digital transformation in companies with Lean Philosophy? Contributions based on a practical case. *International Journal of Industrial Engineering and Management*, *14*(2), 94-104. doi: 10.24867/IJIEM-2023-2-326

Bilgen, H. (2021). A global comparison methodology to determine critical requirements for achieving industry 4.0. *Technological Forecasting and Social Change*, *172*, 121036.

Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. *International journal of mechanical, industrial science and engineering*, *8*(1), 37-44.

Butt, J. (2020). A strategic roadmap for the manufacturing industry to implement industry 4.0. *Designs*, *4*(2), 11.

Carayannis, E. G., & Morawska-Jancelewicz, J. (2022). The futures of Europe: Society 5.0 and Industry 5.0 as driving forces of future universities. *Journal of the Knowledge Economy*, *13*(4), 3445-3471.

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.

Da Silva, V. L., Kovaleski, J. L., Pagani, R. N., Silva, J. D. M., & Corsi, A. (2020). Implementation of Industry 4.0 concept in companies: Empirical evidences. *International Journal of Computer Integrated Manufacturing*, *33*(4), 325-342.

Foidl, H., & Felderer, M. (2015, November). Research challenges of industry 4.0 for quality management. In *International Conference on Enterprise Resource Planning Systems* (pp. 121-137). Springer, Cham.

Franciosi, C., Iung, B., Miranda, S., & Riemma, S. (2018).Maintenance for Sustainability in the Industry 4.0 context: a Scoping Literature Review.*IFAC-PapersOnLine*, *51*(11), 903-908.https://doi.org/10.1016/j.ifacol.2018.08.459

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.

Hernandez-de-Menendez, M., Morales-Menendez, R., Escobar, C. A., & McGovern, M. (2020). Competencies for industry 4.0. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *14*, 1511-1524.

Jovicic, A., Savković, M., Stefanovic, M., & Macuzic, I. (2023) The impact of horizontal and vertical system integration on quality 4.0. *Journal of Innovations in Business and Industry, 1* (4), 191-200.

Khalil, R. A., Saeed, N., Masood, M., Fard, Y. M., Alouini, M. S., & Al-Naffouri, T. Y. (2021). Deep learning in the industrial internet of things: Potentials, challenges, and emerging applications. *IEEE Internet of Things Journal*, *8*(14), 11016-11040.

Kipper, L. M., Furstenau, L. B., Hoppe, D., Frozza, R., & Iepsen, S. (2020). Scopus scientific mapping production in industry 4.0 (2011–2018): a bibliometric analysis. *International Journal of Production Research*, *58*(6), 1605-1627.

Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters*, *3(2015)*, 18-23.

Pang, T. Y., Lee, T. K., & Murshed, M. (2023). Towards a New Paradigm for Digital Health Training and Education in Australia: Exploring the Implication of the Fifth Industrial Revolution. *Applied Sciences*, *13*(11), 6854.

Peruzzini, M., Grandi, F., & Pellicciari, M. (2018). Exploring the potential of Operator 4.0 interface and monitoring. *Computers & Industrial Engineering*. https://doi.org/10.1016/j.cie.2018.12.047.

Rajput, S., & Singh, S. P. (2021). Industry 4.0− challenges to implement circular economy. *Benchmarking: An International Journal*, *28*(5), 1717-1739.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*(1), 54-89.

Sader, S., Husti, I., & Daroczi, M. (2022). A review of quality 4.0: Definitions, features, technologies, applications, and challenges. *Total Quality Management & Business Excellence*, *33*(9-10), 1164-1182.

Sader, S., Husti, I., & Daroczi, M. (2022). A review of quality 4.0: Definitions, features, technologies, applications, and challenges. *Total Quality Management & Business Excellence*, *33*(9-10), 1164-1182.

Saihi, A., Awad, M., & Ben-Daya, M. (2023). Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices–a systematic review. *International Journal of Quality & Reliability Management*, 40(2), 628-650.

Sanders, A., Elangeswaran, C., & Wulfsberg, J. P. (2016). Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management (JIEM)*, *9*(3), 811-833.

Santos, G., Sá, J. C., Félix, M. J., Barreto, L., Carvalho, F., Doiro, M., Zgodavová K., & Stefanović, M. (2021). New needed quality management skills for quality managers 4.0. *Sustainability*, *13*(11), 6149.

Scurati, G. W., Gattullo, M., Fiorentino, M., Ferrise, F., Bordegoni, M., & Uva, A. E. (2018). Converting maintenance actions into standard symbols for Augmented Reality applications in Industry 4.0. *Computers in Industry*, *98*, 68-79.https://doi.org/10.1016/j.compind.2018.02.001.

Sony, M., & Naik, S. (2020). Critical factors for the successful implementation of Industry 4.0: a review and future research direction. *Production Planning & Control*, *31*(10), 799-815.

Tavares, M. C., Azevedo, G., & Marques, R. P. (2022). The challenges and opportunities of era 5.0 for a more humanistic and sustainable society—a literature review. *Societies*, *12*(6), 149.

Veile, J. W., Kiel, D., Müller, J. M., & Voigt, K. I. (2020). Lessons learned from Industry 4.0 implementation in the German manufacturing industry. *Journal of Manufacturing Technology Management*, *31*(5), 977-997.

Williams, L. D. (2021). Concepts of Digital Economy and Industry 4.0 in Intelligent and information systems. *International Journal of Intelligent Networks*, *2*, 122-129.

Zengin, Y., Naktiyok, S., Kaygın, E., Kavak, O., & Topçuoğlu, E. (2021). An investigation upon industry 4.0 and society 5.0 within the context of sustainable development goals. *Sustainability*, *13*(5), 2682.

Zizic, M. C., Mladineo, M., Gjeldum, N., & Celent, L. (2022). From industry 4.0 towards industry 5.0: A review and analysis of paradigm shift for the people, organization and technology. *Energies*, *15*(14), 5221.

Zonnenshain, A., & Kenett, R. S. (2020). Quality 4.0—the challenging future of quality engineering. *Quality Engineering*, *32*(4), 614-626.

Miladin Stefanovic
Faculty of Engineering,
University of Kragujevac,
Serbia
miladin@kg.ac.rs
ORCID 0000-0002-2681-0875

Slawomir Wawak
Cracow University of Economics,
Poland
slawomir.wawak@uek.krakow.pl
ORCID 0000-0001-6206-4489

Elena Popkova
Armenian State University of Economics,
Yerevan,
Armenia
elenapopkova@yahoo.com
ORCID 0000-0003-2136-2767

Milan Eric
Faculty of Engineering,
University of Kragujevac,
Serbia
ericm@kg.ac.rs
ORCID 0000-0001-8691-4863

Slobodan Mitrovic
Faculty of Engineering,
University of Kragujevac,
Serbia
boban@kg.ac.rs
ORCID 0000-0003-3290-7873

Aleksandar Djordjevic
Faculty of Engineering,
University of Kragujevac,
Serbia
adjordjevic@kg.ac.rs
ORCID 0000-0003-2856-6578

Marija Zahar Djordjevic
Faculty of Engineering,
University of Kragujevac,
Serbia
maja_199@yahoo.com
ORCID 0000-0003-4905-2728