SUSTAINABLE-ERP SYSTEM: A PRELIMINARY STUDY ON SUSTAINABILITY INDICATORS

M.S. Hasan[*1], Z. Ebrahim[2], W.H. Wan Mahmood[3] and M.N. Ab Rahman[4]

Sustainable and Responsive Manufacturing Research Group
[1,2]Faculty of Manufacturing Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia

[3]Faculty of Engineering Technology,
Universiti Teknikal Malaysia Melaka, Technology Campus,
75450 Hang Tuah Jaya, Melaka, Malaysia

[4]Advanced Manufacturing Research Group,
Faculty of Engineering and Built Environment,
Universiti Kebangsaan Malaysia, UKM Bangi,
43600, Selangor, Malaysia

Email: [*1]syahidhasan@gmail.com

ABSTRACT: The purpose of this paper was to identify the indicators for sustainability performance that were integrated into the Enterprise Resource Planning (ERP) system. It is crucial for a manufacturing company to embed the sustainability elements into their performance indicators in order to be sustainable in the economic, social, and environment dimensions. In this study, a set of criteria has been used to explore the sustainability indicators through a thorough literature study of related sustainability issues discussed in Scopus Index journals from year 2007 until 2016. In this regard, the indicators were clustered based on their respective sustainability dimensions (i.e. economy, social, and environment). Pareto charts were developed for the analysis process. The most frequent sustainability indicators can be determined based on Pareto 80-20 rule. Results of the analysis showed that from an initial 63 sustainability indicators, 32 indicators were listed as highly influential sustainability indicators. The findings of this study provide an early insight for researchers and industrial practitioners in selecting the most significant sustainability indicators to be integrated into their ERP system.

KEYWORDS: *Enterprise resource planning, sustainable manufacturing, indicators, sustainable performance measure*

1.0 INTRODUCTION

As world population growth increases, the demand for sustainable development has also increased. In the Brundtland report [1], sustainable development is defined as a development that meets current generation's needs without jeopardizing the ability of future generations to meet their needs. The growing concerns in sustainable development has put manufacturers under pressure and challenged them not only to evaluate their operations' impacts on environment but also to engage the triple bottom line reporting [2]. The triple bottom line approach proposed that alongside economic performance, organizations also need to engage in both social and environmental performance and by balancing all three elements, companies can sustain their profitability and existence for a long term [3]. Many initiatives have been undertaken such as deploying Life Cycle Assessment (LCA) to evaluate possible environmental impact, designing for X including design for sustainability to emphasize the concern on sustainability at the early stage of product development, adopting cleaner production (CP) as environmental prevention strategy [4], and also developing tools or system to measure sustainability performance.

In developing tools or system to measure sustainability performance, reliable and accurate indicators are essential. Thus, the real challenge in this study is to develop an integrated system between sustainability and Enterprise Resource Planning (ERP) system in order to provide a holistic performance indicator towards sustainable business operations. Chofreh et al. [3] proposed the integration of sustainability elements into enterprise resource planning (ERP) system to solve the problem of lack of integration among sustainable business functions. The concept of sustainable-ERP (S-ERP) system is claimed as a holistic and integrative information system that is driven by sustainability concern that covers all aspects of the value chain. However, research in S-ERP system is still in the introduction stage, which means a lot of study in this area can be carried out. The objective of this paper was to determine the most frequent sustainability indicators discussed in the academic literature that could later be integrated into ERP system.

2.0 RESEARCH METHOD

In this paper, a literature review on sustainability indicators for manufacturing operation was carried out in two stages. In the first stage, collection of relevant articles about sustainability indicators was done based on following criteria; (i) The selection of articles was limited to Scopus indexed journals or proceedings that have been published from year 2007 until year 2016, and (ii) the scope of literature focused on sustainability indicators in manufacturing operation (internal operation). In this regard, two sets of keywords were used to perform the literature browsing. The first set of keyword contains "sustainability evaluation", "sustainability performance", "sustainability indicators" and "key performance indicators for sustainability". The second set of keywords contains "sustainable", "manufacturing", and "indicators" keywords. These criteria were set as it is important to set the scope of research in order to give an overview of its extent and boundary [5]. All related articles found based on the stated criteria were selected carefully in order to ensure the knowledge discovered is accurate and rigorous [6]. In the second stage, all selected articles from the first stage were reviewed and analyzed. Pareto charts were developed to determine the indicators that had been frequently discussed in the academic literature. Then, the most frequent sustainability indicators were determined using Pareto 80-20 rule.

3.0 SUSTAINABILITY INDICATORS

Developing indicators for sustainability evaluation is important [7] as it is an absolute measuring tools that can be used by government, manufacturers, or consumers to evaluate not only their environmental performance but also both social and economic performance. Currently, a number of indicators can be found in current literature such as Global report initiative (GRI), Dow Jones sustainability indexes (DJSI), Organization for Economic Co-operation and Development (OECD) core environmental indicators, Eco-Indicators 99, and United Nations Commission on Sustainable Development (UNCSD) as indicators for sustainable development. All of the mentioned indicators are discussed by Feng and Joung [8] in their work.

Choosing suitable indicators for evaluation purpose is a complex and vital challenge for everyone [9]. There are risks of choosing incorrect, misused, or misinterpreted indicators which may lead to misleading decisions. In addition, all existing indicators cannot simply be applied to every sector as it is very difficult to regulate which indicators to be deployed as some indicators might be effective and some indicators might not [10]. To some extent, in order to select proper indicators for sustainability evaluation, it is essential to closely perform the indicators selection process together with respective industries. Despite the complexity in selecting proper and suitable sustainable indicators, there are guidelines for characteristic of indicators from previous studies [10–12] that can be used to assist the indicators selection process.

Table 1 shows the characteristic for sustainability indicators together with their descriptions. In total, 23 academic articles were analyzed which fulfilled the criteria for the scope of literature study. As a result from the literature study, 63 sustainability indicators were identified. From a total of 63 indicators, 21 of them represented economy performance indicators, 26 represented environment performance indicators and the remaining 16 represented social performance indicators.

Table 1: Characteristic for sustainability indicators

Characteristic	Description	[11]	[12]	[13]
Measurability	Indicator should be able to be measured either quantitatively or qualitatively. It should also be able to identify changes in the all three sustainable elements' performance.	•	•	•
Relevance	Indicator must be relevant and meaningful to sustainability evaluation purpose.	•	•	•
Clarity	Indicator must be clear, specific, and easy to understand without leading to misunderstanding.	•	•	•
Continuity	Indicator should be able to be continuously used in measuring current and future performance. Continuously used indicator should be able to track any changes that occurred to the sustainable performance.	•	•	
Efficient and effective	Indicator must be efficient and effective in evaluating sustainable performance by indicating the right technical and functional performance.	•		•
Accessible	Data or information which the indicators are constructed on should be easily retrieved within the business operation or the organization itself.		•	•
Integrity	Indicator should be able to cover all of the elements in sustainable performance evaluation which consists of social, environment, and economic performance.	•		
Reliable	Indicators must be used with trusted and accurate data or information from the organization or operation under evaluation process.		•	
Timely manner	Data or information used by the indicator should be able to be accessed in timely manner in order to have instructive decision making capability.		•	
Robustness	Indicator should be able to be used under any state of conditions.			•

Table 2 lists all the identified sustainability indicators with their designated codes. These codes were used to represent the indicators and to show which sustainability elements they represented. Further explanations on each code are shown in Table 2.

Table 2: Codes for sustainability indicators

Economy performance indicators	
Ief	Financial health
Iep	Performance
Ieq	Quality
Iec	Cost
Ief	Flexibility
Social performance indicators	
Isi	Internal human resources
Environment performance indicators	
Ina	Air resource
Inw	Water resource
Inl	Land resource
Inm	Mineral and material resource
Ine	Energy resource
Inwi	Waste and impact
Inc	Environmental commitment

Code definition:

Code	***Ie***	***f***	#
Definition	*Sustainability element*	*Element's sub-category*	*number*

According to the results (Table 3), 21 economy performance indicators were grouped into five sub-categories namely financial health, performance, quality, cost, and flexibility. Meanwhile, there was only one sub-category under social performance indicator which was internal human resources. On the other hand, 26 environment performance indicators were clustered into seven sub-categories including waste and impact, air resource, land resource, mineral and material resource, energy resource, water resource, and environmental commitment. Table 4 shows the articles that discuss the sustainability indicators accordingly.

Table 3: Sustainability indicators

Social performance indicators			
Internal human resources			
Isi1	Job opportunities	Isi9	Equity
Isi2	Employment compensation	Isi10	Diversity
Isi3	Quality of life	Isi11	Labor sources
Isi4	Turnover rate	Isi12	Health and safety practices
Isi5	Number of employee	Isi13	Health and safety incidents
Isi6	Labor productivity	Isi14	Risk working environment
Isi7	Disciplinary & security practices	Isi15	Career development / education
Isi8	Employee contracts	Isi16	Research and development

Economy performance indicators			
Financial health		**Performance**	
Ief1	Profit	Iep1	Productivity
Ief2	Liquidity	Iep2	Market share performance
Ief3	Margin	Iep3	Delivery
Ief4	Revenue / Turnover	**Quality**	
Ief5	Investment %	Ieq1	Quality
Ief6	R.O.I	Ieq2	Customer complaint
Ief7	R.O.E	Ieq3	Product reliability
Ief8	R.O.S	Ieq4	Product durability
Ief9	R.O.A	**Cost**	
Ief10	Cash flow	Iec1	Operating cost
Ief11	Debt	**Flexibility**	
Ief12	Cost saving	Ief1	Operation Flexibility
Environment performance indicators			
Air resource		**Energy resource**	
Ina1	Air emission	Ine1	Primary (fuel, etc.)
Ina2	Stratospheric ozone depletion	Ine2	Electricity
Water resource		Ine3	Renewable energy
Inw1	Water consumption	Ine4	Energy saved
Inw2	Refrigerant load	**Waste & Impact**	
Inw3	Discharge water / wastewater	Inwi1	Solid waste
Inw4	water pollution	Inwi2	Hazardous waste
Inw5	% of recycle water used	Inwi3	Toxic waste
		Inwi4	Energy waste
Land resource		Inwi5	Noise
Inl1	Land usage	Inwi6	% of defected product
Inl2	Soil pollution	**Environmental commitment**	
Inl3	Product innovativeness	Inc1	Green manufacturing
Mineral & material resource		Inc2	Carbon footprint
Inm1	material consumption	Inc3	6R concepts
Inm2	recycle input material	Inc4	Expenses in environment activity

Table 4: Rate of recurrence for sustainability indicators in previous literatures

Economy performance indicators			
Financial health		**Performance**	
Ief1	[14], [15], [12], [16], [17], [18], [19]	Iep1	[15], [20]
Ief2	[17]	Iep2	[19]
Ief3	[14]	Iep3	[21]
Ief4	[14], [17], [22]	**Quality**	
Ief5	[14], [10], [15], [12]	Ieq1	[21]
Ief6	[17], [18]	Ieq2	[10], [23], [21]
Ief7	[17]	Ieq3	[21]
Ief8	[17]	Ieq4	[21]
Ief9	[17], [24]	**Cost**	
Ief10	[17], [24]	Iec1	[23], [21], [15], [12], [16], [20], [25], [18], [22], [19], [26]
Ief11	[17], [22]	**Flexibility**	
Ief12	[18]	Ief1	[21]

Social performance indicators			
Internal human resources			
Isi1	[14], [27], [20], [28]	Isi9	[14], [27], [16], [17], [20]
Isi2	[14], [27], [21], [20], [28], [22], [26]	Isi10	[14], [10], [16]
Isi3	[14], [10], [15], [12], [20], [25]	Isi11	[14], [27], [20]
Isi4	[10], [21], [17], [18], [22], [19], [26]	Isi12	[27], [15], [12], [29], [20], [18], [19]
Isi5	[16], [22]	Isi13	[14], [27], [10], [16], [17], [25], [26]
Isi6	[18]	Isi14	[29]
Isi7	[14], [27], [26]	Isi15	[14], [27], [10], [21], [15], [12], [17], [20], [25], [22], [19]
Isi8	[27]	Isi16	[27], [28]
Environment performance indicators			
Waste & Impact		**Energy resource**	
Inwi1	[14], [10], [23], [21], [30], [15], [31], [17], [32], [18], [22], [19], [26]	Ine1	[10], [23], [21], [30], [15], [12], [33], [29], [34], [25], [32], [18], [22], [19]
Inwi2	[14], [10], [21], [31], [17], [20],	Ine2	[10], [23], [21], [30], [15], [31], [12], [17], [33], [29], [25], [32], [18], [22], [19], [26]
Inwi3	[14]	Ine3	[10], [31], [12], [17], [20]
Inwi4	[18]	Ine4	[10]
Inwi5	[14], [23], [32], [26]	**Water resource**	
Inwi6	[18]	Inw1	[14], [10], [23], [21], [15], [31], [12], [17], [33], [29], [34], [32], [18], [22], [19], [26]
Air resource		Inw2	[14], [15]
Ina1	[14], [10], [21], [15], [31], [12], [17], [33], [20], [34], [25], [18], [19], [26]	Inw3	[14], [10], [21], [34], [18], [22], [19]
Ina2	[34]	Inw4	[21], [20]
Land resource		Inw5	[10], [20]
Inl1	[15], [31], [12], [33], [20], [34], [22], [19]		
Inl2	[23], [21], [20], [34]	**Environmental commitment**	
Inl3	[34]	Inc1	[34]
Mineral & material resource		Inc2	[34]
Inm1	[14], [10], [15], [31], [12], [17], [29], [34], [25], [32], [22]	Inc3	[10], [20], [34], [32], [18]
Inm2	[10], [23], [31], [12], [17]	Inc4	[10], [23], [31], [22], [19]

Based on information gathered in Table 4, Pareto charts were developed and the analysis was done based on Pareto 80-20 rule. Figures 1, 2, and 3 illustrate the Pareto chart for sustainability indicators for three different aspects; (i) economic performance, (ii) social performance, and (iii) environmental performance respectively.

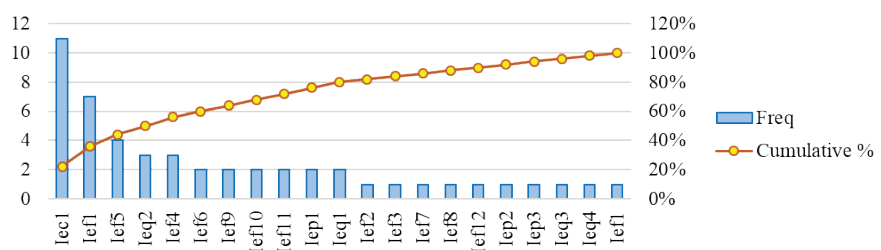

Figure 1: Pareto chart for economic performance indicators

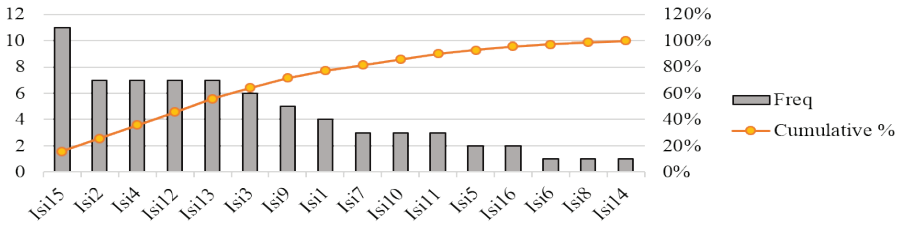

Figure 2: Pareto chart for social performance indicators

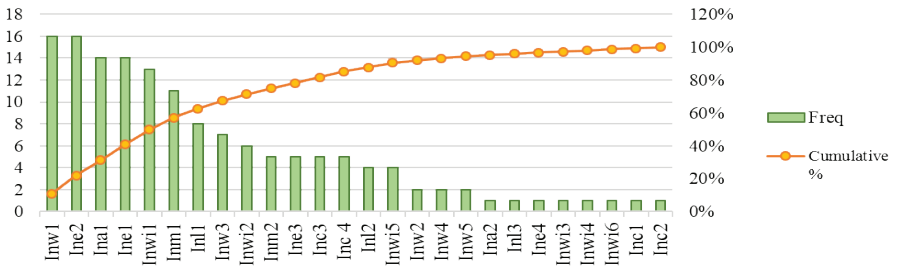

Figure 3: Pareto chart for environmental performance indicators

Among the 21 economy performance indicators, the most mentioned indicator (11 different articles) in literature was Iec1 (operating cost). Operating cost included all costs under manufacturing operation such as material cost, overhead cost, inventory cost, and others. Indicator Ief1 (profit) was the second most mentioned (seven articles). The third most mentioned economic performance indicator was Ief5 (investment percentage) (four different articles). It refers to the percentage of value that manufacturers invest their money in order to sustain their business operation such as investment in equipment, as well as investment in employee training and education. High percentage of investment indicates a good financial health of manufacturers. The fourth most mentioned indicators was Ieq2 (customer complaint) and Ief4 (turnover) which were both mentioned in three different articles. Next on the list were six indicators that were mentioned in two different articles each. These indicators include Ief6 (R.O.I), Ief9 (R.O.A), Ief10 (cash flow), Ief11 (debt), Iep1 (productivity), and Ieq1 (quality). All of these 11 indicators contributed to a total of 80% from the total frequency of economy performance indicators mentioned in literature. Thus, 11 from 21 indicators in this study can be considered as most influential indicators in evaluating economic performance for manufacturing operation.

Based on Figure 2, the first most mentioned indicator among the initial 16 social performance indicators was Isi5 (career development/education). Indicator Isi5 was mentioned in 11 different articles. Career development and education are important as they positively affect skill and knowledge development of employees. The second most mentioned indicator was Isi2 (employment compensation), Isi4 (turnover rate), Isi12 (health and safety practices), and Isi13 (health and safety incidents). All four indicators were stated in seven different articles each. Isi3 (quality of life) was the third most mentioned sustainability performance indicator as it was mentioned in six different articles. Next was Isi9 (equity) and Isi1 (job opportunities) which were stated in five and four different articles respectively. All aforementioned eight indicators contributed to a total of 77% from the total frequency of social performance indicators mentioned in literature. From Figure 2, the next indicators that contributed to the remaining 3% to make up a total of 80% could not be clearly specified as there were three indicators that shared the same number of mentions in literature where each of them was mentioned in three different articles and one of these three indicators could be included along with the eight aforementioned social performance indicators. These three indicators were Isi7 (disciplinary & security practices), Isi10 (diversity), and Isi11 (labor sources). In general, from 16 initial indicators, there were nine indicators that could be considered as highly influential indicators to be used to measure social sustainability based on their numbers of mentions in literature.

In Figure 3, Inw1 (water consumption) and Ine2 (electricity) were the first most mentioned indicator compared to other environmental performance indicators and the two indicators were mentioned in 16 different articles. The second most mentioned environment indicator were Ina1 (air emission) and Ine1 (primary energy), where each of them was mentioned in 14 different articles. On the other hand, Inwil1 (solid waste) was the third most mentioned environment indicator which was mentioned in 13 articles. It is then followed by Inm1 (material consumption) and Inl1 (land usage) which were mentioned in 11 and eight articles respectively. Mentioned by seven and six different articles, Inw3 (discharge water) and Inwi2 (hazardous waste) were next in the list respectively.

Another four environmental indicators werew Inm2 (recycle input material), Ine3 (renewable energy), Inc3 (6R concept), and Inc4 (expenses in environment activity). Each of these indicators was mentioned in five different articles. Yet, from these four indicators, selecting three of them was enough in order to meet the 80:20 rule. In short, from the initial 26 environment indicators, 12 indicators were shortlisted which made up 81% of the total frequency of environment al indicators mentioned in the last 10 years of academic literature.

4.0 CONCLUSION

In conclusion, the objective of this paper is to identify the indicators of sustainability performance that can be adopted as a part of the integration of sustainability elements into the ERP system. Through literature, 63 initial sustainability indicators are listed, where each of them is clustered to its respective sustainability performance dimensions namely economic performance indicators, social performance indicators, and environmental performance indicators. Based on Pareto 80-20 rule, 32 out of 63 sustainability indicators are shortlisted as highly influential sustainability indicators. From the 32 selected sustainability indicators, 11 of the indicators are listed as economic performance indicators, nine indicators listed as social performance indicators, and another 12 indicators listed as environmental performance indicators. The 32 indicators that are shortlisted in this study have yet to be acknowledged as significant indicators for sustainability performance as this study simply shows the sustainability of indicators' rate of recurrence for being mentioned in the last 10 years of academic literature. Thus, for future study, these indicators will be verified by experts from manufacturing industries. Major-minor rule will be used in analyzing data in order to finalize the sustainability indicators.

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