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Metrics for measuring industrial sustainability performance in small and medium-sized enterprises

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Abstract

Purpose – This paper aims to identify and empirically analyze useful and applicable metrics for measuring and managing the sustainability performance of small and medium-sized enterprises (SMEs).

Design/methodology/approach – To achieve the objective of the paper, potential metrics were adopted from previous research related to industrial sustainability and an empirical analysis was carried to assess the applicability of the metrics by collecting empirical data from Italian footwear SMEs using a structured questionnaire. The SMEs were selected using a convenience sampling method.

Findings – The results of the within-case analysis and the cross-case analysis indicate that the majority of the metrics were found to be useful and applicable to each of the SMEs and across the SMEs, respectively. These metrics emphasized measuring industrial sustainability performance related to financial benefits, costs and market competitiveness for the economic sustainability dimension; resources for the environmental sustainability dimension; and customers, employees and the community for the social sustainability dimension.

Research limitations/implications – Apart from the within-case analysis and cross-case analysis, it was not possible to conduct statistical analysis since a small number of SMEs were accessible to collect empirical data.

Originality/value – The findings of the paper have considerable academic, managerial and policy implications and will provide a theoretical basis for future research on measuring and managing industrial sustainability performance. By providing a set of empirically supported metrics based on the triple bottom line approach (i.e. economic, environmental and social metrics), this paper contributes to the existing knowledge in the field of industrial sustainability performance measurement.

Keywords Sustainability metrics, Triple bottom line, Performance measurement, Industrial sustainability, Sustainable manufacturing, Sustainable development goals

Paper type Research paper

1. Introduction

The concept of sustainable manufacturing has been used to properly manage the environmental and social impacts of manufacturing companies (Ahmad and Wong, 2019; Singh *et al.*, 2014). The adoption of sustainability practices in manufacturing companies can be achieved in various areas of application, from the production line to plant, firm and supply chain levels (Huang and Badurdeen, 2018). Industrial sustainability considers the adoption of sustainability practices at the firm level (Trianni *et al.*, 2017). It has become a major topic of discussion (Cagno *et al.*, 2019) and has gained considerable attention among decision-makers, policymakers and scholars (Neri *et al.*, 2018; Trianni *et al.*, 2017). The manufacturing sector is

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the main driver of a country's economic growth and social development (Galal and Moneim, 2015; Zeng *et al.*, 2008). However, it is considered as one of the main causes of unintended environmental and social consequences (Zeng *et al.*, 2008). It is therefore imperative for manufacturing companies to improve their sustainability performance and be transparent about their sustainability practices (Trianni *et al.*, 2019).

Manufacturing companies need to adopt sustainability practices primarily for the following reasons: (1) pressure from stakeholders (Huang and Badurdeen, 2018; Ocampo *et al.*, 2016; Zarte *et al.*, 2019), which include governments, investors, political groups, trade associations, suppliers, employees, customers and communities (Paramanathan *et al.*, 2004; Veleva and Ellenbecker, 2001), (2) growing concerns of environmental and social impacts (Beekaroo *et al.*, 2019; Samuel *et al.*, 2013; Wang *et al.*, 2018) and (3) for gaining a competitive advantage (Tseng *et al.*, 2009; Veleva *et al.*, 2001; Wang *et al.*, 2018). To effectively adopt sustainability practices in manufacturing companies, measuring and managing sustainability performance is essential (Cagno *et al.*, 2019; Trianni *et al.*, 2019). For this purpose, there is a need for identifying an appropriate set of metrics to effectively measure and manage industrial sustainability performance. More specifically, research is needed on the identification and selection of metrics to measure and manage the sustainability performance of the footwear sector (SMEs in particular) based on the triple bottom line (TBL) approach (i.e. gap in the literature).

The main objective of this paper is therefore to identify and empirically analyze useful and applicable metrics for measuring and managing the sustainability performance of Italian footwear SMEs. To achieve this objective (i.e. to fill the aforementioned gap):

(1) A literature review regarding the topics related to industrial sustainability and metrics was conducted;

(2) A structured questionnaire based on the identified metrics from the literature was developed;

(3) Empirical data on the applicability of the metrics was collected from the selected Italian footwear SMEs; and

(4) An empirical data analysis (i.e. within-case analysis and cross-case analysis to check the applicability of the metrics to each of the SMEs or across the SMEs, respectively) was carried out.

The findings of the paper indicate that the majority of the metrics were found to be applicable to each of the SMEs and across SMEs. Specifically, metrics linked to financial benefits, costs and market competitiveness can be used to measure and manage economic sustainability performance. Whereas, metrics associated with resources (i.e. materials and energy) can be used for measuring and managing environmental sustainability. In addition, metrics related to employees, customers and the community can be used to measure and manage social sustainability performance. In other words, these metrics can help SMEs to measure and manage progress toward achieving industrial sustainability goals such as increasing financial benefits, reducing costs, improving market competitiveness, improving the effectiveness of resources utilization and promoting the well-being of employees, customers and the community.

Ultimately, this paper has important implications for academicians, managers (SMEs) and policymakers. It will provide a theoretical foundation for future research work on industrial sustainability performance management using a set of metrics based on the TBL approach. Managers can use the metrics identified in this paper to measure and manage the sustainability performance of their companies and achieve their sustainability goals. The results of the paper will also be useful for policymakers involved in assessing the sustainability performance of manufacturing industries (footwear industry in particular).

The rest of the work in this paper is organized into four sections. Section 2 presents an overview of the literature review. Section 3 briefly describes the research methodology applied to conduct this study. The results of the paper are discussed in Section 4. Finally, conclusions and future research directions are presented in Section 5.

2. Literature review

Industrial sustainability considers the adoption of sustainability practices at the industrial plant (firm) level (Trianni *et al.*, 2017). It takes into account the actions taken at the material, product, process, plant and production system levels (Tonelli *et al.*, 2013). More broadly, industrial sustainability is defined by a set of activities consisting of the simultaneous consideration of economic, environmental and social aspects when producing products and services; ensuring economic growth, conserving resources and minimizing negative environmental and social impacts; and meeting the short-term and long-term requirements of stakeholders (Mengistu and Panizzolo, 2021).

The concept of sustainability primarily includes economic, environmental and social aspects (Paramanathan *et al.*, 2004; Zeng *et al.*, 2008), referred to as TBL sustainability, which are the three interrelated dimensions of sustainability (Elkington, 1997). To adequately address industrial sustainability, a holistic approach based on TBL is needed (Cagno *et al.*, 2019). Manufacturing companies have a significant impact on the three dimensions of sustainability (Ahmad *et al.*, 2019b; Ghadimi *et al.*, 2012). Hence, they should simultaneously consider economic, environmental and social sustainability aspects while producing their products and services (Eastwood and Haapala, 2015; Haapala *et al.*, 2013; Lacasa *et al.*, 2016; Watanabe *et al.*, 2016). To achieve this, they should measure and manage their sustainability performance using an appropriate set of metrics.

Defining useful and applicable metrics is key to measure and manage sustainability performance in manufacturing companies (Murad *et al.*, 2021; Shuaib *et al.*, 2014). The use of suitable metrics for measuring and managing industrial sustainability performance is used to improve the decision-making process of manufacturing companies (Haapala *et al.*, 2013; Sartal *et al.*, 2020). Metrics can enable manufacturing companies to effectively measure their sustainability performance using data science. Both absolute and relative metrics can be used to measure sustainability performance in manufacturing companies. Absolute metrics measure the overall sustainability performance in specific areas (e.g. a company overall water consumption). On the other hand, relative metrics measure a company's sustainability performance in one area (e.g. water consumption) relative to the performance in another area (e.g. total production) (Ahi and Searcy, 2015). In this paper, both absolute and relative metrics have been identified to measure and manage industrial sustainability performance.

Small and medium-sized enterprises (SMEs) contribute significantly to a country's economic growth through innovation, production volume and job creation (Belas *et al.*, 2019; Kassem and Trenz, 2020; Lopes de Sousa Jabbour *et al.*, 2020; Sajan *et al.*, 2017). Although SMEs have significant economic, environmental and social impacts, they still struggle to address the environmental and social sustainability dimensions to measure and manage their sustainability performance (Journeault *et al.*, 2021; Mitchell *et al.*, 2020), and they primarily focus on the economic aspect (Choi and Lee, 2017; Trianni *et al.*, 2019). This is due to limited resources (Hsu *et al.*, 2017; Journeault *et al.*, 2021; Singh *et al.*, 2014; Trianni *et al.*, 2019; Winroth *et al.*, 2016), lack of awareness about the impacts and benefits of sustainability practices (Journeault *et al.*, 2021; Singh *et al.*, 2014) and lack of skills and expertise (Journeault *et al.*, 2021; Singh *et al.*, 2014; Trianni *et al.*, 2019). To properly address the challenges of measuring and managing sustainability performance, it is important to use economic, environmental and social metrics tailored to the needs of SMEs.

Table 1 summarizes some of the previous research based on a number of key features such as the methodology used by the authors, the application of metrics, and the identification of firm-specific and core (common) metrics to provide an overview of the existing literature related to metrics-based sustainability performance measurement.

As shown in Table 1, previous research used different methodological approaches such as literature review, modeling (framework development, system dynamics and Monte Carlo simulation), and case study at various industry sectors to measure (assess) sustainability performance using a set of metrics. The metrics used in previous research were not identified as firm-specific (i.e. metrics applicable to each firm) and core (i.e. metrics commonly applicable across firms). However, it would be useful to identify firm-specific metrics and core metrics to increase the flexibility and applicability of the metrics in measuring and managing the sustainability performance of manufacturing firms. On the other hand, although the footwear industry has significant potential to address issues of sustainability, it is less studied in terms of sustainability performance measurement and management. Consequently, research regarding the sustainability performance of the footwear industry is needed.

The footwear industry is one of the main drivers of Italy's economic growth and social development. According to Assocalzaturifici (2020), the Italian footwear sector created job opportunities for about 75,000 employees and generated an annual turnover of 14.3 billion euro in 2019. It consumes a large quantity of input materials such as leather, synthetic, rubber and textiles for production. These figures imply that the sector has significant potential to address sustainability issues. The lack of clear sustainability goals, the lack of suitable metrics and limited resources are major challenges in measuring and managing the sustainability performance of footwear firms, SMEs in particular. The existing literature indicates that research is needed on the sustainability performance measurement of the footwear industry (SMEs in particular) based on the TBL approach. Previous research on the sustainability of the footwear industry is limited and mainly focused on the environmental sustainability dimension (Deselnicu *et al.*, 2014; Subic *et al.*, 2012, 2013). These rationales led to the consideration of Italian footwear SMEs as a research context. Therefore, the purpose of this paper is to identify and empirically analyze metrics for measuring and managing sustainability performance in Italian footwear SMEs. The paper focuses on Italian footwear SMEs rather than large firms. This is mainly because, unlike large firms, SMEs have limited resources to measure and manage sustainability performance. Subsequently, they need a set of metrics that are simple and easy to use and manage. Furthermore, the Italian footwear sector includes a large number of SMEs, which together have a significant impact on the sustainable development of Italy.

3. Methodology

3.1 Overall methodological approach

To achieve the objective of the paper, the following methodological approach, shown in Figure 1, was applied. This methodology mainly consists of (1) adopting metrics from previous research (Mengistu and Panizzolo, 2021), which performed a detailed analysis of metrics available in the literature such as (Ahmad *et al.*, 2019b; GRI, 2016; Huang and Badurdeen, 2018; Veleva and Ellenbecker, 2001), (2) collecting empirical data (i.e. experts' opinions) from the selected Italian footwear SMEs using a structured questionnaire and (3) conducting an empirical data analysis (i.e. within-case analysis and cross-case analysis) to assess the applicability metrics in SMEs. One of the limitations of the previous research by Mengistu and Panizzolo (2021) was the lack of empirical analysis of the metrics, which paved the way for this study.

3.2 Data collection

To collect empirical data on the applicability of the metrics, a structured questionnaire was first developed. In the structured questionnaire, the SMEs were asked to assess the applicability of

Authors	Methodology used by the authors	Application of metrics	Firm-specific and core (common) metrics
Hapuwatte *et al.* (2022)	• Literature review • A framework based on Monte Carlo method	• To evaluate product sustainability performance for promoting circular economy	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Hapuwatte and Jawahir (2021)	• A comprehensive methodological approach, which includes (1) literature review, (2) proposing sustainable product design for the circular economy and (3) proposing a metrics-based product evaluation framework	• To evaluate product sustainability throughout the product life cycle	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Murad *et al.* (2021)	• Literature review • Case study at sugarcane mills	• To assess sustainable manufacturing performance at manufacturing process levels	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Zhang *et al.* (2021)	• Literature review • System dynamics modeling • Case study at a laboratory equipment manufacturing enterprise	• To analyze the interconnections between technical, economic, environmental, and social performance of SMEs	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Jamil *et al.* (2020)	• Define, measure, analyze, improve, and control (DMAIC) • Case study at hard disk drive substrate manufacturing companies in Malaysia	• To conduct sustainable value stream mapping (Sus-VSM) toward achieving sustainable manufacturing	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Ahmad *et al.* (2019)	• Monte Carlo simulation and fuzzy logic approaches • Case study at a Malaysian food manufacturing company	• To assess sustainability performance of a manufacturing company	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Song and Moon (2019)	• Distance-to-target methodology • Case study at plastic parts inspection and packaging in traditional manufacturing system and cyber manufacturing system	• To measure progress toward sustainability targets	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)

(*continued*)

Table 1.
Overview of previous research according to some key features

Authors	Methodology used by the authors	Application of metrics	Firm-specific and core (common) metrics
Huang and Badurdeen (2018)	• Literature review • Index-based method • Case study at a satellite television dish production	• To assess sustainable manufacturing performance at the production line and plant levels	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)
Ahi and Searcy (2015)	• Systematic literature review	• To measure performance in green and sustainable supply chains	• Did not provide firm-specific metrics (i.e. metrics applicable to each firm) and core metrics (i.e. metrics commonly applicable across firms)

Table 1.

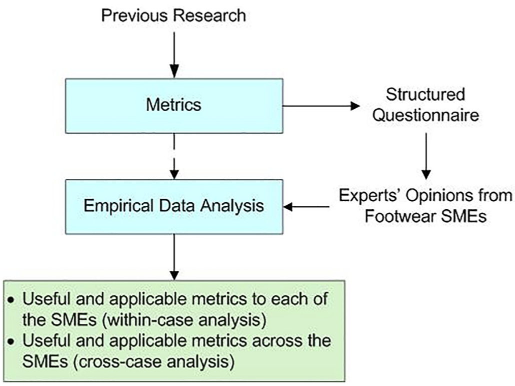

Figure 1.
Overall methodological approach to conduct the study

the metrics (i.e. whether the metrics are currently used by them, will be applicable in the future, or are not applicable to them). Second, pretesting of the questionnaire was conducted with selected researchers to check the clarity of the questionnaire (clarity of language, context and content), time (to complete the questionnaire as much as possible in a few minutes), level of redundancy (likelihood of redundant questions) and relevance of the questionnaire (relation to the purpose of the study). Third, the footwear SMEs involved in the assessment of the metrics were identified and selected, as shown in Table 2, using a convenience sampling method. It was

SMEs	Year of establishment	Number of employees	Market segment
1	1947	172	Local and export
2	1987	86	Local and export
3	1975	40	Local
4	1960	76	Local and export
5	1959	44	Local and export
6	1947	53	Local and export

Table 2.
List of SMEs involved in assessing the applicability of the metrics

difficult to apply the common survey procedure and involve as many SMEs as required. This is due to the reason that this study was carried out at a time when the COVID-19 pandemic hit the world and made it impossible to involve SMEs in research activities and have direct contact with them for months.

As can be seen from Table 2, the numbers 1, 2, 3, 4, 5 and 6 were used to represent the six firms (SMEs) from which empirical data regarding the applicability of the metrics was collected, as the names of the SMEs should remain anonymous.

3.3 Data analysis

Based on the collected empirical data (i.e. experts' opinions), the within-case analysis to assess the applicability of the metrics in each of the SMEs (i.e. to identify the metrics that are useful and applicable to each of the SMEs) was carried out. Moreover, the cross-case analysis to assess the applicability of the metrics across the SMEs (i.e. to identify the common metrics that are useful and applicable across the SMEs) was conducted. The empirical data analysis provides results that are more directly usable in practice. In other words, it specifically provides Italian footwear SMEs with a set of metrics that can be used to measure and manage their economic, environmental and social sustainability performance.

4. Results and discussion

4.1 Results

4.1.1 Metrics adopted from previous research. This section presents the metrics adopted from Mengistu and Panizzolo (2021), who conducted a detailed literature analysis of the metrics as mentioned in Section 3 above. In this paper, these metrics organized into their respective categories (themes) related to industrial sustainability, as presented in Table 3. As a result, a total of 16 metrics were identified for the economic sustainability dimension (four metrics for financial benefits, four metrics for costs and eight metrics for market competitiveness). For the environmental sustainability dimension, a total of 13 metrics were considered (five metrics for resources: energy and eight metrics for resources: materials). In addition, a total of 33 metrics were identified for the social sustainability dimension (25 metrics for employees, six metrics for customers and two metrics for the community).

4.1.2 Applicability of the metrics to each of the footwear SMEs: within-case analysis. The empirical data analysis shows that the overwhelming majority of the metrics (i.e. 55 metrics out of 62) were found to be useful and applicable to firm 1 (SME 1) to measure its sustainability performance. From these applicable metrics, 31 metrics are currently used by this SME and the remaining 24 metrics are contributed to SME 1 by this paper. As shown in Figure 2, SME 1 currently uses 12 metrics to measure the economic sustainability performance related to financial benefits, costs and market competitiveness, and three metrics associated with market competitiveness were identified to be applicable in the future. In addition, a total of seven metrics were identified as useful and applicable for measuring the environmental sustainability performance linked to resources (materials); out of which, two metrics are currently used by this SME. It can also be seen that SME 1 currently uses 17 metrics to measure the social sustainability performance related to employees, customers and the community, and 16 metrics linked to employees and customers were found to be applicable in the future.

In the case of firm 2 (SME 2), 49 metrics out of 62 were identified as useful and applicable. Of these applicable metrics, 22 metrics are currently used by this SME and 27 additional metrics are provided for SME 2 by this paper. From Figure 3, it can be seen that a total of 11 metrics were found to be useful and applicable to SME 2 for measuring the economic sustainability performance associated with financial benefits, costs and market

Sustainability dimensions	Categories	Metrics
Economic	Financial benefits	Net profit gained (USD, Euro)
		Net profit to total revenue ratio (%)
		Total revenue generated (USD, Euro)
		Revenue generated per unit of product sold (USD, Euro/uop)
	Costs	Total material cost (USD, Euro)
		Percentage of material cost relative to total revenue (%)
		Total labor cost (USD, Euro)
		Percentage of labor cost relative to total revenue (%)
	Market competitiveness	R&D spending (USD, Euro)
		R&D spending to total revenue ratio (%)
		Total number of products that met customer requirements (#)
		Percentage of products that met customer requirements (%)
		Total number of products produced within the required lead time (#)
		Percentage of products produced within the required lead time (%)
		Total number of products delivered on-time (#)
		Percentage of products delivered on-time (%)
Environmental	Resources (energy)	Total electricity consumed (kWh)
		Total amount of fuel consumed (L, m3, tonne)
		Electricity consumption per unit of product produced (kWh/uop)
		Fuel consumption per unit of product produced (L, m3, tonne/uop)
		Ratio of final energy used for production to the total input energy (%)
	Resources (materials)	Total weight or volume of materials consumed (kg, m3, L, m2, pc)
		Material consumption per unit of product produced (kg, m3, L, m2, pc /uop)
		Material efficiency (%)
		Percentage of biodegradable materials used (%)
		Percentage of renewable materials used (%)
		Percentage of hazardous materials used (%)
		Total weight or volume of recycled materials used (kg, m3, L, m2, pc)
		Percentage of recycled materials used (%)
Social	Employees	Average salary per employee (USD, Euro/emp)
		Total number of employee turnover (#)
		Percentage of employee turnover (%)
		Total number of employees who reported job satisfaction (#)
		Percentage of employees who reported job satisfaction (%)
		Total number of employees covered by OHS program (#)
		Total number of fatalities as a result of work-related injuries (#)
		Total number of fatalities as a result of work-related illnesses (#)
		Total number of cases of work-related illnesses (#)
		Percentage of employees covered by OHS program (%)
		Percentage of fatalities as a result of work-related injuries (%)
		Percentage of fatalities as a result of work-related illnesses (%)
		Percentage of cases of work-related illnesses (%)
		Total number of total employees who received a regular PCD review (#)
		Total training hours (h)
		Percentage of employees who received a regular PCD review (%)
		Average training hours per employee (h/emp)
		Total number of employees working in decent conditions (#)
		Percentage employees working in decent conditions (%)
		Total number of work-related injuries (#)
		Work-related injuries per employee (#/emp)
		Total working hours (h)
		Average working hours per employee (h/emp)
		Total lost working days due to injuries and illnesses (day)
		Percentage of lost working days due to injuries and illnesses (%)
	Customers	Total number of incidents concerning the health and safety impacts of products and services provided (#)
		Customer health and safety incidents per unit of product sold (#/uop)
		Total number of customers who reported satisfaction with products and services offered (#)
		Percentage of customers who reported satisfaction with products and services offered (%)
		Total number of customer complaints (#)
		Customer complaints per unit of product sold (#/uop)
	Community	Total number of new employees hired (#)
		Recruitment efficiency (%)

Note(s): USD: United State dollar, R&D: research and development, #: number, kWh: kilowatt hour, kg: kilogram, m^3: cubic meter, L: liter, m^2: square meter, pc: piece, OHS: occupational health and safety, PCD: performance and career development, h: hour, emp: employee, uop: unit of product

Table 3. Summary of the metrics with their respective categories

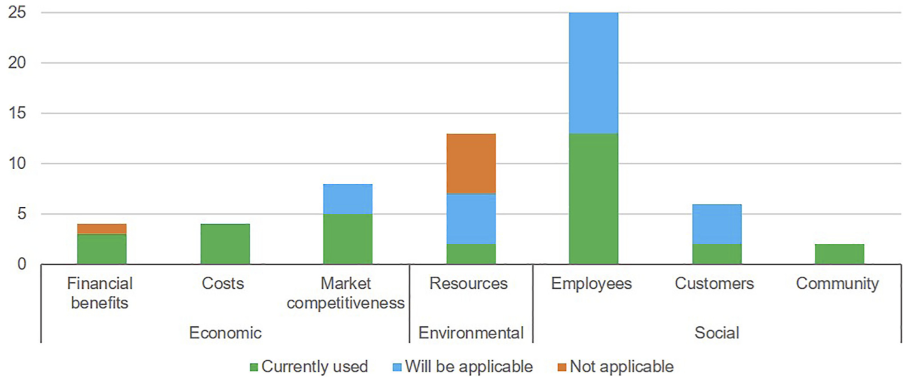

Figure 2. Applicability of the metrics in SME 1 by category

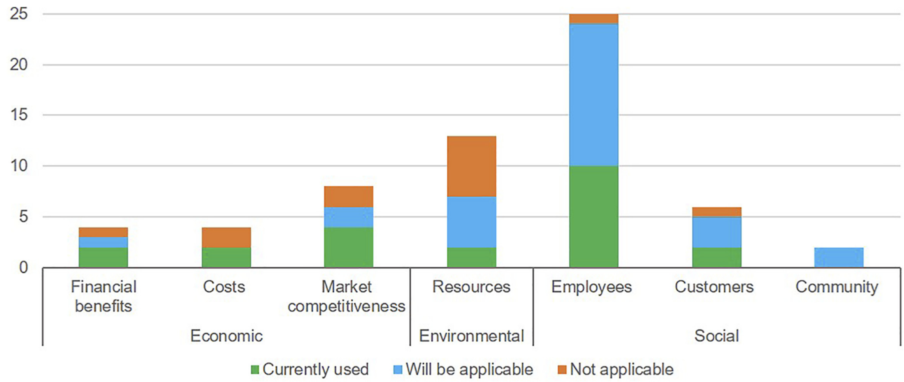

Figure 3. Applicability of the metrics in SME 2 by category

competitiveness; from which, three metrics related to financial benefits and market competitiveness were identified to be applicable in the future. This SME currently uses two metrics to measure the environmental sustainability performance related to resources (materials) and five metrics were found to be applicable in the future. Moreover, a total of 31 metrics were identified as useful and applicable for measuring the social sustainability performance related to employees, customers and the community; out of which, 12 metrics related to employees and customers are currently used by SME 2.

The vast majority of the metrics (i.e. 52 out of 62) were found to be useful and applicable to firm 3 (SME 3). Out of these applicable metrics, 20 metrics are currently used by this SME and this paper contributes the remaining 32 metrics to SME 3. As can be seen from Figure 4, a total of 16 metrics were identified as useful and applicable to SME 3 for measuring the economic sustainability performance linked to financial benefits, costs and market competitiveness; of which, eight metrics are currently used by this SME. It can also be seen that SME 3 currently uses three metrics to measure the environmental sustainability performance associated with resources (materials) and one metric was found to be applicable in the future. In addition, a total of 32 metrics were identified as useful and applicable for measuring the social sustainability performance linked to employees, customers and the community; from which, nine metrics associated with employees and customers are currently used by this SME.

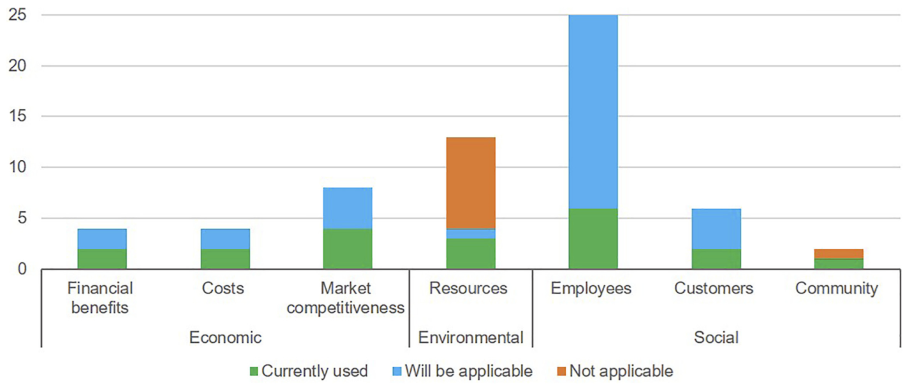

Figure 4. Applicability of the metrics in SME 3 by category

For firm 4 (SME 4), 45 metrics out of 62 were identified as useful and applicable. From these applicable metrics, 40 metrics are currently used by this SME and this paper provides five additional metrics to SME 4. As shown in Figure 5, SME 4 currently uses 15 metrics to measure the economic sustainability performance related to financial benefits, costs and market competitiveness. Moreover, six metrics are currently used by this SME for measuring the environmental sustainability performance linked to resources (materials). It can also be seen that SME 4 currently uses 19 metrics to measure the social sustainability performance related to employees and customers, and five metrics linked to employees were found to be applicable in the future.

The majority of the metrics (i.e. 49 metrics out of 62) were found to be useful and applicable to firm 5 (SME 5). Out of these applicable metrics, 33 metrics are currently used by this SME and the remaining 16 metrics are provided to SME 5 by this paper. From Figure 6, it can be seen that a total of 16 metrics were identified as useful and applicable to SME 5 for measuring the economic sustainability performance associated with financial benefits, costs, and market competitiveness; from which, five metrics related to financial benefits and market competitiveness were found to be applicable in the future. This SME currently uses two metrics to measure the environmental sustainability performance related to resources (materials). In addition, a total of 31 metrics were identified as useful and applicable for measuring the social sustainability performance related to employees, customers and the

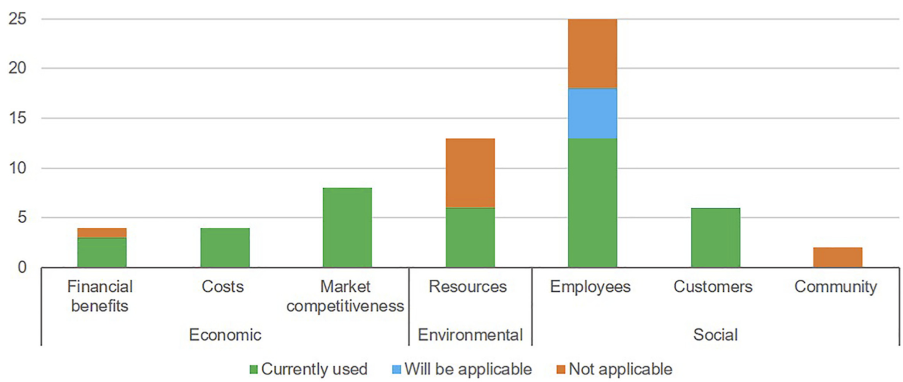

Figure 5. Applicability of the metrics in SME 4 by category

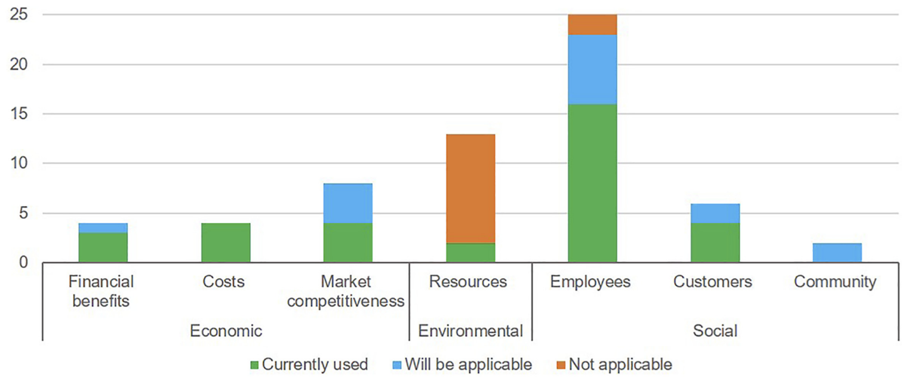

Figure 6.
Applicability of the metrics in SME 5 by category

community; out of which, 20 metrics related to employees and customers are currently used by SME 5.

In the case of firm 6 (SME 6), 55 metrics out of 62 were identified as useful and applicable. Of these applicable metrics, 31 metrics are being used by this SME and 24 additional metrics are contributed to SME 6 by this paper. As can be seen from Figure 7, a total of 15 metrics were found to be useful and applicable to SME 6 for measuring the economic sustainability performance linked to financial benefits, costs and market competitiveness; of which, four metrics related to market competitiveness are currently used by this SME. It can also be seen that SME 6 currently uses four metrics to measure the environmental sustainability performance associated with resources (materials) and three metrics were identified to be applicable in the future. Moreover, a total of 33 metrics were found to be useful and applicable for measuring the social sustainability performance linked to employees, customers and the community; from which, 16 metrics associated with employees, customers and the community are currently used by this SME.

4.1.3 Applicability of the metrics across footwear SMEs: cross-case analysis. From the cross-case analysis presented in Table 4, it can be seen that 16 common economic metrics were found to be applicable in at least two footwear firms (SMEs) to measure and manage the economic sustainability performance associated with economic benefits, costs and market competitiveness. Out of these metrics, 11 metrics were identified as applicable in all six SMEs.

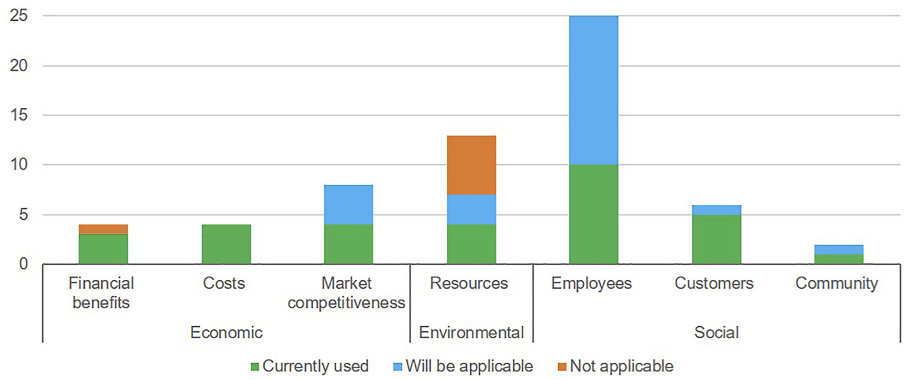

Figure 7.
Applicability of the metrics in SME 6 by category

Table 4. Cross-case analysis matrix for the applicability of the metrics

Sustainability dimensions	Metrics	Firms (SMEs) 1	2	3	4	5	6
Economic	Net profit gained (USD, Euro)	x	x	x	x	x	x
	Net profit to total revenue ratio (%)	x	x	x	x	x	x
	Total revenue generated (USD, Euro)	x	x	x	x	x	x
	Revenue generated per unit of product sold (USD, Euro/uop)			x		x	
	Total material cost (USD, Euro)	x	x	x	x	x	x
	Percentage of material cost relative to total revenue (%)	x		x	x	x	x
	Total labor cost (USD, Euro)	x	x	x	x	x	x
	Percentage of labor cost relative to total revenue (%)	x		x	x	x	x
	R&D spending (USD, Euro)	x	x	x	x	x	x
	R&D spending to total revenue ratio (%)	x	x	x	x	x	x
	Total number of products that met customer requirements (#)	x		x	x	x	x
	Percentage of products that met customer requirements (%)	x	x	x	x	x	x
	Total number of products produced within the required lead time (#)	x		x	x	x	x
	Percentage of products produced within the required lead time (%)	x	x	x	x	x	x
	Total number of products delivered on-time (#)	x	x	x	x	x	x
	Percentage of products delivered on-time (%)	x	x	x	x	x	x
Environmental	Total electricity consumed (kWh)						
	Total amount of fuel consumed (L, m3, tonne)						
	Electricity consumption per unit of product produced (kWh/uop)						
	Fuel consumption per unit of product produced (L, m3, tonne/uop)						
	Ratio of final energy used for production to the total input energy (%)						
	Total weight or volume of materials consumed (kg, m3, L, m2, pc)	x	x	x	x	x	x
	Material consumption per unit of product produced (kg, m3, L, m2, pc /uop)	x	x		x		
	Material efficiency (%)	x				x	x
	Percentage of biodegradable materials used (%)	x	x				x
	Percentage of renewable materials used (%)	x	x	x	x		x
	Percentage of hazardous materials used (%)		x		x		x
	Total weight or volume of recycled materials used (kg, m3, L, m2, pc)	x	x	x	x		x
	Percentage of recycled materials used (%)	x	x	x	x		x

(*continued*)

Table 4.

Sustainability dimensions	Metrics	Firms (SMEs) 1	2	3	4	5	6
Social	Average salary per employee (USD, Euro/emp)	x	x	x	x	x	x
	Total number of employee turnover (#)	x		x	x	x	x
	Percentage of employee turnover (%)	x	x	x	x	x	x
	Total number of employees who reported job satisfaction (#)	x	x	x	x	x	x
	Percentage of employees who reported job satisfaction (%)	x	x	x	x	x	x
	Total number of employees covered by OHS program (#)	x	x	x		x	x
	Total number of fatalities as a result of work-related injuries (#)	x	x	x	x	x	x
	Total number of fatalities as a result of work-related illnesses (#)	x	x	x	x	x	x
	Total number of cases of work-related illnesses (#)	x	x	x	x	x	x
	Percentage of employees covered by OHS program (%)	x	x	x		x	x
	Percentage of fatalities as a result of work-related injuries (%)	x	x	x	x	x	x
	Percentage of fatalities as a result of work-related illnesses (%)	x	x	x	x	x	x
	Percentage of cases of work-related illnesses (%)	x	x	x	x	x	x
	Total number of total employees who received a regular PCD review (#)	x	x	x		x	x
	Total training hours (h)	x	x	x	x	x	x
	Percentage of employees who received a regular PCD review (%)	x	x	x	x	x	x
	Average training hours per employee (h/emp)	x	x	x	x	x	x
	Total number of employees working in decent conditions (#)	x	x	x			x
	Percentage employees working in decent conditions (%)	x	x	x			x
	Total number of work-related injuries (#)	x	x	x	x	x	x
	Work-related injuries per employee (#/emp)	x	x	x	x	x	x
	Total working hours (h)	x	x	x	x	x	x
	Average working hours per employee (h/emp)	x	x	x	x	x	x
	Total lost working days due to injuries and illnesses (day)	x	x	x		x	x
	Percentage of lost working days due to injuries and illnesses (%)	x	x	x		x	x
	Total number of incidents concerning the health and safety impacts of products and services provided (#)	x	x	x	x	x	x
	Customer health and safety incidents per unit of product sold (#/uop)	x		x	x	x	x
	Total number of customers who reported satisfaction with products and services offered (#)	x	x	x	x	x	x
	Percentage of customers who reported satisfaction with products and services offered (%)	x	x	x	x	x	x
	Total number of customer complaints (#)	x	x	x	x	x	x
	Customer complaints per unit of product sold (#/uop)	x	x	x	x	x	x
	Total number of new employees hired (#)	x	x	x		x	x
	Recruitment efficiency (%)	x	x			x	x

On the other hand, eight common environmental metrics related to resources (materials) were found to be applicable in at least three SMEs for measuring and managing the environmental sustainability performance. Of these metrics, the total weight or volume of materials consumed (kg, m^3, L, m^2, pc) was identified as applicable in all six SMEs. In addition, 33 common social metrics were found to be applicable in at least four SMEs to measure and manage the social sustainability performance linked to employees, customers and the community. From these metrics, 22 metrics were identified as applicable in all six SMEs.

Figure 8 presents the common economic, environmental and social metrics, which were identified as applicable in all six footwear firms (SMEs) after the cross-case analysis. And, these metrics can be considered as core metrics used to measure and manage sustainability performance across SMEs.

4.2 Discussion

As stakeholders seek to play an important role in the transition toward a sustainable lifestyle, SMEs should respond by improving their economic, environmental and social sustainability performance. To measure and manage the economic sustainability performance of SMEs, metrics associated with financial benefits (profit and revenue), costs (labor cost and material cost) and market competitiveness (R&D expenditure, on-time delivery, lead time and product quality) were found to be useful and applicable. Product quality, on-time delivery and lead time are crucial to ensure market competitiveness and financial performance of SMEs in the short run. Moreover, SMEs need to allocate appropriate expenditure for conducting R&D activities to promote innovation, produce sustainable products and enhance market competitiveness in the long run. More specifically, the R&D department should explore innovative manufacturing technologies and engage in new product development (Demartini *et al.*, 2018) to ensure sustainable manufacturing. Due to the introduction of new laws and policies for sustainable manufacturing, the development of innovative technologies, processes, applications and products that take into account the environmental and social sustainability aspects has increasingly become essential for manufacturing companies (Zarte *et al.*, 2019).

Unlike other industrial sectors such as food and beverage, the manufacturing process of footwear SMEs does not consume a large quantity of water and emits less. However, it consumes a large amount of different input materials to produce a variety of products (Staikos and Rahimifard, 2007). Leather, synthetics, plastic, rubber and textiles are the most common input materials used by the footwear industry for its manufacturing process (Sellitto and Almeida, 2019). From the results of this study, the Italian footwear SMEs have paid more attention to metrics related to material consumption for measuring and managing the environmental sustainability performance in order to improve material efficiency, reduce the use of hazardous materials and increase the use of eco-friendly and biodegradable materials. Specifically, SMEs can reduce waste generation by improving material efficiency. The safety of consumer products can be improved by reducing the use of hazardous materials. In addition, increasing the use of eco-friendly and biodegradable materials, promoting the use of recycled materials and reducing the use of hazardous materials are key to minimize the growing concerns regarding the environmental and social impacts of the end-of-life products in the post-use phase.

In the social sustainability dimension, metrics that promote sustainability performance measurement linked to employees, customers and the community were found to be useful and applicable to SMEs. Measuring the social sustainability performance has been challenging compared to the economic and environmental sustainability dimensions (Ahmad *et al.*, 2019a). These social metrics can help SMEs to effectively measure and manage their social sustainability performance associated with the well-being of their employees, customers and

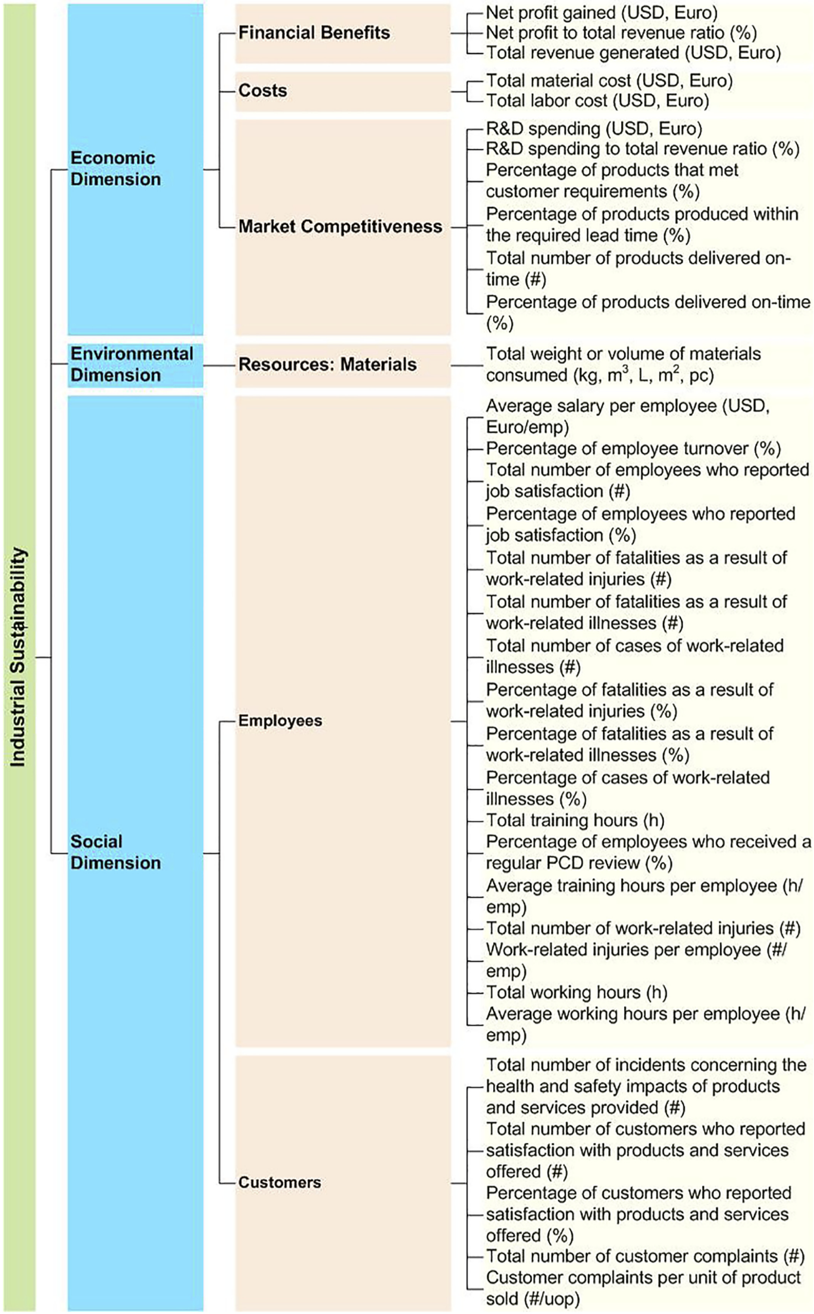

Figure 8.
The common (core) metrics by hierarchical structure

the community. The footwear industry is one of the labor-intensive and low-tech industries (Scott, 2006). As a labor-intensive industry, ensuring the well-being of the employees is a key factor in Italian footwear SMEs. To measure and manage progress on improving employee well-being, metrics related to working conditions, occupational health and safety, work-related injuries, fair salary, training and development and employee satisfaction were emphasized. SMEs should measure and manage the progress made in improving the well-being of their customers. To achieve this, metrics linked to customer satisfaction, customer complaints and customer health and safety were identified as more appropriate. On the other hand, metrics related to employment/job opportunity were found to be useful for measuring and managing progress on community development. In addition, metrics linked to working hours and lost-working days were identified as crucial to measure and manage employee time management performance.

As stakeholders' awareness of sustainability increases, sustainability will be one of the key business drivers for manufacturing companies. Stakeholders raise the issues of sustainability in manufacturing companies, such as sustainability assessment of products from manufacturing companies and how products are sustainably produced. Hence, manufacturing companies should improve their sustainability performance to address the legitimate concerns of their customers and stakeholders and enhance their competitiveness in the market. However, sustainability performance improvement will not be an easy task if it is not supported by effective sustainability measurement and management, which requires a set of suitable metrics. This paper provides a set of useful and applicable metrics based on the TBL approach to guide Italian footwear SMEs in measuring and managing sustainability performance. Furthermore, SMEs can use these metrics to track their progress toward achieving the sustainable development goals such as promoting the well-being of stakeholders, promoting sustainable economic growth, providing productive employment and decent work and ensuring sustainable consumption and production.

This paper provides a set of metrics linked to many aspects of industrial sustainability such as financial benefits, costs and market competitiveness regarding the economic sustainability dimension; resources regarding the environmental sustainability dimension; and employees, customers and the community regarding the social sustainability dimension. These aspects of industrial sustainability have also been addressed directly and indirectly in previous research on the fashion industry sustainability. Specifically, Tebaldi *et al.* (2022) addressed financial benefits (e.g. profit and revenue), costs (e.g. material and energy costs), market competitiveness (e.g. quality), resources (e.g. materials, water and energy), employees (e.g. employee satisfaction) and customers (e.g. customer satisfaction) in their research on sustainability issues in the fashion supply chain. Financial benefits (e.g. profit), market competitiveness (e.g. quality), resources (e.g. materials and energy), employees (e.g. training), customers (e.g. customer satisfaction and customer complaints) and the community (e.g. health and development) were discussed by Wang *et al.* (2019) in their study about sustainable fashion index model. Poh and Liang (2017) addressed financial benefits (profit and revenue), costs (e.g. material cost), market competitiveness (e.g. quality), resources (e.g. materials) and employees (e.g. workplace health and safety) in their research on sustainable supply chain of the fashion industry. Costs (e.g. production costs), market competitiveness (e.g. R&D, quality and lead time), resources (e.g. materials, water and energy), employees (e.g. health and safety, working conditions, and working hours), and customers (e.g. customer satisfaction), the community (e.g. employment) were discussed by Turker and Altuntas (2014) in their study about sustainable supply chain management in the fast fashion industry. de Brito *et al.* (2008) addressed financial benefits (e.g. profit), costs (e.g. material and energy costs), market competitiveness (e.g. quality, lead time and on-time delivery), resources (materials, water and energy), employees (training and development), customers (e.g. consumer health) and the community (e.g. employment) in their research on sustainable fashion retail supply chain in Europe. However, unlike this study, the research papers on the fashion industry sustainability did not provide a set of metrics applicable to each of manufacturing firms (i.e. metrics applicable to each of fashion manufacturing firms by conducting within-case analysis) and metrics applicable across manufacturing firms (i.e. core metrics for fashion manufacturing firms by performing cross-case analysis). Eventually, the metrics analyzed in this study will be more flexible and applicable to measure and manage the sustainability performance of an individual footwear firm and footwear firms as a whole. Moreover, the metrics can easily be adapted to other footwear firms that were not involved in this study.

5. Conclusions

This paper provides a set of metrics that are useful and applicable for measuring and managing sustainability performance in Italian footwear SMEs. To achieve this, a comprehensive methodological approach, which includes (1) adopting metrics from previous research, (2) collecting empirical data on the applicability of the metrics from the selected Italian footwear SMEs and (3) conducting an empirical data analysis to assess the applicability of the metrics in SMEs, was applied.

The results of the empirical data analysis indicate that the majority of the metrics adopted were found to be useful and applicable to each of the SMEs (i.e. within-case analysis) and across the SMEs (i.e. cross-case analysis). These metrics put emphasis on measuring and managing industrial sustainability performance related to financial benefits, costs and market competitiveness for the economic sustainability dimension; resources for the environmental sustainability dimension; and employees, customers and the community for the social sustainability dimension. And, these suggest that SMEs need to allocate their limited resources to effectively apply the metrics to measure and manage progress toward achieving industrial sustainability goals, which includes (1) increasing financial benefits, reducing costs and improving market competitiveness for the economic sustainability goals; (2) improving the effectiveness of resources utilization for the environmental sustainability goals; and (3) promoting the well-being of stakeholders (employees, customers and the community) for the social sustainability goals. Moreover, the metrics can help SMEs to improve the effectiveness of their efforts in measuring and managing sustainability performance without overloading them with uncertain information.

5.1 Academic implications

This paper has significant academic implications. Primarily, it provides a theoretical basis for future research on measuring and managing the sustainability performance of the manufacturing industry, the footwear industry in particular. More specifically, future research can use the metrics identified in this paper as a basis for setting sustainability targets, measuring, evaluating and interpreting the sustainability performance of a manufacturing company by comparing the actual performance with respective sustainability targets and recommending actions to ensure continuous sustainability performance improvement. Future research can adapt the metrics to other industry sectors (such as leather, textile and apparel) to measure and manage sustainability performance. This paper can also be used as a reference material to develop guidelines for measuring and managing sustainability performance in the footwear industry. In this regard, universities, colleges, research institutes and training centers engaged in the footwear industry sustainability can use the results of this paper in their teaching and research activities. It will also encourage further discussions on how to use the metrics to measure and manage the sustainability performance of the footwear industry and contribute to the achievement of the sustainable development goals at the national and global levels. In addition, it provides recommendations for future research on the sustainability performance of the footwear industry, as presented in Section 5.4 below.

5.2 Managerial implications

From a managerial viewpoint, by providing useful and applicable metrics based on empirical analysis, this paper can be used as a managerial tool to evaluate and improve the sustainability performance of the footwear industry so that it can fulfill the requirements of stakeholders regarding sustainable manufacturing practices. In other words, footwear SMEs can use the metrics provided in this paper to measure and manage their sustainability performance and meet stakeholder requirements. As stakeholders seek to play a key role toward achieving sustainable manufacturing, managers should also play an important role in improving the sustainability performance of their company and being transparent about the sustainability practices of their company with the stakeholders. In doing so, SMEs can built a high level of trust with the stakeholders, improve company image and enhance their competitiveness to stay relevant in today's market (where sustainability is one of the key market drivers). Therefore, successful implementation of the results of this paper can benefit SMEs in terms of building trust with stakeholders, improving corporate image and enhancing market competitiveness. Furthermore, the results of this paper can help SMEs to assess their contribution toward achieving the sustainable development goals in terms of promoting the well-being of stakeholders, promoting sustainable economic growth, creating productive employment and decent work and ensuring sustainable consumption and production.

5.3 Policy implications

This paper also has policy implications, which will be useful for the successful implementation of policies related to industrial sustainability. It addresses performance measurement and management issues of economic, environmental and social sustainability that can affect policies such as environmental policy, socio-economic and social responsibility. Hence, the results of this paper will be useful to policymakers involved in the implementation of policies related to industrial sustainability. More specifically, for the effective implementation of policies related to sustainable manufacturing, the sustainability performance of manufacturing companies needs to be measured and communicated to stakeholders (including policymakers) so that they can monitor and support the implementation. For this purpose, a suitable set of sustainability metrics is required. In this regard, the metrics identified in this paper can help policymakers to assess and monitor the contribution of the footwear industry (footwear SMEs in particular) toward achieving the sustainable development goals such as good health and well-being, decent work and economic growth, and responsible consumption and production.

5.4 Limitations and avenues for future research

By providing a set of empirically supported metrics in the context of SMEs, this paper contributes to the existing knowledge in the field of industrial sustainability performance measurement. However, it is subjected to the following limitations, which open opportunities for future research. Some of the limitations are due to the COVID-19 pandemic that has hit the world and made it impossible to engage SMEs in research activities and have direct contact with them for months.

(1) Due to the limited number of footwear SMEs participating in this study, statistical analysis was not carried out. Therefore, it would be interesting for future research to perform statistical analysis by involving a larger number of SMEs.

(2) The scope of this study was limited to the firm level. However, it would be helpful to look at additional metrics that could be used to measure sustainability performance at the supply chain level for a more holistic view of sustainable manufacturing. Hence, it would be useful for future research to extend the scope to the entire supply chain in the supply, production, distribution, use and post-use stages.

(3) This paper focuses on economic, environmental and social metrics. However, it would also be interesting for future research to consider governance metrics.

(4) In addition to Italian footwear firms, it would also be useful for future research to conduct a comparative analysis by looking at footwear companies from different countries (e.g. European countries) to assess the similarities and differences in the metrics from a geographical or national diversity perspective.

References

Ahi, P. and Searcy, C. (2015), "An analysis of metrics used to measure performance in green and sustainable supply chains", *Journal of Cleaner Production*, Vol. 86, pp. 360-377, doi: 10.1016/j.jclepro.2014.08.005.

Ahmad, S. and Wong, K.Y. (2019), "Development of weighted triple-bottom line sustainability indicators for the Malaysian food manufacturing industry using the Delphi method", *Journal of Cleaner Production*, Vol. 229, pp. 1167-1182, doi: 10.1016/j.jclepro.2019.04.399.

Ahmad, S., Wong, K.Y. and Rajoo, S. (2019a), "Sustainability indicators for manufacturing sectors: a literature survey and maturity analysis from the triple-bottom line perspective", *Journal of Manufacturing Technology Management*, Vol. 30, pp. 312-334, doi: 10.1108/JMTM-03-2018-0091.

Ahmad, S., Wong, K.Y. and Zaman, B. (2019b), "A comprehensive and integrated stochastic-fuzzy method for sustainability assessment in the Malaysian food manufacturing industry", *Sustainability*, Vol. 11, p. 948, doi: 10.3390/su11040948.

Assocalzaturifici (2020), *The Italian Footwear Industry - 2019 Preliminary Results*, Confindustria Moda Research Centre, Milan.

Beekaroo, D., Callychurn, D.S. and Hurreeram, D.K. (2019), "Developing a sustainability index for Mauritian manufacturing companies", *Ecological Indicators*, Vol. 96, pp. 250-257, doi: 10.1016/j.ecolind.2018.09.003.

Belas, J., Strnad, Z., Gavurová, B., Cepel, M. and Bilan, Y. (2019), "Business environment quality factors research - SME MANAGEMENT'S platform", *Polish Journal of Management Studies*, Vol. 20, pp. 64-75, doi: 10.17512/pjms.2019.20.1.06.

Cagno, E., Neri, A., Howard, M., Brenna, G. and Trianni, A. (2019), "Industrial sustainability performance measurement systems: a novel framework", *Journal of Cleaner Production*, Vol. 230, pp. 1354-1375, doi: 10.1016/j.jclepro.2019.05.021.

Choi, S. and Lee, J.Y. (2017), "Development of a framework for the integration and management of sustainability for small- and medium-sized enterprises", *International Journal of Computer Integrated Manufacturing*, Vol. 30 No. 11, pp. 1190-1202, doi: 10.1080/0951192X.2017.1305506.

de Brito, M.P., Carbone, V. and Blanquart, C.M. (2008), "Towards a sustainable fashion retail supply chain in Europe: organisation and performance", *International Journal of Production Economics*, Vol. 114 No. 2, pp. 534-553, doi: 10.1016/j.ijpe.2007.06.012.

Demartini, M., Pinna, C., Aliakbarian, B., Tonelli, F. and Terzi, S. (2018), "Soft drink supply chain sustainability: a case based approach to identify and explain best practices and key performance indicators", *Sustainability*, Vol. 10 No. 10, p. 3540, doi: 10.3390/su10103540.

Deselnicu, V., Crudu, M., Zăinescu, G., Albu, M.G., Deselnicu, D.C., Guţă, S.A., Ioannidis, I., Gurău, D., Alexandrescu, L., Constantinescu, R.R., Chirilă, C., Macovescu, G. and Bostaca, G. (2014), "Innovative materials and technologies for sustainable production in leather and footwear sector", *Leather and Footwear Journal*, Vol. 14 No. 3, pp. 147-158, doi: 10.24264/lfj.14.3.2.

Eastwood, M.D. and Haapala, K.R. (2015), "A unit process model based methodology to assist product sustainability assessment during design for manufacturing", *Journal of Cleaner Production*, Vol. 108, pp. 54-64, doi: 10.1016/j.jclepro.2015.08.105.

Elkington, J. (1997), *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*, Capstone, Oxford.

Galal, N.M. and Moneim, A.F.A. (2015), "A mathematical programming approach to the optimal sustainable product mix for the process industry", *Sustainability*, Vol. 7 No. 10, pp. 13085-13103, doi: 10.3390/su71013085.

Ghadimi, P., Azadnia, A.H., Mohd Yusof, N. and Mat Saman, M.Z. (2012), "A weighted fuzzy approach for product sustainability assessment: a case study in automotive industry", *Journal of Cleaner Production*, Vol. 33, pp. 10-21, doi: 10.1016/j.jclepro.2012.05.010.

GRI (2016), "GRI sustainability reporting standards (GRI standards)", Amsterdam.

Haapala, K.R., Zhao, F., Camelio, J., Sutherland, J.W., Skerlos, S.J., Dornfeld, D.A., Jawahir, I.S., Clarens, A.F. and Rickli, J.L. (2013), "A review of engineering research in sustainable manufacturing", *Journal of Manufacturing Science and Engineering-Transactions of the Asme*, Vol. 135 No. 4, 041013, doi: 10.1115/1.4024040.

Hapuwatte, B.M. and Jawahir, I.S. (2021), "Closed-loop sustainable product design for circular economy", *Journal of Industrial Ecology*, Vol. 25 No. 6, pp. 1430-1446, doi: 10.1111/jiec.13154.

Hapuwatte, B.M., Seevers, K.D. and Jawahir, I.S. (2022), "Metrics-based dynamic product sustainability performance evaluation for advancing the circular economy", *Journal of Manufacturing Systems*, Vol. 64, pp. 275-287, doi: 10.1016/j.jmsy.2022.06.013.

Hsu, C.H., Chang, A.Y. and Luo, W. (2017), "Identifying key performance factors for sustainability development of SMEs – integrating QFD and fuzzy MADM methods", *Journal of Cleaner Production*, Vol. 161, pp. 629-645, doi: 10.1016/j.jclepro.2017.05.063.

Huang, A. and Badurdeen, F. (2018), "Metrics-based approach to evaluate sustainable manufacturing performance at the production line and plant levels", *Journal of Cleaner Production*, Vol. 192, pp. 462-476, doi: 10.1016/j.jclepro.2018.04.234.

Jamil, N., Gholami, H., Saman, M.Z.M., Streimikiene, D., Sharif, S. and Zakuan, N. (2020), "DMAIC-based approach to sustainable value stream mapping: towards a sustainable manufacturing system", *Economic Research-Ekonomska Istraživanja*, Vol. 33 No. 1, pp. 331-360, doi: 10.1080/1331677X.2020.1715236.

Journeault, M., Perron, A. and Vallières, L. (2021), "The collaborative roles of stakeholders in supporting the adoption of sustainability in SMEs", *Journal of Environmental Management*, Vol. 287, 112349, doi: 10.1016/j.jenvman.2021.112349.

Kassem, E. and Trenz, O. (2020), "Automated sustainability assessment system for small and medium enterprises reporting", *Sustainability*, Vol. 12 No. 14, p. 5687, doi: 10.3390/su12145687.

Lacasa, E., Santolaya, J.L. and Biedermann, A. (2016), "Obtaining sustainable production from the product design analysis", *Journal of Cleaner Production*, Vol. 139, pp. 706-716, doi: 10.1016/j.jclepro.2016.08.078.

Lopes de Sousa Jabbour, A.B., Ndubisi, N.O. and Roman Pais Seles, B.M. (2020), "Sustainable development in Asian manufacturing SMEs: progress and directions", *International Journal of Production Economics*, Vol. 225, 107567, doi: 10.1016/j.ijpe.2019.107567.

Mengistu, A.T. and Panizzolo, R. (2021), "Indicators and framework for measuring industrial sustainability in Italian footwear small and medium enterprises", *Sustainability*, Vol. 13 No. 10, p. 5472, doi: 10.3390/su13105472.

Mitchell, S., O'Dowd, P. and Dimache, A. (2020), "Manufacturing SMEs doing it for themselves: developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs", *International Journal of Sustainable Engineering*, Vol. 13 No. 3, pp. 159-170, doi: 10.1080/19397038.2019.1685609.

Murad, M.D.Q., Sales, W.F. and Feraressi, V.A. (2021), "Metric-based approach to assess sustainable manufacturing performance at manufacturing process levels", *International Journal of Sustainable Engineering*, Vol. 14 No. 6, pp. 1342-1352, doi: 10.1080/19397038.2021.1978588.

Neri, A., Cagno, E., Di Sebastiano, G. and Trianni, A. (2018), "Industrial sustainability: modelling drivers and mechanisms with barriers", *Journal of Cleaner Production*, Vol. 194, pp. 452-472, doi: 10.1016/j.jclepro.2018.05.140.

Ocampo, L.A., Clark, E.E. and Promentilla, M.A.B. (2016), "Computing sustainable manufacturing index with fuzzy analytic hierarchy process", *International Journal of Sustainable Engineering*, Vol. 9 No. 5, pp. 305-314, doi: 10.1080/19397038.2016.1144828.

Paramanathan, S., Farrukh, C., Phaal, R. and Probert, D. (2004), "Implementing industrial sustainability: the research issues in technology management", *R&D Management*, Vol. 34 No. 5, pp. 527-537, doi: 10.1111/j.1467-9310.2004.00360.x.

Poh, K.L. and Liang, Y. (2017), "Multiple-criteria decision support for a sustainable supply chain: applications to the fashion industry", *Informatics*, Vol. 4 No. 4, p. 36, doi: 10.3390/informatics4040036.

Sajan, M.P., Shalij, P.R., Ramesh, A. and Biju, A.P. (2017), "Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance", *Journal of Manufacturing Technology Management*, Vol. 28 No. 6, pp. 772-793, doi: 10.1108/JMTM-12-2016-0188.

Samuel, V.B., Agamuthu, P. and Hashim, M.A. (2013), "Indicators for assessment of sustainable production: a case study of the petrochemical industry in Malaysia", *Ecological Indicators*, Vol. 24, pp. 392-402, doi: 10.1016/j.ecolind.2012.07.017.

Sartal, A., Bellas, R., Mejías, A.M. and García-Collado, A. (2020), "The sustainable manufacturing concept, evolution and opportunities within Industry 4.0: a literature review", *Advances in Mechanical Engineering*, Vol. 12 No. 5, pp. 1-17, doi: 10.1177/1687814020925232.

Scott, A.J. (2006), "The changing global geography of low-technology, labor-intensive industry: clothing, footwear, and furniture", *World Development*, Vol. 34 No. 9, pp. 1517-1536, doi: 10.1016/j.worlddev.2006.01.003.

Sellitto, M.A. and Almeida, F.A.D. (2019), "Strategies for value recovery from industrial waste: case studies of six industries from Brazil", *Benchmarking: An International Journal*, Vol. 27 No. 2, pp. 867-885, doi: 10.1108/BIJ-03-2019-0138.

Shuaib, M., Seevers, D., Zhang, X., Badurdeen, F., Rouch, K.E. and Jawahir, I.S. (2014), "Product sustainability index (ProdSI): a metrics-based framework to evaluate the total life cycle sustainability of manufactured products", *Journal of Industrial Ecology*, Vol. 18 No. 4, pp. 491-507, doi: 10.1111/jiec.12179.

Singh, S., Olugu, E.U. and Fallahpour, A. (2014), "Fuzzy-based sustainable manufacturing assessment model for SMEs", *Clean Technologies and Environmental Policy*, Vol. 16 No. 5, pp. 847-860, doi: 10.1007/s10098-013-0676-5.

Song, Z. and Moon, Y. (2019), "Sustainability metrics for assessing manufacturing systems: a distance-to-target methodology", *Environment, Development and Sustainability*, Vol. 21 No. 6, pp. 2811-2834, doi: 10.1007/s10668-018-0162-7.

Staikos, T. and Rahimifard, S. (2007), "An end-of-life decision support tool for product recovery considerations in the footwear industry", *International Journal of Computer Integrated Manufacturing*, Vol. 20 No. 6, pp. 602-615, doi: 10.1080/09511920701416549.

Subic, A., Shabani, B., Hedayati, M. and Crossin, E. (2012), "Capability framework for sustainable manufacturing of sports apparel and footwear", *Sustainability*, Vol. 4 No. 9, pp. 2127-2145, doi: 10.3390/su4092127.

Subic, A., Shabani, B., Hedayati, M. and Crossin, E. (2013), "Performance analysis of the capability assessment tool for sustainable manufacturing", *Sustainability (Switzerland)*, Vol. 5 No. 8, pp. 3543-3561, doi: 10.3390/su5083543.

Tebaldi, L., Brun, A. and Bottani, E. (2022), "Evidences on sustainability issues in the Fashion Supply Chain: an empirical study in Italy", *Sustainable Production and Consumption*, Vol. 33, pp. 651-663, doi: 10.1016/j.spc.2022.07.032.

Tonelli, F., Evans, S. and Taticchi, P. (2013), "Industrial Sustainability: challenges, perspectives, actions", *International Journal of Business Innovation Research*, Vol. 7 No. 2, pp. 1751-0252, doi: 10.1504/IJBIR.2013.052576.

Trianni, A., Cagno, E. and Neri, A. (2017), "Modelling barriers to the adoption of industrial sustainability measures", *Journal of Cleaner Production*, Vol. 168, pp. 1482-1504, doi: 10.1016/j.jclepro.2017.07.244.

Trianni, A., Cagno, E., Neri, A. and Howard, M. (2019), "Measuring industrial sustainability performance: empirical evidence from Italian and German manufacturing small and medium enterprises", *Journal of Cleaner Production*, Vol. 229, pp. 1355-1376, doi: 10.1016/j.jclepro.2019.05.076.

Tseng, M.L., Divinagracia, L. and Divinagracia, R. (2009), "Evaluating firm's sustainable production indicators in uncertainty", *Computers and Industrial Engineering*, Vol. 57 No. 4, pp. 1393-1403, doi: 10.1016/j.cie.2009.07.009.

Turker, D. and Altuntas, C. (2014), "Sustainable supply chain management in the fast fashion industry: an analysis of corporate reports", *European Management Journal*, Vol. 32 No. 5, pp. 837-849, doi: 10.1016/j.emj.2014.02.001.

Veleva, V. and Ellenbecker, M. (2001), "Indicators of sustainable production: framework and methodology", *Journal of Cleaner Production*, Vol. 9 No. 6, pp. 519-549, doi: 10.1016/S0959-6526(01)00010-5.

Veleva, V., Bailey, J. and Jurczyk, N. (2001), "Using sustainable production indicators to measure progress in ISO 14001, EHS system and EPA achievement track", *Corporate Environmental Strategy*, Vol. 8 No. 4, pp. 326-338, doi: 10.1016/S1066-7938(01)00138-5.

Wang, C., Wang, L. and Dai, S. (2018), "An indicator approach to industrial sustainability assessment: the case of China's Capital Economic Circle", *Journal of Cleaner Production*, Vol. 194, pp. 473-482, doi: 10.1016/j.jclepro.2018.05.125.

Wang, H., Liu, H., Kim, S.J. and Kim, K.H. (2019), "Sustainable fashion index model and its implication", *Journal of Business Research*, Vol. 99, pp. 430-437, doi: 10.1016/j.jbusres.2017.12.027.

Watanabe, E.H., da Silva, R.M., Tsuzuki, M.S.G., Junqueira, F., dos Santos Filho, D.J. and Miyagi, P.E. (2016), "A framework to evaluate the performance of a new industrial business model", *IFAC-PapersOnLine*, Vol. 49 No. 31, pp. 61-66, doi: 10.1016/j.ifacol.2016.12.162.

Winroth, M., Almstrom, P. and Andersson, C. (2016), "Sustainable production indicators at factory level", *Journal of Manufacturing Technology Management*, Vol. 27 No. 6, pp. 842-873, doi: 10.1108/JMTM-04-2016-0054.

Zarte, M., Pechmann, A. and Nunes, I.L. (2019), "Indicator framework for sustainable production planning and controlling", *International Journal of Sustainable Engineering*, Vol. 12 No. 3, pp. 149-158, doi: 10.1080/19397038.2019.1566410.

Zeng, S.X., Liu, H.C., Tam, C.M. and Shao, Y.K. (2008), "Cluster analysis for studying industrial sustainability: an empirical study in Shanghai", *Journal of Cleaner Production*, Vol. 16 No. 10, pp. 1090-1097, doi: 10.1016/j.jclepro.2007.06.004.

Zhang, H., Veltri, A., Calvo-Amodio, J. and Haapala, K.R. (2021), "Making the business case for sustainable manufacturing in small and medium-sized manufacturing enterprises: a systems decision making approach", *Journal of Cleaner Production*, Vol. 287, 125038, doi: 10.1016/j.jclepro.2020.125038.

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