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Measurement Through Sustainability Indicators in Production Processes: a Systematic Review

Mensuração da Sustentabilidade em Processos Produtivos por meio de Indicadores: uma Revisão Sistemática

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Abstract

Purpose: Sustainability in the organizational context reveals itself as a significant and emerging factor to curb socio-environmental impacts. The study aims are to present a systematic literature review about the models of indicators to assess sustainability in production processes, in the period from 2015 to 2019.
Design/methodology/approach: The bibliographic search comprised multiple academic databases. In total, 97 papers composed the research corpus.
Research, Practical & Social implications: The results reveal that studies on sustainability indicators have been growing, especially in 2019, predominantly in the civil construction and manufacturing sectors. The models with identified names were highlighted and their characteristics presented.
Originality/value: In general, the study provides insights into models of sustainability indicators that can be used to measure sustainability in the productive environment.
Keywords: Sustainability Measurement; Sustainability Indicators; Organizational Sustainability; Production Processes.

Resumo

Objetivo: A sustentabilidade no contexto organizacional, revela-se como um fator significativo e emergente para coibir os impactos socioambientais. O objetivo deste estudo é apresentar uma revisão sistemática da literatura sobre os modelos de indicadores para avaliar a sustentabilidade nos processos produtivos, no período de 2015 a 2019.
Método/abordagem: A pesquisa bibliográfica compreendeu múltiplas bases de dados de periódicos internacionais. No total 97 artigos compuseram corpus de pesquisa.
Contribuições teóricas/práticas/sociais: Os resultados revelam que os estudos sobre indicadores de sustentabilidade vêm crescendo, especialmente em 2019, predominantemente, nos setores de construção civil e manufatura. Foram apresentados os modelos que tiveram uma nomenclatura identificada e foram demonstradas as suas características.
Originalidade/relevância: De um modo geral, o estudo fornece *insights* sobre modelos de indicadores de sustentabilidade que podem ser utilizados para mensurar a sustentabilidade no ambiente produtivo.
Palavras-chave: Mensuração da Sustentabilidade; Indicadores de Sustentabilidade; Sustentabilidade Organizacional; Processos produtivos.

Introduction

During the 1970s, the concern with survival on the planet emerged due to the environmental impacts caused by the current production and consumption model. Debates, studies, and reflections were started to bring awareness to society and organizations about the scarcity of natural resources and their unequal distribution, which also entailed inequality in the distribution of wealth among peoples, in turn causing poverty and social exclusion.

Several conferences concentrated efforts to ally countries in successive accords for sustainable development, such as the Stockholm Declaration (1972), the Brundtland Report (1987), the Convention on Climate Change (1994), the Kyoto Protocol (1997), among others. Currently, the 2030 Agenda, which encompasses the countries integrating the United Nations, is a crucial mission with goals to be achieved toward sustainability on the planet, balancing the social, environmental, and economic dimensions, as defended by Elkington (2001).

Thus, it became evident, from the start of the 1990s, that the global economy would go through great changes to fulfill environmental goals. In this context, corporations had to rethink the traditional management model, in which assessing a company valued only its economic performance. According to Elkington (2001), from that moment on, considering the environmental and social performances, besides finances, would be unavoidable. This new concept, which integrates these three spheres – social, environmental, and economic – into the values and results of a company, became known as the Triple Bottom Line (Elkington, 2001).

The late 20th century saw a huge expansion in Socially Responsible Investing (SRI). From its first measurement in 1995 to 2012, the SRI market in the United States had grown 486%. Moreover, in the perspective of corporations, voluntary participation in sustainability initiatives generated intangible gains, like reputation and experience sharing in the business community (Gvces, 2012).

This movement toward reorganizing corporate management would bring significant consequences to the stock market. Not long after, investment portfolios comprising only companies that adopted corporate management based on the Triple Bottom Line appeared. These portfolios would compose indices in the stock markets known as Sustainability Indices.

The first sustainability index appeared in the United States in 1999, the Dow Jones Sustainability Index (DJSI). Two years later, the London Stock Exchange launched the FTSE4good jointly with the Ethical Investment Research Service (EIRIS). The sustainability index wave spread through emerging countries too, and in 2004 the Johannesburg Stock Exchange launched the JSE SRI. Only a year later, the São Paulo

Stock Exchange created the first sustainability index in Latin America, the Corporate Sustainability Index (ISE). Thus, arises the commitment to achieving the goals toward a more just and equal society, employing natural resources in a balanced manner to protect ecosystems and conserve biodiversity, as a challenge for governments, organizations, companies, and people of the world as a whole.

The commitment to achieving the goal of a more equal and fair society, using natural resources in a balanced manner to protect ecosystems and conserve biodiversity, is a challenge for governments, organizations, companies, and the population. (Considere apagar, o final do último parágrafo diz a mesma coisa.)

At the corporate level, sustainability is a constant challenge, and often companies do not know how to implement strategies that combine the dimensions effectively or to measure their actions. Managers need to have feedback so that they can implement constant improvements in their sustainability actions, establishing metrics that assess the process.

One of the methods to measure/assess the effectiveness of organizational sustainability initiatives is employing specific indicators. Even with a significant number of studies on this aspect, the subject still requires a more in-depth look.

The goal is to present a systematic literature review about the models of indicators to assess sustainability in production processes, in the period from 2015 to 2019. The relevance of this study lies in knowing the models of sustainability measurement and assessment employed by business activities and whether they are specific to a sector. A summary of these models allows us to identify gaps for their improvement, as well as their expansion to other activities and the development of new constructs.

The results showed that researchers have a growing interest in studying sustainability indicators, like Arbolino, Simone, Carlucci, Yigitcanlar and Ioppolo (2018), Bissoli-Dalvi et al. (2016), Espinosa (2015), Ghoddousi, Nasirzadeh and Hashemi (2018), Goyal, Rahman and Kazmi (2015), Hasheminasab, Gholipour, Kharrazi and Streimikiene (2018), Helleno, De Moraes and Simon (2017), Ingwersen et al. (2016), Jonkutė and Staniškis (2016), Lähtinen and Myllyviita (2015), Neugebauer, Martinez-Blanco, Scheumann and Finkbeiner (2015), Nicoletti Junior, Oliveira and Helleno. (2018), Opon and Henry (2019), Rajak and Vinodh (2015); Pask, Lake, Yang, Tokos and Sadhukhan (2017), Pillain, Gemechu and Sonnemann (2017), Rahdari and Anvary Rostamy (2015), Scholl, Hourneaux and Galleli (2015), Taulo and Sebitosi (2016), Whitehead (2016). We also observed a predominance of studies in the fields of civil construction and manufacturing, and that most studies are empirical and quantitative.

Besides, this paper sought to compile sustainability assessment and measurement methodologies through indicators, contributing to identifying the existing approaches in the literature and fomenting studies in organizational practice, which constitutes the gap that this study fills by filling. The theoretical implications of this paper concern the insights that might arise in proposing new studies on sustainability indicators adopting the listed methodologies, and even the practical implication in the organizations that choose a methodology that contributes to sustainability assessment and measurement.

This paper is organized into five parts. The first contains the introduction, presenting an overview of the theme and the goals and relevance of this study. The second section consists of the theoretical framework on sustainability indicators. The third presents the methodological procedures employed by the study. The fourth section analyzes and discusses the research results and, finally, the fifth part brings the final considerations on the study, its limitations, and suggestions for future works.

Theoretical Framework

Sustainability indicators

The concept of sustainable development was introduced in 1987 by the Brundtland Commission, formally known as the World Commission on Environment and Development (WCED), as a part of the report "Our Common Future". The report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 43). The definition broadly comprises equity and global intergenerational justice in the distribution of welfare, utilities, and resources.

The growing discussion and debates on sustainability in the corporate world have brought several approaches to establish metrics for managing socio-environmental impacts. One approach to measuring the progress toward sustainable development is employing sustainability indicators (SIs). Many SI frameworks have been published, dating back nearly two decades (Bell; Morse, 2001). The need for qualitative and quantitative sustainability indices was also emphasized, because they allow companies to continually monitor sustainability in processes and business systems, improving their current sustainability status (Haapala et al., 2013).

The literature presents concepts related to the term sustainability indicators. According to Gallopin (1996), indicators are operational representations of attributes. Attributes and indicators are selected to describe the evolution of the desired system and/or assess performance in relation to goals, with this selection being a critical stage. Tayra and Ribeiro (2006) mention that "[…] the purpose of indicator systems is the construction of a set of indicators that show linking and/or synergistic trends, variables that when analyzed within a set can explain the central trends, tensions, and underlying causes of sustainability problems". For Searcy (2012), an indicator system presents information to aid a company in short and long-term management, control, planning, and economic performance, besides the environmental and social activities performed.

So that an indicator system can encompass the phenomena and allow the interested parties to make decisions, it is essential to observe a few requisites, as the ones approached in the studies of Gallopin (1996) and Bell and Morse (2001), as follows.

The ideal set of indicators represents the relevant phenomena in a way that is simultaneously comprehensive and enables decision-making. Thus, desirable indicators summarize or simplify relevant information, making the pertinent phenomena visible or perceptible, while quantifying, measuring, and communicating these data (Gallopin, 1996).

In 1995, Prescott-Allen sought to assess sustainability by focusing on the integration of social and environmental aspects, presenting thus an evolution of dimensions, and the level of sustainable development originating from welfare on a two-dimension scale. It is a hierarchical scale that selects indices and indicators and presents the state of welfare in the society and environment (Van Bellen, 2002). Thus, he defined intervals between preset standards so that indices and indicators were in the same standard for analysis.

In 1996, Wackernagel and Ress created the ecological footprint, seen as an all-encompassing indicator to assess the eco-environmental pressure caused by human behavior (Kalimeris et al., 2020). The ecological footprint refers to the total area of biomass-producing land necessary to produce resources for a population and to absorb the waste generated by the consumption of this population (Wackernagel & Rees, 1996). Many countries currently employ the calculation of the ecological footprint to measure the sustainability of urban social ecosystems, as it compares resource consumption by human activities with nature's support capability, showing whether the environmental impacts are sustainable in the long term (Kalimeris et al., 2020).

Bell and Morse (2001) report that the effectiveness of sustainability indicators must include the opinions of the interested parties that, in a final analysis, intend to benefit from them. The authors explain that when the interested parties are involved and engaged in the conceptualization and development of an SI, it is more likely that they employ and appreciate the results.

One doubt that may arise concerns the selection of indicators to be employed to establish the sustainability analysis. Observing a few characteristics is crucial, such as the ones reported in the studies of Copus and Crabtree (1996), Spangenberg and Bonniot (1998), Bell and Morse (2001), Chong, Teo and Tang (2016), and Dohnal and Kocmanova (2016). These characteristics concern the fact that the set of sustainability indicators applied in a study is usually selected based on the local context, for instance, the policies at hand, data availability, and the researchers' opinions (Chong et al., 2016). Besides, sustainability indicators may offer a wide array of information in a simplified manner to facilitate the user's understanding, allowing sustainability comparisons in time and space (Copus & Crabtree, 1996). Dohnal and Kocmanova (2016) point to a consensus in the literature regarding the fact that sustainability indicators must be intentional, measurable, representative, reliable, and reproducible.

Analysis dimension	Characteristics
Whose indicator?	The first dimension by which sustainability indicators can be characterized is their origin. They can stem from within or outside the community.
Which indicator?	Sustainability indicators may be quantitative (numerical) or qualitative (subjective).
How is the indicator defined?	Sustainability indicators may be explicit (clearly articulated with standard methodologies for assessment and presentation) or implicit (not clearly articulated but applicable). An explicit sustainability indicator clearly provides the methodology and units that must be employed to ascertain its value. Besides, there may be a goal declared for the indicator, even if it is simply a change expression.

Table 1. Characteristics of sustainability indicators
Source: Adapted from Bell and Morse (2001).

Spangenberg and Bonniot (1998) present three characteristics inherent to simple, secure, and significant indicators. To ensure simplicity, the number of indicators must be limited and the calculation methodology transparent. To ensure security, the set of indicators must be obvious and indicate a relevant sustainability aspect. To ensure significance, it must be open to changes and therefore able to signal progress or lack thereof at the particular application level.

Defining which sustainability indicators to employ in decision-making processes is crucial, considering the singularities of each case. As Spangenberg and Bonniot (1998) observe, the changes required to achieve sustainability are different in each market sector. Besides, tracking specific indicators may demonstrate to the public that the company is in fact concerned with sustainability (Frank, Dalle Molle, Gerstlberger, Bernardi & Pedrini, 2016).

Sustainability indicators allow us to assess economic, environmental, and social aspects of a process, company, product development, city, industrial park, among others (Valenzuela-Venegas, Salgado & Díaz-Alvarado, 2016).

Once the sustainable development indicators are defined, they must be measured extensively, quantitatively, qualitatively, and increasingly more often with data availability. The main obstacles are related to the selection, interpretation, and use of indicators (Moldan, Janouška & Hák, 2012). The study conducted by Gallopin (1996) demonstrated that useful indicators are not limited to numerical values, which illustrates the relevance of qualitative aspects in the phenomena analyzed.

Another factor that hampers the implementation of sustainability actions is the lack of consensus among indicators (Azevedo & Barros, 2017). The literature presents several initiatives to measure sustainability, but the integration of the environmental, economic, and social dimensions is still challenging (Gallopin, 1996; Morse, Mcnamara, Acholo and Okwoliet, 2001; Jonkutė & Staniškis, 2016; Azevedo & Barros, 2017).

The biggest challenge for the integration is the qualitative nature of most social indicators, which makes the assessment too dependent on the decision-makers' personal views (Negri et al., 2016).

Gallopin (1996) reported that the use of indicators to operationalize the concept of sustainable development and anticipate the impact of policies and human actions on sustainability would require a growing use of modeling approaches and frameworks to generate explanations and predictions. Over the years, the statement by Gallopin (1996) revealed itself valid, as Jonkutė and Staniškis (2016) present. These authors report that there are several approaches to creating structures and methodologies for the development of integrated sustainability indicators that measure, monitor, and assess the progress of a company toward sustainability.

Long, Pan, Farooq and Boer (2016) determine that the relevance of an indicator must be directly linked to a significant and intentional sustainability aspect for the company at hand. The information in an indicator must be easy to identify within a reasonable time.

Bell and Morse (2001) state that the methodology employed to measure sustainability needs to be sensitive to what it intends to measure, easy to replicate, and viable in terms of costs and data collection. However, there are obstacles to operationalizing sustainability indicators. According to Whitehead (2016), they are often limited in their capability to determine which questions to measure and how to answer them. Moreover, environmentally speaking, a problem inherent to many environmental indicators in systems, and to all of the approaches to transforming an economic financial environmental perspective, is that the unknown cannot be measured (Spangenberg & Bonniot, 1998).

Thus, an all-encompassing structure for an integrated assessment of sustainability in a company based on the processes of manufacturing, products/services, and relationship with several interested parties has yet to be created (Jonkutė & Staniškis, 2016). Given the still enormous limitations in our understanding of the dynamic of complex socio-ecological systems, there is not a single universally accepted model or even a theory on the dynamic of socio-ecological systems. Therefore, it would be prudent to employ significant criteria in the selection of indicators for a wide array of models (Gallopin, 1996).

Methodology

The systematic literature review followed the protocol based on Pollock and Berge (2018), who suggest: (i) clarifying research goals and objectives; (ii) searching for relevant studies; (iii) collecting data; (iv) assessing the quality of the studies; (v) summarizing the evidence; (vi) interpreting the findings. The stages and activities presented aim to ensure the accuracy and robustness desired in this type of research.

The search in the literature about sustainability indicators in production processes was conducted in the databases Emerald, Sage, Science Direct, Scopus, Web of Science, and Wiley Online Library. The selection of these databases is justified because they encompass scientific production in the Business, Management, and Accounting fields, from which the papers were extracted. The search period comprised the years from 2015 to 2019.

The search employed the following keywords and Boolean operators: "sustainability indicators" AND NOT "agribusiness" AND NOT "agricultural" AND NOT "livestock" AND NOT "cattle", over the 2015-2019 period. The selection included only papers, filtered by title, abstract, and keywords, returning 1,146 results. The search stages can be viewed in the flowchart presented in Figure 1.

The information in the selected papers was downloaded and migrated into the reference manager Zotero, which removed the duplicate documents and papers that did not match the research scope. This stage discarded 918 studies, with 228 papers remaining for further analysis of titles, abstracts, and keywords, considering the following inclusion and exclusion criteria:

1) Inclusion criteria: this stage included a) the papers that presented a connection between the search query (sustainability indicators) and its relation to production processes; b) complete studies published in scientific journals.
2) Exclusion criteria: a) papers that did not belong to the fields of Business, Management and Accounting; b) duplicate papers; c) publications that were not scientific papers (papers published in conferences or

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similar, books, book chapters, etc.); d) papers whose title, abstract or keywords were not in line with the scope of this study; e) papers on sustainability indicators that are unrelated to production processes (for instance, in the fields of tourism, sustainability of cities, regions, countries, etc.); f) papers on sustainability indicators related to the agri-food system

After the operationalization, we selected 228 studies and analyzed their relevance through the InOrdinatio equation, resulting in the selection of 97 scientific papers.

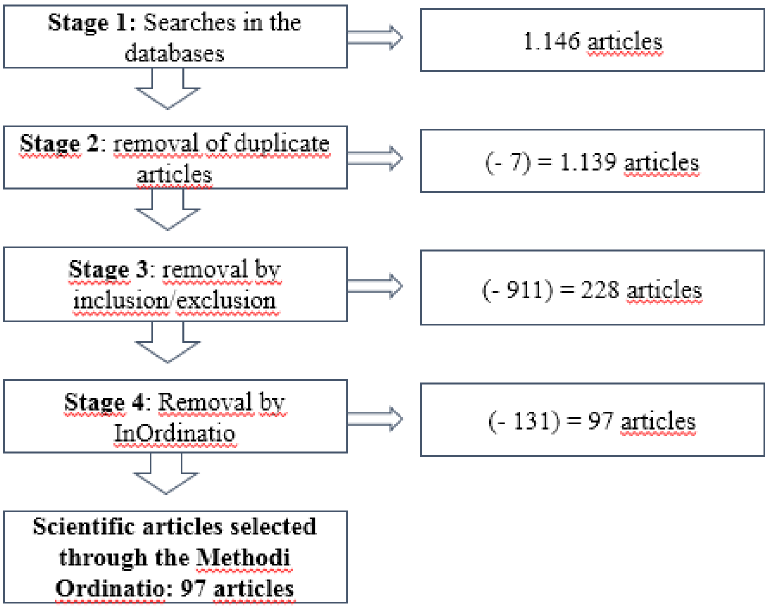

Figure 1. Stages in the selection of scientific papers utilized in the review
Source: Research data (2019).

This method is a multicriteria tool for decision-making in the selection of scientific papers to create a bibliographic research portfolio, selecting papers according to the impact factor of the journal, the year of publication, and the number of citations obtained (Pagani, Kovaleski & Resende 2015), according to the following equation.

$$\text{InOdinatio} = (\text{Fi}/1000) + a^{*}\,[10 - (\text{AnoPesq} - \text{AnoPub})] + (\Sigma\ \text{Ci})$$

In which:
-InOrdinatio: corresponds to the index attained by the scientific paper;
-Fi: impact factor of the Journal that published the scientific paper;
a: it is a value ranging from 1 to 10, selected by the researcher, corresponding to the relevance of the year of publication of the scientific paper;

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-AnoPesq: The research was developed; in the year
-AnoPub: it is the year of publication of the scientific paper;
-Ci: it is the number of citations of the scientific paper.

Regarding the results, the analysis encompassed the works that scored higher than sixty did (InOrdinatio > 60). In this research, we attributed a value of 10 to the coefficient "a" for all of the scientific papers, considering that recent publications are relevant. After the application of the Methodi Ordinatio, the highest-rated paper selected scored 363.00 and the lowest-rated, 61.00. The application of the Methodi Ordinatio returned the final sample, composed of 97 papers. It is worth highlighting that, due to this final selection of papers, the analysis focused on the period from 2015 to 2019. Sustainability indicators were categorized into environmental, social and economic dimensions.

Results and Discussions

This section presents the study results and their discussion. Graph 1 displays the number of scientific paper publications from 2015 to 2019. It is noticeable that studies on sustainability indicators in production processes have been growing over the years, with the years 2018 and 2019 standing out in the sample selected. It is possible to observe, therefore, a direction given to studies on the theme, meaning that, due to the progression of the discussions on sustainability, more studies are seeking to establish acknowledged and reliable indicators that measure and assess sustainability in the organizational field.

In percentile terms, there was a 5% increase in the production of 2016 in comparison with 2015 and 2017 in comparison with 2016. The production increased 2% in 2019 in relation to the previous year. The accumulated growth corresponded to 12%.

One relevant aspect of systematic literature reviews is that they highlight which journals are publishing about the theme, allowing researchers to find more material. Within the scope of this literature review, the Revista de Administração Contabilidade e Sustentabilidade (REUNIR) stood out, having published 37.1% of the papers in the sample. Other journals, like Logforum (6.2%) and the European Journal of Operational Research (5.2%), were also more expressive regarding publications on the theme. Journals with only one paper published within the scope were listed in the "Others" category.

Concerning empirical analyses conducted by the papers in the selected sample, Brazil stands out with 12 studies, followed by India with seven, Italy and China with five each, and the United States with four studies.

The civil construction sector presented ten studies from 2015 to 2019, followed by manufacturing companies with eight. In lower numbers, the oil and gas sector presented four studies, and the biofuel, chemical/metal/metallurgy, and supplies sectors presented three studies each.

It is worth mentioning that a significant number of publications (12 papers) did not specify the sector in which the investigated company acted, informing only their location. Similarly, 22 papers did not specify the sector, including in this category the systematic literature reviews that targeted a specific sector for analysis. The "Others" category lists works from several other sectors that presented only one or two studies.

Regarding the dimension of the indicators, most studies focus on the triple bottom line approach to sustainability, which balances the social, environmental, and economic pillars (Elkington, 2001). Albeit in smaller numbers, a few studies focus on a single pillar or combine only two dimensions. The review revealed that some studies prioritize environmental aspects, others focus on the social or economic pillars, and even others combine the environmental and economic dimensions. Moreover, a few studies add cultural aspects to the three pillars, considering the cultural aspect a sustainability dimension, as defended by Sachs (1997).

The systematic review allows us to identify possible models for sustainability assessment in production processes. Two pertinent points should be emphasized: 1) the models presented in Table 2 do not exhaust the literature in terms of methods for sustainability indicators employed in production processes; 2) within the selected sample, Table 2 displays only the models with specific names. Other structures have been developed but do not present a specific name for the set of indicators developed or applied in the study.

Methodologies for sustainability indicators	Authors who approached the methodology	Methodologies for sustainability indicators	Authors who approached the methodology
Industrial Environmental Sustainability Index (IESI)	Arbolino *et al*. (2018)	Instrument for the Selection of More Sustainable Materials (ISMAS)	Bissoli-Dalvi *et al*. (2016)
Methodology to support self-transformation	Espinosa (2015)	Multicriteria group decision-making (MCGDM)	Ghoddousi et al. (2018)
Analytical Hierarchy Process (AHP)	Goyal et al. (2015)	Metric of Sustainability (MOS)	Hasheminasab *et al*. (2018)
Value Stream Mapping (VSM)	Helleno *et al*. (2017)	Industrial Process System Assessment (IPSA)	Ingwersen *et al*. (2016)
Responsible and Sustainable Company (SURESCOM)	Jonkutė and Staniškis (2016)	Global Reporting Initiative (GRI) Standards	Lähtinen and Myllyviita (2015)
Tiered approach	Neugebauer *et al*. (2015)	Sustainability Evaluation Model (SEM)	Nicoletti Junior et al. (2018).

Table 2. Sustainability indicator models and their main characteristics
Source: Research data (2019).

Methodologies for sustainability indicators	Authors who approached the methodology	Methodologies for sustainability indicators	Authors who approached the methodology
Sustainable Concrete Material Indicators (SCMI)	Opon and Henry (2019).	Fuzzy and Monte Carlo	Rajak and Vinodh (2015); Pask *et al*. (2017)
Life Cycle Impact (LCIA)	Pillain et al., (2017)	Most Common Indicators (MCIs)	Rahdari and Anvary Rostamy (2015)
Composite Sustainable Development Index (ICSD)	Scholl et al. (2015)	Material and energy flow analysis (MEFA)	Taulo and Sebitosi (2016)
Driver-Focused Prioritization (DFP) of Sustainability Indicators	Whitehead (2016)		

Table 2. Sustainability indicator models and their main characteristics (cont.).
Source: Research data (2019).

The Industrial Environmental Sustainability Index (IESI) enables a vertical comparison between regions so as to assess the achievements of the national sustainable industrial policy. This indicator was employed by Arbolino et al. (2018) in industries in general. Its two sub-indices also allow horizontal comparisons between regions to encompass the role performed by public and private actors (Arbolino et al., 2018).

According to Bissoli-Dalvi et al. (2016), the Instrument for the Selection of More Sustainable Materials (ISMAS) proposes a context for conceptual fragmentation focusing on sustainability analyses targeting specific topics such as raw material savings, waste generation, and management in the industry of civil construction materials. Some assessment methods are limited in reach, seeing that they do not encompass every impact type but rather those considered more relevant or business-centered.

The Methodology to Support Self-transformation seeks to encourage learning on organizational self-transformations employing the viable system model (Value Stream Mapping – VSM) and other systemic tools as the theoretical organization model. It suggests six central stages for the learning process: organizational identity and limits, mapping complexity levels, structural diagnosis (VSM diagnosis), strategy and structure alignment, decisions about the transformation plan, and implementation and learning. The VSM model was applied in a socio-ecological system in a community and a company (Espinosa, 2015). Value Stream Mapping employs environmental indicators related to the consumption of raw materials, water, and energy. The social indicators are linked to work safety, ergonomic aspects, and noise levels. The economic dimension employed the same indicators of the traditional VSM, namely cycle time of operations that aggregate and do not aggregate value (Helleno et al., 2017).

Another method for assessing sustainability indicators identified in the scientific papers portfolio is the Multicriteria Group Decision-Making (MCGDM). It is a simulation-based model to aid in the assessment of alternative construction projects based on capability indicators, highlighted by Ghoddousi et al. (2018).

Goyal et al. (2015) worked with the Analytical Hierarchy Process (AHP), which consists of a mathematical decision-making technique introduced by Saaty (1980) to solve complex decision-making for problems containing uncertainty and complexity. The AHP breaks down a complex problem into a hierarchy of simple factors and sub-factors to facilitate their measurement with the aid of comparative analysis. One of its central characteristics is that it can be applied both to the subjective and objective aspects of a problem.

The Metric of Sustainability (MOS) employs an approach introduced by Chong et al. (2016) in which he proposes a sustainability measurement tool for assessing the life cycle of waste-to-energy systems. To ensure assessment integrity, the approach was applied in a study of the oil sector. The MOS seeks to integrate inputs perfectly and obtain reliable results, to act as the basis for decision-making (Hasheminasab et al., 2018).

The Industrial Process System Assessment (IPSA) is an approach of multiple-stage allocation to connect information from the production line level to the installation level and vice-versa, employing a multi-scale model of process systems applied in the paper and cellulose sector. The method helps to solve challenges in the assessment of multi-product systems or multi-production lines, and it was employed in the study of Ingwersen et al. (2016).

Another approach utilized was the Sustainable and Responsible Company (SURESCOM), identified in the study of Jonkutė and Staniškis (2016). The SURESCOM model offers methodical suggestions to assess the customers' opinion about the presence of activities and initiatives of environmental and social sustainability in the company to identify and select the most appropriate sustainability indicators, determine their importance according to the analytical hierarchy process (AHP), and solve the most significant sustainability problems at three levels: manufacturing processes or activities, products/services of the company, and the relationship with several interested parties. This investigation developed two case studies, in the construction and telecommunication sectors (Jonkutė & Staniškis, 2016).

Lähtinen and Myllyviita (2015) employed the Global Reporting Initiative (GRI) Standards, which is one of the most extensive guidelines for the implementation and development of volunteer systems for reporting on corporate social responsibility in dimensions of social, economic, and ecological sustainability. The approach was utilized in a case study in the forest bioenergy production sector.

Neugebauer et al. (2015) employed the tiered approach. This methodology develops a new approach to facilitate the practical implementation of Life Cycle Analysis (LCSA) by including an indicator hierarchy. This tiered approach works as a gradual technique through the implementation of the LCSA indicator. Its purpose is to improve the assessment practice into a more holistic approach, away from single-dimension assessments.

The Sustainability Evaluation Model (SEM), based on the literature, aims to integrate sustainability into a manufacturing system. The SEM is associated with the four perspectives from the Balanced Scorecard (BSC) and the three dimensions from the Triple Bottom Line. The methodology was employed in the food and drinks sector (Nicoletti Junior et al., 2018).

The Sustainable Concrete Material Indicators (SCMI) model consists of a structure that reveals the existing causality between indicators, portrayed in a causal network that shapes the strength-state-impact relationship. The SCMI structure could simplify the complex nature of concrete sustainability into a form relatively easy to communicate to the interested parties. It provides an all-encompassing perspective that constitutes the sustainability of the material, as presented in the work of Opon and Henry (2019).

Fuzzy methods are useful to assess complex or poorly defined problems. As such, they can be valuable for sustainability indicators. Indicator uncertainty is not caused by errors or randomness but rather attributed to generality, ambiguity, or inaccuracy. The fuzzy method was applied in the manufacturing sector (ovens) and the automotive parts sector (Rajak & Vinodh, 2015; Pask et al., 2017).

The Monte Carlo simulation is a sampling technique employed for result generation that depends on probability distribution data and parameters. It was utilized jointly with the fuzzy method in the manufacturing sector (ovens) (Pask et al., 2017).

The Life Cycle Impact (LCIA) model employs inventory results to quantify significant potential environmental impacts of a product, the connection between the inventory results, and the environmental impacts, which can be determined in two ways: through developing an approach problem in which the flows are classified and characterized into environmental themes to which they contribute (approach midpoint) or connecting the environmental themes to their possible damage to human health and ecosystemic services even further, developing a cause-and-effect chain. The latter is often referred to as a damage-oriented approach. The LCIA was applied in the paper and cellulose sector (Pillain et al., 2017).

Managers and professionals may employ the most Common Indicators (MCIs) method as a construct for performance assessment and reports in their companies. Using the MCIs, companies can drastically cut conformity costs when they desire and meet several sustainability or social corporate responsibility standards (Rahdari & Anvary Rostamy, 2015).

Scholl et al. (2015) studied the Composite Sustainable Development Index (ICSD) in a chemical company. This method is generated by aggregating several economic, environmental, and social indicators to accompany the sustainability performance of a company. The indicators related to strategic themes for the company, after their selection, are normalized, weighted, and aggregated, constituting three sub-indices that are finally combined to generate a global indicator.

In the study of Taulo and Sebitosi (2016) in the tea industry, the Material and Energy Flow Analysis (MEFA) employs process material and energy input-output data to characterize the use and emission of materials within and between processes. Every flow and indicator is measured in mass units, providing a physical quantification of the need for material in the system.

Finally, the last model identified in the papers selected by this review is the Driver-Focused Prioritization (DFP) of Sustainability Indicators. The DFP prioritizes questions based on the demand and desires of multiple interested parties. Besides making data available and being practical to measure, it also explicitly defines which sustainability questions are of more concern to the stakeholders. The DFP was applied in a study of wineries (Whitehead, 2016).

Thus, Table 3 sought to present the methodologies of sustainability measurement and assessment through indicators. The comments presented in the same Table aim to conceptualize these methodologies. Moreover, Table 3 classifies the sustainability indicators of each methodology and their contribution to the problem based on the studies that composed the bibliographic portfolio.

Indicators	Indicator classification	Contribution to measure sustainability
Industrial Environmental Sustainability Index (IESI)	Economic, social, environmental	The authors proposed an innovative composite indicator, easily reproducible to measure the performance of green industrial policies. It is an index constructed at the local level to assess the green industrial activities of a region within an integrated territorial approach. It allowed the investigation of the factors that contribute the most to the green goals in the industrial sector, providing a vertical analysis of the actors' contribution within the regions toward the efficiency of industrial environmental politics (Arbolino *et al.*, 2018).

Table 3. Classification of the sustainability indicators and their contributions.
Source: Research data (2019).

Indicators	Indicator classification	Contribution to measure sustainability
Methodology to support self-transformation	Governance	This methodology models organizational systems of all types and at different scales and complexity levels to observe core questions of viability and sustainability. It demonstrated how it represents the complexity of these multiple arrays of agents and interactions with a unified language. It also illustrates the usefulness of VSM as a language to learn about complexity management and governance challenges in organizations of different sizes, contexts, and moments (Espinosa, 2015).
Analytical Hierarchy Process (AHP)	Economic, social, environmental	This methodology allows decision-makers in the manufacturing sector to be aware of the main practices of corporate sustainability. The authors stress that this method to assess sustainability may be more suitable for large organizations (Goyal et al., 2015).
Value Stream Mapping (VSM)	Economic, social, environmental	This conceptual method aimed to assess sustainability in the manufacturing process based on reference values established by the company. Therefore, it does not allow comparisons between manufacturing processes (Helleno *et al.*, 2017).
Sustainable and Responsible Company – SURESCOM	Economic, social, environmental	This model acts as a management system that can be applied in production, services, and stakeholder relations, through material flow, energy, and information (Jonkutė & Staniškis, 2016).
Tiered approach	Economic, social, environmental	This approach enables a hierarchy of indicators and supports the practical application, development, and gradual implementation of sustainability indicators. The benefits result from the in-depth review of indicators, which seems essential as the groundwork for new developments in the structure of life cycle sustainability assessment (Neugebauer *et al.*, 2015).
Sustainable Concrete Material Indicators (SCMI)	Economic, social, environmental	In this structure, notable changes can be observed and tracked, which is also useful for selecting sustainability assessment indicators and reinforces the identification of focus areas that can be improved to potentialize concrete sustainability, to support the decision-making process and generate consensus to ensure sustainability (Opon & Henry, 2019).
Life Cycle Impact (LCIA)	Economic, social, environmental	The authors state that, although several methods exist, they all focus only on the environmental aspect. The socioeconomic factors, such as geopolitical and social restrictions that limit accessibility in the short and medium term, are highly relevant for resources that are fundamental for modern technology applications (Pillain et al., 2017).

Table 3. Classification of the sustainability indicators and their contributions (cont.).
Source: Research data (2019).

Indicators	Indicator classification	Contribution to measure sustainability
Composite Index of Sustainable Development (ICDS)	Economic, social, environmental	The method is flexible and can be applied in companies with different goals, fields of activity, and dimensions. The model helps to point out improvement opportunities and show where the best practices can be identified and reproduced, revealing itself as an important subsidy for sustainability decision-making (Scholl et al., 2015).
Driver-Focused Prioritization (DFP) of Sustainability Indicators	Social and environmental	It provides more analytical resources to a structure of sustainability indicators, attributing the desire for specific sustainability indicators to different groups of interested parties, and directing strategic and management responses (Whitehead, 2016).
Instrument for the Selection of More Sustainable Materials (ISMAS)	Environmental	This tool, proposed by Bissoli-Dalvi *et al.* (2016), provides simplified criteria to define the sustainability index of materials for creating an easy-to-use system, arguing that a reduced array of indicators tends to be more effective.
Multicriteria group decision-making (MCGDM)	Economic, social, environmental	This method considers every sustainability indicator simultaneously. Integrating economic, environmental, or social indicators and attributing them weights has a crucial influence in selecting sustainable solutions (Ghoddousi et al., 2018).
Metric of Sustainability (MOS)	Economic, social, environmental	This method helps decision-makers, especially strategy managers, to properly configure the process of projecting, constructing, and operating new refinery projects or auditing and assessing operations (Hasheminasab *et al.*, 2018).
Industrial Process System Assessment (IPSA)	Environmental	This method contributes to the development of new integrated metrics of sustainability, which may guide improvements in the supply chain, manufacturing, and design of products related to environmental protection and resource sustainability (Ingwersen *et al.*, 2016).
Guidelines of the Global Reporting Initiative (GRI)	Economic, social, environmental	The authors point out that the results show that increasing the acceptability of forest industries in energy production, as well as in other fields of forest industries, requires new insights on the integration of cultural aspects into RSE management (Lähtinen & Myllyviita, 2015).
Sustainability Evaluation Model (SEM)	Economic, social, environmental	The practical contribution of the model is to provide an assessment system directed at decision-making for companies and managers. It is suitable for identifying improvement opportunities for the organization (Nicoletti Junior et al., 2018).

Table 3. Classification of the sustainability indicators and their contributions (cont.).
Source: Research data (2019).

Indicators	Indicator classification	Contribution to measure sustainability
Fuzzy and Monte Carlo	Social (RAJAK; VINODH, 2015). Social, economic, environmental (PASK *et al.*, 2017).	This method provides a useful tool to handle decisions related to imprecise, vague phenomena. The approach can be applied in any organization (Rajak & Vinodh, 2015). Pask *et al.* (2017) highlight that this tool helps decision-makers in several analysis criteria. They are usually employed with sustainability indicators due to the uncertainty that is inherent to many indicators. It provides the industrial decision-makers with more information than many previous methodologies.
Most Common Indicators (MCIs)	Governance, social, environmental	This tool contributes by ensuring that all extracted indicators are general sustainability indicators, suitable for application in every sector, which is one of the merits of this system (Rahdari & Anvary Rostamy, 2015).
Material and energy flow analysis (MEFA)	Environmental	Taulo and Sebitosi (2016) state that this method contributes to reducing energy, raw material, and water consumption, in addition to effluent discharge. MEFA is increasingly more applied in industrial ecology, environmental management and protection, resource management, and waste management. It is also employed as a basis for life cycle assessment, ecological balance, and environmental impacts.

Table 3. Classification of the sustainability indicators and their contributions (cont.).
Source: Research data (2019).

Table 3 presents the classification of sustainability indicators and their contribution to the proposed problem. The indicator dimensions in each methodology are linked to the Triple Bottom Line concept. Most methodologies comprise the three pillars, including Fuzzy and Monte Carlo (Pask et al., 2017), SEM, GRI, MOS, MCGDM, ICDS, LCIA, SCMI, SURESCOM, Tiered approach, IESI, AHP, VSM. A few methodologies focused only on the environmental aspect of the Triple Bottom Line, such as MEFA, IPSA, ISMAS, and DFP. The MCIs methodology approached the environmental, social, and governance aspects, while another study that addressed the Fuzzy and Monte Carlo methodology (Rajak & Vinodh, 2015) focused only on the social aspect. The Methodology to Support Self-Transformation approached governance for sustainability.

It is worth highlighting, more in-depth, the indices employed by each of the methodologies that encompassed the dimensions of environmental, social, and economic sustainability. This contributes to providing an array of elements that have been analyzed to develop the index of each methodology among the production sectors examined.

The MOS encompasses environmental, social, and economic indicators directed at the construction field. In environmental terms, the indicators concern water, soil pollution, natural resources use, and biodiversity. The social indicators measure poverty, equality, health, safety, education, training, and welfare. Finally, the economic indicators address energy consumption, finances, economic performance, and occupation growth (Hasheminasab et al., 2018).

Lähtinen and Myllyviita (2015) approach the GRI, which adopts the three sustainability dimensions. The economic aspects measure economic performance, market presence, and direct economic impacts. The environmental indicators focus on the use of materials, energy, water, biodiversity, emissions, effluents, and waste. The social indicators concern products, services, jobs, work relations management, occupational safety and health, education and training, diversity and equality, equal compensation for men and women, investment in acquisition practices, non-discrimination, freedom to unionize and collective bargain, child labor, forced and mandatory labor, safety practices, indigenous rights, assessment of local communities, corruption, public policies, anti-competitive behavior, acting in conformity with society, customer health and safety, product and service branding, customer privacy, product conformity and responsibility.

The Fuzzy and Monte Carlo model, in the study of Rajak and Vinodh (2015), encompassed only the social aspect. Its indicators concern internal human resources, outside population, participation holders, and macro-social performance. In the study of Pask et al. (2017), the same model comprised the three sustainability dimensions. The environmental indicators encompassed system airflow (energy and environmental impact), production efficiency (energy and waste management), and operational costs (labor, energy, and materials). The economic indicators approached quality and capital investments, while the social indicators focused on toxicity, jobs, and opportunities.

The SCMI addressed only the environmental and economic dimensions. The environmental indicators approached consumption (energy, raw materials, water, and recycled, recovered, or residual materials), atmosphere emissions, ecotoxicity, and acidification. The economic indicators concerned general costs in the production environment and energy savings (Opon & Henry, 2019).

Ingwersen et al. (2016) approached the IPSA, which focused only on environmental indicators concerning the effects of emissions on human health (global climate, destruction of the ozone layer, and ionizing radiation), on natural resources (depletion of fossil fuels and metals, water consumption, the demand of non-renewable energy, and land occupation), and environmental quality (eutrophication of fresh and sea water and acidification).

The MCGDM employs the three sustainability dimensions. The environmental indicators concern water pollution, air pollution, and soil contamination. The social indicators address job opportunity, health, and safety (Ghoddousi et al., 2018).

The VSM encompasses sustainability indicators in the three dimensions. The social indicators approached worker satisfaction and work environment conditions (absenteeism, turnover rate, accidents, and noise levels), salaries and financial benefits, and contribution to the community. The environmental indicators addressed water and energy consumption, environmental responsibility in the production process (harmful gas emissions, waste separation and treatment), recycling, and environmental management. The economic aspect employed indicators of operation costs and cost-effectiveness (Helleno et al., 2017).

The Methodology to Support Self-Transformation, in the study conducted by Espinosa (2015), works with governance for sustainability with the following criteria: co-evolution with the environment (developing the capability to deal with core sustainability questions at every level of the organization, working with what matters, real-time information, closed-circuit information flow for effective governance, responses to environment changes, environments for decision-making, identity, and closure), autonomy and cohesion (developing meta-systemic management to support autonomous communities/organizations to self-regulate sustainably, increase operational autonomy, develop mechanisms to handle conflicting interests to generate synergy, develop systems of knowledge management regarding critical sustainability matters, provide closure concerning sustainability matters), recursive governance (connecting questions and decisions of local and global governance, favorable conditions for sustainable governance at every organizational level).

The AHP method brings environmental indicators related to environmental and strategic management, pollution prevention, recycling, minimizing resource consumption, and green products. The social indicators concern the community and responsibility (accountability of employees, customers, suppliers, and investors). The economic indicators comprise market value, corporate governance, R&D, and innovation (Goyal et al., 2015).

The LCIA methodology approaches only environmental indicators, related to global warming, acidification, destruction of the ozone layer, eutrophication (land and water), photochemical oxidants, human toxicity (carcinogen and non-carcinogen toxicity), ecotoxicity (sea, land, and fresh water), and resource depletion (Pillain et al., 2017).

The MEFA model, proposed by Taulo and Sebitosi (2016), employed environmental indicators directed at materials and energy inputs (consumption of raw materials and energy, water use, waste, and emissions).

The Composite Index of Sustainable Development (ICDS) encompassed the three sustainability dimensions. The economic indicators are EBITDA, investments, direct economic value generated, accumulated economic value, significant financial aid received from the government. The environmental indicators addressed the monetary value of significant fines, total consumption of primary energy, energy rate, greenhouse gas emissions, quantity and volume of significant spills, percentile of recycled/reused water, water consumption rate, investments and spending in environmental protection, total generation of solid waste, waste rate, total generation of liquid effluents, and effluent rate. The social indicators measured the number of members and outsourced employees, discrimination cases, the ratio of remuneration between men and women (leadership positions), absenteeism rate, accident occurrence rate, number of accidents with and without leave, accident severity rate, number of occupational diseases, deaths, investments in health, safety, and environment (Scholl et al., 2015).

The Sustainability Evaluation Model (SEM) presents economic indicators concerning attractiveness, productivity, cost, quality, delays, innovation, and profitability. The social indicators refer to acknowledgment, compliance with social legislation, social impacts, and social investments. The environmental indicators relate to company reputation, compliance with environmental legislation, environmental impacts and investments (Nicoletti Junior et al., 2018).

The IESI applies in three categories: Facilitators (in the human resources and financial support subcategories), Company activity (investments and intellectual assets), and Results (innovations and economic effects).

The ISMAS addresses only environmental indicators: reuse, renovation, maintenance, durability regardless of maintenance, disassembly for reuse, additional materials necessary for finishing, low waste generation, raw material savings, and waste generation management (Bissoli-Dalvi et al., 2016).

The SURESCOM integrates environmental, social, and economic aspects of sustainability. It incorporates known tools of engineering, management, and communication, controls attributes of industrial processes, products, and services, engages several stakeholders, and involves customers/clients as active partners within the general SCP system (Jonkutė & Staniškis, 2016).

The DFP employs environmental, social, economic, and governance indicators. The environmental indicators concern climate changes, use of chemical products, water quality, waste, biodiversity loss, and soil. The social indicators refer to safety (Whitehead, 2016).

The Tiered Approach addresses the three sustainability dimensions. The environmental indicators concern climate changes, destruction of the ozone layer, eutrophication, and formation of photochemical oxidants, acidification, material particles, ionizing radiation, ecotoxicity, land use, water catchment, and resource depletion. In the economic scope, the indicators approach production costs, manufacturing, labor, and energy, transportation, and maintenance costs. The social indicators refer to fair compensation, health, work conditions, education, human rights, workplace satisfaction, and culture (Neugebauer et al., 2015).

The MCI addressed environmental, social, and governance aspects. The environmental indicators approached risk assessment, climate changes, environmental education, biodiversity, energy and water efficiency, emissions, pollution and waste, environmental regulations, and transparency in the disclosure of reports. The social indicators comprised investments in social responsibility, product safety, workers and labor, community development and philanthropy, education and training, health and safety, interested parties, social inclusion and non-discrimination, human rights, anticompetitive behavior, customers and supply chain, and transparency in the disclosure of reports. The governance indicators approached compliance with legislation, councils and committees, financial stability, management and policies, governance and risk management, ethics, corruption and code of conduct, compensation, stakeholders, activism, and property (Rahdari & Anvary Rostamy, 2015).

Therefore, this review sought to gather and categorize the main methodologies used to measure and assess sustainability through indicators. This helps to identify the approaches that are being used, in the organizational scope, so that other researches can be developed, having a method already in the literature. In this way, methodologies can give rise to other research.

Some observations should be made about the scope of this systematic review research. First, it was focused only on production processes, excluding articles that did not address this specific aspect. Second, production processes in agriculture and livestock were not addressed. This is because it is understood that there is a need for a specific study in this emerging field of research. The Methodi Ordinatio, used to prepare a ranking of selected articles, was used as a material cutout, due to the large number of articles that were, until then, developed on sustainability indicators. This allowed us to include 97 articles in the analysis, which presented a higher indicator through this method. This cut to compose the bibliographic portfolio presents itself as a limitation of this research, in addition to the time period covered.

The results revealed that the methodologies to assess and measure sustainability are rather diverse in terms of the production sectors addressed, each meeting the specifics of the case studies where they were developed and the sectors to which the organizations belong. A few methodologies cannot be generalized for other companies, like the VSM, because they

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were specifically designed for specific case studies. This illustrates the limitations and restriction of this methodology and its reproduction requires specific data from the organization to be analyzed.

Other methodologies, like the IESI, AHP, SCMI, ISMAS, MCGDM, MOS, IPSA, and SEM, have been expanded to different companies in the same field. Thus, the studies that composed the portfolio of this review encourage the application of the same indicator structure to different organizations belonging to the same sector.

Moreover, a few methodologies apply in different contexts to assess and measure sustainability in companies of different sectors, like the SURESCOM, Tiered Approach, LCIA, ICDS, DFP, Fuzzy and Monte Carlo, MCIs, and MEFA.

Therefore, it is possible to infer that some sustainability assessment and measurement methods are conducted in different forms, scales and extensions. In every case, the authors who applied these methodologies in the selected studies reported their effectiveness to respond to decision-making demands.

Another crucial finding of the portfolio was the indicator classification in terms of environmental, social, and economic aspects. We found that, among the methodologies analyzed, some did not comprise the triple bottom line, focusing only on one or two dimensions. The literature has shown that the integration of environmental, economic, and social dimensions is still a challenge (Gallopin, 1996; Morse et al., 2001; Jonkutė & Staniškis, 2016; Azevedo & Barros, 2017).

Considering the balance between the sustainability pillars and the finding that some assessment and measurement methodologies do not comprise the three dimensions, it is important to emphasize that organizations must manage the three pillars, seeing that focusing on only one may hamper the proper management of the others. Searcy (2012) states that an indicator system seeks to bring information to the company's decision-making, in the short and long term, reflecting on the control, planning, economic performance, and environmental and social activities performed.

The methodologies developed in the studies examined provide a tool that may contribute to organizations enhancing their production activities, finding a balance between the three sustainability pillars. These tools can be tracked and improved constantly, even though some do not address the three sustainability dimensions. However, the selection of sustainability indicators employed for decision-making in the company must be careful, considering the specifics of each organization and market sector, as recommended by Spangenberg and Bonniot (1998). Thus, organizations can work toward finding sustainability indicators increasingly more suitable, contributing to a more fair and balanced society.

Final Considerations

The purpose of this paper was to present a systematic literature review on the indicator models to assess sustainability in production processes. The study performed a literature review of scientific papers published between 2015 and 2019 in the databases Emerald, Sage, Science Direct, Scopus, Web of Science, and Wiley Online Library, employing the Methodi Ordinatio.

The results pointed that the sustainability assessment models in the analyzed papers revealed structures that focused on the Triple Bottom Line, models that combined only two dimensions, or even centered on a single sustainability pillar. Furthermore, the models with specific names were identified, as follows: Industrial Environmental Sustainability Index (IESI), Methodology to Support Self-Transformation, Analytical Hierarchy Process (AHP), Value Stream Mapping (VSM), Sustainable and Responsible Company (SURESCOM), Tiered Approach, Sustainable Concrete Material Indicators (SCMI), Life Cycle Impact (LCIA), Composite Sustainable Development Index (ICSD), and Driver-Focused Prioritization (DFP) of Sustainability Indicators. The use of these models is encouraged by the researchers who applied them in their studies. However, it is worth pointing out that certain models are specific to the sector in which they were applied, and that their dissemination must be cautious especially due to this peculiarity.

Moreover, the results revealed that the methodologies of sustainability assessment and measurement focused on specific production sectors to meet the sustainability management demands in different areas. Therefore, we were able to categorize the methodologies analyzed in the portfolio. First, the VSM methodology cannot be generalized for the sector, nor is it applicable in different sectors, making it restricted to its case study. Second, the IESI, AHP, SCMI, ISMAS, MCGDM, MOS, IPSA, and SEM methodologies apply in different cases in the same field of activity. Third, the SURESCOM, Tiered Approach, LCIA, ICDS, DFP, Fuzzy and Monte Carlo, MCIs, and MEFA methodologies apply in different contexts to assess and measure sustainability in companies of different sectors.

Another finding of the portfolio was the classification of sustainability indicators. A few methodologies did not comprise the triple bottom line, focusing only on one or two dimensions, which illustrates that integrating the three sustainability dimensions into a single indicator system that helps decision-making in companies is still a challenge. However, the studies reveal that these sustainability assessment and measurement methodologies provide a tool that contributes to decision-making. Moreover, they can be constantly enhanced, even though some do not encompass the three sustainability dimensions.

Thus, this paper sought to compile sustainability assessment and measurement methodologies through indicators, contributing to identifying the existing approaches in the literature and fomenting studies in organizational practice. The theoretical implications of this paper concern the insights that might arise in proposing new studies on sustainability indicators adopting the listed methodologies, and even the practical implication in the organizations that choose a methodology that contributes to sustainability assessment and measurement.

This paper did not intend to define which model presents the best sustainability assessment, considering the specificity of each method and the array of sustainability-related events inherent to each case, due to the complexity of the sustainability theme and its current process of betterment. Furthermore, the sustainability assessment models listed by this review do not exhaust the sample selected, seeing that other methodologies were identified but not detailed due to their lack of a specific name. This fact is one of the limitations of this study. Another is its sample of selected papers, considering that the findings are limited to it.

A suggestion for future research is to analyze aspects of sustainability assessment models in contexts other than production processes, including cities, regions, agriculture and livestock, among others.

References

Arbolino, R., De Simone, L., Carlucci, F., Yigitcanlar, T., & Ioppolo, G. (2018). Towards a sustainable industrial ecology: Implementation of a novel approach in the performance evaluation of Italian regions. *Journal of Cleaner Production*, *178*, 220-236.

Azevedo, S. G., & Barros, M. (2017). The application of the triple bottom line approach to sustainability assessment: The case study of the UK automotive supply chain. *Journal of Industrial Engineering and Management (JIEM)*, *10*(2), 286-322.

Bell, S., & Morse, S. (2001). Breaking through the glass ceiling: who really cares about sustainability indicators?. *Local environment*, *6*(3), 291-309.

Bissoli-Dalvi, M., Nico-Rodrigues, E. A., de Alvarez, C. E., Fuica, G. E. S., & Montarroyos, D. C. G. (2016). The sustainability of the materials under the approach of ISMAS. *Construction and Building Materials*, *106*, 357-363.

Brundtland, G. H., & Comum, N. F. (1987). Relatório Brundtland. *Our Common Future*: United Nations.

Chong, Y. T., Teo, K. M., & Tang, L. C. (2016). A lifecycle-based sustainability indicator framework for waste-to-energy systems and a proposed metric of sustainability. *Renewable and Sustainable Energy Reviews*, *56*, 797-809.

Copus, A. K., & Crabtree, J. R. (1996). Indicators of socio-economic sustainability: An application to remote rural

Scotland. *Journal of Rural studies*, *12*(1), 41-54.

Dohnal, M., & Kocmanova, A. (2016). Qualitative models of complex sustainability systems using integrations of equations and equationless knowledge items generated by several experts. *Ecological Indicators*, *62*, 201-211.

Elkington, J. (2001). *Canibais com garfo e faca*. São Paulo: Makron Books, 2001.

Frank, A. G., Dalle Molle, N., Gerstlberger, W., Bernardi, J. A. B., & Pedrini, D. C. (2016). An integrative environmental performance index for benchmarking in oil and gas industry. *Journal of cleaner production*, 133, 1190-1203.

Gallopin, G. C. (1996). Environmental and sustainability indicators and the concept of situational indicators. A systems approach. *Environmental modeling & assessment*, *1*(3), 101-117.

Ghoddousi, P., Nasirzadeh, F., & Hashemi, H. (2018). Evaluating highway construction projects' sustainability using a multicriteria group decision-making model based on bootstrap simulation. *Journal of construction engineering and management*, *144*(9), 04018092.

Goyal, P., Rahman, Z., & Kazmi, A. A. (2015). Identification and prioritization of corporate sustainability practices using analytical hierarchy process. *Journal of Modelling in Management*, *10*(1).

GVCES. (2012). *O Valor do ISE - Principais estudos e perspectiva dos investidores*. São Paulo, São Paulo, Brasil. Disponível em: http://gvces.com.br/o-valor-do-ise-principais-estudos-e-a-perspectiva-dos-investidores?locale=pt-br.

Haapala, K. R., Zhao, F., Camelio, J., Sutherland, J. W., Skerlos, S. J., Dornfeld, D. A., ... & Rickli, J. L. (2013). A review of engineering research in sustainable manufacturing. *Journal of manufacturing science and engineering*, *135*(4).

Hasheminasab, H., Gholipour, Y., Kharrazi, M., & Streimikiene, D. (2018). A novel Metric of Sustainability for petroleum refinery projects. *Journal of Cleaner Production*, *171*, 1215-1224.

Helleno, A. L., de Moraes, A. J. I., & Simon, A. T. (2017). Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: Application case studies in Brazilian industry. *Journal of cleaner production*, *153*, 405-416.

Ingwersen, W., Gausman, M., Weisbrod, A., Sengupta, D., Lee, S. J., Bare, J., ... & Ceja, M. (2016). Detailed life cycle assessment of Bounty® paper towel operations in the United States. *Journal of cleaner production*, *131*, 509-522.

Jonkutė, G., & Staniškis, J. K. (2016). Realising sustainable consumption and production in companies: the SUstainable and RESponsible COMpany

(SURESCOM) model. *Journal of cleaner production*, *138*, 170-180.

Kalimeris, P., Bithas, K., Richardson, C., & Nijkamp, P. (2020). Hidden linkages between resources and economy: A "Beyond-GDP" approach using alternative welfare indicators. *Ecological Economics*, *169*, 106508.

Lähtinen, K., & Myllyviita, T. (2015). Cultural sustainability in reference to the global reporting initiative (GRI) guidelines: Case forest bioenergy production in North Karelia, Finland. *Journal of Cultural Heritage Management and Sustainable Development*, *5*(3), 290-318.

Long, Y., Pan, J., Farooq, S., & Boer, H. (2016). A sustainability assessment system for Chinese iron and steel firms. *Journal of Cleaner Production*, *125*, 133-144.

Moldan, B., Janoušková, S., & Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators*, *17*, 4-13.

Morse, S., McNamara, N., Acholo, M., & Okwoli, B. (2001). Sustainability indicators: the problem of integration. *Sustainable development*, *9*(1), 1-15.

Negri, E., Holgado, M., Wagner, D., Grefrath, C., Macchi, M., & Gudergan, G. (2016). Continuous improvement planning through sustainability assessment of product-service systems. International *Journal of Productivity and Quality Management*, *18*(2/3), 168-190.

Neugebauer, S., Martinez-Blanco, J., Scheumann, R., & Finkbeiner, M. (2015). Enhancing the practical implementation of life cycle sustainability assessment–proposal of a Tiered approach. *Journal of Cleaner Production*, *102*, 165-176.

Junior, A. N., de Oliveira, M. C., & Helleno, A. L. (2018). Sustainability evaluation model for manufacturing systems based on the correlation between triple bottom line dimensions and balanced scorecard perspectives. *Journal of Cleaner Production*, *190*, 84-93.

Opon, J., & Henry, M. (2019). An indicator framework for quantifying the sustainability of concrete materials from the perspectives of global sustainable development. *Journal of Cleaner Production*, *218*, 718-737.

Pagani, R. N., Kovaleski, J. L., & Resende, L. M. (2015). Methodi Ordinatio: a proposed methodology to select and rank relevant scientific papers encompassing the impact factor, number of citation, and year of publication. *Scientometrics*, *105*(3), 2109-2135.

Pask, F., Lake, P., Yang, A., Tokos, H., & Sadhukhan, J. (2017). Sustainability indicators for industrial ovens and assessment using Fuzzy set theory and Monte Carlo simulation. *Journal of Cleaner Production*, *140*, 1217-1225.

Pillain, B., Gemechu, E., & Sonnemann, G. (2017). Identification of Key Sustainability Performance Indicators and related assessment methods for the carbon fiber recycling sector. *Ecological Indicators*, *72*, 833-847.

Rahdari, A. H., & Rostamy, A. A. A. (2015). Designing a general set of sustainability indicators at the corporate level. *Journal of Cleaner Production*, *108*, 757-771.

Rajak, S., & Vinodh, S. (2015). Application of fuzzy logic for social sustainability performance evaluation: A case study of an Indian automotive component manufacturing organization. *Journal of Cleaner Production*, *108*, 1184-1192.

Sachs, I. (1997). Desenvolvimento numa economia mundial liberalizada e globalizante: um desafio impossível?. *Estudos Avançados*, *11*, 213-242.

Scholl, C. A., Hourneaux Junior, F., & Galleli, B. (2015). Sustentabilidade organizacional: aplicação de índice composto em uma empresa do setor químico. *Gestão & Produção*, *22*, 695-710.

Searcy, C. (2012). Corporate sustainability performance measurement systems: A review and research agenda. *Journal of Business Ethics*, *107*(3), 239-253.

Spangenberg, J. H., & Bonniot, O. (1998). Sustainability indicators: a compass on the road towards sustainability (81). *Wuppertal Papers*.

Taulo, J. L., & Sebitosi, A. B. (2016). Material and energy flow analysis of the Malawian tea industry. *Renewable and Sustainable Energy Reviews*, *56*, 1337-1350.

Tayra, F., & Ribeiro, H. (2006). Modelos de indicadores de sustentabilidade: síntese e avaliação crítica das principais experiências. *Saúde e Sociedade*, *15*(1), 84-95.

Valenzuela-Venegas, G., Salgado, J. C., & Díaz-Alvarado, F. A. (2016). Sustainability indicators for the assessment of eco-industrial parks: classification and criteria for selection. *Journal of Cleaner Production*, *133*, 99-116.

Van Bellen, H. M. (2005). *Indicadores de sustentabilidade: uma análise comparativa*. FGV editora.

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: reducing human impact on the earth*, (9). New society publishers.

Whitehead, J. (2017). Prioritizing sustainability indicators: Using materiality analysis to guide sustainability assessment and strategy. *Business Strategy and the Environment*, *26*(3), 399-412.

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