Analysis and Prioritization of Quality 4.0 dimensions and companies' readiness to adapt to industry 4.0 evolutions through Bayesian Best - Worst method

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Abstract

Introduction: The evolutions of the Fourth Industrial Revolution helped many companies and organizations to survive, achieving economic success and ensuring competitiveness, and has put them under pressure to align their goals, policies, strategies, and the nature of their operations with these changes. Therefore, the concept of quality and the nature of its operations to meet customers' needs in the digital era must be changed and updated in accordance with these developments. Quality 4.0 facilitates coordination between quality management and industry 4.0. A review of the literature shows that the concepts and perspectives of quality 4.0 have not yet evolved and matured, and therefore there is little research on the alignment of quality 4.0 management with industry 4.0 technologies.

Purpose: The main purpose of this study is to identify and evaluate quality 4.0 indicators to draw a roadmap for organizations to align quality 4.0 management with industry 4.0 technologies. **Methodology**: To achieve the goal, first the literature of quality 4.0, quality 4.0 management as well as industry 4.0 technologies were studied to gain a broad understanding of the subject. Then the dimensions and quality 4.0 indicators that are potentially affected by the implementation of Industry 4.0 are identified. Next, the importance and prioritization of dimensions and quality 4.0 indicators for alignment with Industry 4.0 using the Bayesian Best-Worst method are determined.

Findings: The research findings identify the dimensions and quality 4.0 indicators in different classes and then prioritize each of the indicators according to their importance in aligning quality 4.0 management with industry 4.0 technologies.

Conclusion: The results of this study help to facilitate the process of change management towards quality 4.0 in companies and outline a roadmap for companies to prioritize the nature of their operations regarding the changes and developments and the need for revision and provides investment in quality 4.0 management.

Keywords: Quality 4.0, Quality 4.0 Management, Change Management, Quality 4.0 Organizational Dimensions, Bayesian Best-Worst Method

Category: Research paper

Introduction

The development of the Fourth Industrial Revolution (FIR) enabled the connection between the digital and physical worlds and integrated individuals, devices and processes (Arsovski, 2019). This poses a significant challenge to the quality profession by emphasizing the need to adapt to technological innovations, modern data analysis, and the entrepreneurial ecosystem that characterized the Fourth Industrial Revolution (Zonnenshain and Kenett, 2020).

Quality 4.0 expanded as a response to production changes, both by digitizing quality management systems and by using digital tools to enhance productivity and quality of products Moreover, Quality 4.0 supports the digitization of management of quality, not only of products and technologies but also of processes and their cooperative integration with individuals. Another aspect that should be considered by Quality 4.0 is that the cost of technology has been decreasing over time, while the cost of labor increases over time. Therefore, to stay competitive in business, Quality 4.0 acceptance is inevitable (Yadav et al., 2021). However, understanding the various aspects and functions and implementing the tools of Industry 4.0 in diverse industrial environments continues to pose major challenges for academia and business alike. A review of the literature shows that the concepts and perspectives of Quality 4.0 have not yet evolved and hence there is little research on the alignment of quality management with Industry 4.0 technologies.

Given that the Industry 4.0 research literature is evolving rapidly and a great deal of conceptual and experimental work has taken place around the world over the past few years. However, research work, especially experimental work on Quality 4.0 is still evolving. Researchers believe that Quality 4.0 can be considered as a social and technical system. So far, the main tasks of quality management are process monitoring, and failures were controlled by in-process controls. However, due to advanced measurement technologies and advanced analytical capabilities, there is a shift in predicting and recognizing process conditions (changes in process performance) and understanding the quality performance characteristics that are important to customers and the company. Such a change helps us to measure and predict the system quality much sooner than those offered by traditional preventive quality assurance approaches. Such thinking is possible due to the emergence of big data, automation and data analytics. In this regard, the main purpose of this study is to identify the dimensions and quality 4.0 indicators in order to prepare companies to adapt to Industry 4.0 developments.

In this paper, the concept of Quality 4.0 is first examined. Then, various Quality 4.0 factors are presented to adapt the traditional quality management to the developments of the Fourth Industrial Revolution. In the methodology section, the importance of each of the Quality 4.0 factors is determined and finally, according to the priorities and the importance of Quality 4.0 factors, suggestions are presented for the studied industries.

Literature Review

Quality 4.0

The term Quality 4.0 is to pursue quality performance in the age of digital transformation. Quality 4.0 does not focus solely on technology, and other basic principles of quality such as people, processes, tools, techniques, methodologies, analytical thinking, etc. are an integral part of the current quality revolution. Quality 4.0 does not replace traditional quality methods, but is built and improved based on them.

Jacob (2017) states that the goal of Quality 4.0 is to prepare quality performance and play a leading role in the use of I4.0 technologies to continuously deliver high quality products (Chiarini and Kumar, 2021, Jacob, 2017). Quality 4.0 provides industry-leading quality, framework, and language leaders to reap the benefits of step-by-step performance that extends across the entire value chain, including consumers, customers, field services, logistics, manufacturing, engineering, R&D, and suppliers (Chiarini and Kumar, 2021). According Sony et al. (2020), under the Quality 4.0 concept, digital tools may be used to improve the ability of organizations to consistently deliver high quality products (Sony et al., 2021). Chiarini and Kumar (2021) attempted to explain the concept of Quality 4.0 using an exploratory method. Based on their findings, a theoretical model for Quality 4.0 was proposed that included eleven Quality 4.0 topics in three categories - people, process and technology. These topics include model development, top management, process mapping, data collection and integration with enterprise resource planning systems, use of artificial intelligence software, machine-to-machine data communications, product identification and traceability, document control and skills digital for quality control staff. In general, the evolution of quality concepts in accordance with the evolution of the Industrial Revolution in different periods is shown in Table 1.

Table 1- The evolution of quality concepts in relation to the Industrial Revolution (Sader et al., 2021)

Evolution	**Industry 1.0**	**Industry 2.0**	**Industry 3.0**	**Industry 4.0**
Product	Steam Age - Mechanical Production Systems	The Age of Electricity - Mass Production	Information Age - ICT and Automation Systems	The Age of Cyber Physical Systems - Mass Customization
Quality	Quality control - inspection	Quality Assurance	Total Quality Management	Quality responsibility - open quality

There are five main motivations for implementing Quality 4.0 in organizations (Sader et al., 2021): (1) reliable information, (2) big data to drive quality applications, (3) improving customer satisfaction, (4) improving productivity and (5) long-term savings.

Quality 4.0 Management

With globalization and industrialization, meeting customer expectations is constantly increasing, and the pressure on organizations to provide high quality products and services on time and at a lower cost to maintain its position in the market is increasing day by day (Antony et al., 2021a). In such situations, Quality Management (QM) seeks to optimize processes and maintain the quality of products or services and further develop them (Hehenberger, 2011).

Quality management is an essential basis for companies due to increasing expectations of customers, market competition and is therefore part of the company's goals, strategies and policies (Zonnenshain and Kenett, 2020). With the advent of I4.0, quality management has evolved through the use of digital technologies related to external or internal data networks (Dias et al., 2021). Industry 4.0 tools can help increase the quality of production processes, such as the quality of information needed for optimization, planning and operation, the quality of forecasting, simulation and prototyping, and better employee participation (Godina and Matias 2018). Quality 4.0 refers to the digitalization of quality management in the Industry 4.0, and different perspectives must be considered in order to enable decisive implementation and thus monitor the progress of the production environment towards the acquisition of new technologies (Jamkhaneh et al., 2021). Thus, proper quality management, based on industry-based processes and technologies, facilitates product development, reduces failure, and increases customer satisfaction (Glogovac et al., 2022).

Quality 4.0 criteria and dimensions

Quality 4.0 is a novel approach to manage quality where digital tools enhance the organization's ability to consistently deliver high-performance products to customers (Küpper et al., 2019). Even employee readiness to comply with the quality management program in Industry 4.0 has become a common theme in research circles (Gunasekaran et al., 2019). Research by Küpper et al. (2019) found that one-third of the 221 manufacturing companies knew how to digitize the skills and plans of quality management, and seventeen percent thought their factory had the right people to implement the Quality 4.0 plan. Five main barriers for implementing Q4.0 are: lack of digital skills and talents, lack of uncertain digital strategy and culture, outdated infrastructure and dispersion of quality data. Krubasik et al. (2015) found that the use of quality methods in I4.0 is low (27%), but the majority of respondents (73%) believe Q4.0 benefits of innovative quality. In a study by Jacob (2017) 11 axes consist of: (1) Data, (2) Analysis, (3) Connectivity, (4) Collaboration, (5) Application development, (6) Scalability, (7) Management system, (8) Compliance, (9) Culture, (10) Leadership, and (11) Competence. Radziwill (2018) argued that quality professionals should lead the transformation from the classical perspective to Quality 4.0. Required skills are: A) Systemic thinking, B) Data-based decision making; C) Leadership for organizational learning, D) Creating processes for continuous improvement; E) Understand how decisions affect individuals: life, relationships, communities, welfare, health and society in general.

Kwon et al. (2014) presented big data analytics as an innovative information technology capability and a strategic resource that can create a competitive advantage for a host company. Given this situation, they examined the dynamics between data quality management at the company level and its impact on data use and the intention to accept big data analysis. Janssen et al. (2020) provides a conceptual framework for the adoption of China blockchain technology that depicts the complex relationships between institutional, market and technical factors. Their findings show that the factors presented in the framework (institutional, market and technical) interact with each other and affect each other. Adoption of advanced technologies can be more challenging for emerging countries (Kumar and Siddharthan 2013). Factors such as ICT infrastructure, culture, level of education, and economic and political instability can also play a role in perceiving value and thus the level of investment in advanced technologies (Frank et al., 2016). Dalenogare et al. (2018) in a study analyzed the benefits of development of product, operations and aspects of the expected side effects of an industry to implement I4.0 technologies. They found that only some of them are beneficial for the industry. Frank et al. (2015) believe that there are three socio-technical dimensions to technology to consider the process of digitalization in order to implement the Industry 4.0, which are: work organization, human factors and external environment. Gunasekaran et al. (2019) sought to explore quality improvements and their implications for economics, decision-making models, business models, human perspectives, and technology, and future research paths such as the importance of human issues in quality management in line with the industrial revolution and alignment. Determine the technological revolution over time and the involvement of human aspects in quality management.

Dovleac (2021) Research focuses on providing knowledge management practices for companies seeking Quality 4.0 acceptance to ensure that these companies use relevant data in their day-to-day operations. In other words, identifying relevant data and ways to manage it is considered as a major obstacle in implementing Quality 4.0 practices. Sony et al. (2020) believes that one of the key components of Quality 4.0 is the integration and use of data, as well as knowledge, to improve design quality, quality of compliance and performance quality, and to optimize activities in a company. Another key aspect of Quality 4.0 is senior management support and the selection of current training tools and modules that apply to companies that are seeking to integrate Quality 4.0. Sony et al. (2021) used online surveys of experts in top companies in Europe and the United States to examine the motivations, readiness, and barriers factors for Quality 4.0 implementation. Their findings show that five motivational factors, as well as barriers and readiness for Quality 4.0 were identified and then ranked in order of importance.

According to the literature, research by Jacob (2017) is one of the most comprehensive research that has identified indicators and effective factors in adapting the traditional quality management system to the developments of the FIR and is the main basis of this study. An overview of the literature review is shown in Table 2.

Table 2- An overview of the literature review

Cod	**Dimensions of Quality 4.0**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Present study
C1	Data	●	●	●		●	●	●	●	●	●	●	●			●
C2	Analytics	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
C3	Connectivity	●		●		●		●			●		●	●	●	●
C4	Collaboration	●	●		●	●		●	●	●	●	●	●		●	●
C5	App development	●				●										●
C6	Scalability	●				●	●	●	●	●	●		●	●	●	●
C7	Management system	●	●	●	●	●		●	●			●	●		●	●
C8	Compliance	●			●	●	●			●	●	●	●		●	●
C9	Culture	●	●	●	●	●	●	●		●		●	●	●	●	●
C10	Leadership	●	●		●	●			●	●		●		●	●	●
C11	Competence	●	●			●	●		●	●	●	●		●	●	●

1.Alzahrani et al. (2021) 2.Antony et al. (2021b) 3.Dias et al. (2021) 4.Glogovac et al. (2022) 5.Jacob (2017) 6.Sader et al. (2021) 7.Sony et al. (2021) 8.Sureshchandar (2021) 9.Yadav et al. (2021) 10.Zonnenshain and Kenett (2020) 11.Chiarini and Kumar (2021) 12.Gunasekaran et al. (2019) 13.Foidl and Felderer (2015) 14.Fonseca et al. (2021)

Methodology

The present work is an applied and descriptive-analytical research study. To identify the dimensions, the library method was used and research information and data were collected through the distribution of questionnaires among managers and experts in the studied industries. According to the purpose of the research, first, by reviewing the literature, dimensions and Quality 4.0 indicators were identified. Then, a questionnaire for pairwise comparisons was prepared and provided to the experts, and finally, the importance of dimensions was determined using the Bayesian Best-Worst Method (BWM). BWM is one of the approaches to evaluate the weight of indicators and options based on pairwise comparisons developed by Rezaei (2015). The basis of this technique is the division of pairwise comparisons into two parts, main and secondary comparisons. When evaluating, experts generally consider one option as the best and the other as the worst, and compare the other options to the two. In this case, the main comparison is formed. When the best and worst options are not selected and comparisons are made, a sub-comparison is made. In this technique, only the main comparisons are made and there is no need for sub-comparisons. Accordingly, experts should make fewer comparisons, thus increasing accuracy and speeding up the decision-making process (Rezaei, 2016). Also, by reducing the number of comparisons, data collection is done more easily and accurately and the rate of inconsistency in comparisons is reduced.

The best-worst method has five steps as follows:

Step 1: Determine the set of decision criteria

Step 2: Determine the best and worst criteria

Step 3: Select the best criterion and prioritize the best criterion over other criteria: For this purpose, a comparison is made using a number between 1 and 9. The more important this criterion is than other criteria, the greater the number we attribute to it. The result is the best vector (BO), which indicates the priority of the best criterion (B) over the criterion j ($A_B = a_{Bj} \{a_{B1}, \mathrm{a}_{B2}, ..., \mathrm{a}_{Bn}\}$).

Step 4: Select the worst criterion and determine the priority of all criteria on the worst criterion: for this purpose, the worst criterion is selected and then the importance of other criteria to the worst criterion is determined by numbers 1 to 9. The result is the worst vector (WO), which indicates the priority of criterion (j) over the worst criterion (W) ($A_w = a_{wi} (a_{w1}, \mathrm{a}_{w2}, ..., \mathrm{a}_{wn})^T$).

Step 5: Determining the optimal weight: In this step, the optimal weight of the criteria is obtained. The weight of the criteria is obtained using the following model in such a way that the difference between all the criteria is reduced:

$$\min-\max_j = \left\{ \left| \frac{w_B}{W_j} - a_{Bj} \right| , \left| \frac{w_j}{W_B} - a_{jw} \right| \right\}$$

$$\sum w_j = 1 \qquad ,w_j \geq 0 \ , \forall \ j$$

To solve this problem, linear programming can be changed as follows:

$$w^{\alpha gg}$$

Bayesian best-worst method:

This method is a hierarchical model for finding the priority of criteria according to the following figure, the application and development of which requires the identification of independence and conditional independence between variables (Mohammadi and Rezaei, 2020).

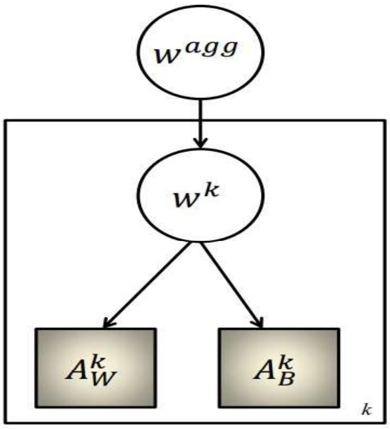

Figure 1- The probabilistic graphical model of the Bayesian BWM (Mohammadi and Rezaei, 2020)

In Figure 1, the nodes represent the variables to be estimated and the rectangles represent the observed variables that are the main inputs of this model. Arrows also indicate the connection node and that the node is originally dependent on the node at the other end. Accordingly, the value of w_k depends on A^k_w and A^k_B the value of $w^{\alpha gg}$ depends on w_k. This figure, which contains a set of variables, means that the corresponding variables are repeated for each decision. Since there is only one decision to make for $w^{\alpha gg}$, $w^{\alpha gg}$ is out of the page. Conditional independence between variables can also be extracted based on this figure. For example, A^k_B dependents on w_k and $w^{\alpha gg}$ being itself dependent; therefore:

$$P\left(A_w^k \middle| w^{\alpha gg}, w^k\right) = \left(A_w^k \middle| w^k\right)$$

Taking into account all the independence relations between the different variables, the Bayesian rule is written as follows:

$$P\left(w^{\alpha gg}, w^{1:k} \middle| A_B^{1:k}, A_w^{1:k}\right) \alpha \, \mathrm{P}\left(\middle| A_B^{1:k}, A_w^{1:k} \middle| w^{\alpha gg}, w^{1:k}\right) P\left(w^{\alpha gg}, w^{1:k}\right)$$
$$= \mathrm{P}\left(w^{\alpha gg}\right) \prod_{k=1}^{K} P\left(A_w^k \middle| w^k\right) P\left(A_B^k \middle| w^k\right) P\left(w^k w^{\alpha gg}\right)$$

Accordingly, the last equation is created using the rule of probability chain and conditional independence between different variables and indicates that each decision maker expresses his priorities. Since the estimation of the parameters in the above relation depends on the estimation of other variables, it can be said that there is a chain between different parameters, hence this model is called hierarchical.

In this study, the necessary information was collected through a survey of researchers and a questionnaire. As mentioned, this research seeks to examine the dimensions of Quality 4.0 in order to prepare companies to adapt to the developments of industry 4.0 in the Energy, Food and Shipbuilding industries. Therefore, using purposive sampling method, 15 experts and quality managers in these industries who had at least 10 years of experience were interviewed.

Findings

In this study and after reviewing the literature on the subject of basic criteria (see Table 2), Quality 4.0 criteria were identified in order to prepare companies to adapt to industry developments. Then, these criteria were provided to the experts and after review, they were finalized in Table 3.

Table 3- Identify and localize Quality 4.0 criteria using expert opinions

Criteria	Symbol	Definition
Data	C1	Ability of the organization to record, store, analyze, identify trends and patterns in the big data and data from the organization's processes and operations
Analytics	C2	Applying various approaches and methods to analyze the business in order to cooperate in the decision-making process, increase organizational competitiveness, adopt customer-centered approaches and ...
Connectivity	C3	In the digital and industry 4.0 era, communication is very important and enables interaction between people, organizations, products, devices and processes.
Collaboration	C4	The increasing products, processes and technologies complexity has led to participatory partnership solutions and

		industrial collaboration to increase productivity. Also, according to the view of total quality management, there is a need for participation and cooperation of all employees at different levels of an organization.
App development	C5	Development of products to decrease human intervention and the possibility to control remotely and the developing interactive programs for total quality management.
Scalability	C6	The ability to support data, devices, analyze, people and information
Management system	C7	To stay competitive, companies have to make some technological changes to their management processes, practices, and systems. An appropriate quality management system according to industry-based processes and technologies enables product development, increases customer satisfaction, and reduces the cost of business failure.
Compliance	C8	Compliance activities include compliance with legal, industrial, customer, and domestic requirements
Culture	C9	Organizational culture plays an important role in implementing Industry 4.0 to support the company's novel strategies and goals.
Leadership	C10	Quality sector leaders, by supporting new goals, policies and approaches, play an important role in preparing companies to keep pace with industry developments.
Competence	C11	The new technologies usage, scale customization, process digitization, collaborative data volume requires new competencies, knowledge, skills and attitudes in the field of quality.

Then, in the next step, to determine the importance and priority of the criteria, the Bayesian Best-Worst method has been used. For this purpose, first the best criterion is selected and other criteria are compared with it. In the next step, the worst criterion was selected and other criteria were compared with it. It should be noted that the comparisons were made based on the following spectrum (Mohammadi and Rezaei, 2020):

Verbal expressions	**Equal importance**	**Weak importance**	**moderate importance**	**Moderate plus**	**Strong importance**	**Strong plus importance**	**very strong or demonstrated importance**	**very, very strong importance**	**extreme importance**
Value	1	2	3	4	5	6	7	8	9

Based on the comparisons, the best vector (BO), which indicates the priority of the best criterion (B) over the criterion j, and the worst vector (WO), which indicates the priority of the criterion (j) over the worst criterion (W), are shown in Table 4:

Table 4- Expert opinions in various industries

Industry	Expert	BO	WO
Energy	D1	[6,5,4,7,8,7,3,6,5,1,8]	[6,5,3,4,7,3,5,1,6,7,8]
	D2	[5,4,5,5,3,7,3,8,8,3,1]	[5,5,6,3,5,1,8,2,7,6,7]
	D3	[5,3,6,6,4,6,4,7,9,2,1]	[6,3,4,5,6,1,9,3,6,7,8]
	D4	[6,8,5,7,5,5,1,9,4,3,4]	[5,5,4,7,3,6,8,1,4,8,6]
	D5	[8,7,9,3,6,9,2,8,4,1,5]	[4,5,1,7,6,2,8,3,7,9,6]
Shipbuilding	D6	[3,4,6,2,3,8,2,9,7,2,1]	[8,7,6,8,8,2,9,1,2,9,9]
	D7	[6,4,6,2,4,7,1,3,3,2,2]	[2,4,2,5,4,1,7,5,3,6,6]
	D8	[5,2,6,2,4,7,1,6,4,3,3]	[2,6,2,6,5,2,9,1,3,3,8]
	D9	[6,4,5,5,7,8,3,6,7,2,1]	[6,8,1,7,5,4,9,2,3,4,7]
	D10	[3,5,6,3,4,7,4,9,8,3,1]	[7,5,6,7,6,3,9,1,2,8,7]
Food	D11	[5,4,3,4,3,6,2,8,9,2,1]	[6,7,7,6,8,3,8,1,2,7,8]
	D12	[3,3,5,2,5,7,2,8,8,3,1]	[6,7,4,8,7,3,7,1,3,8,6]
	D13	[2,6,7,5,7,2,1,3,6,8,8]	[3,6,1,4,6,3,9,4,6,7,8]
	D14	[8,7,6,7,8,5,1,5,4,6,4]	[5,6,5,8,8,4,9,4,1,7,5]
	D15	[3,5,5,4,5,7,2,8,9,3,1]	[9,8,6,7,8,3,7,1,3,8,7]

After pairwise comparisons, the implementation model and the weight of the criteria were calculated according to Table 5. As Table 4 shows, in the Energy industry, the criteria of leadership, management system and competency with 0.145, 0.140 and 0.118 points are the most important and the criteria of compliance and scalability with 0.051 and 0.058 points, respectively, have the lowest importance. In the shipbuilding industry, the criteria of management system, competence and cooperation are the most important with 0.152, 0.144 and 0.118 points, respectively, and the criteria of scalability, adaptation and culture are the least important with 0.045, 0.047 and 0.054 points, respectively. In the shipbuilding industry, the criteria of management system, competence and leadership with 0.146, 0.115 and 0.107 points are the most important and the criteria of adaptation and culture with 0.054 points are the least important.

Table 5- Weight of Quality 4.0 criteria in different industries

Criteria	Symbol	Food	Shipbuilding	Energy	Total	Priority
Data	C1	0.093	0.080	0.080	0.085	7
Analytics	C2	0.095	0.099	0.080	0.091	5
Connectivity	C3	0.075	0.059	0.070	0.068	8
Collaboration	C4	0.099	0.118	0.083	0.099	4
App development	C5	0.096	0.088	0.088	0.091	6
Scalability	C6	0.065	0.045	0.058	0.056	10
Management system	C7	0.146	0.152	0.140	0.147	1
Compliance	C8	0.054	0.047	0.051	0.051	11
Culture	C9	0.054	0.054	0.087	0.063	9
Leadership	C10	0.107	0.115	0.145	0.123	3
Competence	C11	0.115	0.144	0.118	0.126	2

As Table 5 shows, in general and based on the results of the three studied industries, the criteria of management system, competence and leadership with 0.147, 0.126 and 0.123 points are the most important, respectively. Conformity and scalability criteria are the least important with 0.051 and 0.056 points, respectively. Compares and prioritizing of Quality 4.0 criteria in studied industries are shown in Figures 2 and 3.

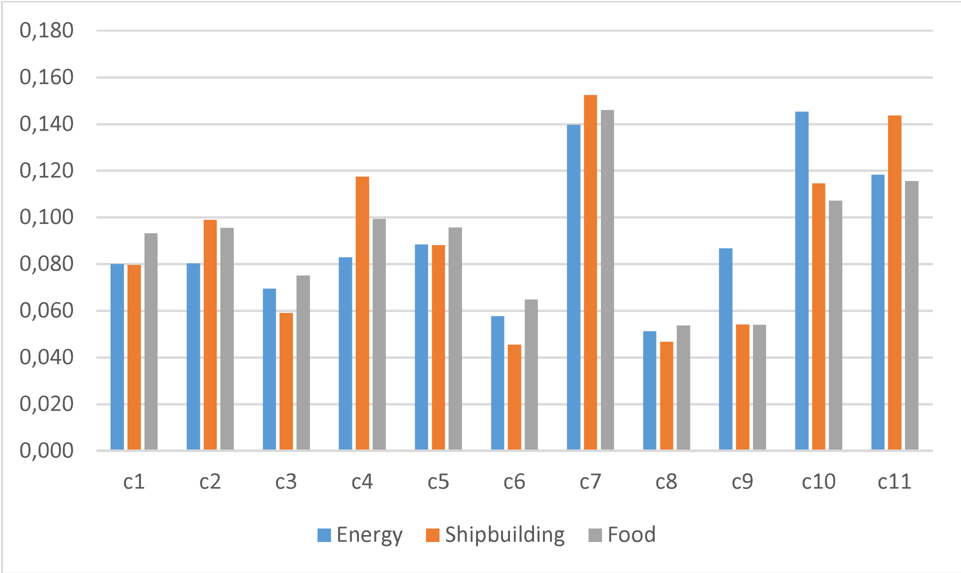

Figure 2- Comparison of criteria weights in the studied industries

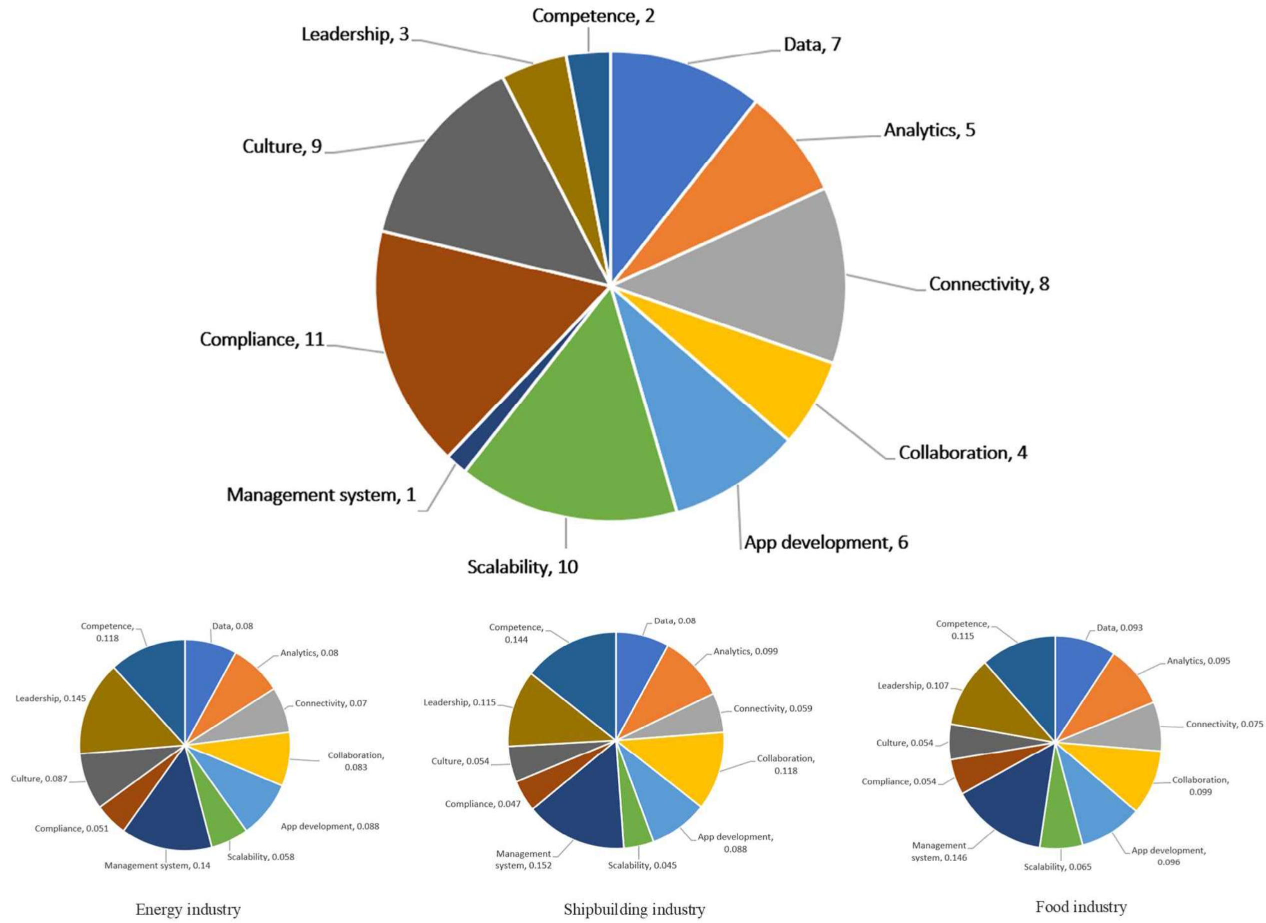

Figure 3- Prioritizing of Quality 4.0 criteria in studied industries

Results and Suggestions

One of the most important criteria that companies must establish in order to adapt to industry 4.0 developments is the ability to store, classify, analyze and identify patterns in big data. This can help the quality of products and services by identifying the needs of customers and identifying their consumption patterns. Due to the huge increase in data volume, traditional management systems does not have adequate capacity for processing. Therefore, it is necessary to invest in this sector to provide analysis tools and techniques for data and information.

In addition to creating the right capacity to collect and store data, organizations must have the capacity to analyze data and processes. Business analysis helps to increase competitiveness and create value for the organization by adopting appropriate customer-centric approaches to quality, making optimal decisions and applying appropriate strategies. The results showed in the digital era and Industry 4.0 communication is very important. Communication and interaction between people, organizations, processes, products, people and devices lead to the creation of large networks of collaboration. In addition, in this era, due to the enhancing products, processes and technology complexity, problem solving requires the participation and cooperation of individuals and organizations at all levels. Especially in terms of TQM, the participation of all employees at all levels and increased collaboration leads to improved productivity. In addition, the development of automated control programs and systems will decrease human interference and enable controlling processes remotely. With the expansion of smart factories, industrial automation and artificial intelligence, organizations will be able to use interactive programs in quality management.

As the results of this study showed, to increase scalability, companies must create the appropriate capacity to respond and process the number of transactions required by users. Ideally, the system should meet the needs of users for any number of transactions. This requires the development of soft skills and competencies such as leadership, organizational culture, employee competence and a strong management system. Top managers and leaders of the organization working in the quality department must pay more attention to the strategic goals of the company and the valuable actions that support the goals. Due to the changes made in the FIR, the leaders of the organization must support the goals by developing technologies, tools, improving processes and analyzing new data.

Organizational culture plays an important role in supporting a company's new strategies and goals and applying Industry 4 approaches. A rich culture in the field of quality promotes production and organizational changes align with the new customers' needs. In this situation, understanding the need for quality to conform to Industry 4, collaborative environment, interactive communication, transparency as well as focus on continuous improvement which is a strategic factor for organizational competitiveness.

In addition, with the industrial revolution and new technologies usage, process digitalization, customization of scale intensity, large volume of data, and a collaborative environment require the development of new competencies. Since the field of quality plays a key role in an intelligent factory, a strategic approach is proposed that periodically evaluates the competence of employees and uses a learning management system to develop their capabilities. The results showed that in Food, Energy and Shipbuilding industries, management system criteria and competencies are very important. Therefore, it is recommended that companies develop management systems and staff training to obtain the required competencies.

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