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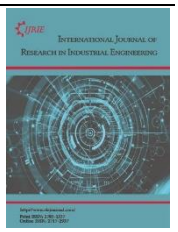

Paper Type: Review Paper

Development of the Field of Organizational Performance During the Industry 4.0 Period

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Abstract

As well as social and cultural life, commercial life has also been affected by the industrial revolutions. Because the structures of enterprises have changed how their performance is evaluated, have indispensably changed. In today's brutally competitive environment, it is of great importance that enterprises constantly assess their performance so that they can maintain their existence firstly and achieve sustainable competitive advantage. Due to the current importance of the topic in this study, it was examined how the field of organizational performance has developed in the Industry 4.0 period. The purpose of this study is to reveal whether Industry 4.0 and the field of organizational performance show parallelism in terms of evolution. This parallelism was examined in terms of use of the artificial intelligence techniques in organizational performance evaluation methods. Therefore, available literature related the topic was reviewed by way of the Systematic Literature Review (SLR) protocol developed by Boell and Cecez-Kecmanovic [6] and the traditional literature review method. As a result of the research, it was seen that the field of organizational performancehas not developed in parallel with Industry 4.0 until now.

Keywords: Industry 4.0, Organizational performance management, Organizational performance measurement, Industrial revolutions, Performance management, Performance measurement.

1 | Introduction

Each of the industrial revolutions which took place has been the turning point of human history and the revolutions which are expected to take place, will bring great events for the development of mankind. While the effects of the first industrial revolution (Industry 1.0), the second industrial revolution (Industry 2.0), and the third industrial revolution (Industry 3.0) have continued, humanity is at the beginning of the 4th industrial revolution which is also called Industry 4.0.

It is accepted that Industry 1 started with the invention of the steam engine by James Watt in the mid part of the eighteenth century in the UK. Through this invention, the coal was transformed into steam and mechanized industrialization emerged with the application of steam power to the industry. The increase of capital accumulation also took place in this period. Industry 2.0 has emerged with changes in basic raw materials and energy sources. The decisive elements of Industry 2.0 are the

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facilitation of transportation, communication, and distribution with the development of railways depending upon the technological transformation created by steel production, acceleration of trade with new shipping opportunities, the importance of oil and its derivatives in the economy, electric, petrol-based internal combustion engines and development of the automotive industry. Industry 3.0 is also known as the era of information technology, which began after the Second World War and accelerated after the 1970's. Synthetic goods, computer and microelectronic technology, fiber optics, telecommunication, biogenetics, biotechnology, laser technology are the innovations belong to this period. Industry and trade have also globalized in this period. Industry 4.0 was on the agenda for the first time at the Hannover Fair in 2011. It is characterized by augmented reality, big data, simulation, end-to-end software integrations, cyber network security, intelligent robotic automation systems, 3D printing, cloud solutions, Internet of Things, and Machine-to- Machine (IoT&M2M). Although the related works continue, Industry 4.0 has not yet been fully realized. But it is also a fact that Industry 4.0 is a phenomenon that will happen inevitably [12].

Undoubtedly, these revolutions have also affected commercial life in addition to cultural and social life. Because the structures of growing enterprises have also changed, it is impossible to manage these enterprises with the old methods anymore. Hence, the methods used for performance measurement have to change and evolve following the structures of the enterprises. Because the first factories newly started to emerge in the Industry 1.0 period, it can not be mentioned a clear method in the organizational performance field. The most important developments of Industry 2.0 in terms of the organizational performance field are the development of the DuPont system and the Tableau De Bord which is known as equivalent to the Balanced Scorecard (BSC). Developments in this field have gained momentum especially in Industry 3.0 period, frequently used popular methods in enterprises (such as Performance Measurement Matrix, EFQM Excellence Model, BSC, Performance Prism, Action-Profit Linkage Model, etc.) have been developed in this period. In the 2011 year which is accepted as the beginning of Industry 4.0, fuzzy sets were started to be used at the organizational performance evaluation methods. This development can be accepted as an entry to artificial intelligence in the field of enterprise performance. As it is known the prominent concept in the Industry 4.0 period is artificial intelligence. In this period, studies that design intelligent performance evaluation systems for also supply chains [17] in addition to businesses, has been started to be carried out.

In this study, based on the current importance of the topic, the development of the organizational performance field in the Industry 4.0 period was examined. The main contribution of the study is to determine whether the development of the organizational performance field in the Industry 4.0 period is in the right direction by shedding light on organizational performance evaluation models in the Industry 4.0 period and to guide the researchers working on the topic for the organizational performance evaluation models to be developed. The study, which is structured according to the mentioned purpose, consists of 5 sections. After the introduction in the first section of the study, the related literature was mentioned in the second section. In the third section, Systematic Literature Review (SLR) protocol ve traditional literature review were used together to determine methods related organizational performance evaluation developed during the Industry 4.0 period. In the fourth section, the identified models were discussed to reveal whether the Industry 4.0 and field of the organizational performance show parallelism in terms of evolution. In the final section, the study was completed with the interpretation of the results.

2 | Literature Background

Although various studies in the literature adress supply chain performance, industry performance, and operational performance with Industry 4.0, since this study is about the development of the organizational performance field in the Industry 4.0 period, only studies that address Industry 4.0 and organizational performance were examined in this section.

Kloviené and Uosytė [23] developed a framework to determine the arrangements that should be made in performance measurement systems due to the changes caused by Industry 4.0. For this purpose, research was conducted using the qualitative research method. According to the results of the study, it has been

observed that technology can affect the performance management system as it affects the planning, measurement, controlling, and decision-making functions of an enterprise. Lin et al. [24] investigated the factors that encourage manufacturing industry of China to Industry 4.0 and the effect of Industry 4.0 on enterprise performance. For this purpose, a text mining approach has been applied to the regular reports of 460 companies to determine the companies that apply the Industry 4.0 strategy in China's manufacturing industry. Later, a probit model was adopted to review the driving factors of Industry 4.0. Finally, Industry 4.0 effect on firm performance was evaluated via the propensity scores suitable the difference-in-difference method. As a result, it has been observed that private and large companies have higher motivation to implement Industry 4.0, government supports don't have an effect on companies' Industry 4.0 decision, and the implementation of Industry 4.0 significantly improves the companies' performance in general.

Büchi et al. [7] examined the relationship between the degree of openness to enabling technologies of Industry 4.0 and organizational performance in their study. For this purpose, data were collected from 1331 local manufacturing units operating in different industries. The openness degree was measured using two indicators as breadth (the number of technologies used) and depth (the number of value chain stages). As a result of the applied regression analyses, it was seen that these two indicators provide great opportunities, and local units of enterprises using Industry 4.0 technologies show higher performance. Kadir and Broberg [20] examined how the transition process to Industry 4.0 affects human welfare and the overall performance of the company in their study. For this purpose, case studies have been conducted to examine the changes before, during, and after implementation. According to the results of the study, while both human well-being and general performance are negatively affected during the implementation of new digital solutions, both human well-being and general performance improve after a successful implementation. Kamble et al. [21] developed a model that investigates the relationship between Industry 4.0, lean manufacturing practices, and sustainable organizational performance. For this purpose, data were collected from 205 managers of 115 manufacturing organizations in India. As a result of the study, it has been seen that Industry 4.0 has significant direct and indirect effects on sustainable organizational performance and lean manufacturing applications are a strong mediating variable. Robert et al. [35] aimed to determine what the features of an Industry 4.0 performance management system should be especially by focusing on the human factor in their study. A case study has been conducted in a large multinational company. As a result of the study, the characteristics that Industry 4.0 performance management systems should have were determined and it was seen that two main management principles such as adherence of all actors and solidarity between actors came to the fore for these systems.

As it can be seen from the existing literature, studies generally focused on the effect of Industry 4.0 on organizational performance and what should be the features of Industry 4.0 performance systems. As far as it could be examined, there is no study examining the development of the organizational performance field in the Industry 4.0 period in the existing literature. This study has been conducted to fill this gap in the existing literature and because of the current importance of the topic. The main contribution of the study is to determine whether the development of the organizational performance field in the Industry 4.0 period is in the right direction by shedding light on organizational performance evaluation models in the Industry 4.0 period and to guide the researchers working on the topic for the organizational performance evaluation models to be developed.

3 | Methodology

At this stage, organizational performance models developed during the Industry 4.0 period were determined using the SLR Protocol proposed by Boell and Cecez-Kecmanovic [6] and the traditional literature review method. Although there are various SLR methods [40], Petticrew and Roberts [31], Morioka and Carvalho [30], Adapa et al. [2], Thomé et al. [39], Glock [16], and Costa and Godinho Filho [10] suggested by different authors in the literature, this method was preferred because it would be more appropriate to apply what we know best. SLRs provide a standard for literature review by identifying

the necessary steps for literature review on the subject under investigation. Some authors argue that SLRs are superior to other methods because they are reproducible, transparent, objective, impartial, and rigorous. As can be seen from *Fig. 1*, a protocol that aims to address a specific research question is developed in the SLR process. In Step 2, database research is carried out according to the protocol to identify the relevant publications. In Step 3, the publications accessed in the previous step are scanned (often based on abstracts) according to the quality of the method and findings (evidence), thus the final set of publications is limited to only to those publications considered suitable for research. In Step 4, research is compiled by 'summarizing' the findings of individual publications based on selected publications, and in Step 5 the results are given [6].

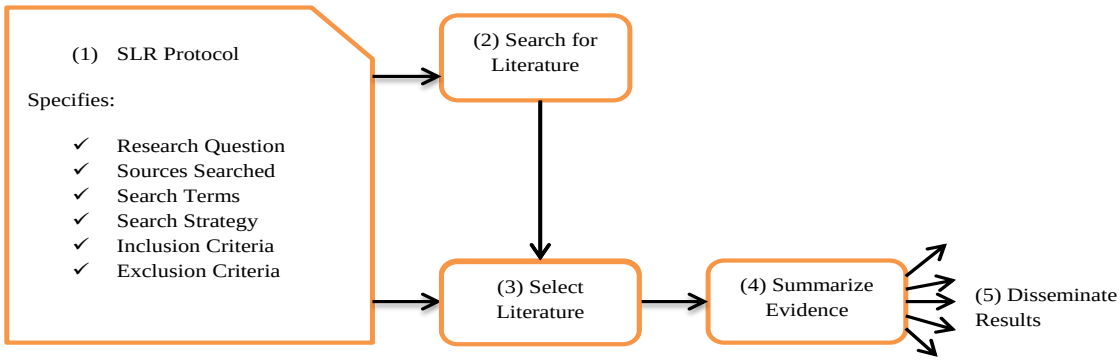

Fig. 1. SLR process [6].

The literature review for determining the organizational performance models developed in the Industry 4.0 period is as shown in *Tables 1* and *2*.

Table 1. SLR Protocol to determine organizational performance models developed in Industry 4.0 period.

Protocol Elements	Application of Protocol
Research Question (RQ)	RQ: What are the organizational performance evaluation methods developed in the Industry 4.0 period?
Sources Searched	Web of Science database (from 2011 until March 2022).
Search Terms	"Enterprise performance"/"corporate performance"/"business performance"/ "organizational performance" and "measurement"/"evaluation"/"assessment".
Search Strategy	Different research queries created by scanning keywords in the topic and title.
Inclusion Criteria	*Include only articles that are defined in research queries and that contain a combination of search terms. *Include only articles which are indexed on the Web of Science from 2011 until March 2022. *Include only articles written in English.
Exclusion Criteria	Do not include articles that do not explicitly claim to address enterprise performance.
Quality Criteria	Only peer-reviewed articles are indexed in the Web of Science database.

The query that offers the most choice is the "Organizational Performance" (topic) ve "Measurement" (topic)/"Evaluation" (topic)/"Assessment" (topic) query, with a total of 1352 articles. The search continues with the articles found in these queries. A total of 175 same articles were found in different combinations of three separate queries ("Organizational Performance" (topic) ve "Measurement" (topic)/"Evaluation" (topic)/"Assessment" (topic)). Therefore, after removing the same articles, the number of articles in the query has dropped to 1177. At the current stage, it will be decided whether the articles are relevant or not with the topic by looking at the title and summary of them. After the examination, it was decided that 88 articles could be related to the subject. The full text of 25 of the 88 articles could not be reached. It was observed that 18 of the 63 articles whose full text was reached are related to the topic [1], [3], [4], [11], [14], [15], [19], [22], [25]-[29], [32], [34], [41], and [42] and [44].

Table 2. Article number on the Web of Science related each research query (from 2011 until March 2022).

	(1) "Measurement"	(2) "Evaluation"	(3) "Assessment"	Total
Keywords in columns are searched in topic				
"Enterprise Performance" (topic)	59	140	50	249
"Enterprise Performance" (title)	13	47	17	77
"Corporate Performance" (topic)	128	95	64	287
"Corporate Performance" (title)	36	17	12	65
"Business Performance" (topic)	478	341	295	1114
"Business Performance" (title)	86	57	54	197
"Organizational Performance" (topic)	621	375	356	1352
"Organizational Performance" (title)	112	59	52	223
Keywords in columns are searched in title				
"Enterprise Performance" (topic)	10	65	9	84
"Enterprise Performance" (title)	5	26	6	37
"Corporate Performance" (topic)	27	24	16	67
"Corporate Performance" (title)	7	2	2	11
"Business Performance" (topic)	95	116	72	283
"Business Performance" (title)	15	21	16	52
"Organizational Performance" (topic)	123	109	91	323
"Organizational Performance" (title)	11	17	16	44

While the organizational performance evaluation models determined using the SLR protocol and the information about them were shown in *Table 1* to *Table 11* (please see Appendix section), the organizational performance evaluation models determined using the traditional literature review method and the information about them are shown in *Table 12* to *Table 18* (please see Appendix section).

4 | Results

When the organizational performance evaluation models developed in the Industry 4.0 period are examined, it is seen that the developed methods are not completely new, but were created by modifying previously developed models or integrating several methods and concepts. In these models, it has been observed that the BSC and Multi-Criteria Decision Making (MCDM) methods are very prominent, and the business excellence models and the concept of sustainability are also emphasized. Performance indicators used for evaluation in the proposed models are very limited when considered in terms of enterprise performance. The majority of the proposed models are not general and are developed either for the enterprise under consideration or a single sector under consideration. Moreover, most of the models are conceptual, while those with empirical verification were generally applied to a single enterprise. The shortcomings observed in the models are because organizational performance evaluation is a multidisciplinary field and the scope of the topic is very wide, complex, and multi-dimensional. In this study, the evolution of the organizational performance field during the Industry 4.0 period was examined. The purpose is to examine whether the organizational performance field is developing in accordance with the changes created by Industry 4.0. This development has been examined in terms of the use of artificial intelligence techniques in organizational performance evaluation methods. Because, as it is known the prominent concept in the Industry 4.0 period is artificial intelligence. From this perspective, when the organizational performance evaluation methods developed in the Industry 4.0 period were examined, it was seen that the artificial intelligence techniques were used in only five models. Mentioned models and techniques used are as follows.

- *Proactive BSC [9]: The fuzzy logic method is included in the model through the fuzzy cognitive maps used in the model.*
- *An integrated fuzzy c-means-TOPSIS approach [4]: The fuzzy logic method is included in the model through the fuzzy C-means used in the model.*
- *An integrated BSC-Fuzzy AHP approach [29]: The fuzzy logic method is included in the model through the fuzzy AHP used in the model.*
- *Hierarchical fuzzy expert system for organizational performance assessment in the construction industry [34]: The fuzzy logic method is included in the model through the Hierarchical Fuzzy Expert System used in the model.*
- *Fuzzy EFQM [22]: The fuzzy logic method is included in the model through the Fuzzy EFQM used in the model.*

While the use of the artificial intelligence technologies has spread all the fields along with Industry 4.0, as a result of the research done as far as we can see, artificial intelligence techniques and softwares are not adequately reflected in the field of organizational performance evaluation. It is seen that except "the proactive BSC, an integrated fuzzy C-Means-TOPSIS approach, an integrated BSC-Fuzzy AHP approach, hierarchical fuzzy expert system for organizational performance assessment in the construction industry, fuzzy EFQM", the organizational performance evaluation methods developed in this period, are a repetition of the past studies in the general sense. Although along with the use of the fuzzy cognitive maps in the proactive BSC, the use of the fuzzy C-means in the integrated fuzzy C-Means-TOPSIS approach, the use of the fuzzy AHP in the integrated BSC-Fuzzy AHP approach, use of fuzzy logic in the hierarchical fuzzy expert system for organizational performance assessment in the construction industry and the fuzzy EFQM, there is an entry to the artificial intelligence at the organizational performance evaluation field in the Industry 4.0 period. Nevertheless, these developments aren't at all sufficient level.

Since the development is not in the desired direction, it can be interpreted from two perspectives. The first perspective is whether the existing methods used to evaluate the organizational performance of traditional factories are sufficient? If not, how the methods should be developed? The second one is about how the methods which will be used to evaluate organizational performance of the smart factories should be. Organizational performance evaluation is a process that is complex, multi-dimensional, costly, and requires a lot of information. The probability of making mistakes in this process is also too much. A great majority of the factories traditionally continue their production activities. The existing organizational performance evaluation methods in the literature are not sufficient due to the shortcomings mentioned below; they were applied only to certain types of enterprises, there is no general method to assess the organizational performance of most enterprises, most of the available methods are not experimentally validated or just validated in the businesses which they are applied. If the performance of the traditional factories is evaluated by intelligent methods, both human-induced evaluation errors will be eliminated and the costs will greatly reduce. In addition, the general methods which can be applied to a great majority of enterprises also can be developed. A small part of the existing factories has begun to turn into smart factories. All works are done automatically by themselves at the smart factories that the most important reason for their emergence is human or instrumental induced disruption of the production activities. The existing systems communicate among themselves via the Internet of Things (IoT) which is possible obtaining real-time data, and ultimately the information obtained, create big data systems. Therefore, it would be a big fallacy to think that the performance evaluation of such factories can be done by traditional methods. Smart factories' organizational performanceevaluation should be done with intelligent methods. Intelligent methods which retrieve all necessary data from the existing big data systems will correctly and economically perform organizational performance evaluation.

5 | Conclusion

Industry 1.0, Industry 2.0 and Industry 3.0 took time about 60 to 70 years when the starting and ending dates of them accepted by the researchers are taken into account. Today, humanity is at the beginning of Industry 4.0. Industrial revolutions have also caused radical changes in organizational processes and activities as they have affected all areas of life. As the structures of enterprises have changed how their performance is evaluated, have inevitably changed. In today's brutally competitive environment, it is of

great importance that enterprises constantly evaluate their performance so that they can continue their existence firstly and gain a sustainable competitive advantage. Based on the current importance of the topic in this study, it was examined how the field of organizational performance has developed in the Industry 4.0 period. The purpose of this study is to reveal whether Industry 4.0 and the field of organizational performance show parallelism in terms of evolution. This parallelism was examined in terms of use of the artificial intelligence techniques in organizational performance evaluation methods. Because, as it is known the prominent concept in the Industry 4.0 period is artificial intelligence. For this purpose, available literature on the topic was examined using the SLR protocol developed by Boell and Cecez-Kecmanovic [6] and the traditional literature review method. As a result of the research, it was seen that the field of organizational performance has not developed in parallel with Industry 4.0 until now. Because, when the field of organizational performance in the Industry 4.0 period is examined, it is observed that the methods don't differ significantly from the methods developed at the end of the 3rd industrial revolution and artificial intelligence techniques were used in only five models. But, it should not be forgotten that we are at the beginning of the 4th industrial revolution. We must emphasize that to keep pace with the rapid development of Industry 4.0, the organizational performance field need to jump level with the artificial intelligence, IoT, and cloud computing lever. The studies [8] and [13] showing that Industry 4.0 technology components increase organizational performance also confirm this idea.

The main contribution of the study is to determine whether the development of the organizational performance field in the Industry 4.0 period is in the right direction by shedding light on organizational performance evaluation models in the Industry 4.0 period and to guide the researchers working on the topic for the organizational performance evaluation models to be developed. The study has some limitations. The first limitation is the number of databases examined, the second one is is the number of perspectives considered to examine the problem. For this reason in future studies, the study can be repeated by increasing the number of databases examined and the development of the organizational performance field in the Industry 4.0 period can be examined from different perspectives. The artificial intelligence that we can say forms the foundation stone of the 4th industrial revolution, is now used extensively in real-life problems. Organizational performance measurement is also a multidisciplinary real-life problem that includes uncertainties and requires multi-criteria decision-making. In this context, the use of artificial intelligence methods in the organizational performance field in the age of the Industry 4.0 is an expected result. It is not known how long Industry 4.0 will end but, it is a fact that along with this revolution it is expected that radical changes in the organizational performance evaluation methods are going to take place.

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Conflicts of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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Appendix

Table 1. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(S) and Year	Model/Framework Feature(S)	Dimensions Related Performance Measures	Advantage(S) of the Model/Framework	Disadvantage(S) of the Model/Framework	Comment Related Model/Framework
An Integrated Fuzzy C-Means-TOPSIS Approach [4]	Bai et al. [4]	The proposed method integrates Fuzzy C-Means and TOPSIS using BSC perspectives for performance evaluation of organizations and the results of the method are compared with the results of latent class clustering.	Financial, customer, business process, learning & growth	The proposed method minimizes the computational effort needed to arrive at rankings, a comparative analysis was made to examine the validity of the proposed method, and application of the proposed method was made with real company data.	The technique has some subjectivity related to the determination of the Number of clusters, probability of not obtaining valid results if the method is applied to different MCDA environments or industries.	The model uses BSC perspectives as performance dimensions and it is one of the rare methods that incorporate artificial intelligence into Organizational performanceevaluation because it uses Fuzzy C-Means.
A Model for Monitoring Organizational Performance [11]	Draghici et al. [11]	The study proposes a model for monitoring organizational performance by considering 3 organizational determinants such as objectives, resources, and results.	*Efficiency (Approached in terms of intellectual capital management), *Effectiveness (Interpreted in terms of organizational and manager/leader behavior), *Pertinence (Interpreted in terms of organizational and manager/leader behavior).	The proposed model is general and can be used in both for-profit and not-for-profit organizations and it provides a holistic perspective on the performance management system under consideration.	The proposed model is conceptual and the performance indicators used for monitoring organizational performance are limited.	The proposed model uses efficiency and effectiveness which are the most commonly used indicators for performance measurement.

Table 2. Organizational performance measurement models developed in Industry 4.0 period.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
An Adapted BSC Approach [14]	Elbanna et al. [14]	The method proposes a scale for the evaluation of organizational performance in the hotel sector using the BSC concept.	Financial, customer, internal business, innovation, learning.	Validation of the developed BSC scale was made, a shortened BSC scale was proposed, the method provides more empirical research to operationalize the BSC in the hotel sector.	The proposed method is a conceptual framework.	The study uses an adapted version of BSC which was developed in the Industry 3.0 period.
A new integrated model for performance measurement in healthcare organizations [32]	Pirozzi and Ferulano [32]	The study proposes an integrated new organizational performance measurement model consisting of the Common Assessment Framework (CAF) model, Intellectual Capital (IC) model, and New Leadership Model for healthcare organizations	*Enablers (leadership, strategies and policies, tangible resources, relational capital, individual capital, internal capital) *Results (results-oriented to human resources, results-oriented to citizen-user, results-oriented to social community, results- oriented to key performances	The ability of the proposed model related to measuring and managing intellectual capital and financial/non-financial performance, easiness related to the interpretation and coherency assessment of measured data due to use of a single measurement system	The proposed model is conceptual and is not general	The study proposes a new model integrating three models available in the literature for performance measurement of healthcare organizations

Table 3. Organizational performance measurement models developed in Industry 4.0 period

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Three-dimensional performance measurement system-SMD3D [41]	Valenzuela and Maturana [41]	The method is a holistic, three-dimensional method developed for evaluating the performance of businesses operating in the wine industry and it is based on sustainability, BSC, and supply chain.	Sustainable, Temporal, and Spatial	The method provides a balanced measurement of sustainability in vineyards in terms of the environmental, social, and economic aspects, it does not focus only on the company itself but also on its suppliers and distributors, it helps link the performance of the everyday activities with the long-term activities and it was compared with other five performance management systems specially developed for the agriculture industry.	The method is a conceptual framework and is designed only for the wine industry.	The method is based on the sustainability concept which was first come up with during the Industry 3.0 period, BSC which was developed in the Industry 3.0 period, and the supply chain.

Table 4. Organizational performance measurement models developed in Industry 4.0 period.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
An Integrated Framework for Organizational Performance Measurement [44]	Yaghoobi and Haddadi [44]	It is an integrated organizational performance evaluation model which is obtained by integrating BSC and Analytical Hierarchy Process methods.	*Financial; reducing the establishing costs of each phone line and ADSL, reducing the maintenance costs of each phone line and ADSL, reducing the percentage of non-collectible, increased monthly revenue per fixed-line and ADSL *Internal processes; the number of sets of fixed telephone and ADSL switches, sets of fixed telephone and ADSL, the number of data ports transfer, the number of network ports, cities having access to the data network, telephone and ADSL fault clearing time, percentage failure of telephone and ADSL. *Customer; penetration coefficient of fixed telephone and ADSL, the success rate of calls, waiting time for fixed telephone and ADSL, pay and benefits of employee performance, education, and promotion. *Learning and growth; time management training, time employee training, the number of offers.	The model's case study was done. The study implements the integrated framework throughout an organization in a new application area and not only shows the characteristics of the company but also the characteristics of the telecommunication industry.	The method ignores the contributions made by employees, suppliers and, stakeholders to achieve the company's goals. The role of community and culture is neglected in describing the environment in which the company works, no firm and environmental dynamics are considered. Due to a long questionnaire and extreme comparisons in the Analytical Hierarchy Process (AHP), the amount of data required and the time to acquire it are limitations for the work. Because in this study, development priorities are based on the opinions of experts and the interpretation of researchers, the risk of self-assessment bias may threaten the internal validity and this creates a limitation for the study.	The method integrates the BSC which was developed during the Industry 3.0 period and the AHP method.

Table 5. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
An Integrated BSC-Fuzzy AHP Approach [29]	Modak et al. [29]	The study proposes an approach that integrates BSC and Fuzzy AHP methods for organizational performance evaluation to see whether outsourcing decision is in alignment with the performance of the Indian coal mining organization.	Financial, customer, internal operations, company learning & growth.	Sensitivity analysis was applied to reduce the impact of uncertainty, gaining cost advantage through the design and evaluation of the entire framework using Microsoft Excel.	Too few indicators were used in evaluating enterprise performance, interrelationships between performance indicators weren't considered, the framework is not general enough to apply to other mining industries.	The method integrates the BSC which was developed during the Industry 3.0 period and the Fuzzy AHP method that incorporate in artificial intelligence into the proposed model with its use.
A Performance Measurement Scale for Higher Institutions [1]	Abubakar et al. [1]	The study proposes a measurement scale for performance evaluation of higher institutions.	*Academic reputations *Employability of graduate *Faculty/student ratio *Research output *Internationalisation *Nobel prizes and fields medals *Research grant *Abundant resources *Infrastructures and facilities *Community service	The validation of the proposed scale was made and the scale is reliable and valid.	Data were collected only from the chief executives (vice-chancellors/ presidents) of the universities addressed in the study.	A new performance measurement scale was developed for higher institutions in the study.

Table 6. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Sustainable Enterprise Excellence: Attribute-Based Assessment Protocol [19]	Hussain et al. [19]	The study proposes a quantitative measurement scale for organizational self-assessment based on the previously developed a Sustainable Enterprise Excellence model.	*Governance and strategy, *Process implementation and execution, *Sustainability performance, *Financial performance, *Innovation performance, *Human capital performance.	The proposed model is beneficial for evaluating sustainable excellence of the organizations operate in rigorously competitive markets and provides improvement proposals related to the organization's current status and further progress.	The proposed model is conceptual, the statistical validity and reliability of the proposed scale are not tested.	The proposed organizational self-assessment scale is based on Previously developed a Sustainable Enterprise Excellence model.
Performance Management Assessment Model for Sustainable Development [15]	Fechete and Nedelcu [15]	The study proposes a mathematical performance management assessment model for determining the global performance of an industrial system.	*The quality of products and processes, * Manufacturing costs, *Deliveries, *The motivation and satisfaction of the employees *Environment	The proposed model provides a measurable result For total performance; the case study of the model was done; since the indicators used in the model are the indicators monitored by the industrial systems, no additional effort is required to calculate them.	If the proposed model is applied to other industries, the indicators may need to be updated; since the case study is applied to only two segments of the company, its validity is limited.	A mathematical performance management assessment model was proposed in the study.

Table 7. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Organizational Performance Assessment Instrument using Constructivist Multicriteria Decision Aid (MCDA-C) [26]	Longaray et al. [26]	The study proposes a customized performance evaluation model to improve organizational management in the fertilizer industry located at a Brazilian maritime port terminal.	*Safety *Environment *Quality *Efficiency *Costs *People	The proposed model itemizes all phases in the development of MCDA-C, decision-makers have participated in all stages in the development of the model, and the case study of the proposed model has been done.	The proposed model in the study is not general, the time required to interview decision-makers and stakeholders, the importance of decision- maker's commitment to the research.	An MCDA-C approach was proposed in the study.
The combined AHP and GRA method [25]	Liu [25]	The study proposes an organizational performance evaluation framework that consists of a combination of the AHP and GRA methods, for travel agencies.	*Quality Performance *Efficiency Performance *Financial Performance	The application of the model is shown, the proposed model is suitable for the multi-criteria structure of travel agencies' performance evaluation problem.	The study does not propose a general model for organizational performance evaluation, the possibility that the information obtained from experts may be subjective may affect the objectivity of the results.	A combination of multi-criteria decision-making methods was used in the study.

Table 8. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
A new SME self-assessment model [27]	Machado et al. [27]	The study proposes a new self-assessment model for SMEs in Brazilia considering the characteristics of the SMEs	*People and Processes; leadership, people, society, process, customers *Strategy; strategy and plans, information and knowledge, results.	It is a new model specially designed for SMEs, an empirical study was conducted for reducing the number of criteria.	The proposed model is exclusive to SMEs in a particular region of Brazil, the application of the model is not shown.	A new self-assessment model exclusive to SMEs was proposed in the study
An Adapted BSC approach for social enterprises in emerging market [28]	Mamabolo and Myres [28]	The study proposes an Adapted BSC approach for performance measurement of 446 social enterprises in South Africa.	*Customer, *Learning and Growth, *Finance, *Internal processes	This study shows an adapted BSC can be used for performance measurement of social enterprises in the emerging markets.	The study is based on self-reported data, secondary data is not available for validation of the data collected and therefore findings, the proposed approach is conceptual.	The study uses an adapted version of BSC which was developed in the Industry 3.0 period

Table 9. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
A DEA Malmquist model for productivity analysis of top global automobile manufacturers [42]	Wang et al. [42]	The study proposes A DEA Malmquist model for performance evaluation of the top 20 global Automobile manufacturers.	*Input Factors (total assets, equity, cost of revenue, operating expenses), *Output Factors (revenue, net income)	Car managers, policy makers, or investors in automobile management can use this study as a valuable reference for automobile management, investment and development decisions, the study is a guide to automakers for forming strategic alliances with one another.	The results of the study are not applicable or relatable to other industries, the input and output variables used in the study are only financial and restricted, some external factors are not taken into account, the insufficient sample size to get a more general overview of the performance of the auto industry.	A DEA Malmquist model was for performance evaluation in the study.

Table 10. Organizational performance measurement models developed in Industry 4.0 period.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Hierarchical Fuzzy Expert System for Organizational Performance Assessment in the Construction Industry [34]	Rathore and Elwakil [34]	The study proposes a comprehensive model for evaluating the organizational performance of firms in the construction industry. The model uses AHP to shortlist critical success factors and Hierarchical Fuzzy Expert System Techniques to evaluate organizational performance.	*Financial parameters; Segmentwise Revenue, Revenue Per Employee, Revenue Growth *Non-Financial Parameters; Administrative and Legal, Technical, Management, Market, and Finance *Market conditions; Market Diversification.	The model uses both Financial and non-financial factors, while the construction industry generally focuses on measuring project success, this model focuses on measuring organizational performance in the construction industry.	The number of collected questionnaires may be insufficient in terms of the accuracy of the model; the ability of the model to predict the category of the rank, not the exact rank; the model can only predict the ranking in the geographic location where the organizations are located; use of a limited number of key financial performance factors due to the non-public nature of the organizations considered.	It is observed that the method made enter to use of artificial intelligence in the Organizational performanceevaluation field by using fuzzy logic.
Fuzzy EFQM [22]	Kiraz and Açıkgöz [22]	In the study, a fuzzy EFQM model is proposed for the evaluation of enterprise performance. The CN2 induction algorithm is used to generate the 'if-then' rules.	Enablers: Leadership; People; Strategy, Partners & Resource; Processes, Products and Services Results: People Results; Customer Results; Society Results; Business Results.	The proposed model reduces the error rates of the classical FMEA model caused by experts, the establishment of the rule base which is suitable for all situations in businesses, the proposed model combines the EFQM model with fuzzy logic and inductive algorithm.	The success of the proposed method depends on the ability of the rule reduction algorithm.	It is observed that the method made enter to use of artificial intelligence in the Organizational performanceevaluation field by using fuzzy logic.

Table 11. Organizational performance measurement models developed in Industry 4.0 period.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Performance Assessment System for Wastewater Utilities [3]	Almeida et al. [3]	In the study, a novel performance evaluation system is proposed considering the strategic planning process. The proposed system has been tested and validated in the wastewater utilities.	*Risk to public health *Risk to public safety *Service coverage and availability *User's satisfaction with provided service *Service continuity in normal conditions and emergencies *Safety and emergencies management *Adaptation to climate change effects in utilities *Reduction of the negative impact on economic activities *Contribution to environmental sustainability& region socio-economic development *Discharges reduction *Wastewater treatment *Pollution prevention and control *Climate change mitigation and adaptation *Compliance with safety and health requirements at work *Hazard monitoring for safety and health at work	The proposed model provides flexibility in application and a holistic perspective for urban water systems; common tactical concerns are appraised at the strategic level; testing and validation of the proposed model for the wastewater utilities.	The proposed model is theoretical, the application of the model is not shown; the proposed model is not general, it is designed for wastewater utilities.	In the study, a performance evaluation system that supports strategic management of wastewater utilities was proposed.

Table 12. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
System Dynamics-Based BSC [5]	Barnabe [5]	The method combines the system dynamics methodology with the traditional BSC to overcome some constraints of the BSC.	Customer, financial, internal processes, learning, and growth perspectives.	The method provides mapping tools, feedback loops; identifies, shapes, and analyzes the systemic structure of the enterprise environment under observation; builds quantitative models, develops and uses spesific BSC-focused management flight simulators; links operational-level strategy better.	The focus of the method is largely on the service-based enterprise, which is very difficult to be implemented as generalized.	The method modified the BSC which is one of the most famous and widely used methods, by using the System Dynamics Methodology. In the Industry 3.0 period, there are different methods that have been developed by modifying the BSC using different methods.

Table 13. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Proactive BSC [9]	Chytas et al. [9]	The method is not a new performance measurement framework, but supports the existing measurement frameworks throughout the design, implementation, and use process of performance measurement systems and develops the decision-making process.	-	The method tries to overcome the problems of the BSC by using the soft computing properties of fuzzy cognitive maps and expands previous research initiatives by allowing fuzzy definitions in cognitive maps, applying a special interpretation mechanism of linguistic variables to fuzzy clusters, allowing dynamic sortation and restructuring of BSC strategy map.	There is a need for deep work to be tested and promoted the usability of the methodology and to be identified potential difficulties.	It is observed that the method made enter to use of artificial intelligence in the Organizational performanceevaluation field by using fuzzy cognitive maps to remedy the deficiencies of the BSC.
Sustainability Performance Measurement System [36]	Searcy [36]	It's presented as a conceptual framework for structuring the evaluation of the corporate sustainability performance measurement system.	-	The framework helps an organization identify the strengths and weaknesses of its SPMS and provides a starting point for implementing the improvements.	Empirically verification is needed for the proposed conceptual framework, there isn't a one-size-fits-all approach for evaluating corporate SPMS, and the process necessarily a little changes from case to case.	The method's focus is the sustainability concept which was first come up with during the Industry 3.0 period and it's aimed to be general and applicable.

Table 14. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
The Performance Wheel [43]	Watts and McNair-Connolly [43]	The model suggests that apparently different control models can be reduced to one inclusive model.	Economic value-added, market value-added, price/quality ratio, reliability (defects per million), % on-time delivery, % correct shipments, time to market, cycle time, cost per unit, waste %.	It is suitable for many organizations; it addresses the identified weaknesses of previous models and includes them, the model includes business control insights and integrates the importance of the mission, strategy, critical success factors, and key performance indicators.	No experimental validation has been done to be tested the applicability of the model.	New method has been proposed by combining various features of organizational performancemeasurement frameworks such as Performance Pyramid, Results and Determinants Framework, and BSC which were developed during the Industry 3.0 period.
The Small Business Performance Pyramid [43]	Watts and McNair-Connolly [43]	Because there is no middle management in small enterprises, the model is obtained with the elimination of the middle of the flattened version of the Performance Wheel to provide harmony of the model to small enterprises.	Value-added cost, customer loyalty, quality/price ratio, waste, time to delivery, inventory days, A/R days, A/P days.	The model suggests solutions to the challenges of assessing the performance of small manufacturing and small service organizations; it addresses the identified weaknesses of previous models and includes them in the model; it contains business control insights and integrates importance of mission, strategy, critical success factors, and key performance indicators.	The model is developed only for small manufacturing and small service organizations, no experimental validation has been done to be tested the applicability of the model.	It is the adapted form of the Performance Wheel method to small enterprises.

Table 15. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
The Comprehensive Reverse Logistics Enterprise Scorecard [37]	Shaik and Abdul-Kader [37]	It is a comprehensive performance measurement framework and scorecard which is proposed for performance measurement of reverse logistics enterprise by integration of BSC and Performance Prism methods. The model was also supported by the AHP for the calculation of the overall comprehensive performance index.	*Financial; Total RL costs, Total capital input, Annual sales of returned products, Revenue recovered. *Innovation & Growth; Management initiatives & Employee competency, Information Technology capability, Process technology, Innovation capability, Product life cycle reviews. *Process: Internal & External; RL cycle time, Network capacity, Transport capacity, Recovery efficiency rate. *Stakeholder; Customer Satisfaction, Government Satisfaction, Employee Satisfaction, Investor Satisfaction. *Environmental; Overall Environmental Compliance, Materials utilization, Energy utilization, Disposing capability. *Social; Corporate image, Relationships, Safety, Security.	The proposed model is a comprehensive performance measurement system and scorecard for reverse logistics enterprises. The model includes a balanced combination of financial and non-financial measures and determines the importance weights of performance measures. Experimental verification was made for the enterprise in which the model was developed.	More experimental work should be done to ensure the validity of the model's applicability to various industries as claimed by the authors. Proposed performance dimensions and measures should be checked over time to see whether they are adequate. A better method should also be used to determine the relationship between the performance measures While determining their importance weights.	The model consists of the integration of the BSC and the Performance Prism methods which are developed during the Industry 3.0 period. The AHP method is also used in the model.

Table 16. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
Comprehensive Reverse Logistics Enterprise Performance Measurement and Decision Making Model [38]	Shaik and Abdul-Kader [38]	The model is a comprehensive performance measurement and decision-making framework for reverse logistics enterprises and integrates the BSC and the Performance Prism. The DEMATEL method is used to learn the internal relations between the performance factors.	*Financial; total RL costs, total capital input, annual sales of returned products, revenue recovered. *Innovation & Growth; management initiatives & employee competency, information technology capability, process technology, innovation capability, product life cycle reviews. *Process: Internal & External; RL cycle time, network capacity, transport capacity, recovery efficiency rate. *Stakeholder; customer satisfaction, government satisfaction, employee satisfaction, investor satisfaction. *Environmental; overall environmental compliance, materials utilization, energy utilization, disposing capability. *Social; corporate image, relationships, safety, security.	Because the proposed framework is comprehensive, causally oriented, vertically and horizontally integrated, internally comparable, and useful it fills the gap in the literature. The framework, based on their business model, can be modified and tested for additional or different features that may be more appropriate for reverse logistics enterprises.	The limitation of the framework is challenging to capture complex performance characteristics with reverse logistics managers. It should be checked whether the proposed performance dimensions and measures are adequate over time. In addition, an experimental case study should be made for the reverse logistics enterprises operating in different industrial sectors, to support and investigate the effectiveness of the proposed approach.	The proposed method integrates the BSC and the Performance Prism which are developed during the Industry 3.0 period and also uses the Dematel method to learn the internal relations between performance factors.

Table 17. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
A Test and Evaluation-Derived Approach to Organizational Performance Measurement [18]	Hester and Meyers [18]	The method is a multi-criteria performance measurement approach that can be used in public and private sector enterprises. The authors benefit from operational test and evaluation (OT & E) for the new framework that they offered. The authors suggest that approaches related measurement of organizational performance can take advantage of the increasingly supported concepts such as critical operational issues (COI), measures of effectiveness (MOE), measures of performance (MOP), within the OT & E community.	-	The approach is sector-agnostic in ways that incorporate mission and investment ideas that involve the industry and offers performance evaluation in an innovative style that can be used regardless of an enterprise's publicness or other like-minded classification.	There is a need for experimental validation of the method's applicability in various sectors.	The proposed method is a multi-criteria performance measurement approach and uses operational test and evaluation (OT & E).

Table 18. Organizational performance measurement models developed in Industry 4.0.

Model/Framework Name	Author(s) and Year	Model/Framework Feature(s)	Dimensions Related Performance Measures	Advantage(s) of the Model/Framework	Disadvantage(s) of the Model/Framework	Comment Related Model/Framework
The sustainability BSC model for hybrid organizations [33]	Ponte et al. [33]	The method is a performance measurement model which is developed on the basis of BSC as a result of the action research project carried out in a hybrid organization which is called ICTCo.	*Financial perspective; financial sustainability. *Customer perspective; customers' satisfaction, market share. *Internal processes perspective; productivity. *Learning and growth perspective; innovation capacity, employees' welfare. *Social responsibility perspective; value creation for the local government, supporting and fostering the local economy.	The proposed model provides a balanced control of both the social objectives and financial performance of the organization. Incorporating corporate social responsibility impacts into the performance measurement system is an important issue for the government-owned corporation because it can help avoid potential mission deviations. The proposed model enables us to have a holistic view of the corporate social responsibility dimensions. Compared to the other models using the BSC, the proposed model follows and considers the effect of social values on other key success factors. The model is used by the company in the current situation and is under a continuous development process. The study provides a roadmap that can be used by other hybrid organizations in the information and communication technology industry.	Because the enterprise discussed in this article has its characteristics, it isn't possible to generalize as it is in quantitative management studies. However, the model can be a guide for "in-house organizations" as some of them may show similar characteristics.	The proposed method is based on the BSC which was developed during the Industry 3.0 period.