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Procedia CIRP 29 (2015) 132 – 137

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The 22nd CIRP conference on Life Cycle Engineering

A sustainability indicator framework for Singapore small and medium-sized manufacturing enterprises

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Abstract

Assessment of industrial sustainability is an important step towards converting the theoretical goal of sustainable development into practice. One category of sustainability assessment tools is indicators. Indicators are useful tool to summarise and condense complex data into meaningful information and track performance progress over time. This article identifies 40 most commonly used sustainability indicators for Singapore small and medium-sized manufacturing enterprises (SMEs) from four internationally-recognised indicator frameworks through a systematic indicator selection method. These indicators could potentially facilitate local SMEs to manage their manufacturing systems. To ensure appropriate categorisation of the indicators into the sub-categories, content of each sub-category is analysed and a concise definition of nine sustainability terms are put forward. This study has proposed a comprehensive indicator framework in the context of Singapore.

Keywords: Indicator framework; Manufacturing industry; Sustainability Assessment

1. Introduction

Today, sustainable development is a hot issue for nations, companies, and individuals. Since the term was first coined in 1987 by the Brundtland Commission, many researchers, governments and organisations around the world began to demonstrate efforts in translating the theoretical goal of sustainable development into practical usage. In particular, manufacturing companies are facing increasing pressure from government and customers to think beyond economic benefits and consider the environmental and social effects.

1.1 Importance of sustainability indicators

One common representation of sustainability is the "three pillars" concept which requires the reconciliation of environmental, economic and social demands. Attributable to the vague definition and lack of clear concept on sustainability, there exist diverse conceptualizations of sustainability and no apparent methods for its practical measurement [1]. Parris and Kates (2003) have reported more than 500 concepts for measuring sustainability [2]. Nonetheless, its unclear definition actually created room for interpretation of sustainability because ideas about sustainability could be discussed and improved upon over time and place [3]. This also resulted in numerous works on sustainability assessment [4-6]. Furthermore, it drives the development of more scientific and objective methodologies for sustainability assessment since how one defines sustainability largely determines how one goes about assessing it [7].

Indicators are one category of sustainability assessment tools and techniques [8]. Indicators are useful and important tool to track progress over time, identify problems for performance improvement, and identify considerations that may be overlooked from previous analysis [9]. Business success today is no longer measured only by financial or economy indicators. A more holistic measurement will be through sustainability indicators [10]. Sustainability indicators can better simplify, quantify, analyse and communicate information from the environmental, economic and social perspectives [11]. However, identifying a suitable set of sustainability indicators is one main challenge.

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering
doi:10.1016/j.procir.2015.01.028

1.2 Singapore small and medium-sized manufacturing enterprises

In Singapore, sustainability is becoming a business imperative. The Business Times has reported that Singapore Exchange (SGX) is pushing for more stringent sustainability standards among listed companies in Singapore, and will move to a "comply or explain" basis for reporting such standards [12]. With strict reinforcement going to be in place in Singapore, companies need to embrace the change to make their business sustainable. Local Small and Medium Enterprises (SMEs) are usually part of the supply chain for the listed companies, and hence are likely to be impacted by SGX regulation. In addition, an increase in green consumer's awareness and demand for environmental friendly products is shifting the manufacturing sector towards greener growth. With these pushing factors, there is a need for Singapore small and medium-sized manufacturing enterprises to fulfill their corporate social responsibility (CSR) and assess their sustainability.

There are at present 100,000 SMEs and they constitute 99% of all enterprises locally [13]. These SMEs contribute to nearly half of Singapore's Gross Domestic Product (GDP) by supporting the manufacturing sector [13]. Some structural weaknesses of local SMEs are tight labour market, insufficient use of technology as well as limited resources and time to implement complicated theoretical models.

It is acknowledged that there are many existing indicator frameworks available. However, the drawbacks are that they are either too complicated to be adopted by smaller companies or too high level for practical usage. Hence, a simple yet effective indicator framework that balances between comprehensiveness and manageability would be helpful to SMEs. This streamlined set of indicators serves to contextualize the indicators before local companies can consider adopting them and acts as a driver for local sustainability initiatives. These indicators should also be easy to adopt by Singapore SMEs.

This paper intends to construct a comprehensive, concise, and practical indicator framework for sustainability assessment of Singapore small and medium-sized manufacturing enterprises. The objectives are (1) to establish a systematic indicator selection method, (2) to identify a common set of sustainability indicators from existing indicator framework for Singapore manufacturing companies, and (3) to recommend an improved categorisation of indicators to address the different aspects of sustainability in a holistic manner. By establishing a set of common indicators, it can contribute to providing a coherent assessment framework and allow better local sustainability benchmarking [14].

2. Review of existing indicator frameworks

Joung et al. (2012) have identified 11 indicator sets that are publicly available [15]. These indicator sets are developed to measure sustainability in manufacturing processes. This paper selected four indicator frameworks from the 11 existing sets for further evaluation and analysis as listed in Table 1. The reasons for their selection are as follow. The Environmental Performance Index (EPI) 2014 has the most up-to-date framework. The OECD Sustainable Manufacturing Toolkit focuses on the environmental aspects of sustainable development for the SMEs. The Sustainable Manufacturing Indicator Repository (SMIR) has a detailed compilation of indicators from 14 indicator databases and covers all three dimensions of sustainability. The ISO 14031 provides guidance on the design of environmental performance evaluation and on identification and selection of indicators. These indicator frameworks are categorised into global, country, and product levels to indicate their different purposes and domains of applications [16].

The purpose is to evaluate each indicator framework in details to filter out and identify the commonly used sustainability indicators from all 405 indicators presented. A common set of indicators can prevent the sustainability assessment results from losing its local context. Moreover, it may drive local stakeholders' involvement in achieving their sustainability targets. From the examination of existing frameworks, it is observed that most works generally do not discuss their indicator selection method. Nonetheless, there is at least one relevant work by Fernandez-Sanchez and Rodriguez-Lopez (2010) to establish a method for identifying sustainability indicators in construction project management [17]. However, the proposed method is narrowly focused on urban planning and infrastructure projects.

Table 1. Summary of four existing indicator frameworks.

	Year	Level	Indicator sets	Organisation	No. of Indicators	Environment	Economic	Social
1	2014	Country	Environmental Performance Index (EPI)	Yale University	20	√		/
2	2011	Product	OECD Sustainable Manufacturing Toolkit	Organisation for Economic Cooperation and Development (OECD)	18	√		
3	2010	Global	Sustainable Manufacturing Indicator Repository (SMIR)	National Institute of Standards and Technology (NIST)	212	√	√	√
4	1999	Global	ISO 14031 Environmental management - Environmental performance evaluation - Guidelines	International Organization for Standardization (ISO)	155	√	√	√

√ : indicates comprehensive coverage.

/: indicates minimal coverage.

3. Methodology: selection of indicators

This section will discuss the criteria for screening of indicators, the method for indicator selection, as well as elements of an indicator.

3.1 Criteria for selection

The selected indicators, in general, should possess the following three criteria:

- *Understandable*: Indicators should be simple to understand, use, and implement by non-experts.
- *Applicable*: Indicators should be applicable to manufacturing industry and represent key concerns of local SMEs.
- *Relevant*: Indicators should be directly relevant to continuous sustainability improvement.

3.2 Indicator selection method

Taking into account the literature review above and to design a set of common local indicators, a procedure is developed to provide a systematic approach for indicators identification and selection. This procedure is presented in Fig. 1. Irrelevant indicators are first eliminated based on the three criteria stated earlier. The elimination process is highly based on expert judgment from industry and academic to reduce uncertainties of the process. The intention for filtering is to identify the commonly used indicators and build on the work of previous groups and organisations rather than to "reinvent the wheel". A common set of local indicators can act as a driver for local sustainability initiatives and encourage local stakeholders' involvement in sustainability monitoring. The indicators selected are then combined and categorised into different dimensions and sub-categories through brainstorming. To ensure appropriate categorisation of the indicators into the sub-categories, content of each sub-category is analysed and improved definitions of the terms are proposed. Efforts are also made to gather industry inputs through interviews and discussions with industry collaborators. This feedback mechanism with the industry collaborators allows the selected indicators to evolve into a more applicable and relevant set of indicators for the industry. The classification approach and final set of selected indicators will be presented in the Results and Discussion section.

3.3 Elements of indicators

Ideally, indicators should be presented clearly and their usage should be intuitive. However, it is observed that majority of existing indicators in the four indicator frameworks are not clearly specified. For instance, while ISO 14031 is comprehensive, more details are required for practical applications of its indicators. To allow the indicators to be better understood and applied by industries and SMEs, effort is made to define the indicators in term of the following four elements (Fig. 2) adapted from [18]:

- *Quantification method* – the formula used to calculate an indicator, whether to use the total amount or per unit of product or any other factors to normalise the performance.
- *Unit of measurement* – the metric used to represent an indicator (e.g. kilograms, kilowatts, dollars, percent, days and etc).
- *Improvement goal* – the generic direction of improvement to achieve better sustainability performance.
- *Period of measurement* – the period for calculating an indicator (e.g. yearly, bi-yearly, monthly and etc).

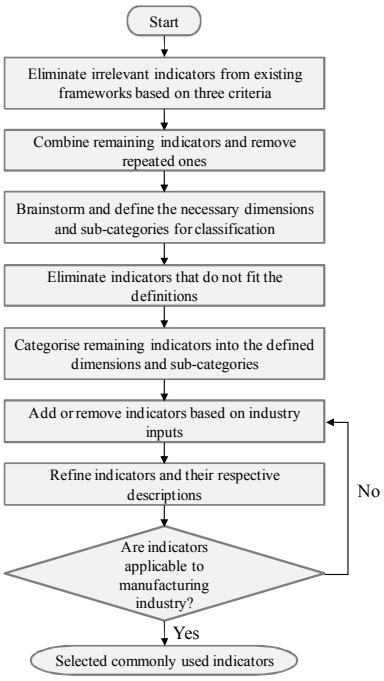

Fig. 1. A systematic indicator selection method.

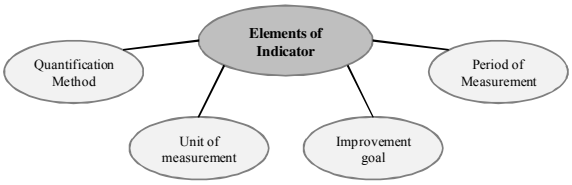

Fig. 2. Elements of an indicator.

4. Results and Discussion

4.1 Definition of Sustainability Terms

The recent growth of research on sustainable development has raised interest in sustainable development terminology. It is noted that various definitions of the same terms are employed by different authors in different scientific papers, textbooks, annual reports of companies, governmental policy usage, and media [19]. As a consequence, when the same term is utilised in different contexts, it may convey

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diverse meanings and cause confusion in its usage. In addition, majority of the terms are multiword units, and hence, their definitions are unavailable in dictionaries [19]. To clarify ambiguity and achieve common understanding, new definitions of terms are put forward. The proposed definitions took references from definitions stated by the National Institute of Standards and Technology (NIST) and from BusinessDictionary, an online business resource [20]. Nine terms are investigated. They represent the nine sub-categories used to categorise the indicators. First, the sub-categories are identified. Then, the content of their definitions are analysed. These definitions are then used to categorise the indicators into the various sub-categories. The sub-categories and their respective definitions are shown in Table 2.

Table 2. Proposed definitions of nine sustainability terms which represent the nine sub-categories.

No.	Definitions of sub-categories
1.	*Emission and Pollution*: The usage of harmful substances and discharge of matter (gas, liquid, solid) or energy (heat, noise, radiation) into the environment that may cause direct or indirect harm to the environment and population.
2.	*Resource consumption*: The usage of material, energy, and other tangible natural assets.
3.	*Financial performance*: The measure of an organisation's profitability, liquidity, efficiency, leverage, and investment potential.
4.	*Manufacturing cost*: A monetary valuation of material, energy, labour, equipment, maintenance, overhead, and all other related cost involved in production of goods and/or services.
5.	*Employee*: The measure of the employee's welfare, equity, workplace health and safety, labour productivity, as well as training and development.
6.	*Customer*: The measure of the customer's satisfaction towards an organisation's goods and/or services.
7.	*Community*: The measure of an organisation's responsibility towards the community.
8.	*Conformance*: The way an organisation adheres to the conduct to meet the requirements of legislation, accepted practices, prescribed rules and regulations, specified standards, or terms of a contract.
9.	*Programme and Policy*: Plans of actions, sets of basic principles, and associated guidelines to accomplish a clear sustainability objective.

4.2 Indicator framework for Singapore manufacturing industry

40 sustainability indicators are identified for Singapore small and medium-sized manufacturing enterprises using the indicator selection method. 37 indicators are chosen from the existing 405 indicators presented in selected frameworks through several rounds of intensive brainstorming. Three new indicators are added. The goal is not to "reinvent the wheel" but to identify the commonly used indicators by drawing on previous research works. The indicators are then organised into four dimensions and nine sub-categories (Fig. 3). The four dimensions are: environmental protection, economic growth, social well-being, and performance management. Performance management is an additional "pillar" to traditional sustainability to measure a company's performance with regard to sustainability. This dimension is necessary to emphasize the importance of management involvement. Under the dimensions, there are nine sub-categories. They are: emission and pollution, resource consumption, financial performance, manufacturing cost, employee, customer, community, conformance, as well as programme and policy. Within the indicator framework, 17 indicators belong to the environmental protection dimension, seven to the economic growth dimension, 10 to the social well-being dimension, and six to the performance management dimension. Each indicator is specified by the quantification method, unit of measurement, improvement goal, and period of measurement as presented in Table 3. The indicator categorisation approach is largely based on NIST's indicator categorisation structure with modification to adapt to local context [15]. Modifications from NIST include enhanced category classification, elimination of irrelevant indicators, and addition of new indicators.

Table 3. Summary of 40 sustainability indicators.

No.	Dimension	Sub-category	Indicator	Unit	Suggested Quantification Method (Yearly)	Goal[1]
1.	1 - Environmental Protection	1.1 - Emission and pollution	1.1.1 - Greenhouse gas emissions	$kgCO_2e$	Mass of CO_2 equivalents emitted [21]	↓
2.			1.1.2 - Waste water discharged	m^3	Volume of waste water discharged	↓
3.			1.1.3 - Solid waste produced	kg	Mass of solid waste produced for disposal by landfill, incineration, and/or non-recycling	↓
4.			1.1.4 - Waste energy emission	kWh	Any form of energy (heat, vibration, etc.) that is emitted by an organisation to air and/or water	↓
5.		1.2 - Resource Consumption	1.2.1 – Reused/recycled materials used in products	$\frac{kg}{Unit}$	$\frac{\text{Mass of reused/recycled materials used}}{\text{Unit of product}}$	↑
6.			1.2.2 - Packaging materials discarded	$\frac{kg}{Unit}$	$\frac{\text{Mass of packaging materials discarded}}{\text{Unit of product}}$	↓
7.			1.2.3 - Packaging materials reused	$\frac{kg}{Unit}$	$\frac{\text{Mass of packaging materials reused}}{\text{Unit of product}}$	↑

[1] ↑ indicates improvement with higher indicator value. ↓ indicates improvement with higher indicator value.
* indicates newly added indicators.

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No.	Dimension	Sub-category	Indicator	Unit	Suggested Quantification Method (Yearly)	Goal[1]
8.			1.2.4 – Materials saved from implemented initiatives*	$\frac{kg}{kg}=1$	$\frac{\text{Mass of materials saved}}{\text{Total mass of initial material used}}$	↑
9.			1.2.5 - Total energy consumption	kWh	Total energy consumed that is directly attributable to the manufacturing process	↓
10.			1.2.6 - Energy intensity	$\frac{kWh}{Unit}$	$\frac{\text{Energy consumed}}{\text{Unit of product}}$	↓
11.			1.2.7 - Energy saved from implemented initiatives	$\frac{kWh}{kWh}=1$	$\frac{\text{Energy saved}}{\text{Total initial energy consumed}}$	↑
12.			1.2.8 - Energy generated from by-products	kWh	Total energy generated from by-product or process streams	↑
13.			1.2.9 - Energy efficiency*	$\frac{kWh}{S\$}$	$\frac{\text{Total energy consumed}}{\text{Value of product sold}}$	↓
14.			1.2.10 - Water intensity	$\frac{m^3}{Unit}$	$\frac{\text{Volume of water consumed}}{\text{Unit of product}}$	↓
15.			1.2.11 - Water reused	m^3	Total volume of water reused	↑
16.			1.2.12 - Vehicle fuel consumption saved from implemented initiatives	$\frac{L}{L}=1$	$\frac{\text{Litres of fuel saved}}{\text{Total initial litres of fuel used}}$	↑
17.			1.2.13 - Percent of defective products	%	$\frac{\text{Number of defective products}}{\text{Total number of products}}\times 100\%$	↓
18.	2 - Economic Growth	2.1 - Financial Performance	2.1.1 - Net profit margin	$\frac{S\$}{S\$}=1$	$\frac{\text{Net income}}{\text{Total revenue}}$	↑
19.			2.1.2 - Return on investment	$\frac{S\$}{S\$}=1$	$\frac{\text{Gain from investment - cost of investment}}{\text{Cost of investment}}$	↑
20.			2.1.3 - Costs saved	S$	Total monetary savings achieved through implemented initiatives	↑
21.		2.2 - Manufacturing cost	2.2.1 - Material costs	S$	Costs of acquiring materials (including water and packaging) used within manufacturing process	↓
22.			2.2.2 - Energy costs	S$	Costs of energy used in production process	↓
23.			2.2.3 - Labour costs	S$	Costs of labour used during manufacturing process	↓
24.			2.2.4 - Operational and capital costs	S$	Costs of operation and capital used during manufacturing process	↓
25.	3 - Social Well-being	3.1 - Employee	3.1.1 - Lost workdays	Days	Number of missed workdays due to accidents.	↓
26.			3.1.2 - Employee attrition rate	$\frac{1}{1}=1$	$\frac{\text{Total number of employees leaving}}{\text{Total number of employees employed}}$	↓
27.			3.1.3 - Personal protective and safety equipment	1	Number and type of provided gears and facilities available to employees and mandated by organisations procedures	↑
28.			3.1.4 - Line stops due to safety concerns	%	$\frac{\text{Number of lines stop}}{\text{Total number of lines}}\times 100\%$	↓
29.			3.1.5 - Labour productivity	$\frac{S\$}{S\$}=1$	$\frac{\text{Total revenue}}{\text{Total labour costs}}$	↑
30.			3.1.6 - Average hours of sustainability training	Hours	Average hours of sustainability training per employee	↑
31.			3.1.7 - Employee trained in sustainability	%	$\frac{\text{Employees trained in sustainabi lity}}{\text{Total number of employees}}\times 100\%$	↑
32.		3.2 - Customer	3.2.1 - Customer complaints	1	Total number of customer complaints related to sustainability performance	↓
33.		3.3 - Community	3.3.1 - Sustainability reports publishing	1	Total number of published assessments and reports and % of completion of these sustainability assessments.	↑
34.			3.3.2 - Sustainability awards*	1	Total number of received awards for an organisation's sustainability achievement	↑
35.	4 - Performance Management	4.1 - Conformance	4.1.1 - Environmental fines and penalties	S$	Total costs of environmental fines attributed to an organisation's performance in regards to environmental laws and regulations	↓
36.			4.1.2 - Environmentally certified service providers	%	$\frac{\text{Number of providers with EMS}}{\text{Total number of providers}}\times 100\%$	↑
37.		4.2 - Programme and Policy	4.2.1 - Sustainability initiatives	1	Total number of sustainability initiatives implemented	↑
38.			4.2.2 - Achieved objectives	%	$\frac{\text{Number of achieved objectives}}{\text{Total number of set objectives}}\times 100\%$	↑

No.	Dimension	Sub-category	Indicator	Unit	Suggested Quantification Method (Yearly)	Goal[1]
39.			4.2.3 - Innovation & R/D investments	S$	Total amount of R&D investments for sustainability efforts	↑
40.			4.2.4 - Employee environmental suggestions	1	Total number of employees' suggestions regarding sustainability improvements	↑

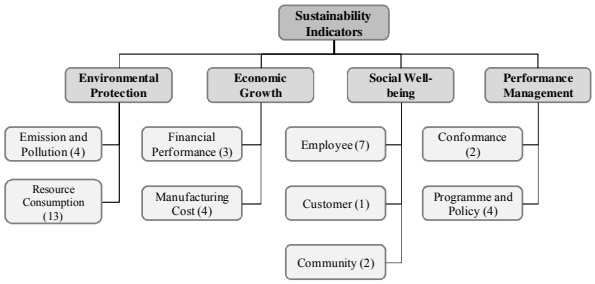

Fig. 3. Overview of indicator categorisation approach.

5. Conclusions and future work

This article identifies 40 sustainability indicators for Singapore small and medium-sized manufacturing enterprises from four internationally-recognised indicator frameworks through a systematic indicator selection method. The indicators are filtered from 405 indicators used in existing indicator frameworks. There are also three newly added indicators. Each indicator is specified by its quantification method, unit of measurement, improvement goal, as well as period of measurement, which are subject to customisation where necessary. Subsequently, the 40 indicators were organised into four dimensions and nine sub-categories to address the four aspects of sustainability in a holistic manner. Performance management is an additional dimension to traditional sustainability to emphasize the importance of management involvement. To ensure appropriate categorisation of the indicators into the sub-categories, content of each sub-category is analysed and improved definition of nine selected sustainability terms are proposed. Since some indicators may be more important to certain industries than others, companies need to further prioritise the 40 indicators based on industries' requirements. Herewith, these indicators could potentially facilitate local SMEs to manage their manufacturing systems. The contribution of current study is a concise and practical indicator framework for Singapore manufacturing SMEs.

The future works will include streamlining the 40 indicators for each industry, implementing the indicators on selected SMEs through case studies and developing an overall sustainability index. This will enhance the validity and applicability of the indicators for SMEs who wish to do internal improvement and external benchmarking. This conceptual indicator framework may provide a baseline for coordination of Singapore sustainability assessment effort.

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