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SUSTAINABILITY PERFORMANCE INDICATORS FOR PRODUCT LIFECYCLE MANAGEMENT

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Abstract. *Product Lifecycle Management (PLM) is an integrated, information driven-approach compromised of processes to all phases of a product's life, from the definition of an initial concept to the product's end-of life processes, like remanufacturing and final disposal. The Performance Measurement System (PMS) is widely seen as a mean to support control and improvement of the performance of these processes. However there is usually little information available to managers to guide them on introducing performance indicators (PI). Further, organizations are trying to develop sustainability indicators for companies due to new regulations and compliance initiatives. For that reason, this paper aims to identify and classify performance indicators addressing the perspective of sustainability for PLM. The methodology adopted is a systematic literature review to identify the PIs and its characteristics. Moreover the PIs are categorized and best practices applications are presented. In addition, a bibliometric analysis of the literature is carried out to outline most relevant articles, authors and periodicals. This work can help companies to attend requirements of ISO 14001, Global Reporting Initiative (GRI) and at the same time intend to leverage PLM to develop sustainable products. The PIs will be integrated in a framework to support organizations in introducing a PMS.*

Keywords: *Product Lifecycle Management, Performance Measurement System, Performance Indicators, Sustainability, ISO 14000 and GRI.*

1. INTRODUCTION

Product lifecycle management (PLM) is defined as a concept for the integrated management of product related information through the entire product lifecycle (Saaksvouri and Immonen, 2008). The PLM is a key element for companies in creating sustainable value and competitiveness factor in a market where customers are interested in the environmental impacts of the products they consume. In fact, PLM perspective is influencing the way organizations plan their business, take strategic decisions, develop products and manufacturing process, manage operations, deal with suppliers and consumers, and plan the end-of-life of its products (Guelere Filho *et al.,* 2009).

After the Brundtland Commission first introduced the concept of sustainable development, a growing number of national and international organizations, governments, communities and companies are embracing sustainability. In this way, companies are facing tough challenges to succeed in a global competitive market especially to address this issue of sustainability (Veleva *et al.,* 2003). It has inspired many researches and practitioners to search for ways to use tools for measuring and evaluating their progress. In this context, sustainability indicators have emerged as one widely accepted tool (Goyal *et al.,* 2013; Searcy, 2012; Veleva *et al.,* 2003).

Therefore, an increasing number of voluntary initiatives and companies have begun developing and using sustainability indicators (Veleva and Ellenbecker, 2000). Such indicators might be used to improve a company's public image and thus create a competitive advantage through product/service differentiation. As a result, companies around the world have recognized the need to respond appropriately to the sustainable development challenge and, consequently, many have changed their business activities in product development (Pujari *et al.,* 2003; Aragon-Correa and Sharma, 2003). This increasing upsurge of incorporation of sustainability in the processes to all phases of a product's life resulted into the need of assessment of its performance.

According to Searcy (2012), over the past decade, several articles on corporate performance measurement system (PMS) for sustainability have been published in a wide variety of journals. A robust PMS can help decision makers overcome the challenges of corporate sustainability by helping them to better understand their current situation and their desired end state. The majority of researches on indicators have focused on design of sets of corporate sustainable development indicators. However, despite several contributions, many corporations still struggle to develop, implement, use, and improve PMS and indicators that address the needs of both their internal and external stakeholders.

Searcy (2012) points out that this is an important gap since a robust PMS and indicators are required for a corporation to assess how well it is doing in meeting its sustainability priorities. This underscores the need for more research and the on the theoretical and practical aspects of PMS and indicators. In this way, a study concerning performance indicators for the measurement of sustainability in the processes to all phases of a product's life can contribute to the fulfillment of this gap.

Therefore, this paper aims to identify and classify performance indicators addressing the perspective of sustainability for PLM. The remaining discussions are structured into four main sections: 2) research background that treats the main concepts addressed in this paper; 3) research method that illustrates the methodology employed; 4) results which display the major findings of the methodology and finally, 5) discussion and conclusion that reason implications of the findings and directions of future research.

2. RESEARCH BACKGROUND

As previously mentioned the definition for Product Lifecycle Management states that PLM is a concept for the integrated management of product-related information throughout the entire product lifecycle (Saaksvouri and Immonen, 2008). This concept is in agreement with the CIMData definition: PLM is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life – integrating people, processes, business systems, and information (Stark, 2005).

Guelere Filho *et al.,* (2009) present a framework for PLM composed by three business process: Research and Development (R&D), New Product Development (NPD) and Product Accompanying and Retirement (PAR). According to Davenport (1993), a business process represents a collection of activities that produces a result (product or service) for a specific group of customers. This definition is more specific than the general definition of a process as the transformation of inputs in outputs.

The Research and Development (R&D) is the fundamental basis of innovation and is largely responsible for value creation in PLM. As stated by Guelere Filho *et al.,* (2009) the purpose of R&D is to provide to New Product Development (NPD) technological solutions which are properly assessed and mature, or even consolidated, in order to be incorporated in the new product's projects. The technological solutions can either be developed from internal R&D's plans and goals or from NPD demands and solicitations or externally to the organization in partnership with research institutions.

The New Product Development can be defined as the systematic activity from the identification of the customer needs until the product sale, an activity that includes product, processes, people and organization (Pugh, 1995). In addition, according to Pahl and Beitz (2006), NPD is the set of activities that aim to reach the design specifications of a product and its manufacturing process in order to provide the organization the required capability of producing it. Moreover, product development consists on the process of transforming information from market and technology into information and required sources to manufacture a product with the purpose of commercializing it (Clark and Wheelwright, 1993).

According to Guelere Filho *et al.,* (2009), the Product Accompanying and Retirement (PAR) business process treats the closing the loop of materials, an important condition to reduce the environmental impact of products. The business processes aforementioned must already consider reuse, remanufacturing and recycling as strategies for the products' end-of-life.

Facing these processes of a product's lifecycle and the need of measurement its performance, the concepts of measurement performance should take place. Neely *et al.,* (1995) define performance as the efficiency and effectiveness of actions within a business context. Effectiveness refers to the compliance with customer requirements while efficiency denotes how the organization's resources are used to achieve customers' satisfaction levels.

As indicated previously, performance measurement is the process of quantifying efficiency and effectiveness. To this end, performance measures should be chosen, implemented, and monitored. Performance indicators are the metric used to quantify the efficiency and/or effectiveness of actions of part or of an entire process or a system in relation to a pattern or target (Neely *et al.,* 2005). These performance indicators are essential elements for planning and strategic control cycles (Neely *et al.,* 1997).

The Balanced Scorecard (BSC) is the most known and frequently applied framework used by companies worldwide to translate strategic objectives into a set of actions and performance indicators. The BSC arranges the indicators in four perspectives: 1) financial; 2) customers; 3) internal processes, and 4) innovation and learning (Kaplan and Norton, 1993).

Braz *et al.,* (2011) argues that several performance indicators can be observed in the literature review. On one hand, Shepherd and Günter (2006) indicated a lack of consensus in the literature on the best way to classify performance indicators. On the other hand, some authors agree on the main characteristics considered for them Braz *et al.,* (2011). Good performance indicators are quantitative and possess objective values instead of subjective ones. They should be straightforward and easy to understand in order to enable a rapid identification of what is being measured and how it is being measured; practical with appropriate scales; consistent and maintain meaning over time; and clear on the objectives.

In this way, the sustainability indicators that have been developed and used by companies as stated by Veleva and Ellenbecker (2000) should also reflect the mentioned characteristics. The sustainability indicators address the sustainable development among the companies. The most common definition of sustainable development was introduced by the Brundtland Report (United Nations, 1987). It defines sustainable development as the development

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that meets the needs of the present without comprising the ability of future generations to meet their needs (Beheiry, et al., 2006).

Accordingly, the Triple Bottom Line (TBL) (Elkington, 1997) emerged as the concept of sustainability as integration of economic, environmental and social dimensions. Hubbard (2009) argues that the TBL is a critic concept for many organizations because it implies that the firm's responsibilities are much wider than simply those related to the economic aspects of producing products and services that customers want, to regulatory standards, at a profit. The TBL adds social and environmental indicators of performance to the economic indicators typically used in most organizations performance. Furthermore, the environmental indicators can address either environmental aspects, defined as any element of an organization's activity, products or services that can interact with the environment, or environmental impact that stands for any change to the environment, whether adverse or beneficial, wholly or partially resulting from the organization's activities, products or services (ISO 14001, 2004).

In accordance with this view, Samuel *et al.,* (2013) presents the Global Reporting Initiative (GRI) as an important initiative that works towards a sustainable global economy by providing sustainability reporting guidance. GRI has pioneered and established a comprehensive sustainability reporting framework for voluntary use. The framework is the world's most widely used sustainability reporting tool (Arena *et al.,* 2013; Bos-Brouwers, 2010) and the performance indicators listed therein are used to measure and report their economic, environmental, and social performance (GRI, 2011).

Besides the GRI, another important tool related to the sustainable performance of companies is the international standard IS0 14001 (Comoglio and Botta, 2012). One of the key elements of the ISO 14001 is the continual improvement of environmental performances, which is the final outcome of the plan-do-check-act (PDCA), which is the core of environmental management systems (EMS). Nevertheless, a critical point is that ISO 14001 does not fix minimum levels of environmental performances that should be achieved and assessed annually in order to maintain the certification, and does not even provide specific requirements or operational methods to be used to measure continual improvement, like performance indicators.

Given that this study aims to identify and classify performance indicators addressing the perspective of sustainability for PLM that encompasses the three business process: R&D, NPD and PAR, it is important to detail the research method, as performed in the following section.

3. RESEARCH METHOD

The systematic literature review was conduct based on the roadmap proposed by Conforto *et al.,* (2011) which was adapted from other knowledge areas with the purpose to guide systematic literature reviews on operations management. Figure 1 illustrates the three phases and its steps. The main characteristics of the proposed roadmap can be described as the conduction of research strings tests and refinements, the iterative processing of the results and its reference research of the results references. The three phases are described in order to detail the methodology employed.

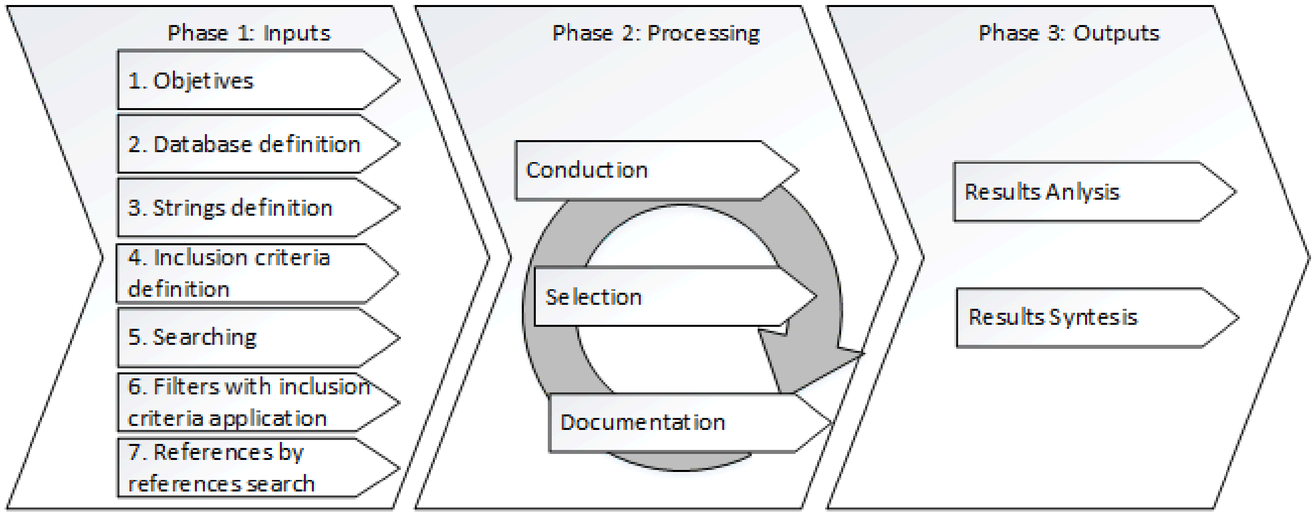

Figure 1. Systematic literature review roadmap (adapted from Conforto *et al.,* 2011)

3.1 Phase 1: Inputs

In this phase, the systematic literature review was planned and its inputs defined. The resulting plan as the inputs defined are shown as followed.

1. Objective definition: identify and classify performance indicators addressing the perspective of sustainability for PLM.
2. Database definition: the source selected was ISI Web of Science (Thomson Reuters) and qualified experts. Articles available in English, free of charge, and authenticated by the researchers' institutions should be considered. Searches should be conducted using the "title," "abstract," and "keywords" fields.
3. Strings definition: the keywords were selected from the list of articles identified by the experts. Two iterations were carried out in order to refine the strings. The keywords were: "performance," "measurement," "indicator," "measure," "metric," "index;" "sustainability," "sustainable development," "environmental sustainability," "corporate social responsibility," "tripple botton line;" "product," "design".
4. Inclusion criteria definition: the established criteria for articles inclusion were: C1) proposition and/or studies for identification of performance indicators related to sustainability of PLM business processes; C2) information about attributes of performance indicators related to sustainability of PLM business processes.
5. Searching: examining the selected database, eliminating duplicates, and exporting results to a table for filters application.
6. Filters with inclusion criteria application: 1st iteration with article's title, keywords and abstract reading; 2nd iteration with article's introduction, results and conclusion reading; 3rd iteration with article's full reading.
7. References by references search: should be performed using the references of the selected articles.

3.2 Phase 2: Processing

A systematic literature review search, results analysis, and documentation were performed. Searching using the chosen string produced 793 articles. During articles' full reading; it is normal to find citations to other relevant articles that did not appear in the references by references search. In our systematic literature review, 26 articles were found through the references by references search. Finally, 215 articles were analyzed, 35 from the filters selection and the references by references search. Figure 2 summarizes these results. The data extracted from the selected articles were transcribed to a preliminary table, listing all the performance indicators and their available information.

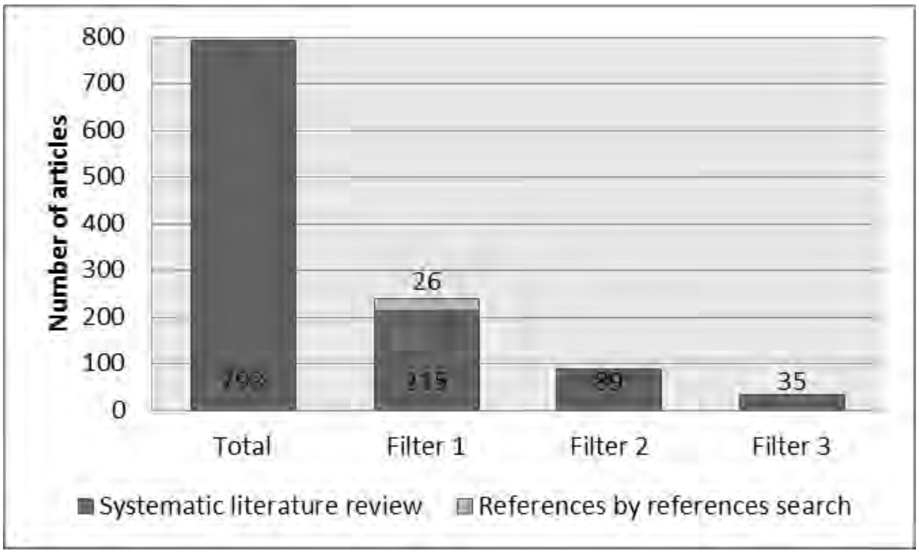

Figure 2. Graphic of the distribution of the systematic literature review search

During the results analysis, the only information considered was what could be found from the set of selected articles; no critical analysis occurred at this point. In this way, an extensive list of 563 performance indicators was conceived.

3.3 Phase 3: Outputs

The literature review's main output was the synthesis table (which is discussed in the next section) and the identification of the main journals and other significant information about the subject. Therefore, after the selection of papers, full paper was thoroughly studied for any categorization. The next section discusses the results of the results analysis and results syntheses.

4. RESULTS

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At first, a result analysis is carried out based on a bibliometic analysis (section 4.1) and secondly it is present the results synthesis grounded in the content of the articles (section 4.2).

4.1 Results Analysis

The results analysis of literature can be based on various criteria. These articles were analyzed on the basis of different criteria: year of publication, country, journal, authors, and methodology related to the obtainment of the performance indicators, empirical and theoretical. Figure 3 illustrates these criteria which were adapted from the Goyal *et al.,* (2013) studies about sustainability performance assessment.

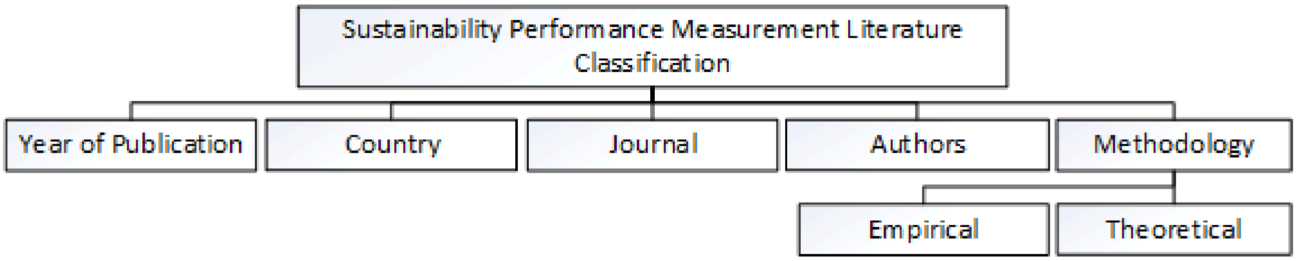

Figure 3. Categories for literature classification (Adapted from Goyal *et al.,* 2013)

All 35 papers were classified by the time of publication. The main reason of this distribution was to provide a quick overview of the evolution of the research field of performance measurement concerning sustainability literature. Figure 4 shows that the publications between the year of 2001 and 2013, which indicates a quite recent research field. It also presents the average of approximately two articles per year, although, in 2012, the number of articles increased with a total of nine. This shows a growth in the number of publications in the latest years, considering the fact that four articles have been already selected in this current year (2013).

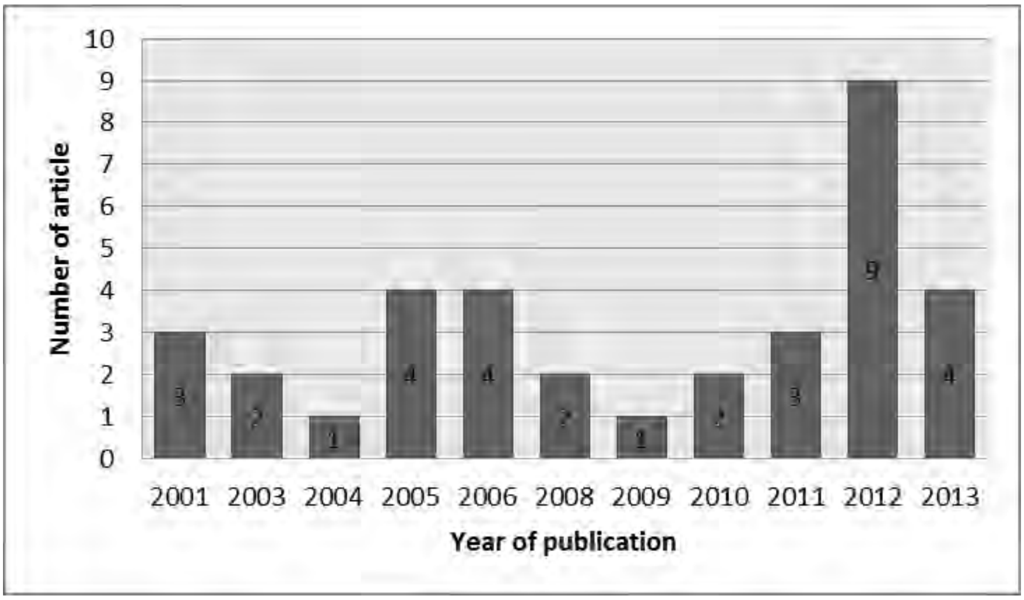

Figure 4. Graphic of the distribution of year publication

According to Goyal *et al.,* (2013), a country-wise classification of literature is very crucial to identify the seriousness of research for this critical issue across the globe. Future research could be focused on the unexploited part of the globe to sensitize the issue of sustainability assessment. The maximum number of articles related to performance measurement concerning sustainability literature for PLM is published by authors based in United States, Germany and Italy presenting eight, three, three articles respectively. The first two countries are identified in the studies of Goyal *et al.,* (2013), as most representatives in the research field of sustainability performance assessment.

The articles related to sustainability performance measurement are widely published in various reputed journals. There are, in total, 21 journals that published papers related to the issue studied in the given time frame. The maximum

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number of papers is published by the Journal of Cleaner Production, corresponding to 48% of the selected ones. Table 1 shows the list of journals, along with number of articles. It is interesting to mention that first six journal are responsible for 60% of the total of papers selected.

Table 1. List of the journals.

ID	Journal	Number
1	Journal of Cleaner Production	10
2	Environmental Science & Technology	2
3	Ecological Indicators	2
4	Journal of Industrial Ecology	2
5	Business Strategy and the Environment	2
6	International Journal of Life Cycle Assessment	2
7	Resources Conservation and Recycling	1
8	Journal of Environmental Management	1
9	Industrial Management & Data Systems	1
10	Ecological Economics	1
11	Journal of Construction Engineering and Management	1
12	Journal of Business Ethics	1
13	Management Decision	1
14	Advanced Engineering Information	1
15	Corporate Social Responsibility and Environmental Management	1
16	*Amfiteatru* Economic	1
17	Supply Chain Management - An International Journal	1
18	International Journal of Operations & Production Management	1
19	Long Range Planning	1
20	Balanced Scorecard Report	1
21	Benchmarking: An International Journal	1

Among the 35 selected articles, it can be inferred that sustainability performance indicators related to PLM receives inputs from different areas such as supply chain, environmental management and operations management. This miscellaneous research fields implies that distinct authors are responsible for the articles. There are four authors that represent many of the performance indicators selected: Epstein, M.J; Labuschagnea, C; Veleva, V. and Brent A.C.

Finally, the classification scheme of the methodology provides more information about the sources of the performance indicator found the selected articles. In this way, the performance indicators' initial proposition can be either theatrical or empirical. Therefore, this classification criterion can help the future researchers to understand changes in the methodologies adopted for the sustainability performance measurement. Figure 5 shows that the majority of the articles, corresponding to 71%, provides performance indicators based on theoretical methodology while 29% of the select articles uses empirical methodology.

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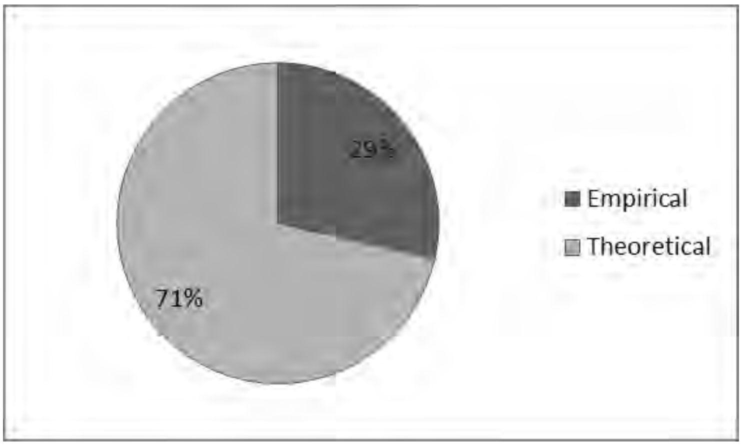

Figure 5. Classification of the selected articles methodology

4.2 Results Synthesis

The systematic literature review enabled the data collection into the preliminary table that recorded 563 performance indicators. This raw data was submitted to a two phased critical analysis in order to refine the recorded performance indicators. Figure 6 presents the two phases of refinement and the established steps. The first phase, identification, occurred in three steps: 1) verification of scope with the purpose of checking if the transcribed performance indicators attended the adapted definition performance indicator (Neely *et al.,* 2005); 2) elimination of duplicates that aimed at the arrange the performance indicator a single name; and 3) rewritten in standard format to provide information about the metric used. The second phase also presented three steps: 1) classification of the TBL dimensions (Elkington, 1997), in order to address performance indicators from environmental and social dimensions and exclude the well consolidated economic ones; 2) classification in PLM processes according to Guelere Filho *et al.,* (2009); and finally, 3) classification in GRI and ISO 14001 according the articles content.

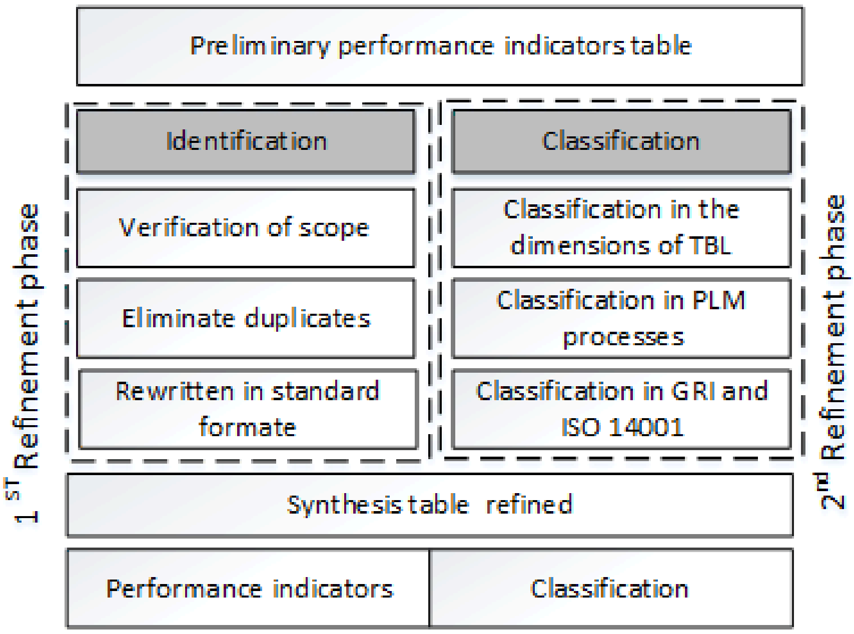

Figure 6. Steps for the elaboration of the performance indicators synthesis

Table 2 is the main result is a set of performance indicator and their categories. Although 190 sustainability performance indicators remained through first and second refinement, these 50 indicators shown are the most related to the PLM process. It is worthy of mention that the first classification, concerning the dimensions of TBL, is no longer shown in the table, because it aims was to remove the economic performance indicator that are well consolidated in literature (Searcy, 2012; Comoglio and Botta, 2012; Kaplan and Norton, 1997). Thus, the performance indicators, along with their references, are categorized in PLM processes, GRI and ISO 14001.

Table 2. Performance indicators synthesis list.

ID	Name	PLM processes	GRI	ISO	References
1	Product Disposal Cost	PAR[(1)]			Traverso *et al.,* (2012); Fiksel (2003); Epstein and Wisner (2001)
2	Warranty claims costs	PAR			Fiksel (2003); Epstein and Wisner (2001)
3	Useful product lifetime	PAR			Fiksel (2003)
4	Percentage of hazardous materials of the product	R&D[(2)]; NPD[(3)]; PAR			Arena et al., (2013); Inoue, et al. (2012); Tsoulfas and Pappis (2008); Fiksel (2003)
5	Percentage recycled material of products	PRP			Arena *et al.,* (2013); Bai *et al.,* (2012); Inoue *et al.,* (2012); Tsoulfas and Pappis (2008); Fiksel (2003); Epstein and Wisner (2001)
6	Nonrenewable materials of products	R&D; NPD; PAR		X	Tugnoli et al., (2008)
7	Renewable materials of products	R&D; NPD		X	Tugnoli *et al.,* (2008)
8	Market share of "green" products	R&D; NPD			Van der Woerd and Van den Brink (2004)
9	Customer retention by product responsibility	NPD; PAR			Van der Woerd and Van den Brink (2004)
10	Number of project applying of eco design	R&D; NPD; PAR			Bai et al., (2012); Van der Woerd and Van den Brink (2004)
11	Remanufacturing time	NPD, PAR			Jiang *et al.,* (2011)
12	Amount and type of raw materials of the products	NPD		X	Arena *et al.,* (2013); Jiang et al., (2011)
13	Weight of produced waste per weight of products	NPD; PAR		X	Comoglio and Botta (2012)
14	Weight of produced waste per product unit	NPD; PAR		X	Comoglio and Botta (2012)
15	Weight of produced waste per number of product units	NPD; PAR		X	Comoglio and Botta (2012)
16	Number of non-conformities ISO 14001	R&D; NPD; PAR		X	Comoglio and Botta (2012)
17	Electricity consumption per product unit	R&D; NPD; PAR		X	Comoglio and Botta (2012)
18	Electricity consumption per number of product units	R&D; NPD; PAR		X	Comoglio and Botta (2012)
19	Electricity consumption per weight of products	R&D; NPD; PAR		X	Comoglio and Botta (2012)
20	Water consumption per unit product (new)	R&D; NPD; PAR		X	Samuel *et al.,* (2013); Comoglio and Botta (2012)
21	Percentage of renewable materials	R&D; NPD; PAR		X	Arena *et al.,* (2013)
22	Materials used by weight or volume	R&D; NPD; PAR	X		Samuel *et al.,* (2013)
23	Percentage of input materials used which are reprocessed materials	R&D; NPD; PAR	X		Samuel *et al.,* (2013)
24	Number of initiatives to mitigate environmental impacts of products and services, and extent of impact mitigation.	R&D; NPD; PAR	X		Samuel *et al.,* (2013)
25	Percentage of packaging materials that are reclaimed by category	PAR	X		Samuel *et al.,* (2013)
26	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, and transporting members of the	NPD; PAR	X		Samuel *et al.,* (2013); Labuschagne and Brent (2006); Veleva *et al.,* (2003);

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	workforce.				
27	Number of community programmes carried out to communicate the impacts of operations on communities, including entering, operating, and exiting	R&D; NPD; PAR	X		Samuel *et al.,* (2013); Radu (2012); Epstein and Wisner (2001)
28	Number of products with eco-label	R&D; NPD; PAR			Inoue *et al.,* (2012)
29	Products that were produced under environmental or social standards	NPD			Inoue *et al.,* (2012)
30	Feasibility of eco-labels	R&D; NPD; PAR			Inoue *et al.,* (2012)
31	Increase the number of facilities with screening procedures against the use of child labor (No. of facilities)	R&D; NPD; PAR			Traverso *et al.,* (2012); Epstein and Roy (2001)
32	Rate of customer complaints and returns	PAR			Radu (2012); Hubbard (2009); Veleva and Ellenbecker (2001); Epstein and Wisner (2001)
33	Waste generated from products and materials	R&D; NPD; PAR			Bai *et al.,* (2012)
34	Response to environmental programs for suppliers	NPD, PAR			Bai *et al.,* (2012)
35	Response to environmental product requests	R&D; NPD			Bai *et al.,* (2012)
36	New environmentally sound processes introduced	NPD			Bai *et al.,* (2012)
37	Investments in cleaner technologies	R&D			Epstein and Roy (2001)
38	Number of ISO 14001 certification	R&D; NPD; PAR			Epstein and Roy (2001)
39	Number of senior managers with environmental responsibilities	R&D; NPD; PAR			Epstein and Roy (2001)
40	Revenues from "green" products	NPD			Epstein and Wisner (2001)
41	Increased sales from improved reputation	R&D; NPD; PAR			Epstein and Wisner (2001)
42	Percentage of product remanufactured	NPD; PAR			Epstein and Wisner (2001)
43	Number of safety improvements projects	R&D; NPD; PAR			Epstein and Wisner (2001)
44	Percentage of products reclaimed after use	PAR			Epstein and Wisner (2001)
45	Number of report requests	R&D; NPD; PAR			Epstein and Wisner (2001)
46	Number of product recalls	NPD; PAR			Epstein and Wisner (2001)
47	Number of employees with incentives linked to environmental goals	R&D; NPD; PAR			Epstein and Wisner (2001)
48	Percentage of products designed for disassembly, reuse or recycling	R&D; NPD; PAR			Veleva and Ellenbecker (2001)
49	Percentage of biodegradable packaging.	NPD; PAR			Veleva and Ellenbecker (2001)
50	Percentage of products with take-back policies in place.	NPD; PAR			Veleva and Ellenbecker (2001)

(1) Product Accompanying and Retirement (PAR)
(2) New Product Development (NPD)
(3) Research and Development (R&D)

In order to incorporate the sustainability performance indicators into a performance measurement system, such as the balanced scorecard (BSC), Moller and Schaltegger (2010), Van der Woerd and Van den Brink (2004), and Figge *et al.,* (2002) recommend three different approaches. The first approach lies in the restructuring of the existing perspectives in order to incorporate sustainability issues; the second refers to a new key perspective and the third is based on the creation of a specific environmental and/or social BSC.

The first approach to integrating sustainability into the BSC does not modify the arrangement of the four perspectives. According to Moller and Schaltegger (2010), research and case studies have shown that this approach allows incorporating all sustainability issues that have direct relevance to the financial market and the customer market.

The financial perspective should describe not only the outcomes in conventional financial terms but also in terms of the market significant corporate sustainability issues.

The second approach integrates a new nonmarket perspective with the purpose of complementing all four conventional perspectives by nonmarket issues that are not yet covered. The introduction of an additional non-market perspective is relevant as long as environmental and social aspects from outside the market system are explicitly representing the strategic core aspects for the successful execution of the strategy of the business. Moreover, the nonmarket perspective does not incorporate all sustainability oriented objectives and indicators of the business, but only nonmarket issues that cannot be covered in the conventional perspectives (Figge *et al.,* 2002).

Finally, the BSC lies in the deduction of an environmental and/or social scorecard in the third approach. This derived environmental or social scorecard cannot be developed parallel to the conventional scorecard, thus it is not an independent alternative for integration, but only an extension of the two approaches previously stated. Therefore, it is predominantly used in order to coordinate, organize and further differentiate the environmental and social aspects, once their strategic relevance and position in the cause-and-effect chains have been identified by the two approaches (Figge *et al.,* 2002; Van der Woerd and Van den Brink, 2004).

5. DISCUSSION AND CONCLUSION

This study provides insights that can help researches and professionals interested in sustainability performance indicators for PLM. The list aggregates the all the sustainability performance indicators available in the selected database concerning the PLM approach. Considering the whole amount of 190 performance indicators identified for PLM, 58% of these indicators were strictly financial indicators. From the remaining ones, the majority addressed environmental aspects corresponding to 82% of the sustainability performance indicators identified, meanwhile 18% related to environmental impacts. Therefore, the resulted list allows the selection of sustainability performance indicators that are able to measure either aspects or impacts environmental.

Furthermore, this study is in accordance with Léon-Soriano *et al.,* (2010) and Medori and Steeple (2006) arguments that to a PMS development the support of a list of performance indicators is a fundamental aid. In addition, the further classification of performance indicators addressing the GRI and ISO 14001 is also a valuable resource, as few studies have sought to identify or classify performance indicator in the same manner.

Despite the systematic review' comprehensive list of the sustainability performance indicators addressing the PLM there are some limitations. The analyzed articles deal with the sustainability performance indicators from several viewpoints, especially from supply chain studies, and this leads to a more limited set of selected performance indicators, since the majority still addresses economic perspective of the supply chain. Besides that, few studies analyzed grasped the concepts of performance measurement, as a result, several performance indicator were not selected because of their highly abstract definitions. The final set of performance indicators presents less abstract definitions like "percentage of products with take-back policies in place". Another important issue worth mentioning is that performance indicators should reflect positive behavior within the company. In this way, performance indicator such as "rate of customer complaints and returns" should be rearranged in order to influence the positive behavior. Furthermore, the sources found did not present much information about the description of the performance indicators.

Future research should conduct the research method adapted in this study with the purpose of identifying and classifying the sustainability of performance indicators for PLM in the remaining databases. In addition, future studies could give more detail, showing the complementary information about the selected performance indicators. Moreover, this study could serve as the starting point for future efforts to propose and develop new sustainability performance indicators more suitable for PLM by addressing unattended critical success factors and related shortcomings. In conclusion, even though an exhaustive list is unfeasible, this study establishes a comprehensive reference for future studies.

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