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SUSTAINABLE SUPPLY CHAIN MANAGEMENT – KEY PERFORMANCE INDICATORS (KPI) AS AN ELEMENT FOR MEASURING OF PROCESSES

Abstract

In the considerations, an attempt was made to organize the knowledge about the KPIs used in the literature and economic practice in relation to the implementation of a new business strategy, which is a sustainable supply chain. Based on the literature, the KPIs used to measure the supply chain were identified and a reference model for the implementation of sustainable indicators (Su-KPI's) at the supply chain level was developed. A content analysis was also carried out in order to indicate the interest of authors in measuring performance in sustainable and green supply chains.

Keywords: KPI, sustainable supply chain management, indicators, measurement
JEL: M2, F2, R4

Introduction

The turbulence of the environment and the dynamics of changes taking place in world economies lead to the necessity to implement and use in organisations new tools allowing for the development and improvement of organisations. One of the applicable solutions is the identification and implementation of key performance indicators (KPIs) in the evaluation system. The literature contains many types and subdivisions of KPIs, key performance indicators, which are designed to support the supply chain performance evaluation processes. However, there is no specific reference and separations to a green and sustainable supply chain. Although

scientific research in this area appears, it does not systematise knowledge, nor does it show too high an element of novelty, being merely an adaptation of already known theories. This is one of the identified research gaps. The literature analysis shows that adapting only known management methods and tools (such as BSC) is insufficient. After distinguishing dedicated KPIs, should be proposed a framework or reference models which would indicate which and how many KPIs should come depending on the nature of the chain and its products. The multitude of theoretical considerations, based on literature, makes it necessary to organize this subject in this area. The main objective of the paper is to present a reference model indicating the possibilities of using appropriate KPIs to assess the functioning of green and sustainable supply chains. The second important element of the discussion, on the basis of bibliometric research, is to present in a quantitative way the interest of scientists in the implementation, use and description of KPIs in the area of sustainable and green supply chain. The issue of defining and identifying a typology of key performance indicators to measure in sustainable supply chains is described in the literature, but needs to be more addressed in the consideration of green and sustainable supply chains. The considerations in this model order knowledge and provide the basis for further research by defining general KPIs for a sustainable supply chain and adapting them to specific industries.

1. Methodology

The main research method used in the paper is literature analysis and content analysis to investigate the phenomenon of identifying key performance indicators to measure the efficiency and effectiveness of processes in a sustainable supply chain. The literature review is the basis for the initiation of in-depth and empirical analyses. It find their place is also in the broadly understood social sciences as an accepted research method (Mentzer, Kahn, 1995; Easterby-Smith et al., 2002), at the same time being an integral part of all research and assisting in the search for theoretical structuring of the research area, in this case creating typologies of KPI's for sustainable supply chains. An auxiliary method is contextual analysis, which allows a broad definition of content as a technique for drawing conclusions by objectively and systematically identifying specific characteristics of messages (Holsti, 1969). The selected research methodology allowed to answer research questions and achieve main goals of the publications. The choice of this research method seems to be appropriate to examine from a theoretical point of view so as to indicate whether a given topic is discussed in literature and to what scope.

2. Theoretical aspects of the measurement in the sustainable supply chain

The use of measurement in the supply chain is, on the one hand desirable to define and, on the other hand, to improve the competitive advantage. The literature indicates that in order to improve competitive advantage, organisations and their chains need to effectively measure and manage performance. This should be done in a new strategy for the management of sustainable chains (Neely et al., 2002; Shepherd, Günter, 2010). The measurement system should be adapted to the specificity of the chain, i.e. the measurement of the effectiveness of activities and processes performed should take into account sustainability aspects. (Bai, Sarkis, 2014). To measure the supply chain in traditional are used terms of the countless measures, indicators and critical factors (Kisperska-Moroń, 2006; Gunasekaran, Kobu, 2007). Creating a dedicated system for measuring the performance of key elements affecting the efficiency of a sustainable supply chain seems to be a challenge and a need. Sustainability aspects must be taken into account when assessing the functioning of the supply chain. The large number of measures and indicators on sustainability and overall measurement in supply chains will contribute to the fact that defining a Su-KPI (Key Performance Index for Sustainable Supply Chain) requires a critical approach and choice that best describes and matches the nature of the actions taken and their evaluation. Measuring in the supply chain is most often done in four areas: quality, time, cost and flexibility (Beamon, 1999; Shepherd et al., 2004; Angerhofer, Angelides, 2006) in addition, the areas of innovation, information flow, as well as the input and output elements of the system (including resources) are often added. Such a traditional approach clearly indicates that there is no reference to sustainability aspects (including sustainable development, whether from the point of view of economic, social or, above all, environmental aspects). The KPIs used can also be considered in the following aspects of measurement: qualitative and quantitative, cost, level of occurrence of phenomenon: operational, tactical or strategic, and from the process point of view. The existence of many measurement systems causes great difficulties in applying one approach, including systemic thinking (Chan, Qi, 2003). This contributes to the impossibility and difficulty of systematically identifying the most appropriate and relevant new management strategy for the KPI's (Cai et al., 2009). Classical measurement in the supply chain includes the methods and techniques presented in Table 1. However, the scope of their impact and components cannot always be included in a sustainable supply chain and its measurement (as they do not cover all 3 areas of sustainable development). The critiques of such an approach are among others Hassini et al. (2012) and Seuring (2013).

Table 1. Supply chain measurement, selected tools and techniques in a classical way

Category and area of measurement	Measurement designated KPI
Cost	Supplier cost-saving initiatives
	Labor efficiency
	Cost variance from expected costs
Time	Supplier lead time against industry norm
	Supplier's booking-in procedures
	Purchase order cycle time
	Percentage of late deliveries
	Information timeliness
	Efficiency of purchase order cycle time
Quality	Buyer-supplier partnership level
	Level of supplier's defect-free deliveries
	Supplier rejection rate
	Delivery reliability
	Percentage of wrong supplier delivery
	Mutual trust
	Satisfaction with knowledge transfer
	Satisfaction with supplier relationship
	Supplier assistance in solving technical problems
	Extent of mutual planning cooperation leading to improved quality
	Extent of mutual assistance leading in problem-solving efforts
	Distribution of decision competences between supplier and customer
	Quality and frequency of exchange of logistics information between supplier and customer
	Quality of perspective taking in supply networks
	Information accuracy
Information availability	
Flexibility	Supplier ability to respond to quality problems
	Response to product changes
	Materials variety (number of materials available)
	Product and service variety
	Product volume variability capabilities
	Product development time
	Supply chain responsiveness
	Manufacturing/production flexibility
	Procurement flexibility (identified)
	Logistics flexibility (identified)
	Information systems flexibility (identified)
	New products flexibility
Delivery flexibility	

Category and area of measurement	Measurement designated KPI
Innovation	Satisfaction with knowledge transfer satisfaction
	Technological capability levels
	Involvement in new product design
	Introduction of new processes
	Rates of sales in new products (identified)
	Number of new products launched (identified)
	Supply chain stability (identified)
	Process improvement (identified)
Resource	Total supply chain management costs
	Distribution costs
	Inventory costs
	Manufacturing costs
	Total turnover costs
	Return on investment (or ratio of net profits to total assets)
	Value-added employee productivity
Information	Information management costs
	Information accuracy
	Information timeliness
	Information sharing
	Information availability
	Warranty costs
Output	Sales (or profit)
	Rates of stockouts (losing sales)
	Fill rate (target fill rate achievement, average item fill rate)
	Order fulfillment lead time
	Percent of on-time deliveries
	Perfect of order fulfillment
	Customer satisfaction
	Rates of customer complaints
	Planned process cycle time
Cash-to-cash cycle time	

Source: (Bai, Sarkis, 2014; Cai et al., 2009)

The presentation of indicators and measures, both in a green and sustainable chain, was presented Ahi and Searcy (2015) and Hassini et al. (2012). Some of the approaches to measurement presented in the literature relate to individual links and actions taken in individual companies and not at the level of the whole chain. The added value of a dedicated measurement system defining KPI's should be both versatility and the ability to measure in an integrated way for the whole chain. In recent years, the authors have increasingly stressed the need for integrated measurement of the supply chain in the context of its balancing and evaluation of the implementation of the sustainable development strategy (Björklund, Martinsen, Abrahamsson, 2012; Qorri, Mujkić, Kraslawski, 2018; Hassini, Surti, Searcy 2012; Reefke, Sundaram, 2017; Taticchi et al., 2015; Varsei et al., 2014).

3. KPI in the sustainable supply chain

The integration of indicators and measurement of sustainability into the supply chain is part of the integration of social, environmental and performance elements into the new business strategy. The danger that arises is related to the complexity of measurement. Such measures can be very complex and their effectiveness is not always proven. Therefore, it is advisable to create dedicated KPI sets, which will serve as the best operational solution related to the measurement and evaluation of the functioning of individual supply chain management subsystems. Manning (2013) points out that measurable benefits of implementing CSR policy are possible only with the use of KPIs. The KPIs for measuring and evaluating a green and sustainable supply chain refer to a sustainable development perspective. Economic, social and environmental aspects must therefore be taken into account. With reference to the classical division, the measurement of environmental aspects can be indicated that the indicators change and the areas remain the same (Table 2).

Table 2. Measurement area and examples of indicators in the environmental aspect

Measurement area	Environmental area – sub-indicators	Performance measurement criteria	Performance measurement sub-criteria
Cost	Environmental costs savings Energy Efficiency of systems Environmental cost performance variance Amount of environmental penalties	Green supplier partnership performance (SSPP)	1. Cost of raw material 2. Embodied carbon footprint 3. Defect rate 4. Flexibility rate 5. Recycling rate 6. Ordering cost
Time	Length to time to implement environmental programs Meeting environmental program implementation period Speed of acquiring environmental information Communication speed on environmental issues to supplier's suppliers	Green production performance (SPDP)	1. Unit manufacturing cost 2. Level of capacity utilization 3. Energy use 4. Product quality 5. Production flexibility
Quality	Environmental relationship and cooperation level Supplier rejection rate Waste generated from products and materials Percentage recycled material Mutual trust on environmental issues Mutual planning for environmental improvements Mutual assistance for environmental improvements Environmental information accuracy Environmental information availability	Green delivery and Logistics performance (SDLP)	1. Transportation cost 2. Greenhouse gas emission 3. Delivery time 4. Delivery reliability

Measurement area	Environmental area – sub-indicators	Performance measurement criteria	Performance measurement sub-criteria
Flexibility	Amount of environmentally safe alternatives Response to environmental programs for suppliers Response to environmental product requests		
Innovation	Environmental Knowledge Transfer Satisfaction Environmental Technology Levels New environmentally sound processes introduced New environmentally sound product development		

Source: (Jakhar, 2014; Bai, Sarkis, 2014)

4. Measuring of the sustainable supply chain

Sustainability performance indicators can be used to measure the sustainability of the supply chain. In order to assess the chain, the knowledge and applicability of an appropriate system of indicators must be demonstrated. In literature, substitutional terms such as ‘indicators’, ‘metrics’ and ‘measures’ are used for the performance measurement (Saeed, Kersten, 2017). The indicators relate to the measurement of performance by indicating both the quantitative and the qualitative effectiveness of the actions taken (Neely, Gregory, Platts, 2005). They are intended both to assess the current state of the system and to identify elements that should be improved. The breakdown of indicators to measure the sustainable supply chain is presented in Table 3.

Table 3. Categories of indicators for measuring a sustainable supply chain

Categories	Author/Source
Quantitative and qualitative	Ben Abdelaziz SI, Saeed MA, Benleulmi AZ (2015) Social media effect on sustainable products purchase. In: Kersten W, Blecker T, Ringle CM (eds) Innovations and strategies for logistics and supply chains: Technologies, business models and risk management, 1st edn. epubli GmbH, Berlin, 64–93,
Financial and non-financial	Agami N, Saleh M, Rasmy M (2012) Supply chain performance measurement approaches: Review and classification. The Journal of Organizational Management Studies:1–20,
absolute and relative	Ahi P, Searcy C (2015) An analysis of metrics used to measure performance in green and sustainable supply chains. Journal of Cleaner Production 86:360– 377
Strategic, tactical, operational	Handfield R, Walton SV, Sroufe R, Melnyk SA (2002) Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process. European Journal of Operational Research 141:70–87.

Source: (Saeed, Kersten, 2017)

Selected categories of indicators referring to sustainable development areas are presented in Table 4.

Table 4. KPIs in a sustainable supply chain – literature analysis

Sustainability area	Indicator	Definition
Environmental	energy efficiency	It classifies information related to the total energy consumption from all forms of renewable as well non-renewable energy sources and specific energy consumption within an organization
	material efficiency	It deals with all forms of material input and classifies KPIs related to the total material input as well an renewable, hazardous and recycled material input of the organization
	water management	It describes all forms of water consumption and classifies KPIs related to the total water consumption as well as the total water discharge and the quality of water discharge
	waste management	It classifies information related to the all forms of waste produced and recycled by an organization i.e. the total waste produced, total hazardous waste produced, and the total amount of waste recycled
	emissions	It collects information related to all forms of emissions by an organization and classifies KPIs related to the total GHGs emission (direct and indirect), ozone-depleting substances, VOCS, NOx, SOx, and particulate matters
	land use	It deals with the information related to the area of land use for conducting organization's operations and classifies KPIs related to the total land area used by an organization
	environment as compliance	It collects information related to the compliance with environmental regulations and classifies KPIs related to the number of fines for non-compliance, the total number of environmental accidents, and the total number of environmental standards and certificates obtained by organization
	supplier assesment	It collects information related to suppliers' environmental performance and their selection criteria. It classifies KPIs the measure a supplier's sustainability – related performance and the number of local or national suppliers
Social	human rights and anticorruption	It collects information related to corruption and the violation of basic human rights. It classifies KPIs related to incidents of discrimination, forced and child labor, corruption, and violation of the rights to the freedom of association
	human resource	It deals with all forms of information related to the management of human resource. It classifies KPIs related to the total number of jobs created, the ratio of male and female employees, the number of local and national employees, turn-over rates, employees' benefits, employees' satisfaction, and employees' performance evaluations
	health and safety	It collects information regarding health and safety issues related to the work in an organization. It classifies KPIs related to the number of injuries and illness, days lost due to occupational injuries and fatalities associated with the work
	training and education	It deals with the training and education opportunities provided to employees. It classifies KPIs related to the number of employees given training and the hours of training provided to both male and female employees of the organization

Sustainability area	Indicator	Definition
	consumer issues	It classifies information related to consumer issues such as consumer's complaints, product returns, and incidents of misleading, deceptive or fraudulent information to the consumer by an organisation
	social comppliance	It describes information related to the compliance with social regulations and classifies KPIs that measure the number of fines for non-compliance and the total number of social standards and certificates obtained by an organization
Economic	stability and profitability	It illustrates the financial health of the organization. This attribute category classifies information related to total sales/revenue, operating profit, free cash flow, and the total number of product produced
	Incom distribution	It deals with information related to salaries and benefits given to employees, payments made to government and community. It classifies KPIs related to payments made to the government in the form of taxes, employese wages and benefits, community investments, and operating costs
	market competitiveness	It deals with information related to an organization's economic performance as compared to its competitors in the same market. It classifies KPIs related to an organization's market share performance, the offering of competitive wages and the earning per share performance
	sustainability expenditures	It describes and considers and organization's economic performance in terms of organization's spending on sustainable initiatives, local procurement, as well as expenditures on research and development for a particular period of time

Source: (own elaboration based on: Saeed, Kersten, 2017)

Moving on to the analysis, it is necessary to indicate in which areas and which KPI's can be identified and applied for a sustainable supply chain. The characteristics and model of creating KPI's are presented in Table 4. On this basis it is possible to create a set of specific, dedicated KPI's needed to measure the sustainable supply chain in further steps of research. The reference model presented in Figure 1 may serve as a basis for further in-depth empirical research.

Identified KPI categories allow for in-depth bibliometric analyses. The content analysis method has been chosen. Selected qualitative method (Moldavska, Welo, 2017). However, in conjunction with a quantitative method, to assess both structural (descriptive) phenomena and the use of content criteria (Brewerton, Millward 2001). The selected method, thanks to appropriate coding and interpretation of results, allows to classify the studied phenomena. (Hsieh, Shannon, 2005). The content analysis allows for a better understanding of the examined areas and the identification and drawing of repeatable and correct conclusions (Griffin, 2013) using the methodology proposed by Mayring (from: Seuring, Müller, 2008). The analysis shall be carried out in four steps, comprising:

- material collection,
- descriptive analysis,
- category selection,
- material evaluation.

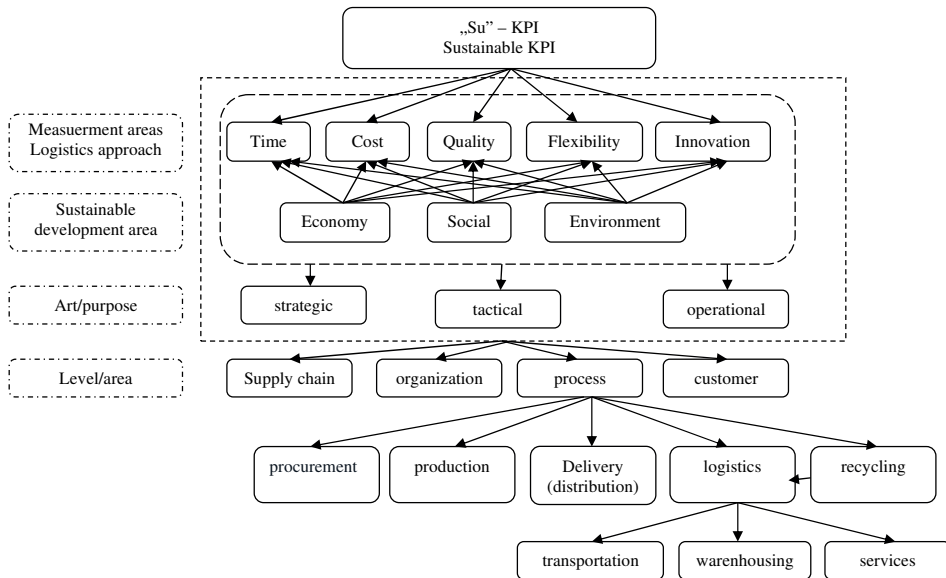


Figure 1. Reference model of creation of Su-KPI system in the supply chain
Source: (own elaboration)

The following analyses were made using papers in peer-reviewed scientific journals in English, which are available in web of science and science direct databases. To analyze the content of documents related to supply chain performance measurement, it is also possible to use the theoretical framework presented by Cuthbertson and Piotrowicz (2011), their included: the content, context, and process (CCP) Framework (Figure 2).

The KPI, particularly in terms of implementation of sustainable development elements, is important for the assessment of the supply chain. According to the surveying of companies in Poland in 2015 (Tundys, 2018), which declare that they know and implement green and supply chain principles in their business strategies, generally sustainable performance indicators are not popular enough. In general, there is an opinion among the surveyed companies that this is only a tool supporting the processes of assessing the sustainable supply chain. Nevertheless, it seems important to show appropriately constructed indicators to organisations as a decisive element of support for business process evaluation. It is worth considering creating a general catalogue of such indicators and adjusting subindicators to the specificity of a given industry, organisation or chain. Undoubtedly, from the point of view of the organisation and the environmental aspect such elements as Landfill waste; waste types; gas, water and electricity usage; per cent of energy from renewable resources; fuel efficiency; per cent of fuel efficient vehicles; miles/year travelled; percent of ISO 14001 certified suppliers; and airfreight level as such indicators can serve as such indicators.

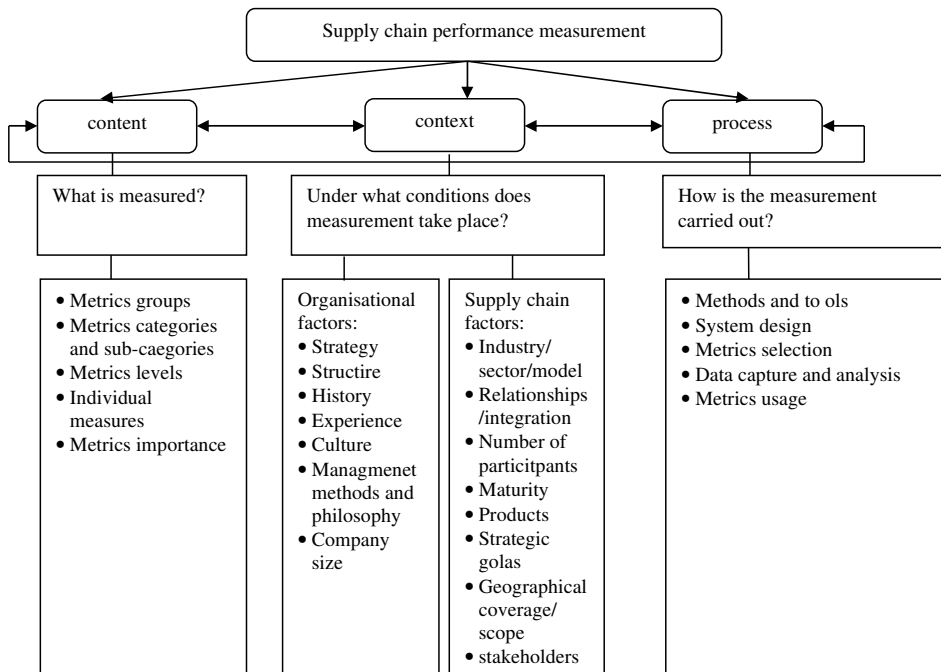


Figure 2. Framework for performance measurement in supply chain – the content, context, and process point of view

Source: (own elaboration based on: Cuthbertson, Piotrowicz, 2011)

5. Results

Selection and identification of the KPI is needed for further analysis of the measurement. They are particularly useful for quantitative measurement, in which AHP, MCDA can be used. The set of indicators and identified KPIs provides a basis for understanding the scope of the organisation's activities and actions taken for sustainable development. KPIs that are intended to serve as part of a sustainable supply chain measurement should therefore be defined as: indicators that help to measure the performance of an organisation and its chain, taking into account the three dimensions of sustainable development. Not every area needs to be equally represented (number of indicators and their burden) depends on the type of chain and the organisation itself. It is important to refer to each area in the measurement. The choice of indicators can be considered a critical element and all types and categories should be taken into account. A properly selected and structured measurement helps to implement a sustainable supply chain strategy and allows for the correction of errors that occur, as well as indicating in which areas more attention should be paid to.

The following assumptions were made for a context analysis to identify whether the KPIs are being used to measure a sustainable or green supply chain:

1. The analysis covered the bases: scopus, Web of science oraz sciencedirect.
2. The analysis covered: słowa kluczowe, tytuł, abstract.
3. Conceptual limitation: „sustainable” or „sustainability” or „green”, or “social” “supply chain”, “green supply chain”, “sustainable supply chain”, “KPI” or “key performance index”, “measurement”, “evaluation”, “assessment” “performance measurement”.
4. The analysis covered: peer review and research articles.

After filtration of the research material, the record-generating records were eliminated and further analyses were carried out. As a result, 73 publications were taken into account in the analysis, 9 of which were published in the Proceedings.

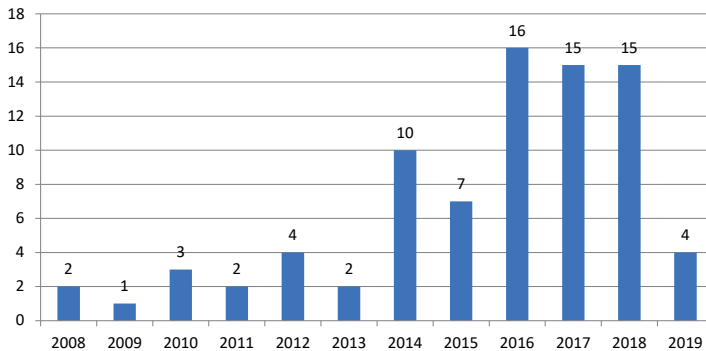


Figure 3. Number of publications covering the phenomena studied
Source: (own elaboration)

The analysis shows that the interest of KPIs in the area of implementation into the sustainable supply chain is growing and considering that the analysis was carried out in March 2019, it can be predicted that in 2019 there will be the largest number of publications. Until now, 2016 is the largest number of publications, i.e. 16, of which in 2017 and 2018 the number was not much smaller, i.e. 15 publications in this respect. As you can see, the subject matter is still definitely niche, it is not very popular among the authors, which indicates, although some interest can be seen. Therefore, it can be concluded that this is an interesting not yet researched area, which should be noticed by scientists, on the one hand in order to develop knowledge and science, and on the other hand to indicate to practitioners and the business side what tools and instruments can be used in order to better and more effectively evaluate their supply chain and organisation, which on the other hand may translate into a better competitive position.

Analysing Figure 4 (only journals in which publications appeared at least twice, those in which the subject matter appeared only once are presented in Table 5) it can be pointed out that the subject matter of KPIs for sustainable supply chain implementation is reflected both in economic and business journals, as well as in the field of technical sciences. In total, more than 40 of the publications analysed were published in business and management magazines and related sciences. The rest is in the field of technical sciences and publications point to solutions related to models (including mainly mathematical ones). The presence of a publication

related to this subject in the area of business may indicate the practical nature of the considerations undertaken and the great potential for implementation into business activity.

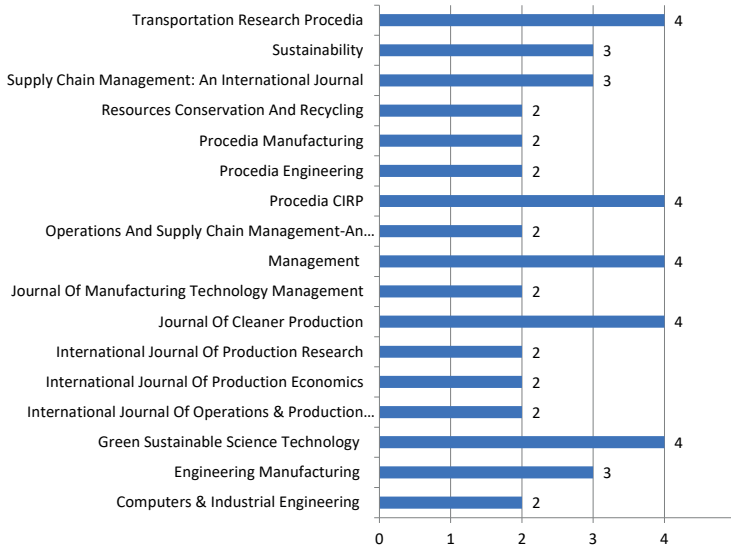


Figure 4. Names of journals in which the companies appeared (at least twice during the period considered)
Source: (own elaboration)

Table 5. Names of journals in which the researched topic in the space 2008–2019 appeared in 1 article

Accounting Forum	Journal Of Natural Gas Science And Engineering,
Advances In Intelligent Systems Research	Knowledge-Based Systems
Applied Energy	Logistics Research And Practice In China
Applied Mechanics And Materials	Procedia Computer Science
Arab Economic And Business Journal,	Research In Transportation Economics,
Built Environment Project And Asset Management	Science Of The Total Environment
Business And Economic Horizons	Smart And Sustainable Manufacturing Systems
Cogent Engineering	Supply Chain Management
Computer Standards & Interfaces	Sustainable Production And Consumption
Computers In Industry	Transport And Telecommunication Journal
Decision Support Systems	Transportation Research Part A: Policy And Practice
European Journal Of Operational Research	Transportation Research Part D: Transport And Environment
Global Business Review	International Journal Of Sustainable Engineering

Source: (own elaboration)

Table 6 presents the classification of research areas to which individual publications are included. It shows that, on the one hand, the interest in the use of performance measurement is the domain of business, on the other hand, there are many mathematical models and technical sciences, including those related to computer science.

Table 6. Classification of research areas to which publications of particular journals

Automation Control Systems	Engineering Environmental
Business	Engineering Industrial
Business Finance	Engineering Manufacturing
Business Management and Accounting	Engineering Multidisciplinary
Computer Science	Environmental Sciences
Computer Science Artificial Intelligence	Environmental Studies
Computer Science Information Systems	Green Sustainable Science Technology
Computer Science Interdisciplinary Applications	Management
Computer Science Theory Methods	Materials Science Multidisciplinary
Economics	Operations Research Management Science
Energy Fuels	Public Environmental Occupational Health
Engineering	Transportation
Engineering Civil	Transportation Science Technology
Engineering Electrical Electronic	Urban Studies

Source: (own elaboration)

6. Discussion

The presented considerations were aimed, firstly, to identify model areas and the extent to which a KPI should be sought for assessing the functioning of a sustainable supply chain. The presented simplified reference model may serve as a basis for the search for specific indicators, which will also be a further area and scope of authors' research. The bibliometric analysis, which was an element supporting the discussion, aimed at indicating that a given subject matter is still poorly described in literature. What is an interesting element for the development of this area of science. Through in-depth analysis of literature, analysis and synthesis of ascending content, it is possible to better understand the scope and areas in which KPIs are used to assess the functioning of a sustainable supply chain. This can be helpful not only from a theoretical point of view, but also in terms of practical implementation of solutions to the economy.

Considerations have their limitations, only selected articles have been taken into account, which in their titles or abstracts and keywords contained the term KPI, research can be further extended and analysed other terms, or specific measures and indicators. Secondly, the presented model was not verified in the economic reality, it only reflects the actions taken on the basis of theoretical considerations and the literature of the subject.

Conclusions

The literature review shows that studies on the use of KPIs to measure supply chain sustainability performance are fragmented and incomplete, while at the same time representing a relatively new research area. The results show that organisations know that such indicators exist but are not aware of and do not know how to design and implement them in order to be sustainable. Implementations are sporadic, rather theoretical. The biggest problem is the lack of knowledge of how many and which indicators should be included in this context as KPIs, which will allow to assess the supply chain in terms of sustainable development implementation. This research is important and provides a good starting point for both researchers and managers to understand the measurement methods, tools and instruments that can help to assess the sustainability performance of the chain.

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