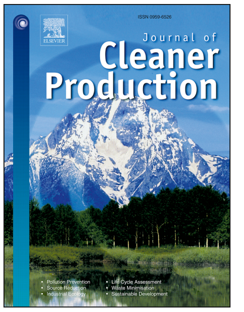
Accepted Manuscript



Industrial sustainability performance measurement systems: A novel framework

Enrico Cagno, Alessandra Neri, Mickey Howard, Gianluca Brenna, Andrea Trianni

PII: S0959-6526(19)31537-9

DOI: https://doi.org/10.1016/j.jclepro.2019.05.021

Reference: JCLP 16786

To appear in: *Journal of Cleaner Production*

Received Date: 21 December 2018

Revised Date: 18 April 2019

Accepted Date: 3 May 2019

Please cite this article as: Cagno E, Neri A, Howard M, Brenna G, Trianni A, Industrial sustainability performance measurement systems: A novel framework, *Journal of Cleaner Production* (2019), doi: https://doi.org/10.1016/j.jclepro.2019.05.021.

Industrial Sustainability Performance Measurement Systems: A Novel Framework

Enrico Cagno [a], Alessandra Neri [a] *, Mickey Howard [b], Gianluca Brenna [a], Andrea Trianni [c]

[a] *Politecnico di Milano, Department of Management, Economics and Industrial Engineering, Milan, Italy*

[b] *University of Exeter Business School, Department of Management Studies, Exeter, United Kingdom*

[c] *University of Technology Sydney, Faculty of Engineering and Information Technology, Sydney, Australia*

*corresponding author: alessandra.neri@polimi.it

Words: manuscript 10,495; tables 3,999; references 4,035

Industrial Sustainability Performance Measurement Systems: A Novel Framework

Abstract

Improved sustainability of industrial activities and measurement of its performance are becoming prime topics of discussion among policy-makers and industrial decision-makers. The current literature proposes a number of performance measurement systems and related indicators, but mainly lack a real capability to address all sustainability pillars and their intersections, as well as scalability to firms of different sizes, availability of internal resources, and maturity over sustainability issues, suggesting that further research is needed in this area. Building on the literature, our work develops a new framework for the evaluation of industrial sustainability performance, proposing three different Industrial Sustainability Performance Measurement Systems (ISPMSs), with a decreasing number of indicators suitable in different contexts of application. In the framework, selection mechanisms have been conceived and used to reduce the number of indicators considered, while still guaranteeing complete and adequate coverage of all sustainability pillars, as well as their intersections. The framework has been tested through semi-structured case studies in heterogeneous Northern Italian manufacturing firms. The preliminary results are sound as the different ISPMSs proved to be complete, useful, and easy to use. The proposed ISPMSs provide industrial decision-makers with a scalable framework applicable in different contexts, allowing benchmarking and development of specific implementation strategies for increased sustainability, and provide policy-makers with a framework to develop a more effective regulatory policy, better understanding how sustainability performance can be addressed in an integrated manner across industrial firms.

Keywords

Industrial Sustainability, Sustainability Indicators, Performance Measurement System.

1. Introduction

Improved sustainability of industrial activities has become a main topic of discussion among policy-makers and industrial decision-makers (Scordato et al., 2018; Stoycheva et al., 2018). Several authors recently referred to industrial sustainability focusing on all the activities related to the industrial plant level and the entirety of operations (i.e. not just the production line), requiring actions involving materials, products, processes, plants and production systems, in addition to integration with the normal activities of the firm (Neri et al., 2018). In order to properly address industrial sustainability, a holistic approach should be adopted that accounts for interrelations among the different pillars of the Triple Bottom Line (TBL) – environment, social, economic (Gimenez et al., 2012; Pagell and Gobeli, 2009; Trianni et al., 2017). However, there are several difficulties in managing industrial sustainability as a whole (Cagno et al., 2018), given the complexity of the decision-making process (Gibson, 2006) and the presence of trade-offs (Haffar and Searcy, 2017; Salzmann et al., 2005), which is also related to the different industrial decision-makers involved in the process (Gong et al., 2018).

Measuring and improving industrial sustainability are therefore crucial issues (Howard et al., 2018), also foreseeing sustainability as a major competitive factor (Engida et al., 2018; Morioka et al., 2018).

Internal stakeholders, in particular, need to effectively understand where specific actions should be undertaken towards increased sustainability (Collins et al., 2016; Singh et al., 2012). An assessment of industrial sustainability performance is thus necessary for firms to identify which measures should be adopted (Bhanot et al., 2017; Trianni et al., 2017) and evaluate and track the effect of the adoption (Arena and Azzone, 2012; Winroth et al., 2016). To do this, the use of performance measurement indicators tailored to the firm’s needs is necessary (Clarke-sather et al., 2011; Singh et al., 2016). However, the measurement of performance may also allow benchmarking activities with respect to sustainability (Ghadimi et al., 2012), for which the use of standardized indicators has been recommended (Ferrari et al., 2019; Paju et al., 2010). Benchmarking support requires comparison with peers operating in the same sector (Ferrari et al., 2019), but also depends on other contextual factors, such as the geographical area (Apaydin et al., 2018; Tanzil and Beloff, 2006) or firm size (Siebert et al., 2018).

Sustainability performance indicators are thus crucial for increased sustainability in industrial firms, given that it is not possible to improve what is not measured (Engida et al., 2018; Singh et al., 2012). Performance indicators are metrics used to enable the performance measurement process (Neely et al., 1995) and to motivate industrial decision-makers in the achievement of goals (Globerson, 1985) by more precisely identifying which measures should be adopted (Veleva and Ellenbecker, 2001). If performance indicators are organized in a set, they are referred to as Performance Measurement System (PMS) (Krajnc and Glavič, 2003; Neely et al., 1995).

PMSs are very useful for properly evaluating performance (Johnson and Schaltegger, 2016), and can lead to improved firm management (Staniškis and Arbačiauskas, 2009). The development of PMS is, however, rather challenging (Neely et al., 2000), especially regarding the identification and selection of the performance indicators to be included (Hailey and Sorgenfrei, 2003; Singh et al., 2014), which is often difficult to carry out (Lee and Lee, 2014).

Further problems in selection arise when trying to include all the aspects related to industrial sustainability, given the higher complexity and heterogeneity to be managed. The encompassing of the appropriate indicators in the routine activity of performance measurement is still rather low (Bilge et al., 2014). Indeed, for the assessment of industrial sustainability performance, firms may either adopt previously developed methods or develop their own: in the first case, benchmarking would be allowed, but the methods may not be properly applicable in specific contexts (Hallstedt et al., 2015); in the second case, the development of a tailored method might be too resource intensive and would threaten benchmarking activities (Staniškis and Arbačiauskas, 2009). Despite the claimed evolution of the manufacturing system towards sustainability, standardized methods for assessing sustainability performance are still missing (Harik et al., 2015; Helleno et al., 2017) as are complete and simple tools (Witjes et al., 2015).

Previous literature has proposed models to measure sustainability performance in industrial firms in different contexts (Feil et al., 2015; Helleno et al., 2017; Long et al., 2016) and with different methodological approaches (Butnariu and Avasilcai, 2015; Kocmanová et al., 2017; Watanabe et al., 2016), but there are a number of research gaps that still need to be addressed, both in terms of content of the PMSs and context of application. Particularly, the extant literature appears to not properly cover all the TBL pillars with their intersections and presents too many indicators as well as different methodologies for their selection and prioritization. Moreover, methods for the assessment of sustainability performance have been developed for a specific context in terms of contextual factors and maturity toward sustainability. There is the need for a comprehensive PMS that is able to describe all the areas related to sustainability and their intersections, and which is appropriate to be used by firms with different characteristics in terms of contextual factors and maturity over sustainability issues. It should thus be scalable and characterized by different levels of application, ascribable to different goals and situations, as suggested by Azapagic (2004). In this way, the same system can be applied to firms with different characteristics, guiding the firm during its specific path to improved sustainability, but also allowing benchmarking among firms characterized by the same contextual factors.

The remainder of the paper is structured as follows: in Section 2, a literature background analysis is conducted and the emerging gaps underlined; in Section 3, the new framework is introduced: the development of the different PMSs is presented, as well as the analysis of the coverage of the TBL's pillars and their intersections; in Section 4 the research method for the empirical test of the framework is addressed; in Section 5, the results of the test are presented; in Section 6, a concluding discussion is provided, along with limitations of the study and possible further research.

2. Literature background

A literature background analysis was carried out to obtain an understanding of the extant knowledge base and highlight research gaps (Saunders et al., 2009). We searched for relevant literature by querying an international database (SCOPUS). We used terms related to the system of indicators (*framework, model, approach, assessment),* combined with terms related to performance measurement (*indicators, KPI, performance indicator, metric)*, and terms related to the topic *(sustainability, sustainable development, sustainable),* and context of interest *(plant, industry, company, firm, corporate, manufacturing, production)*. We limited the analysis to contributions published in English from the year 2000 onwards, and excluded areas of not interest (Table 1). Taking inspiration from previous research, we also searched for additional relevant literature looking at references and citations of the initial set of selected contributions using the snowball method (Heckathorn and Cameron, 2017; Skolarus et al., 2017; Wohlin, 2014).

Criteria selection for the literature review			
Keywords	**Language**	**Publication year**	**Areas**
TITLE-ABS-KEY ("framework" OR "model" OR "approach" OR "assessment") AND TITLE-ABS-KEY ("indicator" OR "KPI" OR "performance indicator" OR "metric") AND TITLE-ABS-KEY ("sustainability" OR "sustainable development" OR "sustainable") AND TITLE-ABS-KEY ("plant" OR "industry" OR "company" OR "firm" OR "corporate" OR "manufacturing" OR "production")	(LIMIT-TO (LANGUAGE, "English")	PUBYEAR > 1999	EXCLUDE (SUBJAREA, "AGRI") OR EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "MATH") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "PHAR") OR EXCLUDE (SUBJAREA, "VETE")

Table 1. Detail of the criteria selection used in the conduction of the literature background analysis.

2.1. Analysis of the literature

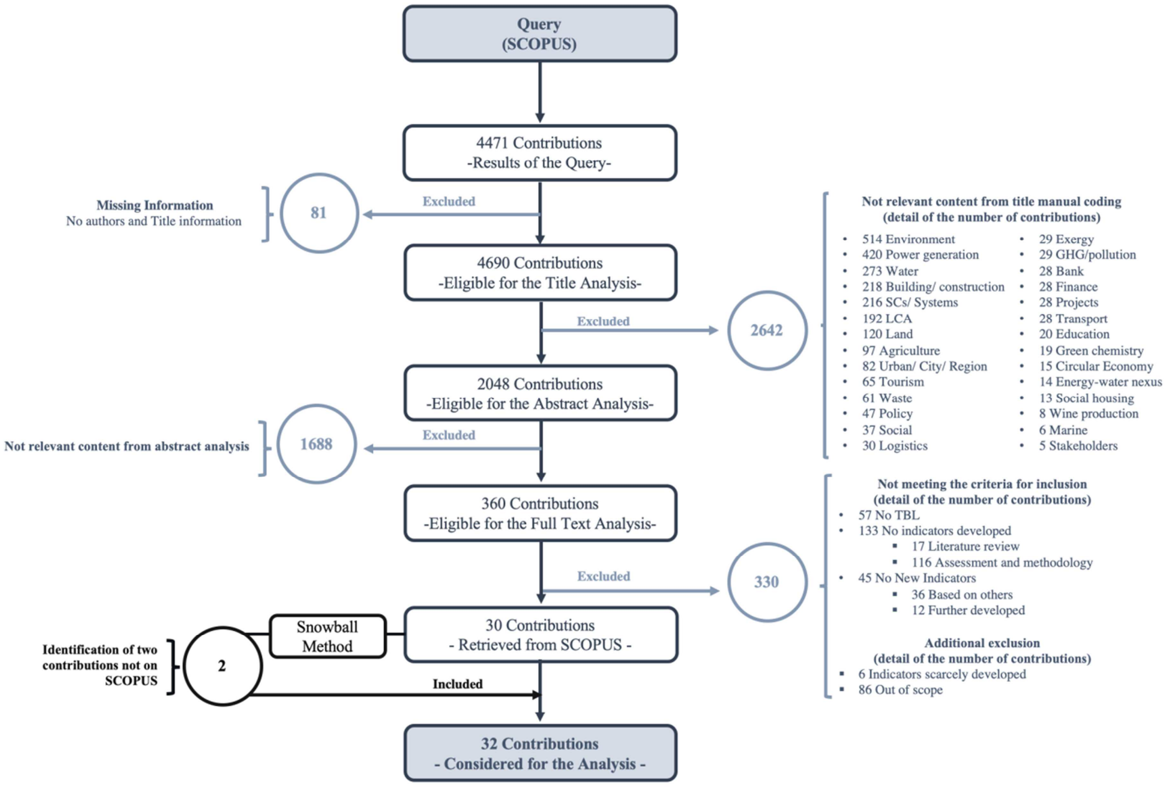
The literature research generated 4,771 contributions (articles, conference proceedings, books, and book chapters), witnessing the soaring importance of the topic, especially after the year 2011. To identify relevant contributions for the literature analysis, we adopted the following procedure, also displayed in Figure 1:

1. *Missing information*: the initial set of 4,771 contributions was reduced to 4,690 since for 81 contributions no information related both to Authors and Title were not provided by Scopus.
2. *Title analysis*: the 4,690 contributions were submitted to a title analysis. For this analysis, we performed a manual coding excluding those contributions not relevant to the present work, as for example "Agriculture", "Building" or "Construction" (further details can be found in Figure 1). The title analysis led to the exclusion of 2,642 contributions, and the identification of 2,048 contributions eligible for an abstract analysis.
3. *Abstract* analysis: performing the abstract analysis, 1,688 out of the starting 2,048 were excluded, since the content of the abstract was considered not relevant for the present research. A set of 360 contributions was thus obtained and deemed eligible for full text analysis.
4. *Full -text analysis*: conducting the full text analysis, we focused on three criteria:

- we included only contributions providing a simultaneous and holistic analysis of indicators in all the TBL areas: this criterion led to the exclusion of 57 contributions;
- we included only contributions providing a set of indicators, thus eliminating 17 contributions providing only a literature review and 116 contributions providing an assessment methodology or performing analysis of indicators retrieved from company reports;
- we included only contributions providing a new or an improved set of indicators compared to previous literature, eliminating 36 contributions conducting empirical analysis based on previously developed indicators and 12 contributions proposing a set of indicators improved with respect to previous work from the same authors.

Besides, we also excluded 86 contributions still resulting out of scope and 6 contributions that we deemed to provide scarcely developed indicators. We obtained a final set of 30 contributions. After the application of the snowball method on this set, 2 further contributions were added, for a total of 32 contributions considered for the literature analysis.

Figure 1.Procedure for the identification of the contributions to be included in the literature analysis



A detailed analysis of each contribution, reported in Table 2, allowed to identify 1,416 sustainability performance indicators. All the reviewed contributions categorize sustainability performance indicators: some base the categorization on the areas of the TBL (Azapagic and Perdan, 2000; Barbosa and Gomes, 2015; Krajnc and Glavič, 2005), while others develop further categories and subcategories within the TBL (Li et al., 2012; Veleva and Ellenbecker, 2001; Winroth et al., 2016). The proposed sustainability performance indicators stem from a broad set of approaches: existent literature (Medini et al., 2015; Ocampo et al., 2016; Singh et al., 2014), literature and expert involvement (Azapagic, 2004; Jiang et al., 2018), literature and the Delphi method (Ahmad et al., 2019), surveys (Singh et al., 2007; Watanabe et al., 2016), case studies (Butnariu and Avasilcai, 2015), combined literature and case studies (Sureeyatanapas et al., 2015), and previously developed tools and frameworks (Dočekalová and Kocmanová, 2016; Ruiz-Mercado et al., 2012). Following Martín-Peña et al. (2014) and Murillo-Luna et al. (2011), we divided the reviewed contributions as theoretical (only the new theoretical model) and theoretical-empirical (with theoretical model coupled with empirical application).

The theoretical models proposed are either generic (Krajnc and Glavič, 2003) or related to specific contexts. We have, indeed, different spotlights on sectors, geographical areas, and firm sizes. Regarding sectors, sustainability performance indicators have been addressed for the manufacturing industry as a whole (Helleno et al., 2017; Ocampo et al., 2016), but also with a focus on specific sectors (Krajnc and Glavič, 2003; Medini et al., 2015), for example, iron and steel (Long et al., 2016), automotive (Amrina and Yusof, 2012), chemical (Barbosa and Gomes, 2015; Ruiz-Mercado et al., 2012), palm oil (Lim and Biswas, 2015), sugar (Tan et al., 2015), cement (Amrina and Vilsi, 2014), and mining (Azapagic, 2004). Regarding geographical areas, contributions target different countries, mainly Asian, - such as Malaysia (Lim and Biswas, 2015), Thailand (Sureeyatanapas et al., 2015), Singapore (Tan et al., 2015), China (Long et al., 2016) and European - such as Czech Republic (Kocmanová et al., 2017). Lastly, only a few contributions focus on a specific size, i.e. Small-Medium Enterprises (SMEs) (Feil et al., 2015; Singh et al., 2014).

Theoretical-Empirical studies address different contexts, in terms of sectors, geographical areas and firm size. We can find contributions focusing on the textile industry (Butnariu and Avasilcai, 2015), plastic (Ocampo et al., 2016), food (Ahmad et al., 2019), automotive (Madanchi et al., 2019), and more specific manufacturers such as original equipment (Singh et al., 2014), kitchens (Medini et al., 2015), electrical items (Dočekalová and Kocmanová, 2016), combustion engine (Jiang et al., 2018), and satellite television dishes (Huang and Badurdeen, 2018). With reference to geographical area, contributions address South Africa (Du Plessis and Bam, 2018), Oman (Garbie, 2014), India (Singh et al., 2014), China (Jiang et al., 2018), Philippines (Ocampo et al., 2016), Brazil (Helleno et al., 2017), USA (Huang and Badurdeen, 2018), Sweden (Winroth et al., 2016), and Switzerland (Medini et al., 2015). Only a few contributions focus on a specific size, i.e. SMEs (Feil et al., 2017; Winroth et al., 2016) and Large Enterprises (LEs) (Bhanot et al., 2016; Krajnc and Glavič, 2005). Interestingly, different research methods have been adopted, ranging from case studies (Li et al., 2012; Watanabe et al., 2016) to historical data (Barbosa and Gomes, 2015), as well as simulation (Butnariu and Avasilcai, 2015), secondary data (Madanchi et al., 2019), interviews (Medini et al., 2015), surveys (Kocmanová et al., 2017; Sureeyatanapas et al., 2015), and combined use of surveys and case studies (Dočekalová and Kocmanová, 2016; Long et al., 2016).

The number of sustainability performance indicators proposed presents great variance, ranging from a minimum of 9 (Amrina and Yusof, 2012) to a maximum of 140 (Ruiz-Mercado et al., 2012), with an average of 44. The majority of sustainability performance indicators fall within the environment pillar, followed by economic and social ones, but with different behaviour over the years: by looking at contributions in the period 2001-2010, environmental indicators are half of the sustainability performance indicators proposed; considering contributions from year 2011 onwards, more importance is given to economic aspects.

Some authors tried to prioritize the proposed sustainability performance indicators. The methods used are different, such as a fuzzy interference based model (Singh et al., 2014), stochastic-fuzzy approach (Ahmad et al., 2019) analytical hierarchy process (AHP) (Barbosa and Gomes, 2015; Butnariu and Avasilcai, 2015), gray relational analysis (GRA), and particle swarm optimization (PSO) (Bhanot et al., 2016). Beyond prioritization of sustainability performance indicators, the contributions also tried to create an index for each pillar of TBL (Huang and Badurdeen, 2018), or an index for overall sustainability (Li et al., 2012; Lim and Biswas, 2015; Singh et al., 2007).

General information		*Theoretical development*				*Indicators*					*Empirical application*					
Authors and date	**Journal**	**Sector**	**Geographical Area**	**Size**	**Development based on**	**Eco**	**Env**	**Soc**	**Other**	**Tot**	**Sector**	**Geographical Area**	**Size**	**Method**	**Prioritization**	**Index**
Azapagic and Perdan (2000)	Trans IChemE	-	-	-	-	9	16	10	-	35	-	-	-	-	-	No
Veleva and Ellenbecker (2001)	Journal of Cleaner Production	-	-	-	-	3	8	8	3	22	-	-	-	-	-	No
Krajnc and Glavič (2003)	Clean Technologies and Environmental Policy	Different	-	-	Literature	16	63	10	-	89	-	-	-	-	-	No
Azapagic (2004)	Journal of Cleaner Production	Mining and Mineral	-	-	Literature and interview	24	60	45	-	129	-	-	-	-	-	No
Krajnc and Glavič (2005)	Resources, conservation and Recycling	-	-	-	Literature and case study	6	22	10	-	39	Different manufacturing	-	LEs	Case study	AHP	Yes
Singh et al. (2007)	Ecological Indicators	Steel	-	-	Survey	5	15	14	26	60	Steel	-	-	Case study	AHP	Yes
Amrina and Yusof (2012)	Conference Paper (IEEE)	Automotive	-	-	Literature	4	3	2	-	9	-	-	-	-	-	No
Ruiz-Mercado et al. (2012)	Industrial and Engineering Chemical Research	Chemical	-	-	GREENSCOPE	33	81	-	26	140	-	-	-	-	-	No
Li et al. (2012)	International Journal of Life Cycle Assessment	Manufacturing	-	-	Literature and survey	10	12	10	-	32	-	-	-	Case study	PCA	Yes
Amrina and Vilsi (2014)	Conference Paper (Procedia CIRP)	Cement	-	-	Literature and survey	5	8	6	-	19	-	-	-	-	-	No
Garbie (2014)	International Journal of Production Research	Manufacturing	-	-	Literature	43	17	20	-	80	Aluminium	Oman		Case study	Analytical Technique	Yes (3)
Singh et al. (2014)	Clean Technologies and Environmental Policy	-	-	SMEs	Literature	4	12	5	-	21	OEM	India	-	Case	Fuzzy inference system	Yes
Barbosa and Gomes (2015)	Procedia Computer Science	Chemical	-	-	Existent framework	3	12	6	-	21	-	-	-	Simulation	Goal programming, AHP	-
Butnariu and Avasilcai (2015)	Procedia Economics and Finance	-	-	-	Case study	5	17	4	-	26	Textile	Romania		Simulation	AHP	No
Feil et al. (2015)	Sustainable Production and Consumption	Furniture	-	SMEs	Literature and Delphi methods	7	12	7	-	26	-	-	-	-	-	-
Lim and Biswas (2015)	Sustainability	Palm oil	Malaysia	-	Literature	6	9	7	-	22	Palm oil	Malaysia		Case study	-	Yes
Medini et al. (2015)	International Journal of Production Research	Different	-	-	Literature	9	11	11	3	34	Kitchen manufacturer	Switzerland	-	Interviews	AHP	Yes
Sureeyatanapas et al. (2015)	Production Planning and Control	Sugar	Thai		Literature and case studies	9	7	8	6	30	Sugar	-	-	Surveys	-	No
Tan et al. (2015)	Conference Paper Procedia (CIRP)	-	Singapore	SMEs	Existent framework	7	17	10	6	40	-	-	-	-	-	No
Bhanot et al. (2016)	Clean Technologies and Environmental Policy	Turning process	-	-	Literature	18	28	24	-	70	Manufacturing	-	LEs	Case study	GRA, PSO	
Dočekalová and Kocmanová (2016)	Ecological Indicators	-	-	-	Existent framework	25	17	16	11	69	Electrical equipment	-	LEs	Survey and Case study	KMO statistics, Bartlett's sphericity test	Yes
Long et al. (2016)	Journal of Cleaner Production	Iron and Steel	China	-	Literature and interview	7	4	6	-	17	Iron and Steel	China	LEs	Survey and Case study		Yes
Ocampo et al. (2016)	International Journal of Sustainable Engineering	Manufacturing	-	-	Literature	8	16	9	-	33	Plastic	Philippines	LEs	Case study	FUZAHP	Yes
Watanabe et al. (2016)	Conference Paper (IFAC)	-	-	-	Survey	10	10	10	10	40	-	-	-	Case study	Petri net Tèhcnique	Yes
Winroth et al. (2016)	Journal of Manufacturing Technology Management	-	-	-		18	20	14	-	52	-	Sweden	SMEs	Survey	-	-
Kocmanová et al. (2017)	Engineering Economics	Manufacturing	Czech Republic	-	Literature	5	6	4	4	19	Manufacturing	Czech Republic	-	Interviews and survey	PCA	Yes
Helleno et al. (2017)	Journal of Cleaner Production	Manufacturing	-		Literature	6	9	9	-	24	Different	Brazil	-	Case studies	-	-
Du Plessis and Bam (2018)	Sustainability	-	-	-	Literature and GRI'S guidelines	6	6	6	-	18	Platinum Industry	South Africa	-	Case study	Normalization, weighting, aggregation	Yes (3)
Huang and Badurdeen (2018)	Journal of Cleaner Production	Manufacturing	-	-	Literature	17	47	26	-	90	Satellite television dish	USA	-	Case studies	Normalization and weighting	Yes (3)
Jiang et al. (2018)	Journal of Cleaner Production	-	-	-	Literature and Survey	12	8	8	-	28	Combustion engine	China	-	Case study	PCA	Yes
Ahmad et al. (2019)	Sustainability	Food	Malaysia	-	Literature and Delphi method	14	19	24	-	57	Food	Malaysia	SMEs	Case study	Normalization Stochastic- Fuzzy	Yes (3)
Madanchi et al. (2019)	Book Chapter	-	-	-	Literature	11	6	9	-	26	Automotive	-	-	Secondary data	AHP	Yes

Table 2. Details of the reviewed contributions. For each contribution considered in the literature background analysis information about the following are provided: i) General information, in particular authors and date of publication, and Journal; ii) Theoretical development, in particular the context considered for the theoretical development (sector, geographical area, firm's size) and the base for the development; iii) Indicators, in particular the number of indicators identified with reference to each pillar of the TBL (Eco =Economic; Env =Environment; Soc=Social), the number of other indicators identified, the total number of indicators identified; iv) Empirical application, in particular the context considered for empirical application (sector, geographical area, firm's size), the methodology used for the empirical application, the method used for the prioritization of the indicators and if the contribution try to create an index of sustainability (Yes= yes, a sustainability indicator; Yes (3)= yes, an index for each pillar of sustainability).

2.2. Emerging gaps

The literature background analysis shed light on several challenging and intertwined issues.

1. *Holistic perspective on sustainability*: literature contributions still do not provide a holistic perspective on the sustainability of industrial activities, either in terms of adequate simultaneous focus on the three pillars or their intersections. In particular, the social pillar appears to be less developed than the others, as stressed by Neri et al. (2017). Even though some studies do address TBL, by proposing a large number of sustainability performance indicators, too little has been done to evaluate the mutual benefits among the different pillars (British Safety Council, 2014; Cagno et al., 2018; Nehler and Rasmussen, 2016) and consider interdependencies among them. Despite the attempt by Azapagic (2004) to do this, there was a focus exclusively on the mining and minerals sector, also not accounting for the intersections of all three pillars.
2. *Selection and prioritization of indicators*: given the abundance of developed indicators covering all three pillars of sustainability, selection and prioritization become crucial (Sloan, 2010; Veleva et al., 2003). Considering the existence of multiple industrial decision-makers acknowledgeable for the different pillars of TBL and areas of industrial sustainability (Cagno et al., 2018), with different (if not conflicting) perspectives, priorities and interests (Frini and Benamor, 2017; Gong et al., 2018; Nicolăescu et al., 2015), the proper selection of indicators to be included in a PMS is a huge challenge with only a few examples in the literature, deserving additional efforts by scholars. In fact, Veleva and Ellenbecker (2001) made an interesting distinction between core and supplemental indicators: unfortunately, their considerations were made exclusively on the literature occurrence rate. The methods applied in literature for the selection of indicators, including the AHP, may suffer from possible inconsistency related to subjectivity (Calabrese et al., 2016; Madanchi et al., 2019). In general terms, when the weighting and prioritization of indicators is left only to industrial

decision-makers, the process may suffer from a high degree of subjectivity (Callens and Tyteca, 1999); when, on the other hand, it is left only to external stakeholders and researchers, the effectiveness of the measurement may be reduced, not being sufficiently grounded on the firms' perspectives and needs (Delai and Takahashi, 2011; Salvado et al., 2015). Therefore, it is crucial to develop a PMS that is able to prioritize sustainability. As mentioned, we need a system tailored to specific contexts of application, but at the same time allowing to benchmark.

3. *Number of indicators:* the number of performance indicators a firm should (could) measure is disputable. Given that the use of a single indicator has been proven not to be appropriate (Cayzer et al., 2017), the threshold number should be in line with the human brain's capacity for processing information (Hubbard, 2009), but no alignment on the value of this threshold has yet been reached. Some authors limit to 5-9 indicators (Collins et al., 2016), others to 10-20 (Krajnc and Glavič, 2003), or 30 (Siskos, 2014), or up to 36-60 (Globerson, 1985), while some others suggest there is not a correct number, but too many indicators could distract from following a focused strategy (Epstein and Widener, 2010). Nevertheless, a complete overview of the sustainability performance requires a large number of indicators, which in turn may negatively affect the decision-making process (Medini et al., 2015).
4. *Applicability:* the applicability of the previously developed PMSs in different contexts can be questioned. Most of the PMSs, indeed, are still designed for large enterprises (Singh et al., 2016), and have been proven to be rather difficult to be applied in SMEs (Arena and Azzone, 2010; Singh et al., 2014). SMEs - that often are not even aware of their impact (Feil et al., 2017) – are indeed characterized by a scarce availability of resources – e.g., time, staff, money - (Borga et al., 2009; Stubblefield Loucks et al., 2010; Veleva et al., 2003) to properly and effectively measure performance (Tremblay and Badri, 2018), above all considering the large amount of information required for the assessment through the PMSs (Laurinkevičiute and Stasiškiene, 2011; Winroth et al., 2016), The same reasoning can be

applied to firms that are introducing sustainability into their daily activities, regardless of their size (Johnson, 2015; Witjes et al., 2015). Moreover, the presence and the use of too many different PMSs (Christofi et al., 2012) makes difficult to compare the performance.

To address the aforementioned research gaps, the present paper aims to develop a scalable system, featured with different levels of application, and suitable for firms characterized by different contextual factors and different levels of sustainability (Gap 4). The developed PMS must be easy to manage by firms (Gap 2) and must consider all the different sustainability pillars as well as their intersections, in all its level of application (Gap 1). The selection of indicators to be included in the different levels of the PMS should reduce subjectivity of the choice as much as possible, including different perspectives in the process (Gap 3).

3. A novel framework for measuring sustainability in industrial companies

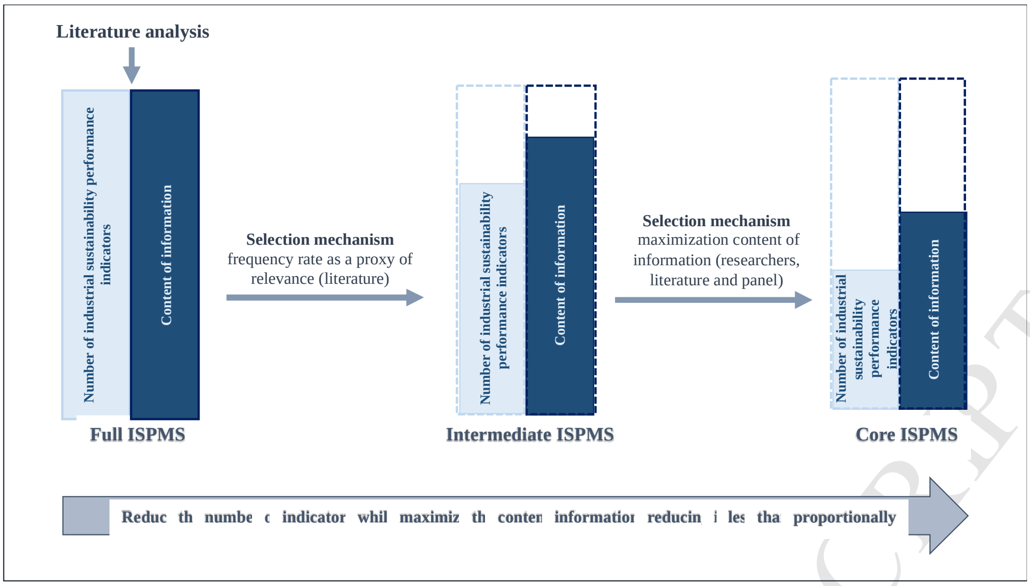
3.1. Rationale for the development of the framework

Stemming from the gaps identified, there is a clear need for a new framework for evaluation of industrial sustainability performance. The framework proposed in the present work includes three different industrial sustainability performance measurement systems (ISPMSs). Consequent from this, it is suitable to properly scale and adapt according to different contexts related to different contextual factors and to different degrees of commitment towards sustainability by a firm – considering different availability of resources, competencies, and awareness toward sustainability. The ISPMSs are organized in three areas related to the TBL's pillars; each area is then divided into categories of performance, and different performance indicators are related to each category. The different ISPMSs are characterized by a decreasing number of indicators, while aiming to maintain adequate coverage of the TBL's pillars and their intersections. The first ISPMS developed, *Full ISPMS*, has been obtained through by re-categorization of the existent literature and contains the largest number of indicators. We believe this ISPMS is important for a thorough assessment of sustainability, requiring a proper evaluation of all the related indicators and returning a picture of the performance measured (and not measured). The second ISPMS (*Intermediate ISPMS)* represents an intermediate step, aiming for a significant reduction in terms of number of indicators, trying to avoid resource-consuming unnecessary overlaps between them. The third ISPMS (*Core ISPMS)* contains the fewest number of indicators, focusing on indicators able to provide information on the intersections of the different pillars, thus consuming as few resources as possible while still guaranteeing good coverage of all sustainability areas.

We created selection mechanisms by reducing the number of indicators to consider and guarantee adequate coverage of all the sustainability aspects when shifting from one ISPMS to another. In the first transition (*Full ISPMS* to *Intermediate ISPMS),* we selected indicators based on their relevance - using the frequency of occurrence in the literature as a proxy of relevance. In the second transition (*Intermediate ISPMS* to *Core ISPMS),* we selected indicators with the aim of reducing the number of indicators considered, based on Globerson (1985), while also maximizing the information about sustainability issues collected by gathering those indicators.

The conceptual model of the development of the framework is reported in Figure 2 in which the whole procedure for the development of the ISPMSs is shown. The comprehensive framework of the three ISPMSs is reported in Table 3.

Figure 2. Conceptual model of the development of the framework. The heights of the columns and the decreasing in the heights are qualitative. The three ISPMSs are characterized by a different number of indicators and different content of information.



3.1.1. Full ISPMS

The Full ISPMS has been created by thorough re-categorization of the indicators provided by the reviewed literature contributions. We divided the 1,416 indicators gathered -obtained as the sum of all the single indicators identified in each contribution - in three lists (one for each TBL pillar), according to the categorization provided in the contributions reviewed.

We merged indicators referring to the same performance but presenting different names, such as e.g. *work accidents* (Butnariu and Avasilcai, 2015) and *accident rate* (Amrina and Vilsi, 2014), and incorporated indicators that could be easily derived one from the other through a third factor, e.g.. *total energy cost* (Krajnc and Glavič, 2003) with *energy consumption* (Li et al., 2012) by means of energy prices.

We also acknowledged that the previous literature assigned some indicators to two different pillars simultaneously, underlining how forcing a clear distinction among them could be inappropriate: the interconnections among them should constantly be highlighted, pinpointing the necessity to not only look at the three pillars of TBL as if they were independent, but rather focus on their intersections. In case the reviewed contributions assigned the same indicator to different pillars, we assigned it to the pillar with highest occurrences in literature, but taking note that it is not possible to overlook their impacts on other pillars, as further shown for the *Intermediate* and *Core ISPMSs* -

described respectively in Sections 3.1.2 and 3.1.3. The following examples should clarify our rationale:

- the *total energy cost* was incorporated in *energy consumption:* the indicator was considered by 78% of the contributions in the environmental pillar, e.g. (Winroth et al., 2016), and by the remaining ones in the economic pillar, e.g. (Watanabe et al., 2016), and we thus assigned it to the environmental pillar;
- *training of employees*: being considered by about the 85% and 15% of the contributions as belonging to social and economic pillar, respectively, we assigned it to the social pillar;
- some indicators related to suppliers were diverse and considered in each pillar by only a few contributions: given the relevant impact of suppliers on the economic performance of the firm, we decided to assign them to that pillar, acknowledging, however, the impact on the others (Klibi et al., 2010).

Furthermore, we decided to focus on indicators addressing operative performance, rather than on a generic performance area. For instance, we preferred detailed indicators on solid (Krajnc and Glavič, 2003) or liquid (Huang and Badurdeen, 2018) waste, or rather disposed (Ruiz-Mercado et al., 2012) or recycled waste (Garbie, 2014), over generic *waste management* proposed by Bhanot et al. (2016). Similarly, we discharged indicators beyond the direct action of the firm (Howard et al., 2018), related to external policies and procedures, e.g., policies and agreements (Li et al., 2012). Moreover, we preferred indicators related to economic performance on daily operations rather than, for example, financial performance, such as the debt asset ratio (Long et al., 2016).

We further categorized indicators within each list, and created the main categories of performance taking inspiration from the extant literature (Saeed and Kersten, 2017; Stindt, 2017), assigning each indicator to a single performance. In conclusion, the *Full ISPMS* is composed of 104 indicators (Table 3, third column) offering highly detailed information over sustainability issues for a company.

3.1.2. Intermediate ISPMS

A firm with a medium availability of resources and/or maturity toward sustainability could find the *Full ISPMS* too detailed and cumbersome. For this reason, we developed the *Intermediate ISPMS* (Table 3, fourth column), which aims to represent a valuable solution with a reduced number of indicators (76), based on their relevance in the literature (as a proxy of the relevance for practitioners), following the approach of Veleva and Ellenbecker (2001). To do so, for each indicator of the *Full ISPMS*, we calculated the occurrences in the literature, discharging those considered by less than the 5% of the contributions reviewed - thus eliminating *Near misses* as an indicator (Bhanot et al., 2016). The analysis of frequency also led to the aggregation of previously identified indicators. For example, when developing the *Full ISPMS*, we specified the difference between *Environmental training* and *Safety training*: nevertheless, the literature does not seem to give the same attention to their distinction, focusing particularly on the latter one, as also observed for practitioners by Cagno et al. (2018).

3.1.3. Core ISPMS

Following literature suggestions (Collins et al., 2016; Globerson, 1985; Krajnc and Glavič, 2003; Siskos, 2014), we developed the *Core ISPMS*, which is aimed to be suitable for firms with limited availability of resources and/or sustainability maturity. The *Core ISPMS* has been designed to have a further reduced number of indicators, but at the same time keeping thorough coverage of all the pillars of TBL. We based our analysis on the content of information owned by each indicator of the *Intermediate ISPMS* with respect to every other indicator and to the different categories of performance, in order to fully address and exploit the interdependences among the different TBL pillars (Cagno et al., 2018). The analysis was structured in two parallel steps. In both the two steps the procedure followed was the same. For each indicator of the *Intermediate ISPMS*, the level of information the indicators were able to provide with reference to every other indicator and category of performance - always within the *Intermediate ISPMS*- was quantified. The level of information was assessed using an even 6 point Likert-like scale, as suggested by Vagias (2006), to force the respondent to take a position beyond neutral one - with 1: no information, up to 6: total coverage of information. Having already performed a selection of the indicators based on their frequency in literature, we aimed at understanding the information content of each indicator, in order to reduce the number of indicators for the *Core ISPMS* by discharging those that, presenting the same literature frequency rate, offer a lower content of sustainability information.

In the first step, the analysis was conducted by the authors of the manuscripts. Each researcher conducted the evaluation autonomously and then the different perspectives were discussed, arriving at a shared vision of the content of information of each indicators of the *Intermediate ISPMS*, also relying on literature when possible (i.e. available) and making sure that indicators fall under one or more pillars - such as for the *safety training* indicator, providing information both on the economic and the social pillars. In the second step, a panel of eight experts was interviewed. The panel was created to guarantee that different backgrounds and profiles relevant for the purposes of the study were included, following Fernández-Viñé et al. (2013). The number of experts involved was considered adequate, based on Knol et al. (2010) and Sleep et al. (2017). The selected experts had the following profiles:

- Two senior academic scientists, one devoted to sustainability, the other to performance measurement;
- Four industrial experts from different industrial associations: two from manufacturing company's associations (one with previous experience as a plant manager); one expert from an SME association (previously technical director of a manufacturing firm); one expert from a manufacturing and service company association (previously chief executive officer in a firm);
- Four industry consultants with specific expertise on safety, environment, accounting, and operations, respectively.

This procedure aims at avoidance of selecting indicators based exclusively on the subjective evaluation of only industrial decision-makers (Callens and Tyteca, 1999) or only external stakeholders (Delai and Takahashi, 2011). The involvement of experts with different roles and background in the development of the ISPMSs was thus considered as an interesting opportunity, since industry and academia may have a different perspective on the relevance of indicators (Li et al., 2012). Moreover, we deemed that the inclusion of academia and practitioners helped to avoid bias deriving from different personal experiences, background, values, and attitudes (Bettis and Prahalad, 1995; Cooremans, 2012; Prahalad and Bettis, 1986; Thollander and Palm, 2012).

The evaluations of the panel were aligned with those of the researchers, allowing us to have a solid base for the development of the *Core PMS*. To further clarify the rationale of our work, some examples are provided below:

- *OHS performance*: in this category, *Accidents*, *Injuries*, and *Fatalities* resulted to be those with the highest level of information regarding *OHS performance*, *Work satisfaction*, *Throughput*, *EHS (Environment-Health-Safety) fines*, and *Safety investments*. Since the expert panel also related these indicators to evaluation of safety within the working environment (i.e. *Noise, Dust, Toxic substances)*, we eliminated the latter, focusing on the evaluation of indicators related to *Accidents*, *Injuries* and *Fatalities*, as supported by the previous literature (Anker et al., 2003; ILO, 2013). Moreover, *Accidents*, *Injuries*, and *Fatalities*, together with *EHS fines*, were reported to be able to provide information on possible *OHS Administration Citations*, making this indicator unnecessary.
- *Air emissions*: in this category, there is CO_2, other *GHGs*, NO_x, SO_x, and *ODS*; a detailed measurement of all these emissions could require a large amount of resources (in terms of time and money). All the experts agreed that CO_2 alone can provide a very high level of information on *Air emissions performance*, thus making it as a proxy for all the other air emissions, except *Toxic emissions*. This consideration was well aligned with the previous literature (EPA, 2018), especially considering our focus on manufacturing activities (Burtraw and Toman, 2000).

This further selection and aggregation process led to the identification of 44 indicators for the *Core ISPMS* (Table 3, fifth column).

Area of Performance	**Category of Performance**	**Full ISPMS Performance indicators**	**Intermediate ISPMS Performance indicators**	**Core ISPMS Performance indicators**
<u>*Economic*</u>	*Investments*	R&D investment Pollution prevention and control investment Environment investment Energy efficiency investment Safety investment Community investment Ethics/ philanthropy investment	R&D investment Environment investment Safety investment Ethics/ philanthropy investment	R&D investment Environment investment Safety investment
	Costs and Incomes	Operating cost Overhead cost Packaging cost Production cost Set up cost Inventory cost Labor cost Unit cost Maintenance cost Taxes EHS fines Sales Market share Revenues Profit Turnover	Operating cost Production cost Inventory cost Labor cost Unit cost Maintenance cost EHS fines Sales Market share Revenues Profit	Production cost Inventory cost Labor cost Unit cost Maintenance cost EHS fines Sales Profit
	Production	Throughput New products Lead time Scrap Quality Mix flexibility Volume Flexibility DFx Green product IT level	Throughput New products Lead time Scrap Quality DFx	Throughput New products Lead time Quality
	Suppliers	Number of suppliers Local suppliers Certified suppliers	Number of suppliers Local suppliers Certified suppliers	Number of suppliers Local suppliers
<u>*Social*</u>	*Community*	Community complaints Community projects Local employment Involvement of local community	Community complaints Community projects Local employment Involvement of local community	Community complaints Community projects
	Customers	Customer satisfaction Personalized products Services offered	Customer satisfaction Personalized products Services offered	Customer satisfaction Personalized products
	Employees	Number of employees Wage level Work satisfaction Involvement of employees Gender discrimination Ethnic group discrimination Safety training Environmental training	Number of employees Wage level Work satisfaction Involvement of employees Discrimination Training	Number of employees Work satisfaction Training
	OHS	Accidents Injuries Fatalities Near misses PPE Absenteeism Noise	Accidents Injuries Fatalities PPE Absenteeism Noise Dust	Accidents Injuries Fatalities PPE Absenteeism

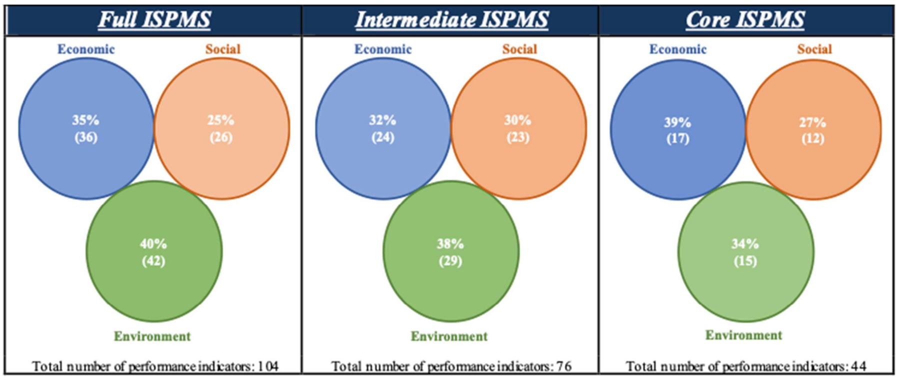
		Dust Toxic substances OHS Administration Citations Safety expenditure	Toxic substances OHS Administration Citations Safety expenditure	
Environment	*Water*	Total water use Fresh water use Recycled water use Quality of water	Total water use Fresh water use Recycled water use Quality of water	Total water use Recycled water use
	Material	Total material use Recycled material use Hazardous material use Toxic material use	Total material use Recycled material use Hazardous material use	Total material use Recycled material use Hazardous material use
	Energy	Total energy use for production Renewable energy use for production Fuel use for production Gas use for production Coal use for production Total energy use not for production Renewable energy use not for production Fuel use not for production Gas use not for production Coal use not for production	Total energy use Renewable energy use Fuel use Gas use Coal use	Total energy use Renewable energy use Fossil fuel use
	Air emissions	CO2 Other GHG NOX SO2 ODS Metal emissions Other emissions Toxic emissions	CO2 Other GHG NOX SO2 ODS Toxic emissions	CO2 Toxic emissions
	Waste	Hazardous solid waste Non-hazardous solid waste Hazardous liquid waste Non-hazardous liquid waste COD BOD Waste water Chemical waste Waste disposed Waste recycled Energy recovery Material recovery	Hazardous solid waste Non-hazardous solid waste Hazardous liquid waste Non-hazardous liquid waste Waste water Waste disposed Waste recycled	Hazardous solid waste Non-hazardous solid waste Hazardous liquid waste Non-hazardous liquid waste Waste recycled
	Environmental management	Environmental accidents Environmental fines Environmental certification Cost of compliance	Environmental accidents Environmental fines Environmental certification Cost of compliance	

Table 3. The framework of Industrial Sustainability Performance Measurement Systems.

3.2. Analysis of TBL pillars coverage

When developing the framework, we aimed at guaranteeing a complete and adequate coverage of information for the different ISMPSs over sustainability issues. For this reason, we performed a first analysis of the coverage on the three pillars of sustainability by the indicators proposed and relying on the categorization of indicators proposed in each ISPMS (reported in Table 3): the coverage of the single pillar for each ISPMS was evaluated as the number of indicators referred to the specific pillar on the total number of indicators considered by the ISMPS. The results are graphically displayed in Figure 3.

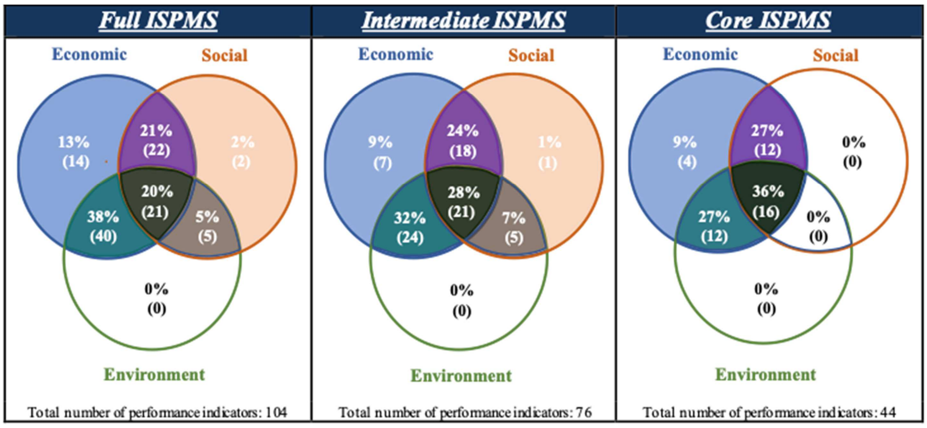
Figure 3. Coverage of the three TBL pillars. For each ISPMS, the three pillars of sustainability are reported. For each pillar, the percentage of indicators considered in it by the different ISPMS is reported, as well as the total number (in brackets).



Moving from the *Full ISPMS* to the *Core PMS*, few differences can be spotted among the coverage of the different pillars. In the *Full ISPMS*, we can note that the environmental aspect seems to have received more attention in the literature (40% of coverage) with respect to the social area (25% of coverage). By looking at the *Intermediate ISPMS*, there is a more balanced distribution among the three different pillars, while in the *Core PMS* economic indicators appear to be prevalent (39% of coverage).

However, by simultaneously analyzing the coverage of TBL pillars and related intersections, interesting results emerged. To conduct this analysis, we characterized the indicators considered in each ISPMS according to their coverage of TBL pillars and related intersections, obtaining seven categories as follows (Trianni et al., 2017): Economic; Social; Environment; Environment-Economic; Socio-Economic; Socio-Environment; Sustainability. The classification was based on the pillars about which a single indicator can provide information, regardless of the initial classification of the ISPMSs. In this way, we aimed at double-checking our considerations during the initial development of the model, considering that forcing a clear distinction among the different pillars of sustainability would be inappropriate. As the results (reported in Figure 4) show, the interconnections among pillars should constantly be highlighted, and proper attention should be paid to their intersections.

Figure 4. Coverage of the TBL pillars and their intersections. For each ISPMS, the three pillars of sustainability and their intersections are reported. For each pillar and for each intersection, the percentage of indicators in the different ISPMS able to provide information is reported, as well as the total number (in brackets).



Our analysis allows drawing two important considerations when looking at the intersections among sustainability pillars. First, the share of indicators providing information on more than one pillar increases when shifting from the *Full ISPMS* to the *Core PMS*. This is particularly evident when looking at the joint intersection between the three pillars, shifting from 20% (*Full ISPMS*) to 28% and 36% (respectively *Intermediate* and *Core PMS*). Secondly, by shifting from the *Full ISPMS* to the *Intermediate ISPMS*, and then to the Core *PMS*, the number of indicators providing information exclusively on economic pillar diminishes, and the same holds true for indicators exclusively focused on social aspects, which are longer found in the *Core PMS*. In addition, none of the ISPMSs considers indicators that provide information purely on environmental aspects. Those findings seem to corroborate the discussion over the need for a company to simultaneously encompass economic issues when dealing with other ones, as previously underlined for the environmental dimension by Winroth et al. (2016).

4. Research method

4.1. Selection of companies

The empirical investigation is based on explanatory case studies (Voss et al., 2002; Yin, 2009) with semi-structured interviews, questionnaires, and secondary material, as for the purposes pointed out by previous research of confirming (or disconfirming) an already conceptualized theory (Lynham, 2002) in a specific context of interest (Denzin and Lincoln, 2011; Ketokivi and Choi, 2014), anticipated empirical findings by a priori formulation of propositions (Ketokivi and Choi, 2014).

Through the case studies we have tested the theoretical framework with respect to: (i) represent, i.e. to properly consider all the performance indicators relate to sustainability in industrial firms, according to the different firm characteristics; and (ii) ease of use, i.e. the effort required for the application of the proposed ISPMSs, in terms of resources and possible difficulties according to different characteristics of a firm.

In defining the aim of the study, it is necessary to identify the case to be studied and whom to interview within the case study (Meredith, 1998). The unit of analysis of the present study is the single firm (Dooley, 2002). Based on the distinction made by Handfield and Melnyk (1998) and Voss et al. (2002), we have relied on multiple case studies, but each has been treated as a single case: the conclusions of each study will be considered in the light of multiple case studies, but examined on their own (Dooley, 2002). As for interviewees for each case, we selected people involved in the decision-making process and knowledgeable of all the aspects related to sustainability.

Case studies were carried out in five manufacturing firms located in the Lombardy region in Italy (Table 3), given the importance of manufacturing to Europe as well as at the national level (European Commission, 2018; Eurostat, 2018; Manyika et al., 2012), and the ample room for improvement of performance in all areas of industrial sustainability (EASHW, 2009; European Commission, 2017; Meng et al., 2018). The sample used to test the framework is heterogeneous by sector (different manufacturing sectors) and size. The selected set of cases was deemed adequate for validation (Eisenhardt, 1989; Pagell and Wu, 2009), also being interested in the theoretical generalizability of results (Eisenhardt, 1989), rather than its statistical one (Hillebrand et al., 2001; Stuart et al., 2002). Our choice of interviewees for the cases (reported in Figure 4) further guarantees that we collected appropriate data with the aim of literal replication (Shakir, 2002; Voss et al., 2002).

Firm	Sector	Employees [#]	Turnover [M€/y]	Size	Interviewees
1	General purpose machinery	35	12	Small	Technical Director
2	Furniture	248	53	Large	Plant Manager
3	Weaving of Textile	13	5	Small	Production Manager
4	Tubes, pipes, hollow profiles	185	42	Medium	Operations Manager
5	Metal products	95	18	Medium	Technical Director

Table 4. Detail of the firms considered for the test of the framework.

4.2. Data collection

The data collection and organization occurred over three stages. Firstly, the sample was selected starting from the database "AIDA" (https://aida.bvdinfo.com/) containing relevant industrial information for Italian firms using EU classification of industrial activities (European Commission, 2008). Firms were contacted by e-mail or telephone and, for those that accepted to participate to the research, secondary data (firm websites, reports) was collected, regarding the firm's structure and production processes. Where available, information regarding projects, initiatives and similar activities toward increased industrial sustainability and sustainability reports were also collected.

Secondly, the investigation within the firm was divided into two parts. The investigation was carried out using semi-structured interviews and lasted, on average, a couple of hours (one hour for each part). We used a questionnaire as a guide that allowed for standardization of the sequence in which the questions were asked and minimization of the impact of contextual effects (Patton, 1990).

We also asked several additional open-ended questions, supplemented by questions emerging during the interview, as well as free comments (Dicicco-Bloom and Crabtree, 2006; Remler and Van Ryzin, 2014).

In the first part of the investigation, interviewees were asked to describe the firm in terms of: i) product and processes, and possible constraints in terms of resources (i.e. money, staff, time) that may influence daily activities; ii) previous performance assessments with regards to sustainability issues; and iii) activities implemented toward increased sustainability, also detailing the decision-making process. We also performed a tour of the plant, so to directly observe the status quo, as well as to identify possible problems related to sustainability areas. This preliminary assessment, also through a triangulation of primary and secondary data, allowed us to understand resource availability, competences, and awareness and commitment towards sustainability issues and to propose one of the three developed ISPMSs accordingly.

In the second part of the investigation, we selected a specific ISPMS for each firm, based on the preliminary assessment. We showed the interviewees the specific ISPMS selected, describing the different performance indicators included. We asked the interviewees to discuss the capability of the ISPMS to adequately represent all the relevant performance indicators related to sustainability in industrial firms and whether the indicators were sufficiently distinct (and with the same level of detail). Furthermore, we have asked to discuss effort given to understand and apply the ISPMS in their specific context.

Thirdly, we transcribed and coded the interviews, and further corroborated with secondary data and other findings emerged during the interviews, such as field notes taken by investigators, in order to identify possible misalignments. In case of misalignments, a second meeting (either face-to-face or via phone) was used for further clarification. Interviews were transcribed as soon as possible after the investigation, in order to maximize recall, facilitating follow up and filling gaps in the data (Voss et al., 2002).

The detail of the case study protocol and of the multiple sources of evidence used during the conduction of the case studies is reported in Table 5.

Source 1. Semi-structured interview	
General questions	• Firm introduction (turnover, employees, sector, certifications) • Interviewee/s introduction (role in the company, main interests, experience)
Products and processes	• What are the products produced? • What are the production process activities performed? • What are the main constraints regarding resources that influence your daily activity?
Sustainability	*Referring to the current situation:* • How are sustainability-related performance measured? • What actions have you so far implemented towards increased sustainability? • What sustainability-related certifications do you hold?
Evaluation of the ISPMS	*Referring to the proposed ISPMS, after the description of it by the interviewers:* • Do you think the proposed system properly represent all the relevant performance indicators related to sustainability in industrial firms? o If yes, what are the features that you appreciate the most? o If no, why? • Do you think it would be easy to apply the proposed system in your specific context? o If yes, what are the features that you appreciate the most? o If no, what are the main criticalities?
Further comments on the ISPMS	*Referring to the proposed ISPMS, if interviewees available:* • Are there further clarifications you would like to receive about the proposed ISPMS? If yes, what? • Are there any other comments and opinions you would like to share about the proposed ISMPS? If yes, what?
Source 2. Direct observations	
Plant tour	Direct observation of the plant during working shifts, with the possibility to ask further questions about the process and the approach towards sustainability to the interviewees.
Source 3. Field notes	
Field notes – semi-structured interview	We collected field notes during the conduction of the semi-structured interview. The collected field notes are both descriptive and reflective.
Field notes – plant tour	We collected field notes during the plant tour. The collected field noted are both descriptive and reflective.
Source 4. Secondary materials	
Company's website	General firm information (e.g. strategy, mission, history); certifications (e.g. ISO 9001, ISO 140001, OHSAS 18001); sustainability report and initiatives.
News and press	Up-to-date news related to the company or its attitude towards increased sustainability (e.g. projects, initiatives)
National database	Economic reports and balance sheets

Table 5. Detail of the case study protocol and of the multiple sources of evidence used.

4.3. Data analysis

Data were analyzed through a content analysis approach. The coding was executed manually by the investigators. Transcriptions were independently coded, and the results were discussed to reach a common understanding of them, and additional insights from secondary data were added to enrich the findings and overcome possible missing information. For analysis of the data, we applied reflective analysis (Dooley, 2002) and adopted an emergent coding (Stemler, 2001), formulating definitions and categories basing on the theoretical background and the research questions (Kohlbacher, 2006; Kolbe and Burnett, 1991; Mayring, 2000).

For the first part of the investigation we applied the Structural code (Saldaña, 2009), generally recognized as being particularly suitable for semi-structured data-gathering protocols. For the second part of the investigation we applied the Evaluation code (Saldaña, 2009), given the need to understand judgments about the merit and worth of the proposed framework. We then applied a second coding to the part of the investigation using an Axial code to reassemble data that were "split" in the first coding, also based on Voss et al. (2002). The findings from the content analysis are reported in the next Section. In Appendices 1 and 2, a summary of the analysis developed is reported for the first part and second parts of the investigation, respectively.

Concerning methodological rigor (Yin, 2009), construct validity was obtained with triangulation of multiple sources of evidence (Baškarada, 2014; Beverland and Lindgreen, 2010) and with the development of a chain of evidence (Benbasat et al., 1987), assessed through the creation of an electronic folder containing all the data collected for each case (Rowley, 2002). Multiple sources of evidence were used to increase the internal validity of the analysis (Voss et al., 2002; Yin, 2009) and obtain rigorous results (Hays, 2004). The specification of the population, replication logic, and use of multiple case studies assessed the extent to which the results can be generalized (Beverland and Lindgreen, 2010; Meredith, 1998). Furthermore, multiple case studies, helped to increase the reliability, together with the use of the case study protocol, (Beverland and Lindgreen, 2010; Voss et al., 2002), and contrasted possible researcher bias (Barratt et al., 2011), also involving more than one interviewer in each investigation (Eisenhardt, 1989; Voss et al., 2002).

5. Main findings of the empirical investigation

5.1. Selection of the ISPMS

Firstly, we analyzed the selection of the proper ISPMS for each firm, based on the firm's profile, sustainability, and sustainability performance measurement. Based on the analysis of the evidence gathered and discussed in the introductory part of the investigation (Appendix 1), we proposed the *Full ISPMS* to Firm 2, the *Intermediate ISPMS* to Firm 4 and 5 and the *Core ISPMS* to Firm 1 and Firm 3:

- Firm 1: Regarding sustainability, the Technical Director said "*to make the firm more efficient is the first step toward sustainability*" but "*I would not say we make true sustainability*". The interviewee of Firm 1 stated they "*mainly based measurement on experience and sensitivity […] without a quantitative approach*" or a "*focus on economic aspects*". Besides traditional economic performance, they focus exclusively on those related to regulation compliance, without any further effort, due to the staff's lack of time. The Technical Director also highlighted that "*a small firm like us has the need for a tool that can be easily used*" and that "*the most important thing is the handling of the set of indicators*" adding that "*firms like ours would be able to implement only an easy-to-manage instrument, otherwise, we would focus only on being compliant with regulations*".
- Firm 2: according to the Plant Manager of firm 2 "*sustainability is a thousand different things, like the environmental issue, the economic issue and the social issue: when a plant tackles all these problems it is sustainable*". The assessment and evaluation of sustainability performance is carried out in detail, as stated by the interviewee: "*once certificated, a firm must concern with every single detail [...] we cannot leave anything up to change and everything must follow a plan*". Noteworthy, for Firm 2 "*one must be compliant with regulation, no matter the effect on performance and market*", adding however that "*the regulation and the performance are not in contrast, sometimes they just don't speak the*

same language". The interviewee also underlined that a PMS should always be simple: "*when things are complex to be used, people get tired of them: less is definitely more*" otherwise it *"could result being inapplicable"*.

- Firm 3: for the Production Manager of Firm 3 "*sustainability is an environmental issue*". So far, the firm does not *"have a system to measure sustainability performance, but it could be interesting to have it"*. According to the interviewee, Firm 3 *"focus on costs"* even if they are *"working for improving our efficiency"*. Firm 3 showed in the overall a rather reactive attitude towards sustainability issues, like the installation of smart metering ("*Our technician suggested us to install smart metering"*), installation of a photovoltaic grid (*"Our cover of the roof was in asbestos cement, so we had to substitute it"* and *"the constructer suggested that we install a photovoltaic grid"*), or for the reduction of noise ("*We were reported and we resorted to soundproofing"*).
- Firm 4: according to Operations Manager of Firm 4 *"sustainability is the possibility for the firm to keep on existing"*. Firm 4 does not have in place an integrated sustainability PMS. They have good control of production performance, thanks to "*different metering allowing us to monitor different areas"*. Regarding the other areas of sustainability, they *"have a person in charge of the supervision of the health, safety and environment areas"* and as a general weak point they think they "*miss an analysis by the operators, who are the ones at the production site every day"*. The Firm has started to identify the relationship between safety and productivity, and as such are now implementing measures to build upon this: *"being compliant with safety regulation may seem an obstacle at the beginning, but in the long term it is an advantage"*. The Operations Manager stated he would like to have a system that allows the firm to have a general view, knowing *"how my firm is going"* and then deepening *"the detail to understand where and how to take actions"*.
    - Firm 5: according to the Technical Director of Firm 5 *"sustainability is the capability of a firm to manage the resources so that external institutions don't compromise the life of the*

firm”. The firm has a very structured PMS that is “*capable of evaluating the productivity of each machine and each worker”*, also considering the flow of wastes. An additional, but not structured, focus is given to *“the relationships among the workers*” the “*exchange of information”* in the firm in the overall context. The other aspects of sustainability in processes are managed so that the *“external authorities don’t bother me”*. The Technical Director added that *“the handling of a system is the most important characteristic”*.

5.2. Evaluation of the ISPMSs

5.2.1. Evaluation of the Full ISMPS

The Plant Manager of Firm 2 appreciated the *“indicators are not production indicators, but definitely indicators covering all the aspects related to production*”, considering all the pillars of sustainability and reflecting his perspective on sustainability. He also considered the ISPMS to be characterized by a high level of generalizability, thus being applicable in different sectors. Indeed, he deemed the model to “*contain all the relevant indicators for our sector”*, adding that *“the system provides a general perspective […] selecting the right indicators, it can be applied in different sectors”*. He provided an example, explaining that indicators like *Throughput* or *Inventory cost* were not deemed particularly relevant for the specific firm (since they are in response to customers’ orders).

In this regard, we found empirical confirmation that those types of indicators are more suitable for make-to-stock production rather than engineering-to-order ones, as previous research has highlighted (Shao and Dong, 2012), but we acknowledge that such indicators could gather relevant information about sustainability issues (Amrina and Vilsi, 2014; Medini et al., 2015).

The Plant Manager of Firm 2 also stated the Full ISPMS can provide *“a complete overview in less than a day”*, reckoning it would allow the firm to collect relevant information in a very short time, without any particular difficulties.

5.2.2. Evaluation of the Intermediate ISPMS

The Operations Manager of Firm 4 deemed the system to be *"really broad and comprehensive"*, spanning *"over all sustainability"*. The same view was shared by the Technical Director of Firm 5, who declared the system to be *"complete and well structured"*. In particular, he underlined that it was "*very well balanced*" and appreciated that *"many indicators in the environment and social area can also tell you a lot about economic performance*". Such a result represents an important finding, since it shows the need to develop an ISPMS that is able to gather indicators related to multiple pillars of sustainability in operations, as previous research has noted (Howard et al., 2018; Neri et al., 2017). Moreover, the Operations Manager of Firm 4 stated that the model can "*clarify all the aspects related to sustainability also to the sloppiest industrial decision-makers*", while the Technical Director of Firm 5 appreciated the fact that the ISPMS is *"a comprehensive measurement system, able to give you a snapshot of your situation"*.

The Technical Director of Firm 5 deemed the proposed ISPMS to be manageable during its use. Notably, he did not underline any difficulty, and declared "*I think I could easily use it*". The Operations Manager of Firm 4, however, believed that the effort required for the evaluation of the ISPMS was rather substantial. This was related to two aspects: on the one hand, because in a firm such as Firm 4 *"such an analysis is not conducted. Much is still left to sensitivity*"; on the other hand, "*everything is perceived as a burden if it is not automated"*. Nevertheless, he thought the system was *"very useful to make firms conscious of where to act"*. He stated that the system "*would be very useful in a firm like ours […] it could be an inspiration for us",* since "*using such an analysis, I can see things better and in advance"*.

5.2.3. Evaluation of the Core ISMPS

Both the Technical Director of Firm 1 and the Production Manager of Firm 3 deemed the Core ISMPS to be complete. The former thought the model was appropriate to "*understand the impact of your activities by also comparing it with other sectors"*, adding "*I had already thought about some of these indicators […] but the structure is much more interesting"*. The system allowed Production

Manager of Firm 3 to identify new indicators: *"I have never thought of measuring these indicators, other than the economic ones"*.

Regarding the applicability of the *Core ISPMS*, Technical Director of Firm 1 stated that *"in half a day you can have a complete view of your performance"*. The system was deemed as helpful in "*understanding with a more scientific approach what it is happening"* by the interviewee of Firm 1, and able to make decision-makers *"aware of important aspects that in the daily activity you would neglect or not properly analyse"* by the interviewee of Firm 3. In particular, the Production Manager of Firm 3 underlined the systems "*would give me more autonomy, allowing me to better understand the situation and clarify some points regarding the validity of specific interventions"*. This consideration stresses one of the common barriers faced by companies in adopting measures for improved sustainability (Orji, 2019). While in Firm 3 no particular difficulties were spotted with reference to the use of the ISPMS, the Technical Director of Firm 1 stated that "*the only obstacle I see in our firm is the indolence that may lead to a partial application"*. We deemed this difficulty to not be related to the ISPSM, as then better explained by the interviewee*: "this work is very helpful for SMEs, because it requires short time to be applied […] The application of a more complex tool would be much more complicated […] it seems like a tool that can be used"*.

5.2.4. Discussion on the results from the evaluation

The capability to represent was confirmed for all the three ISPMSs by all the interviewees, who evaluated the different ISPMSs which were deemed complete and detailed. Furthermore, the capability to be general ISPMSs and easily adaptable to the specific context was particularly appreciated. In this regard, the ISPMSs were able to adapt to different contexts and allow a holistic assessment of all industrial sustainability related performance, as suggested by Garengo et al. (2005). Additionally, our interviewees also considered the distribution of indicators to be balanced among the different pillars of sustainability, as well as process oriented and useful for industrial decision-makers towards the identification of possible improvements, as also suggested by Garengo et al. (2005).

Regarding the applicability of the ISPMSs, the results were also positive. In particular, thinking about the aim of reducing the effort for firms with few resources or low sustainability awareness, the *Intermediate ISPMS* and *Core ISPMS* allowed interviewees to have an ISPMS that is aligned with their resources, while the *Full ISPMS* was more appropriate for firms with more resources, awareness, and commitment regarding sustainability issues.

In this regard, during the interviews, we had the glimpse that our *Intermediate* and *Core ISMPSs* were perceived as a tool that is able to support decision-makers in the transition towards the measurement of sustainability issues, which is an important research gap that has been pointed out (Cayzer et al., 2017; Waas et al., 2014). We, therefore, believe the adoption of the ISPSMs could represent a valuable driver to guide companies in more easily and effectively understanding where to undertake further actions for improved sustainability. Nevertheless, we also share the view of Aiginger (2014) who point out the need for campaigns - promoted by national and/or regional policy-makers - aimed at increasing awareness towards sustainability issues as well as increased technical knowledge and skills through metering (Darton, 2015), as preliminary steps for undertaking a structured ISPMS.

This capability of quickly pointing out critical areas of sustainability, as well as strengths by companies, seems to be an important feature that was particularly appreciated by decision-makers, who are usually involved with lengthy, burdensome, and invasive campaigns of investigation (Schaltegger and Wagner, 2006).

6. Conclusive remarks

6.1. Contribution of the study

The developed ISPMSs we developed can provide a contribution to the discussion by offering instruments to stimulate the adoption of a holistic perspective over industrial sustainability. In fact, the novel framework was conceived considering interdependencies among the different pillars and characterizing each indicator in terms of information provided with regards to sustainability performance. The number of indicators proposed in each ISPMS, as the preliminary discussion with firms, seems to be reasonable and in line with the thresholds identified by several authors in the previous literature (Globerson, 1985). In particular, the different levels of application provided with the framework - the increased number of indicators from the *Core ISPMS* to the *Intermediate ISPMS* (up to the *Full ISPMS*) - allow to start by considering only few indicators, and then move to a larger number, as suggested by (Eckerson, 2009), offering adequate support to firms wishing to move towards a more detailed assessment of sustainability performance, according to increased awareness towards the issue. Our preliminary test of the framework allowed us to investigate the capability of representing the three ISPMSs and their ease of use. As the interviewees confirmed, the proposed ISPMSs are deemed appropriate for use in the specific contexts where they have been proposed: considering our choice of a heterogeneous sample of manufacturing firms in terms of sector, firm size, and awareness towards sustainability issues, our exploratory investigation seems to show that the developed approaches can well address previous concerns regarding applicability of ISPMSs in different contexts related to contextual factors (Arena and Azzone, 2010; Singh et al. 2014) or sustainability awareness (Johnson, 2015; Witjes et al. 2015). The interviewees also stated that the provided ISPMS offers valuable support, and perceived as different from previously developed approaches, which are either too specific on some pillars of sustainability (Feng and Joung, 2009; Graedel and Allenby, 2002; Henri and Journeault, 2009) or too broad and distant from the daily industrial operations of a firm (Sala et al., 2015). The growing pressures experienced by firm to address environmental and social aspects of sustainability from both external and internal stakeholders (Lozano and Huisingh, 2011; Stacchezzini et al., 2016) and the need for a framework with very detailed information over sustainability issues (Azapagic, 2004; Long et al., 2016) represents a critical aspect to which we have tried to offer a contribution.

The capability of the framework to encompass previous approaches for sustainability measurement, its specificity (in terms of resources measured) and, at the same time, its scalability according to different contexts, could represent a valuable advance to the academic discussion over ISPMS. Moreover, such a comprehensive framework could represent the theoretical backbone for empirical investigation and assessment of industrial sustainability issues in different contexts.

As revealed by the preliminary discussion, industrial decision-makers could benefit from the proposed framework by offering a comprehensive approach for assessment industrial sustainability performance, also allowing better understanding what action could be taken to improve performance. Indeed, the holistic approach to sustainability measurement allows a comprehensive and contemporary view of all the different aspects of performance.

We believe the developed framework could also support policy-makers by offering a comprehensive set of indicators for measurement of sustainability in industrial operations, in support of more effective regulatory sustainability policy frameworks, also considering the need for a more specific design of incentives to encourage firms toward improved environmental and social sustainability (Aiginger, 2014), in light of UN sustainable development goals (United Nations, 2015).

6.2. Limitations and further research

While the study provides a preliminary positive empirical test for the initial set of propositions, we would like to acknowledge its limitations.

Even if we aimed at being completely objective in the development of the framework, some bias may be present given the methodologies used. Further research is necessary to evaluate the generalizability in other contexts of application – for example, developed versus developing countries. Moreover, the sample size for application and test is adequate for the purposes of theoretical generalizability (Stuart et al., 2002), but further research would be needed for statistical significance. Future work could further explore different contexts in terms of firm sector, geographic location, and size. Valuable analyses of the critical areas where firms should pay more attention could be offered by increased sample size, which would also support of policy-makers for future actions.

Additionally, due to limitations in sampling of firms, we could not interview those in the same leadership position in all the firms, and did not interview multiple individuals within the same firm. Further research could investigate the perspectives of multiple industrial decision-makers with responsibilities over multiple sustainability aspects. This would allow understanding possible mismatches and conflicting perspectives, which may represent a major barrier to the implementation of measures for improved sustainability (Cagno et al., 2018). Furthermore, we could not assess the effects of assessment of sustainability performance - either in terms of resources used or outcomes – which are required for shifting from one ISPMS to another. To do this, a horizon far beyond the present research would be needed. Indeed, several years may be required for structuring, implementing, and monitoring a given ISPMS as well as gathering adequate information and performing its evaluation before shifting to a different ISPMS. In particular, it would be interesting to evaluate the effect of different organizational strategies that might be implemented towards increased sustainability (Mintzberg and Waters, 1985) and the effect of the application of reward-driven systems, which are proven to foster performance and innovation (Fellnhofer, 2018; Gharaei et al., 2015). Considering the potential trade-offs between cost and completeness and precision of the system, and environmental and economic performance (Arena et al., 2015), the application from an industrial sustainability perspective appears to be quite challenging, considering the additional variables to be considered (Frini and Benamor, 2017; Gong et al., 2018; Nicolăescu et al., 2015).

In the present work, we have only discussed the ISPMS considering single companies, regardless of their involvement in a specific supply chain. In this regard, we believe further insights and comparisons could stem from a simultaneous application of the proposed ISPMS to several companies operating in the same supply chain. Going beyond the firm's boundaries (Salvado et al., 2015; Seuring and Müller, 2008) and considering that competitiveness is increasingly at a supply chain level rather than at a single firm (Massaroni et al., 2015; Shibin et al., 2017), further understanding of sustainability issues and the impact of an industrial sustainability measure could come from the development of a framework to evaluate sustainability performance in an entire supply chain. The simultaneous application of such two frameworks, in the context of a group of firms operating in the same supply chain, could offer additional knowledge to decision-makers and policy-makers about critical sustainability issues in industry.

References

Ahmad, S., Wong, K.Y., Zaman, B., 2019. A comprehensive and integrated stochastic-fuzzy method for sustainability assessment in the Malaysian food manufacturing industry. Sustain. 11. https://doi.org/10.3390/su11040948

Aiginger, K., 2014. Industrial policy for a sustainable growth path, WWW for Europe - Policy Paper Series. https://doi.org/10.1093/acprof:oso/9780198706205.003.0019

Amrina, E., Vilsi, A.L., 2014. Interpretive structural model of key performance indicators for sustainable manufacturing evaluation in cement industry. IEEE Int. Conf. Ind. Eng. Eng. Manag. 2015–Janua, 1111–1115. https://doi.org/10.1109/IEEM.2014.7058811

Amrina, E., Yusof, S.M., 2012. Interpretive structural model of key performance indicators for sustainable manufacturing evaluation in automotive companies. IEEE Int. Conf. Ind. Eng. Eng. Manag. 656–660. https://doi.org/10.1109/IEEM.2012.6837821

Anker, R., Chernyshev, I., Egger, P., Mehran, F., Ritter, J.A., 2003. Measuring decent work with statistical indicators. Internatinal Labor Rev. 142. https://doi.org/www.ers.usda.gov/Publications/ agoutlook/jan2002/ ao288.pdf

Apaydin, M., Bayraktar, E., Hossary, M., 2018. Achieving economic and social sustainability through hyperconnectivity: a cross- country comparison. Benchmarking An Int. J. 25.

https://doi.org/https://doi.org/10.1108/BIJ-07-2017-0205

Arena, M., Azzone, G., 2012. A process-based operational framework for sustainability reporting in SMEs. J. Small Bus. Enterp. Dev. 19, 669–686. https://doi.org/10.1108/14626001211277460

Arena, M., Azzone, G., 2010. Process based approach to select key sustainability indicators for steel companies. Ironmak. Steelmak. 37, 437–444. https://doi.org/10.1179/030192310X12690127076433

Arena, M., Conte, A., Melacini, M., 2015. Linking environmental accounting to reward systems: the case of the Environmental Profit and Loss Account. J. Clean. Prod. 108, 625–636. https://doi.org/10.1016/j.jclepro.2015.07.068

Azapagic, A., 2004. Developing a framework for sustainable development indicators for the mining and minerals industry. J. Clean. Prod. 12, 639–662. https://doi.org/10.1016/S0959-6526(03)00075-1

Azapagic, A., Perdan, S., 2000. Indicators of sustainable development for industry: a general framework. Trans IChemE 78, 243–261. https://doi.org/10.1205/095758200530763

Barbosa, L.C., Gomes, L.F.A.M., 2015. Assessment of efficiency and sustainability in a chemical industry using goal programming and AHP. Procedia Comput. Sci. 55, 165–174. https://doi.org/10.1016/j.procs.2015.07.027

Barratt, M., Choi, T.Y., Li, M., 2011. Qualitative case studies in operations management: trends, research outcomes, and future research implications. J. Oper. Manag. 29, 329–342. https://doi.org/10.1016/j.jom.2010.06.002

Baškarada, S., 2014. Qualitative case study guidelines. Qual. Rep. 19, 1–25. https://doi.org/10.7748/nr2013.05.20.5.28.e327

Benbasat, I., Goldstein, D.K., Mead, M., 1987. The case research strategy in studies of information systems, MIS Quarterly. https://doi.org/10.2307/248684

Bettis, R.A., Prahalad, C.K., 1995. The dominant logic: retrospective and extenstion. Strateg. Manag. J. 16, 5–14. https://doi.org/10.1002/smj.4250160104

Beverland, M., Lindgreen, A., 2010. What makes a good case study? A positivist review of qualitative case research published in Industrial Marketing Management, 1971-2006. Ind. Mark. Manag. 39, 56–63. https://doi.org/10.1016/j.indmarman.2008.09.005

Bhanot, N., Rao, P.V., Deshmukh, S.G., 2017. An integrated approach for analysing the enablers and barriers of sustainable manufacturing. J. Clean. Prod. 142, 4412–4439. https://doi.org/10.1016/j.jclepro.2016.11.123

Bhanot, N., Rao, P.V., Deshmukh, S.G., 2016. An integrated sustainability assessment framework: a case of turning process. Clean Technol. Environ. Policy 18, 1475–1513. https://doi.org/10.1007/s10098-016-1130-2

Bilge, P., Badurdeen, F., Seliger, G., Jawahir, I.S., 2014. Model-based approach for assessing value creation to enhance sustainability in manufacturing. Procedia CIRP 17, 106–111. https://doi.org/10.1016/j.procir.2014.02.031

Borga, F., Citterio, A., Noci, G., Pizzurno, E., 2009. Sustainability report in small enterprises: case studies in Italian furniture companies. Bus. Strateg. Environ. 18, 162–176. https://doi.org/10.1002/bse.561

British Safety Council, 2014. The business benefits of health and safety. A literature review. https://www.britsafe.org/publications/safety-management-magazine/safety-management-magazine/2014/the-business-benefits-of-health-and-safety-a-literature-review/

Burtraw, D., Toman, M., 2000. “Ancillary Benefits” of Greenhouse Gas Mitigation Policies, Climate Change Issues. www.oecd.org/environment/cc/2054700.pdf

Butnariu, A., Avasilcai, S., 2015. The assessment of the companies’ sustainable development performance. Procedia Econ. Financ. 23, 1233–1238. https://doi.org/10.1016/S2212-5671(15)00422-0

Cagno, E., Neri, A., Trianni, A., 2018. Broadening to sustainability the perspective of industrial decision-makers on the energy efficiency measures adoption: some empirical evidence. Energy Effic. 11, 1193–1210. https://doi.org/10.1007/s12053-018-9621-0

Calabrese, A., Costa, R., Levialdi, N., Menichini, T., 2016. A fuzzy analytic hierarchy process method to support materiality assessment in sustainability reporting. J. Clean. Prod. 121, 248–264. https://doi.org/10.1016/j.jclepro.2015.12.005

Callens, I., Tyteca, D., 1999. Towards indicators of sustainable development for firms. Ecol. Econ. 28, 41–53. https://doi.org/10.1016/S0921-8009(98)00035-4

Cayzer, S., Griffiths, P., Beghetto, V., 2017. Design of indicators for measuring product performance in the circular economy. Int. J. Sustain. Eng. 10, 289–298. https://doi.org/10.1080/19397038.2017.1333543

Christofi, A., Christofi, P., Sisaye, S., 2012. Corporate sustainability: historical development and reporting practices. Manag. Res. Rev. 35, 157–172. https://doi.org/10.1108/01409171211195170

Clarke-sather, A.R., Hutchins, M.J., Zhang, Q., Gershenson, J.K., Sutherland, J.W., 2011. Development of social, environmental, and economic indicators for a small/medium enterprise. Int. J. Account. Inf. Manag. 19, 247–266. https://doi.org/https://doi.org/10.1108/18347641111169250

Collins, A.J., Hester, P., Ezell, B., Horst, J., 2016. An improvement selection methodology for key performance indicators. Environ. Syst. Decis. 36, 196–208. https://doi.org/10.1007/s10669-016-9591-8

Cooremans, C., 2012. Energy-efficiency investments and energy management: an interpretative perspective, in: Proceedings of the International Conference on Energy Efficiency in Commercial Buildings. https://doi.org/10.13140/2.1.4787.5529

Darton, R.C., 2015. Setting a policy for sustainability: the importance of measurement, in: Assessing and Measuring Environmental Impact and Sustainability. Butterworth-Heinemann, pp. 479–496. https://doi.org/10.1016/B978-0-12-799968-5.00014-2

Delai, I., Takahashi, S., 2011. Sustainability measurement system: a reference model proposal. Soc. Responsib. J. 7, 438–471. https://doi.org/https://doi.org/10.1108/17471111111154563

Denzin, N.K., Lincoln, Y.S., 2011. Introduction the discipline and practice of qualitative research, in: Denzin, N.K., Lincoln, Y.S. (Eds.), The Sage Handbook of Qualitative Research. SAGE, Thousand Oaks, CA, pp. 1–19.

Dicicco-Bloom, B., Crabtree, B.F., 2006. The qualitative research interview. Med. Educ. 40, 314–21. https://doi.org/10.1111/j.1365-2929.2006.02418.x

Dočekalová, M.P., Kocmanová, A., 2016. Composite indicator for measuring corporate sustainability. Ecol. Indic. 61, 612–623. https://doi.org/10.1016/j.ecolind.2015.10.012

Dooley, L.M., 2002. Case study research and theory building. Adv. Dev. Hum. Resour. 4, 335–354. https://doi.org/10.1177/1523422302043004

Du Plessis, J., Bam, W., 2018. Comparing the sustainable development potential of industries: a role for sustainability disclosures? Sustain. 10. https://doi.org/10.3390/su10030878

EASHW, 2009. Occupational safety and health and economic performance in small and medium-sized enterprises: a review. https://osha.europa.eu/en/tools-and-publications/publications/reports/TE-80-09-640-EN-N_occupational_safety_health_economic_performance_small_medium_sized_enterprises_review/view

Eckerson, W.W., 2009. Performance management strategies: How to Create and Deploy Effective Metrics, TDWI Best Practices Report. https://tdwi.org/research/2009/01/bpr-1q-performance-management-strategies.aspx

Eisenhardt, K.M.E., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550. https://doi.org/10.5465/AMR.1989.4308385

Engida, T.G., Rao, X., Berentsen, P.B.M., Oude Lansink, A.G.J.M., 2018. Measuring corporate sustainability performance– the case of European food and beverage companies. J. Clean. Prod. 195, 734–743. https://doi.org/10.1016/j.jclepro.2018.05.095

EPA, 2018. Overview of Greenhouse Gases [WWW Document]. URL https://www.epa.gov/ghgemissions/overview-greenhouse-gases (accessed 04.17.18).

Epstein, M.J., Widener, S.K., 2010. Identification and use of sustainability performance measures in decision-making. J. Corp. Citizsh. 40, 43–73. https://doi.org/10.9774/GLEAF.4700.2010.wi.00006

European Commission, 2018. GROWTH Internal market, Industry, Entrepreneurship and SMEs [WWW Document]. URL https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/lombardy (accessed 11.28.18).

European Commission, 2017. 2017 SBA Fact Sheet - Italy. https://ec.europa.eu/growth/smes/business-friendly-environment/performance-review_en

European Commission, 2008. NACE Rev. 2- Statistical classification of economic activities in the European Community. https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/KS-RA-07-015

Eurostat, 2018. Statistics on small and medium-sized enterprises [WWW Document]. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Statistics_on_small_and_medium-sized_enterprises (accessed 9.13.18).

Feil, A.A., De Quevedo, D.M., Schreiber, D., 2017. An analysis of the sustainability index of micro- and small-sized furniture industries. Clean Technol. Environ. Policy 19, 1883–1896. https://doi.org/10.1007/s10098-017-1372-7

Feil, A.A., De Quevedo, D.M., Schreiber, D., 2015. Selection and identification of the indicators for quickly measuring sustainability in micro and small furniture industries. Sustain. Prod. Consum. 3, 34–44. https://doi.org/10.1016/j.spc.2015.08.006

Fellnhofer, K., 2018. Drivers of innovation success in sustainable businesses. J. Clean. Prod. 167, 1534–1545. https://doi.org/10.1016/j.jclepro.2017.08.197

Feng, S.C., Joung, C.B., 2009. An overview of a proposed measurement infrastructure for sustainable manufacturing, in: Proceedings of the 7th Global Conference on Sustainable Manufacturing. pp. 1–6.

Fernández-Viñé, M.B., Gómez-Navarro, T., Capuz-Rizo, S.F., 2013. Assessment of the public administration tools for the improvement of the eco-efficiency of Small and Medium Sized Enterprises. J. Clean. Prod. 47, 265–273. https://doi.org/10.1016/j.jclepro.2012.08.026

Ferrari, A.M., Volpi, L., Pini, M., Cristina, S., García-Muiña, F.E., Settembre-Blundo, D., 2019. Building a sustainability benchmarking framework of ceramic tiles based on Life Cycle Sustainability Assessment (LCSA). Resources 8, 1–30. https://doi.org/https://doi.org/10.3390/resources8010011

Frini, A., Benamor, S., 2017. Making decisions in a sustainable development context: a state-of-the-art survey and proposal of a multi-period single synthesizing criterion approach. Comput. Econ. 1–45. https://doi.org/10.1007/s10614-017-9677-5

Garbie, I.H., 2014. An analytical technique to model and assess sustainable development index in manufacturing enterprises. Int. J. Prod. Res. 52, 4876–4915. https://doi.org/10.1080/00207543.2014.893066

Garengo, P., Biazzo, S., Bititci, U.S., 2005. Performance measurement systems in SMEs: a review for a research agenda. Int. J. Manag. Rev. 7, 25–47. https://doi.org/10.1111/j.1468-2370.2005.00105.x

Ghadimi, P., Azadnia, A.H., Mohd Yusof, N., Mat Saman, M.Z., 2012. A weighted fuzzy approach for product sustainability assessment: a case study in automotive industry. J. Clean. Prod. 33, 10–21. https://doi.org/10.1016/j.jclepro.2012.05.010

Gharaei, A., Naderi, B., Mohammadi, M., 2015. Optimization of rewards in single machine scheduling in the rewards-driven systems. Manag. Sci. Lett. 5, 629–638. https://doi.org/10.5267/j.msl.2015.4.002

Gibson, R.B., 2006. Beyond the pillars: sustainability assessment as a framework for effective integration of social, economic and ecological considerations in significant decision-making. J. Environ. Assess. Policy Manag. 8, 259–280. https://doi.org/10.1142/S1464333206002517

Gimenez, C., Sierra, V., Rodon, J., 2012. Sustainable operations: their impact on the triple bottom line. Int. J. Prod. Econ. 140, 149–159. https://doi.org/10.1016/j.ijpe.2012.01.035

Globerson, S., 1985. Issues in developing a performance criteria system for an organization. Int. J. Prod. Res. 23, 639–646. https://doi.org/10.1080/00207548508904734

Gong, M., Simpson, A., Koh, L., Tan, K.H., 2018. Inside out: the interrelationships of sustainable performance metrics and its effect on business decision making: theory and practice. Resour. Conserv. Recycl. 128, 155–166. https://doi.org/10.1016/j.resconrec.2016.11.001

Graedel, T.E., Allenby, B.R., 2002. Hierarchical metrics for sustainability. Environ. Qual. Manag. 12, 21–30. https://doi.org/10.1002/tqem.10060

Haffar, M., Searcy, C., 2017. Classification of trade-offs encountered in the practice of corporate sustainability. J. Bus. Ethics 140, 1–28. https://doi.org/10.1007/s10551-015-2678-1

Hailey, J., Sorgenfrei, M., 2003. Measuring success: issues in performance measurement. Int. NGO Train. Res. Cent. INTRAC 1–30.

Hallstedt, S.I., Bertoni, M., Isaksson, O., 2015. Assessing sustainability and value of manufacturing processes: a case in the aerospace industry. J. Clean. Prod. 108, 169–182. https://doi.org/10.1016/j.jclepro.2015.06.017

Handfield, R.B., Melnyk, S.A., 1998. The scientific theory-building process: a primer using the case of TQM. J. Oper. Manag. 16, 321–339. https://doi.org/https://doi.org/10.1016/S0272-6963(98)00017-5

Harik, R., El Hachem, W., Medini, K., Bernard, A., 2015. Towards a holistic sustainability index for measuring sustainability of manufacturing companies. Int. J. Prod. Res. 53, 4117–4139. https://doi.org/10.1080/00207543.2014.993773

Hays, P.A., 2004. Case study research, in: Foundations for Research: Methods of Inquiry in Education and the Social Sciences. pp. 217–234.

Heckathorn, D.D., Cameron, C.J., 2017. Network sampling: from snowball and multiplicity to respondent-driven sampling. Annu. Rev. Sociol. 43, 101–119. https://doi.org/10.1146/annurev-soc-060116

Helleno, A.L., De Moraes, A.J.I., Simon, A.T., Helleno, A.L., 2017. Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: application case studies in Brazilian industry. J. Clean. Prod. 153, 405–416. https://doi.org/10.1016/j.jclepro.2016.12.072

Henri, J.F., Journeault, M., 2009. Eco-efficiency and organizational practices: an exploratory study of manufacturing firms. Environ. Plan. C Gov. Policy 27, 894–921. https://doi.org/10.1068/c0827

Hillebrand, B., Kok, R.A.W., Biemans, W.G., 2001. Theory-testing using case studies. Ind. Mark. Manag. 30, 651–657. https://doi.org/10.1016/S0019-8501(00)00115-2

Howard, M., Hopkinson, P., Miemczyk, J., 2018. The regenerative supply chain: a framework for developing circular economy indicators. Int. J. Prod. Res. 0, 1–19. https://doi.org/10.1080/00207543.2018.1524166

Huang, A., Badurdeen, F., 2018. Metrics-based approach to evaluate sustainable manufacturing performance at the production line and plant levels. J. Clean. Prod. 192, 462–476. https://doi.org/10.1016/j.jclepro.2018.04.234

Hubbard, G., 2009. Measuring organizational performance: beyond the triple bottom line. Bus. Strateg. Environ. 18, 177–191. https://doi.org/10.1002/Bse.564

ILO, 2013. Decent work indicators : guidelines for producers and users of statistical and legal framework indicators. https://www.ilo.org/stat/Publications/WCMS_223121/lang--en/index.htm

Jiang, Q., Liu, Z., Liu, W., Li, T., Cong, W., Zhang, H., Shi, J., 2018. A principal component analysis based three-dimensional sustainability assessment model to evaluate corporate sustainable performance. J. Clean. Prod. 187, 625–637. https://doi.org/10.1016/j.jclepro.2018.03.255

Johnson, M.P., 2015. Sustainability management and small and medium-sized enterprises: managers' awareness and implementation of innovative tools. Corp. Soc. Responsib. Environ. Manag. 22, 271–285. https://doi.org/10.1002/csr.1343

Johnson, M.P., Schaltegger, S., 2016. Two decades of sustainability management tools for SMEs: how far have we come? J. Small Bus. Manag. 54, 481–505. https://doi.org/10.1111/jsbm.12154

Ketokivi, M., Choi, T., 2014. Renaissance of case research as a scientific method. J. Oper. Manag. 32, 232–240. https://doi.org/10.1016/j.jom.2014.03.004

Klibi, W., Martel, A., Guitouni, A., 2010. The design of robust value-creating supply chain networks: a critical review. Eur. J. Oper. Res. 203, 283–293. https://doi.org/10.1016/j.ejor.2009.06.011

Knol, A.B., Slottje, P., Van Der Sluijs, J.P., Lebret, E., 2010. The use of expert elicitation in environmental health impact assessment: a seven step procedure. Environ. Heal. A Glob. Access Sci. Source 9, 1–16. https://doi.org/10.1186/1476-069X-9-19

Kocmanová, A., Dočekalová, M.P., Simanavičienė, Ž., 2017. Corporate sustainability measurement and assessment of Czech manufacturing companies using a composite indicator. Eng. Econ. 28, 88–100. https://doi.org/10.5755/j01.ee.28.1.15323

Kohlbacher, F., 2006. The Use of Qualitative Content Analysis in Case Study Research. Forum Qual. Soc. Res. 7.

Kolbe, R.H., Burnett, M.S., 1991. Content-analysis research: an examination of applications with directives for improving research reliability and objectivity. J. Consum. Res. 18, 243. https://doi.org/10.1086/209256

Krajnc, D., Glavič, P., 2005. A model for integrated assessment of sustainable development. Resour. Conserv. Recycl. 43, 189–208. https://doi.org/10.1016/j.resconrec.2004.06.002

Krajnc, D., Glavič, P., 2003. Indicators of sustainable production. Clean Technol. Environ. Policy 5, 279–288. https://doi.org/10.1007/s10098-003-0221-z

Laurinkevičiute, A., Stasiškiene, Ž., 2011. SMS for decision making of SMEs. Clean Technol. Environ. Policy 13, 797–807. https://doi.org/10.1007/s10098-011-0349-1

Lee, J.Y., Lee, Y.T., 2014. A framework for a research inventory of sustainability assessment in manufacturing. J. Clean. Prod. 79, 207–218. https://doi.org/10.1016/j.jclepro.2014.05.004

Li, T., Zhang, H., Yuan, C., Liu, Z., Fan, C., 2012. A PCA-based method for construction of composite sustainability indicators. Int. J. Life Cycle Assess. 17, 593–603. https://doi.org/10.1007/s11367-012-0394-y

Lim, C.I., Biswas, W., 2015. An evaluation of holistic sustainability assessment framework for palm oil production in Malaysia. Sustain. 7, 16561–16587. https://doi.org/10.3390/su71215833

Long, Y., Pan, J., Farooq, S., Boer, H., 2016. A sustainability assessment system for Chinese iron and steel firms. J. Clean. Prod. 125, 133–144. https://doi.org/10.1016/j.jclepro.2016.03.030

Lozano, R., Huisingh, D., 2011. Inter-linking issues and dimensions in sustainability reporting. J. Clean. Prod. 19, 99–107. https://doi.org/10.1016/j.jclepro.2010.01.004

Lynham, S.A., 2002. The general method of theory-building research in applied disciplines. Adv. Dev. Hum. Resour. 4, 221–241. https://doi.org/10.1177/1523422302043002

Madanchi, N., Thiede, S., Sohdi, M., Herrmann, C., 2019. Development of a sustainability assessment tool for manufacturing companies, in: Thiede, S., Herrmann, C. (Eds.), Eco-Factories of the Future. Springer International Publishing. https://doi.org/10.1007/978-3-319-93730-4

Manyika, J., Sinclair, J., Dobbs, R., Strube, G., Rassey, L., Mischke, J., Remes, J., Roxburgh, C., George, K., O'Halloran, D., Ramaswamy, S., 2012. Manufacturing the future: the next era of global growth and innovation, McKinsey Global Institute. https://doi.org/https://www.mckinsey.com/business-functions/operations/our-insights/the-future-of-manufacturing

Martín-Peña, M.L., Díaz-Garrido, E., Sánchez-López, J.M., 2014. Analysis of benefits and difficulties associated with firms' Environmental Management Systems: the case of the Spanish automotive industry. J. Clean. Prod. 70, 220–230. https://doi.org/10.1016/j.jclepro.2014.01.085

Massaroni, E., Cozzolino, A., Wankowicz, E., 2015. Sustainability in supply chain management - a literature review. Sinergie 33, 331–355. https://doi.org/10.7433/1115

Mayring, P., 2000. Qualitative content analysis. Forum Qual. Soc. Res. 1. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Medini, K., Da Cunha, C., Bernard, A., 2015. Tailoring performance evaluation to specific industrial contexts - application to sustainable mass customisation enterprises. Int. J. Prod. Res. 53, 2439–2456. https://doi.org/10.1080/00207543.2014.974844

Meng, B., Liu, Y., Andrew, R., Zhou, M., Hubacek, K., Xue, J., Peters, G., Gao, Y., 2018. More than half of China's CO2 emissions are from micro, small and medium-sized enterprises. Appl. Energy 230, 712–725. https://doi.org/10.1016/J.APENERGY.2018.08.107

Meredith, J., 1998. Building operations management theory through case and field research. J. Oper. Manag. 16, 441–454. https://doi.org/10.1108/01443579310048182

Mintzberg, H., Waters, J.A., 1985. Of strategies, deliberate and emergent. Strateg. Manag. J. 6, 257–272. https://doi.org/10.1002/smj.4250060306

Morioka, S.N., Bolis, I., Evans, S., Carvalho, M.M., 2018. Transforming sustainability challenges into competitive advantage: multiple case studies kaleidoscope converging into sustainable business models. J. Clean. Prod. 167, 723–738. https://doi.org/10.1016/j.jclepro.2017.08.118

Murillo-Luna, J.L., Garcés-Ayerbe, C., Rivera-Torres, P., 2011. Barriers to the adoption of proactive environmental strategies. J. Clean. Prod. 19, 1417–1425. https://doi.org/10.1016/j.jclepro.2011.05.005

Neely, A., Gregory, M., Platts, K., 1995. Performance measurement system design: a Literature Review and Research Agenda. Int. J. Oper. Manag. Prod. Manag. 15, 80–116. https://doi.org/https://doi.org/10.1108/01443570010343708

Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M., Kennerley, M., 2000. Performance measurement system design; developing and testing a process-based approach. Int. Jounal Oper. Prod. Manag. 20, 1119–1145. https://doi.org/10.1108/JFM-03-2013-0017

Nehler, T., Rasmussen, J., 2016. How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry. J. Clean. Prod. 113, 472–482. https://doi.org/10.1016/j.jclepro.2015.11.070

Neri, A., Cagno, E., Di Sebastiano, G., Trianni, A., 2018. Industrial sustainability: modelling drivers and mechanisms with barriers. J. Clean. Prod. 194, 452–472. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.05.140

Neri, A., Melià, P., Cagno, E., Trianni, A., 2017. A review of industrial sustainability indicators for Life Cycle Sustainability Assessment, in: Atti Del XI Convegno Dell'Associazione Rete Italiana LCA Resource Efficiency e Sustainable Development Goals: Il Ruolo Del Life Cycle Thinking. ENEA, pp. 414–422.

Nicolăescu, E., Alpopi, C., Zaharia, C., 2015. Measuring corporate sustainability performance. Sustainability 7, 851–865. https://doi.org/10.3390/su7010851

Ocampo, L.A., Clark, E.E., Promentilla, M.A.B., 2016. Computing sustainable manufacturing index with fuzzy analytic hierarchy process. Int. J. Sustain. Eng. 9, 305–314. https://doi.org/10.1080/19397038.2016.1144828

Orji, I.J., 2019. Examining barriers to organizational change for sustainability and drivers of sustainable performance in the metal manufacturing industry. Resour. Conserv. Recycl. 140, 102–114. https://doi.org/10.1016/j.resconrec.2018.08.005

Pagell, M., Gobeli, D., 2009. How plant managers' experiences and attitudes toward sustainability relate to operational performance. Prod. Oper. Manag. 18, 278–299. https://doi.org/10.1111/j.1937-5956.2009.01050.x

Pagell, M., Wu, Z.H., 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. J. Supply Chain Manag. 45, 37–56. https://doi.org/10.1111/j.1745-493X.2009.03162.x

Paju, M., Heilala, J., Hentula, M., Heikkilä, A., Johansson, B., Leong, S., Lyons, K., 2010. Framework and indicators for a sustainable manufacturing mapping methodology, in: Proceedings - Winter Simulation Conference. pp. 3411–3422.

https://doi.org/10.1109/WSC.2010.5679031

Patton, M.Q., 1990. Qualitative evaluation and research methods, 2nd ed. SAGE, Newbury Park, California.

Prahalad, C.K., Bettis, R.A., 1986. The dominant logic: a new linkage between diversity and performance. Strateg. Manag. J. 7, 485–501. https://doi.org/10.1002/smj.4250070602

Remler, D.K., Van Ryzin, G.G., 2014. Research methods in practice: strategies for description and causation, 2nd ed. SAGE.

Rowley, J., 2002. Using case studies in research. Manag. Res. News 25, 16–27. https://doi.org/10.1108/01409170210782990

Ruiz-Mercado, G.J., Smith, R.L., Gonzalez, M.A., 2012. Sustainability indicators for chemical processes: I. Taxonomy. Ind. Eng. Chem. Res. 51, 2309–2328. https://doi.org/10.1021/ie102116e

Saeed, M.A., Kersten, W., 2017. Supply chain sustainability performance indicators - a content analysis based on published standards and guidelines. Logist. Res. 2017, 12. https://doi.org/10.23773/2017

Sala, S., Ciuffo, B., Nijkamp, P., 2015. A systemic framework for sustainability assessment. Ecol. Econ. 119, 314–325. https://doi.org/10.1016/j.ecolecon.2015.09.015

Saldaña, J., 2009. The coding manual for qualitative researchers. SAGE.

Salvado, M.F., Azevedo, S.G., Matias, J.C.O., Ferreira, L.M., 2015. Proposal of a sustainability index for the automotive industry. Sustain. 7, 2113–2144. https://doi.org/10.3390/su7022113

Salzmann, O., Ionescu-Somers, A.M., Steger, U., 2005. The business case for corporate sustainability: literature review and research options. Eur. Manag. J. 23, 27–36. https://doi.org/10.1016/j.emj.2004.12.007

Saunders, M., Lewis, P., Thornhill, A., 2009. Research methods for business students. Pearson.

Schaltegger, S., Wagner, M., 2006. Integrative management of sustainability performance, measurement and reporting. Int. J. Account. Audit. Perform. Eval. 3.

https://doi.org/10.1504/IJAAPE.2006.010098

Scordato, L., Klitkou, A., Tartiu, V.E., Coenen, L., 2018. Policy mixes for the sustainability transition of the pulp and paper industry in Sweden. J. Clean. Prod. 183, 1216–1227. https://doi.org/10.1016/j.jclepro.2018.02.212

Seuring, S., Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16, 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020

Shakir, M., 2002. The selection of case studies: strategies and their applications to IS implementation cases studies. Res. Lett. Inf. Math. Sci. 3, 191–198.

Shao, X.F., Dong, M., 2012. Comparison of order-fulfilment performance in MTO and MTS systems with an inventory cost budget constraint. Int. J. Prod. Res. 50, 1917–1931. https://doi.org/10.1080/00207543.2011.562562

Shibin, K.T., Gunasekaran, A., Dubey, R., 2017. Explaining sustainable supply chain performance using a total interpretive structural modeling approach. Sustain. Prod. Consum. 12, 104–118. https://doi.org/10.1016/j.spc.2017.06.003

Siebert, A., O’Keeffe, S., Bezama, A., Zeug, W., Thrän, D., 2018. How not to compare apples and oranges: generate context-specific performance reference points for a social life cycle assessment model. J. Clean. Prod. 198, 587–600. https://doi.org/10.1016/j.jclepro.2018.06.298

Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2012. An overview of sustainability assessment methodologies. Ecol. Indic. 15, 281–299. https://doi.org/10.1016/j.ecolind.2011.01.007

Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2007. Development of composite sustainability performance index for steel industry. Ecol. Indic. 7, 565–588. https://doi.org/10.1016/j.ecolind.2006.06.004

Singh, S., Olugu, E.U., Fallahpour, A., 2014. Fuzzy-based sustainable manufacturing assessment model for SMEs. Clean Technol. Environ. Policy 16, 847–860.

https://doi.org/10.1007/s10098-013-0676-5

Singh, S., Olugu, E.U., Musa, S.N., 2016. Development of sustainable manufacturing performance evaluation expert system for small and medium enterprises. Procedia CIRP 40, 609–614. https://doi.org/10.1016/j.procir.2016.01.142

Siskos, D. V., 2014. What is the optimal number of KPIs per professional? Operational and tactical dashboards: differences and similarities.

Skolarus, T.A., Lehmann, T., Tabak, R.G., Harris, J., Lecy, J., Sales, A.E., 2017. Assessing citation networks for dissemination and implementation research frameworks. Implement. Sci. 12, 1–17. https://doi.org/10.1186/s13012-017-0628-2

Sleep, S., McKellar, J.M., Bergerson, J.A., MacLean, H.L., 2017. Expert assessments of emerging oil sands technologies. J. Clean. Prod. 144, 90–99. https://doi.org/10.1016/j.jclepro.2016.12.107

Sloan, T.W., 2010. Measuring the sustainability of global supply chains: current practices and future directions. J. Glob. Bus. Manag. 6, 92–107.

Stacchezzini, R., Melloni, G., Lai, A., 2016. Sustainability management and reporting: the role of integrated reporting for communicating corporate sustainability management. J. Clean. Prod. 136, 102–110. https://doi.org/10.1016/j.jclepro.2016.01.109

Staniškis, J.K., Arbačiauskas, V., 2009. Sustainability performance indicators for industrial enterprise management. Environ. Res. Eng. Manag. 2, 42–50. https://doi.org/10.5755/j01.erem.48.2.13

Stemler, S., 2001. An overview of content analysis. Pract. Assessment, Res. Eval. 7.

Stindt, D., 2017. A generic planning approach for sustainable supply chain management - How to integrate concepts and methods to address the issues of sustainability? J. Clean. Prod. 153, 146–163. https://doi.org/10.1016/j.jclepro.2017.03.126

Stoycheva, S., Marchese, D., Paul, C., Padoan, S., Juhmani, A. salam, Linkov, I., 2018. Multi-criteria decision analysis framework for sustainable manufacturing in automotive industry. J.

Clean. Prod. 187, 257–272. https://doi.org/10.1016/j.jclepro.2018.03.133

Stuart, I., Mccutcheon, D., Handfield, R., Mclachlin, R., Samson, D., 2002. Effective case research in operations management: a process perspective. J. Oper. Manag. 20, 419–433. https://doi.org/10.1016/S0272-6963(02)00022-0

Stubblefield Loucks, E., Martens, M.L., Cho, C.H., 2010. Engaging small- and medium-sized businesses in sustainability. Sustain. Accounting, Manag. Policy J. 1, 178–200. https://doi.org/10.1108/20408021011089239

Sureeyatanapas, P., Yang, J.B., Bamford, D., 2015. The sweet spot in sustainability: a framework for corporate assessment in sugar manufacturing. Prod. Plan. Control 26, 1128–1144. https://doi.org/10.1080/09537287.2015.1015470

Tan, H.X., Yeo, Z., Ng, R., Tjandra, T.B., Song, B., 2015. A sustainability indicator framework for Singapore small and medium-sized manufacturing enterprises. Procedia CIRP 29, 132–137. https://doi.org/10.1016/j.procir.2015.01.028

Tanzil, D., Beloff, B.R., 2006. Assessing impacts: overview on sustainability indicators and metrics. Environ. Qual. Manag. 15, 41–56. https://doi.org/10.1002/tqem.20101

Thollander, P., Palm, J., 2012. Efficiency in industrial energy systems: an interdisciplinary perspective on barriers, energy audits, energy management, policies, and programs. Springer, London.

Tremblay, A., Badri, A., 2018. A novel tool for evaluating occupational health and safety performance in small and medium-sized enterprises: the case of the Quebec forestry/pulp and paper industry. Saf. Sci. 101, 282–294. https://doi.org/10.1016/j.ssci.2017.09.017

Trianni, A., Cagno, E., Neri, A., 2017. Modelling barriers to the adoption of industrial sustainability measures. J. Clean. Prod. 168, 1482–1504. https://doi.org/10.1016/j.jclepro.2017.07.244

United Nations, 2015. Transforming our World: The 2030 Agenda for Sustainable Development. https://sustainabledevelopment.un.org/post2015/transformingourworld

Vagias, W.M., 2006. Likert-type scale response anchors. Clemson University.

Veleva, V., Ellenbecker, M., 2001. Indicators of sustainable production: framework and methodology. J. Clean. Prod. 9, 519–549. https://doi.org/https://doi.org/10.1016/S0959-6526(01)00010-5

Veleva, V., Hart, M., Greiner, T., Crumbley, C., 2003. Indicators for measuring environmental sustainability. Benchmarking An Int. J. 10, 107–119. https://doi.org/https://doi.org/10.1016/S0959-6526(01)00010-5

Voss, C., Tsikriktsis, N., Frohlich, M., 2002. Case research in operations management. Int. J. Oper. Prod. Manag. 22, 195–219. https://doi.org/10.1108/01443570210414329

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., Verbruggen, A., 2014. Sustainability assessment and indicators: tools in a decision-making strategy for sustainable development. Sustain. https://doi.org/10.3390/su6095512

Watanabe, E.H., da Silva, R.M., Tsuzuki, M.S.G., Junqueira, F., dos Santos Filho, D.J., Miyagi, P.E., 2016. A framework to evaluate the performance of a new industrial business model. IFAC-PapersOnLine 49, 61–66. https://doi.org/10.1016/j.ifacol.2016.12.162

Winroth, M., Almström, P., Andersson, C., 2016. Sustainable production indicators at factory level. J. Manuf. Technol. Manag. 27, 1–16. https://doi.org/10.1108/JMTM-04-2016-0054

Witjes, S., Vermeulen, W.J. V, Cramer, J.M., 2015. Exploring corporate sustainability integration into business activities. Experiences from 18 small and medium sized enterprises in the Netherlands. J. Clean. Prod. 153, 528–538. https://doi.org/10.1016/j.jclepro.2016.02.027

Wohlin, C., 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering, in: Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE ’14. pp. 1–10. https://doi.org/10.1145/2601248.2601268

Yin, R.K., 2009. Case Study Research Design and Methods, 4th ed. SAGE, Thousand Oaks.

Appendix 1: Analysis of the first part of the investigation

Category	Subcategory	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5
Firm's profile	Size	Small	Large	Small	Medium	Medium
	Sector	*"Mechanical production, we produce machine for soap producers"*	*"We perform all the activities related to the manufacture of furniture"*	*"We produce fabrics for mattresses"*	*"We produce specific components for the energy sector"*	*"We produce connectors for the pneumatic industry"*
	Organization of the production and process	*"We engineer and develop each machine basing on the customer's needs"* *"The machines that we produce can be personalized"* *"We produce basing on orders"* *"We don't consume large amounts of resources, we basically produce capital goods"* *"We don't have a very big plant, we mainly make our suppliers work"* *"The plant does not consume much energy: environmental and pollution related expenses are very low"* *"We target product quality over other possible options*	*"In our sector the "lot one" is very popular"* *"Each product can be potentially different from the others"* *"We have very few finished products in the warehouse"* *"We had to move the production from big lines to smaller ones, whit which it is possible to have more product flexibility"*	*"We produce on order"* *"Our products are personalized"*	*"We design the product if the customer asks us to, otherwise the customers themselves design the product and we produce it"*	*"Our production is made for the 90% by off the shelf products, and for the remaining 10% by custom made products"*
	Certifications held	- *"We don't have any type of certification, not even the Quality one"*	OHSAS 18001, ISO 14001, ISO 9001 *"Our firm is particularly strict regarding the organization"*	-	ISO 9001	*"We hold ISO 9001. The future goal is ISO 14001"*
Sustainability	Definition of sustainability	*"Sustainability is to operate without compromising the resources of our planet, or, very little, without compromising the resources of the Country or of the industrial system"*	*"Fifty years ago, sustainability was the economic return of a machine in a given time. Today sustainability is a thousand different things, like the environmental issue, the economic issue and the social issue: when a plant tackles all these problems it is sustainable"* *"When we talk about environment, we mainly talk in terms of emission, but not only gases, it comprehends, for example, also the noise"*	*"In my opinion sustainability is an environmental issue"*	*"Sustainability is the possibility for the firm to keep on existing"*	*"Sustainability is the capability of a firm to manage the resources so that external institutions don't compromise the life of the firm"*
	Sustainability in the firm	*"It is important to be realistic […]. It is possible to target eco-efficiency in the medium term without compromising the economic aspect […] the risk sometimes is to be oblige to make choices that are not sustainable from an economic perspective"* *"To make the firm more efficient is the first step toward sustainability"* *"I would not say we make true*	*"I think sustainability is a matter also related to the firm size […] it's very difficult to amortize a plant that works with a lot size of one [..] We have been the first one to introduce water- based paints, we started quite a long time ago, so we can same we somehow have a return now"* *"We have now just installed a plant for the reduction of the energy*	*"Sustainability is environmental sustainability […] We also have a photovoltaic plant […] We had to renovate the roof, the constructer suggested that we install a photovoltaic grid"* *"We had benefits from the installation of the photovoltaic plant […] we noted that the energy consumption was increasing over the years […] so we evaluated the*	*"A private firm like our must earn in order to invest and be always up to date [..] All the investments must be justified and allowed from an economic viewpoint, and this derives from the earnings"*	*"I do think we don't consider enough the opportunities deriving from sustainability"*

		sustainability" *"Regarding safety we follow the existing legislation"*	*consumption of the firm […] all the material scraps are considered as biomass"*	*savings"* *"We had some problems with noise [...] We were reported and we resorted to soundproofing"*		
Sustainability Performance Measurement	Sustainability Performance Measurement: How	*"We seldom measure, mainly when some problem arises and we have to take remedial actions"* *"We mainly based measurement on experience and sensitivity […] without a quantitative approach. However, the quantification helps in better developing corrective actions"*	*"A set of performance indicators is fundamental to understand where it is necessary to take actions"* *"Once certificated, a firm must concern with every single detail [...] we cannot leave anything up to change and everything must follow a plan"*	*"We don't have a system to measure sustainability performance, but it could be interesting to have it"*	*"We realised it was necessary to have data to evaluate […] We have different metering allowing us to monitor different areas"* *"Each machine has a data detection system"* *"We have a person in charge of the supervision of the health, safety and environment areas"* *"We miss an analysis by the operators, who are the ones at the production site every day […] we would like to translate the idea of the suggestion box in an integrated system of data collection"*	*"We are developing right now a system capable of evaluating the productivity of each machine and each worker"* *"I'm really focused on […] the exchange of information among them and between them and me"*
	Sustainability Performance Measurement: What	*"We focus on economic aspects"* *"We had never had the time to focus on the measurement of performance other than the ones related to compliance with legislation"*	*"We don't have an index to measure, but different indicators according to the specific needs for example of paints, wood panels production or for the production or purchase of complementary materials"*	*"We focus on costs"* *"We are currently working for improving our efficiency. Our technician suggested us to install smart metering in each department and on each machine for the evaluation of the consumption"*	*"We have a very good control on the production […] for the other performance, we have a person in charge of the supervision of the health, safety and environment areas"*	*"Just measuring we realised how many scraps we were producing and how much we are wasting"* *"I'm really focused on the constant monitoring of the relationships among the workers"*
	Performance and regulation	*"Sometimes being compliant with regulation is not helpful because the regulation is not targeted on specific needs"*	*"The regulation and the performance are not in contrast, sometimes they just don't speak the same language"* *"The performance should be positive regardless the fact that I hold a certification and, at the same time, you can be compliant with regulation and have negative performance"* *"One must be complaint with regulation, no matter the effect on performance and market"*	*"Our cover of the roof was in asbestos cement, so we had to substitute it"* *"We had to perform the adaptation of the existing electric power grid"*	*"We understood that being compliant with safety regulation may seem an obstacle at the beginning, but in the long term it is an advantage"*	*"Processes and work should be organized so that external authorities don't bother me"*
	Needs for an effective performance measurement	*"The most important thing is the handling of the set of indicators"* *"A small and easy tool can be used more than a complex one, and can be also used to introduce the attitude in the firm"* *"A small firm like our has the need for a tool that can be easily used"* *"We lack of resources for a complete performance measurement"* *"Firms like ours would be able to implement only an easy-to-manage instrument, otherwise, we would focus only on being compliant with regulations"*	*"When things are complex to be used, people get tired of them: less is definitely more"* *"A complex system could result being inapplicable"*	-	*"I have always wanted to make it easy, even if it is not. I want to know how my firm is going, only after this I want to know the detail to understand where and how to take actions"*	*"The handling of a system is the most important characteristic"*

Appendix 2: Analysis of the second part of the investigation

Category	Subcategory	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5
Capacity to represent	**Completeness** (Main feature)	*"It is important to be able to understand the impact of your activities by also comparing it with other sectors"*	*"It contains all the relevant indicators for our sector"* *"These indicators are not production indicators, but definitely indicators covering all the aspects related to production"* *"The system reflects my idea of sustainability"*	*"The system is complete, I won't add anything"*	*"Indicators are fine"* *"A very good job, really broad and comprehensive"* *"It spans over all sustainability*	*"I dare to say it is very complete and well structured"* *"It is very well balanced: many indicators in the environment and social area can also tell you a lot about economic performance"*
	Generalization (Additional feature)	*"It is important to be able to understand the impact of your activities also comparing it with other sectors"*	*"I think the system provide a general perspective that however is able to fit to different sectors"* *"This is a general framework, while we operate in a specific sector: selecting the right indicators, it can be applied in different sectors"*	-	-	-
	Identification of new performance indicators (Additional feature)	*"Personally, I had already thought about some of these indicators, like the non-compliant products, but the given structure is much more interesting"*	*"I've never taken into consideration so many indicators"*	*"I have never thought of measuring these indicators, other than the economic ones"*		
Usefulness and Ease of use	**Applicability** (Main feature)	*"If it is possible I would like to have a copy of the system"* *"In half a day you can have a complete view of your performance"*	*"It allows you to have a complete overview in less than a day"*	*"The system would give me more autonomy, allowing me to better understand the situation and clarify some points regarding the validity of specific interventions"*	*"Using such an analysis, I can see things better and in advance"* *"This system is very helpful. It would be very useful in a firm like ours. I would ask you to give us a copy, I think it could be an inspiration"*	*"I am very interested in using this system, it seems really ease to be applied and managed"*
	Usefulness (Additional feature)	*"The system would help in understanding with a more scientific approach what it is happening"* *"The system would allow us to compare the numerical values obtained for example every quarter, and this would be very helpful to improve efficiency in the long-medium term"*	*"This system gives a 360° overview"*	*"The system makes you aware of important aspects that in the daily activity you would neglect or not properly analyse"*	*"It is able to shed light over critical situations, putting down for the record aspects that also the most careful manager would not see"* *"It clarifies all the aspects related to sustainability also to the sloppiest industrial decision-makers"* *"This is a great analysis work and it is very useful to make firms conscious on where to act"* *"In a general firm, like ours, such an analysis is not conducted. Much is still left to sensitivity"*	*"I do appreciate the idea of a comprehensive measurement system, able to give you a snapshot of your situation"*
	Simplicity in the use (Additional feature)	*"This work is very helpful for SMEs, because it requires short time to be applied* […] *The application of a more complex tool would be much more complicated"* *"The set simplifies the actions to be undertaken"*	*"It allows you to have a complete overview in less than a day"*	*"I don't think I will face any difficulties using this system*	-	*"I don't see any difficulties in applying this system and I think I could easily use it"*
	Difficulties (Additional feature)	*"It seems like a tool that can be used: the only obstacle I see in our firm is the indolence that may lead to a partial application"*	-	-	*"Everything is perceived as a burden if it is not automated"*	-

Highlights

- Scalable framework of indicators for the assessment of industrial sustainability
- Proposal of multiple industrial sustainability performance measurement systems
- Measurement system chosen on contextual factors and firm sustainability maturity
- Empirical evidence from Italian manufacturing firms