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AVAILABLE TOOLS AND METHODOLOGIES FOR SUSTAINABILITY ASSESSMENT IN PRODUCTION

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Abstract

The need for a paradigm shift toward a more circular, sustainable, and resilient economic model led to several attempts to better integrate sustainability metrics into the design and optimization phases of industrial processes. The specific focus, the reach, and means of application depend on the adopted tool and methodology. The goal of this paper is to discuss how the sustainability framework in the SMART-Pro project was created and to display how broad is the set of possible instruments that a company could choose from to promote a more sustainable and optimized business management, spanning from specific aspects of a process, the entire company, or the overall value chain up to the scale of industrial symbiosis contexts. All references have been characterized by taking a holistic approach to system analysis and relying on different criteria to stress complementarities, gaps and overlaps in areas of intervention.

Key words: smart production, sustainable production, sustainability metrics, system thinking

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1. Introduction

While the goal of continuous improvement has always existed, what changed through the years is the direction and breadth of such aim. In fact, several frameworks, methods, tools and concepts have been developed to promote performance improvements, at first in terms of production efficiency by maximizing produced units and economic growth, then also as organizational performances, waste reduction and eventually addressing the human component as well. When all these aspects are assessed together, the result is the inclusion of the sustainability perspective in the business strategy.

As of today, there are some standards that can be considered cornerstones in the field due to their completeness, extension and broad adoption, but a common characteristic to all of them, is that they depend on the underlying priorities of those who developed them. In fact, theories such as the Lean Manufacture (Shingo and Dillon,1989), for example, prioritize production efficiency over social aspects of the company performance, the Kaizen (or Continuous Improvement method) highlights also the need for proper communication and involvement within the company as a winning factor (Garza-Reyes et al., 2016), and the Taskforce for Climate-related Financial Disclosure (TCFD) guidelines (TCFD, 2017), keep at their core the economic perspective bound to Greenhouse Gasses (GHG) emission reduction, and so on. The idea at the base of this literature review and classification was to compare tools and give a more complete picture of the possible strategies to promote sustainability integration to the business management. The foundational idea at the base of sustainability for company management is that it is a multifaceted concept that is mostly expressed through the "Triple Bottom Line" principle, as it integrates economic aspects with the environmental and social dimensions, sometimes referred as the Triple P framework: People,

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Planet and Profit (Elkington, 1994, 1998) and that it has to fit inside the "Planetary Boundaries" as described by Chen et al. (2021).

This framework created in this research work analyses which are the overarching parameters and aspects that need to be monitored and integrated by companies, which more focused metrics are more frequently adopted, and introduces the identified gaps and difficulties with carrying out such assessments and following through with the improvement work. Prior to the actual evaluation, it was important to highlight the relationship between sustainability and the circular economy (CE), which can be considered as a sustainability-oriented industrial economy (Ghisellini et al., 2016). In particular, the introduction of CE on an industrial scale is often achieved by the adoption of several key actions aimed at improving the economic and environmental performance of spent resources and closing the loops for the valorization of wastes and their recovery into material and energy commodities (Kalmykova et al., 2017) but do not consider the social component with the same priority.

2. Materials and methods: definition of the classification framework

2.1. Literature sourcing, screening and categorization criteria

To ensure accuracy, objectivity and transparency in the research process, and obtain replicable and valid results, the authors decided to adopt a systematic literature review approach and followed the methodological guidelines proposed by Thomé et al. (2016). The general research question was: "which metrics play an important role in production sustainability?". The preliminary research on academic literature platforms like Scopus and Web of Science led, as suggested by the literature review by Pranugrahaning et al. (2021) to the need for expanding the research to the internationally recognized standards and reference documents already mentioned in the previous section.

Most of the scientific literature has been sourced basing on the keywords' combinations: environmental performances, organizational optimization methods, process efficiency, process optimization methods, smart production, social metrics, sustainability metrics, sustainable production, system thinking, and then screened by reading the abstract. In some cases, the entire document has been read to ensure clarity on the content. The material deemed useful to the framework has been collected in an Excel Spreadsheet that served as repository for the bibliographic references of the documents. Table 1 lists the screened references and how many metrics were identified for each one of them.

2.2. Structure of the classification framework

The goal of identifying meaningful metrics for sustainable production led to the adoption of the categories already mentioned and which will be described in more detail below. The scheme from Fig. 1 provides additional clarity on the structure of the classification framework.

Table 1. List of the screened references and classification

Screened references	***Type of literature source***				***Number of metrics per source***
	International standards	***Reports***	***Scientific papers***	***National standad***	
Amrina and Lutfia Vilsi (2015)			x		16
B Corp Lab (2021)	x				16
Baglieri and Fiorillo (2019)			x		26
CSR Lab (2010)		x			21
Frigerio and Matta, (2015)			x		1
Gong et al. (2019)			x		1
GRI standards 2021	x				49
Klemes (2012)			x		1
Kreitlein et al. (2015)			x		1
Li et al. (2020)			x		1
MCI (2020)	x				6
Mourtzis et al. (2012)			x		1
OECD (2011)		x			18
Pham et al. (2016)			x		1
RIVM (2018)	x				18
Sudhakara Reddy (2013)			x		1
Reich-Weiser et al. (2008)			x		3
TCFD (2017)	x				3
Thiede et al. (2012)			x		1
UNI (2021)				x	56
Wahren et al. (2015)			x		1
Winroth et al. (2017)			x		18
Zheng et al. (2021)			x		1
Total	**5**	**2**	**15**	**1**	**261**

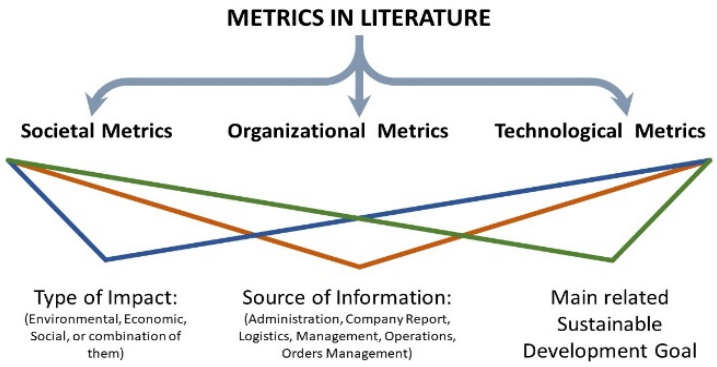

Fig. 1. Structure of the classification framework

2.2.1. Macro categories: Societal, organizational and technological metrics

The first major distinction for all the metrics identified via the literature review has been the clustering into the three following main aspects of sustainability, to capture its multifaceted nature even referring to industrial production systems:

- societal metrics - revolving around the human sphere,
- organizational metrics - influencing the economic, financial and organizational performance of the company,
- technological metrics – linked to the technical aspects of the production process, including the environmental aspects of the organization's activity.

2.2.2. Type of impact: Environmental, economic and social impact

Seemingly in opposition to what stated in the previous paragraph, the metrics involved in the performance assessment and improvement of a business practice can still be labelled basing on the conventional dimensions of sustainability and combination of them. Therefore, every metric has been sorted also based on the following sustainability impact categories: All; Economic; Environmental; Environmental and Economic; Environmental and Social; Social; Social and Economic.

The distinction between impacting the overall sustainability performance of the company, or combination of the three main dimensions: economic, environmental and social, becomes quite relevant to convey the cross-dimensional reach of several parameters and how sustainability should be approached holistically.

2.2.3. Source of information at company level

The source of information allows companies to understand where to source the data for that metric and which company figure should oversee its monitoring and evaluation. Therefore, according to Baglieri and Fiorillo (2019), the following categories have been identified to support the data sourcing:

- *Administration*: sources linked to the definition of policies, directives and objectives, planning and organizational functions.
- *Company Report*: every enterprise accumulates numerical data and information through the accounting records of purchases, sales, employees, banks and so on.
- *Logistics*: Company logistics consists of inbound logistics, internal production logistics, and outbound (distribution) logistics of produced goods.
- *Management*: sources that are linked to the management of the company.
- *Operations:* Business operations refer to the activities that businesses undertake daily to increase the value of the business and make a profit.
- *Orders Management:* Order management starts when a customer places an order and ends once they have received the package or service. It allows a company to coordinate the entire order fulfilment process.

2.2.4. Impact on the Agenda 2030

In terms of sustainability, the fundamental reference sources are the Agenda 2030 (UN, 2015) and the 17 SDGs (SDG, 2015) and related targets which create the roadmap to achieve sustainable development in a holistic and streamlined way. The goals encompass every aspect of sustainable development and therefore can be implemented by single individuals, companies, communities, and even whole countries. Hence, the relationship with the goals is being conjugated in many different forms and becoming paramount in every business strategy and performance assessment. It is important to mention that not all metrics assessed in this work are linked to the expected SDG and to the same Global Reporting Initiative (GRI) Standard as it is generally understood by the definition in the references (GSSB, 2021; SDG, 2015). The classification presented in this work is based on the authors' understanding of the link between the metric and the primarily affected SDG from an industrial perspective.

When it comes to businesses though, not all goals are relevant to the good stewardship of the company as: SDG 1 – No Poverty, SGD2 – Zero Hunger, SDG4 – Quality Education, SDG7 – Affordable and Clean Energy, and SDG17 – Partnership for the Goals, are not directly linked to the

production process or service providing. Nevertheless, actions to support the achievement of those goals can still be carried out, and are encouraged, for brand positioning, reputation and for the higher reason to promote and support the wellbeing of the community. The goals identified in the literature review are: SDG 03: Good Health and Well-being; SDG 05: Gender Equality; SDG 06: Clean Water and Sanitation; SDG 08: Decent Work and Economic Growth; SDG 09: Industry, Innovation and Infrastructure; SDG 10: Reduced Inequalities; SDG 11: Sustainable Cities and Communities; SDG 12: Responsible Consumption and Production; SDG 13: Climate Change; SDG 14: Life Below Water; SDG 15: Life on Land; SDG 16: Peace, Justice and Strong Institutions.

One note on SDG 4 is that it refers to education as in the right of every child in the world to receive proper education regardless of discriminations. Child labour, minorities exploitation and work formation/training are included in SDG 8.

3. Data analysis and remarks on the findings

3.1. Societal, organizational and technological metrics

As described in the previous section, the metrics found in the literature have been screened and grouped into the three categories: Societal, Organizational and Technological. This resulted in a total of 261 metrics divided as in Fig. 2.

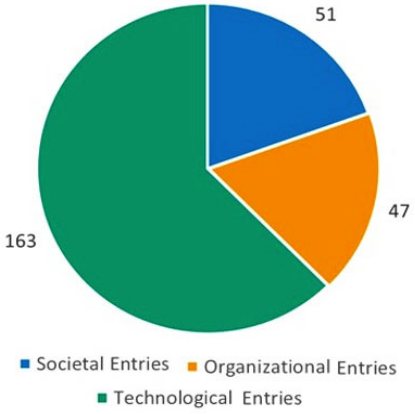

Fig. 2. Clustering of the metrics

This preliminary analysis is already an indication of the direction, or perspective, in which research has moved so far, as the disproportion of technically oriented indicators compared to the other macro-categories shows that technical (and environmental) parameters are both easier to monitor and improve, but at the same time a legacy to the industrial production mindset of the XX century where production volumes, times and profit were the only relevant metrics.

Nevertheless, it is possible to notice the clear low number of metrics collected in the organizational cluster and the societal metrics. The authors would like to go deeper into the research and analyze possible implementations that in the literature are often forgotten or omitted when considering productive sustainability due to a lower attention to human value.

3.2. Environmental, economic and social impact

An additional confirmation of the significant gap in representation that can be found between societal, organizational and technological metrics can be observed by looking at the distribution of indicators based on the three core dimensions of sustainability (Fig. 3). "Environmental and Economic" indicators are preponderant compared to the others, but this can be due to many of those indicators influencing the environmental performances of the company and require an economic investment or are supported by economic drivers like tax cuts or sanctions for missed reduction targets.

The paramount example is that CO_2 emissions reduction strategies are beneficial to the environment but to be implemented can require significant investment from the company to upgrade equipment, streamline processes and rely to other sources of inputs like renewable energy. At the same time, carrying on with business-as-usual leads companies to incur in sanctions, poor rating, and lower profit due to the ever-increasing attention to sustainability metrics by the consumers and lawmakers.

3.3. Source of information

The "source of information" is meant to suggest to companies the right direction for collecting information, while they try to navigate how to achieve more sustainable performances in their short-term and longer-term planning. As most of the identified metrics are technical in nature, the graph below (Fig. 4) further solidifies the observation that technological metrics are mainly related to the actual production process (operational source), while on the contrary, organizational and societal metrics can be directed to Company Reports, Operations and Administration sources.

The "company report" category refers to any sort of report that the business produces every year, regardless of it being purely internal, financial, or non-financial. Several of the metrics identified in the work are also referenced in the GRI Standards, which are the internationally recognized reference for Sustainability Reports. This type of reporting document details the vision, business performance, roadmap for the coming years, and financial performance of a business, often comparing them to the sustainable development goals of the 2030 Agenda (as described in section 3.4).

3.4. Impact on the Agenda 2030

Figure 5 shows how each one of the mapped-out metrics relates to the SDGs of the Agenda 2030. The one indicated in the graph is the main goal impacted by the indicator and as shown by the metrics

distribution, the most prominent ones are SDG 12: Responsible Production and Consumption, SDG 13: Climate Change and SDG 8: Decent work and economic growth. While this is not surprising giving that the focus of the framework is on business sustainability performances, it shows the cross-dimensional nature of the SDGs as SDG 12 and SDG 9: Industry, Innovation and Infrastructure are found in all three macro-categories. The interdimensional nature of the SDGs is also shown from the consideration that although the graph shows the most prominent relationship between a metric and an SDG, in most cases action on one metric affects multiple SDGs at the same time. To give an example, improving gender equality (SGD 5) and minority representations (SDG 10) at all levels of the company brings additional perspectives to the decision table and enriches the conversation.

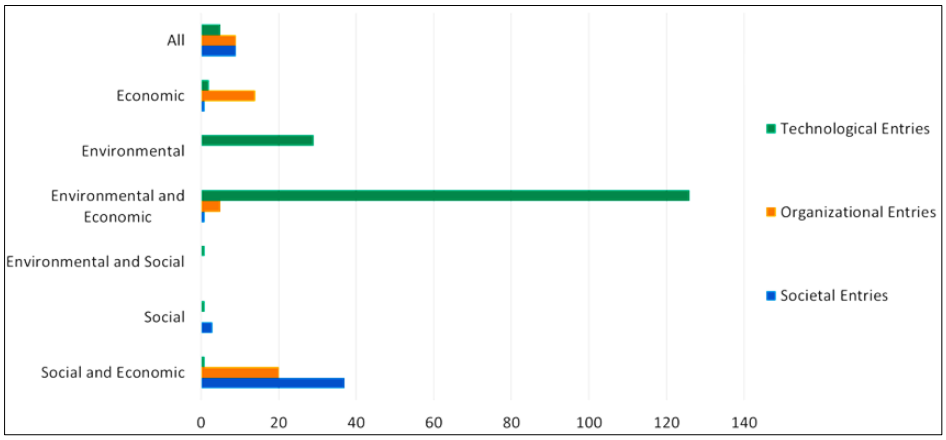

Fig. 3. Impact-based categorization referring to Triple Bottom Line

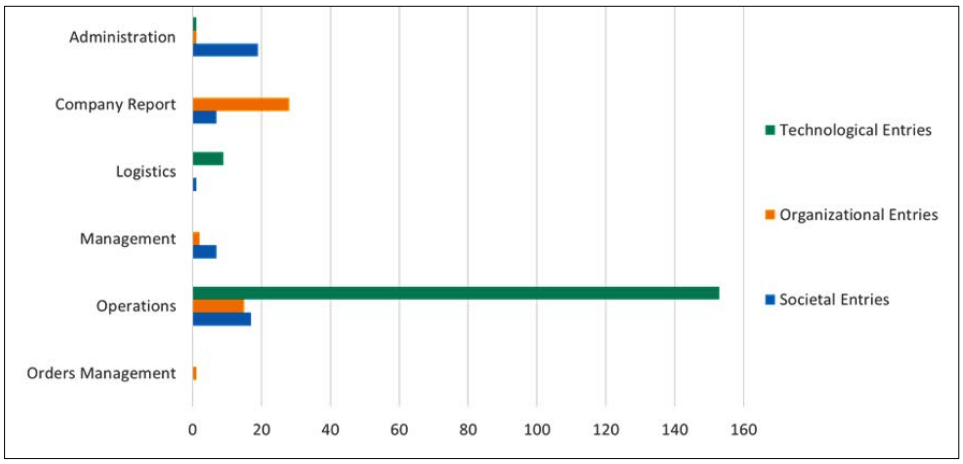

Fig. 4. Source of the metric information at company level

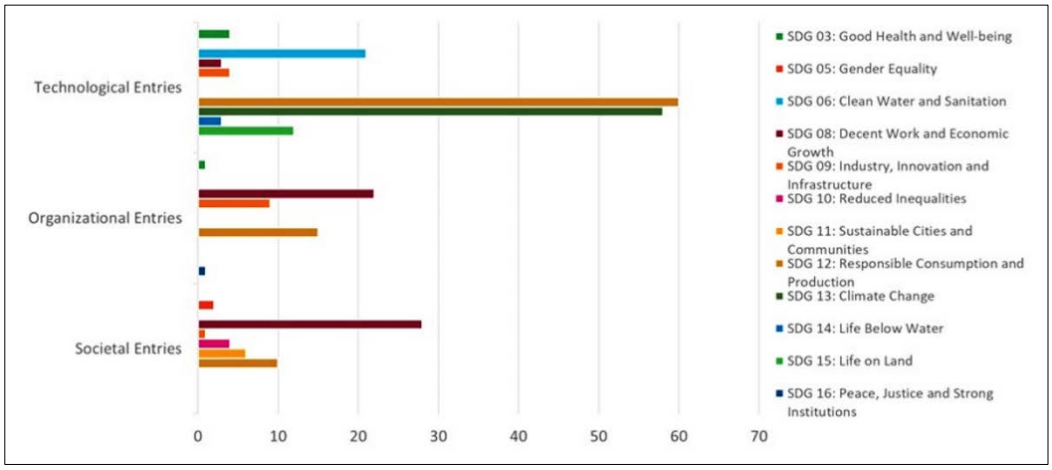

Fig. 5. Breakdown of the metric-SDG relationship

This way enabling to design better solutions for acting also on technological metrics. It is evident how some of the 2030 Agenda goals related to technology fall into SDGs related to conscious production, climate change and good health. On the contrary, organizational and societal metrics fall into similar goals often linked to the theme of decent work and economic development, conscious consumption and more responsible communities.

4. Conclusions

The research work has allowed us to reflect on the complexity of information for overall sustainability and the need for a common language at all stages of the manufacturing process for a comparable and additive outcome. In this sense, as the analyses in this paper show, the different aspects that can be linked to the same metric demonstrate how multifaceted and broad even historically established methods and metrics can be.

Furthermore, it showed how the SDGs are a pervasive and permeating aspect of our lives and that even conventional production processes should be reimagined to include them. The wealth of business-oriented scholarly work on the topic illustrates how sustainability can be approached from what is existing to completely revolutionizing a company's business model. Moreover, regardless of the size of the initial investment, integrating and promoting sustainability choices within the company or across the entire value chain pays off.

Furthermore, future developments could reflect on how companies could benefit from an industrial symbiosis by exchanging information, material and machinery and lower their environmental, social and economic impact. In this way, business performance can be effectively improved, future-proofing companies for unforeseen or impending changes as the world moves toward a more circular and fair economy.

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