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Sustainability Paradigm for Malaysian Manufacturing SMEs: An Operations Research Approach

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ABSTRACT

Small and Medium Enterprises (SMEs) are the driving force for Malaysian economy. They provide employment, stimulate local economy and participate in the supply chain for large companies. However, limited studies were found for SMEs to achieve sustainability in operations perspective. On the other hand, the concept of sustainability is considered new for most Malaysia manufacturing SMEs. On this note, the research question for this study is "what model is useful for Malaysian manufacturing SMEs to measure their sustainability based on current production performance?". The novelty is that this study provides a practical starting point towards the development of sustainable manufacturing SMEs by incorporating production performance. The methodologies used in this work are extensive literature review, conceptual model building and mathematical model building. Findings from this study suggest that underutilized capacity or wastage of inputs creates gap in productivity and appears as non-value added input to production process which reduces degree of sustainability in manufacturing SMEs. This gap contributes to the reduction in production performance, increase the production cost and introduces adverse impact on economy and environment. It is imperative for the manufacturing SMEs to eliminate this waste to achieve sustainability. However, the research area on SMEs waste reduction remains under explored. The findings of this study would serve as guideline for Malaysian SMEs managers to formulate effective approach to achieve sustainability. In this aspect, this work is original as developed from fundamental manufacturing concepts. The model is useful for relevant stakeholders to eliminate the non-value added inputs. This paper will add new information in the manufacturing SMEs knowledge domain. Furthermore, this paper will would serve as basis for future research in sustainable manufacturing SMEs.

Keywords: Manufacturing, production performance, SMEs, sustainability, waste reduction.

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1. INTRODUCTION

Manufacturing Small and Medium Enterprises (SMEs) plays an important role in global development despite operating at small and medium scale. Under minimum Research and Development (R&D) capability, manufacturing SMEs are often operates in traditional manner which is not economic and environmentally sustainable. Currently, global scenarios affecting manufacturing industries such as depletion of natural resources, increasing world population, global warming, pollution control and ever growing world economy have driven the multi-national companies to accommodate sustainability as well as SMEs (Peng, 2014). Other globalization challenges such as the inundation of foreign products, shorter product lifecycles, rapid technological innovation and changes in customer demand have forced the manufacturers to continuously examine their current strategies and improve their existing capabilities (Dolage & Sade, 2012). To cope with such dynamic environments, manufacturers are constantly in search for a new manufacturing paradigm; production of high quality product at low cost, low amount of stock, low manufacturing lead time, high competitiveness, responsive to customer demand fluctuations, operates with low labour cost and at the same time reduce the negative impact of manufacturing to the environment (Saren & Tiberiu, 2016). In order to address these issues, studies on the topics of sustainable manufacturing such as green manufacturing, remanufacturing, and sustainable life cycle engineering have been reported (Anityasari, 2011). However, those studies only place emphasis on general discussions about new requirements for sustainable manufacturing (Brennan et al., 2015). Furthermore, those studies did not have any corresponding methods or models for their implementation. Therefore, this study aims to address the issue by providing a conceptual framework for manufacturing SMEs to evaluate level of sustainability based on production performance.

1.1 The Significance of Manufacturing SMEs to Malaysian Economy and Society

SMEs are critical to future economic growth and job creation within developed and developing countries. In many developing countries, manufacturing SMEs account for a significant share of the production and employment, and directly connected to poverty alleviation. In Malaysia, SMEs are responsible for contributing 37% to Gross Domestic Product (GDP) in 2017 (The Star Online, 2017) and the contribution is expected to increase to 41% by 2020. The main driver forces of the SMEs are manufacturing, services and construction sectors (Musa & Chinniah, 2016). SMEs, especially those in developing countries, are challenged by the globalisation of production and the change in the significance of the various determinants of competitiveness (Bamikole, 2012; Olusola & Oluwaseun, 2013). SMEs represent the largest quantity of the manufacturing sector in every country. Manufacturing SMEs in developing countries are significant, socially and economically, for a number of reasons, including: 1) a

wide dispersion across rural areas and significance for rural economies; 2) their ability to employ a significant amount of the workforce in their local economies; and 3) their ability to provide an opportunity for entrepreneurial and business skill development (Tambunan, 2011).

1.2 Production Process of Manufacturing SMEs

The production process is the main part of manufacturing SMEs and the efficiency of the inputs of the manufacturing process. The inputs are physical inputs (raw materials, energy, water, etc.), operations and management inputs (capital and labour) and other manufacturing resources (engineering design, product and process design, research and development, quality control, etc.) (Shahidul & Shazali, 2011). Therefore, improving existing production process would mean that the new improved process would consume less resources to produce more final products with improved quality (Liyanage, 2007). The economic and technical performance of most manufacturing SMEs depend greatly on the efficiency production process, operations and resources management (Fuller & Martinec, 2005). Therefore, the production performance could be a sustainability determinant of a manufacturing SMEs. In this aspect, it is essential that manufacturing SMEs managers and other relevant stakeholders possessed the adequate technical and economic knowledge in production process to achieve higher production performance and to sustain in business.

1.3 The Concept of Sustainability in Manufacturing SMEs

Manufacturing sustainability evolved from the concept of sustainable development (Rosen & Kishawy, 2012) and first appeared in the 1980s. It was defined by World Commission on Environment and Development (1987) as *"the development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* Later in the 2000s, sustainable manufacturing was defined by Mihelcic et al. (2003) as *"the design of human and industrial systems to ensure that humankind's use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment."* It was further added with green manufacturing by Allwood, Laursen, Russell, de Rodríguez & Bocken (2008) as *"developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste."* Today, the most widely accepted definition is by U.S. Department of Commerce (2010) as *"the creation of manufacturing products that use materials and processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound"*. The definition is that the manufacturing process is design and operates to achieve higher value-added product by optimizing inputs in the process with higher productivity, technical efficiency and economic efficiency.

1.4 The Drivers of Sustainability

Manufacturing SMEs have significant influence over global development as backbone of economy for most countries in the world. However, manufacturing SMEs also contribute significantly in creating negative impact on the environment. In this regards, the concept of environmental sustainability has gain significant attention over the years due to the following factors (Bi, 2011; Peng, 2014):

- Depleting Natural Resources: Natural resources as inputs for manufacturing industries such as oil, coal, and fresh water clean air are depleting. The prices for manufacturing inputs are increasing as the availability is decreasing.
- Increasing World Population: As world population increases, more resources will be consumed to satisfy this dynamic demand and contribute to create more wastes.
- World Economic Growth: Governments around the world are actively involved in formulating policy for manufacturing industries to add values to the society or social-economic development.
- Pollution Control: The society demand products with less negative impact to the environment. Governments are penalizing manufacturing industries that responsible for discharging hazardous waste to the environment.
- Global Warming: Manufacturing industries are responsible for discharging greenhouse gases since industrial age. The world is warmer than ever in human history. Some efforts of governments and non-government organizations are trying to reduce greenhouse gases emissions are such as Paris Agreement and promoting the use of green technology.

2. CONCEPTUAL FRAMEWORK FOR SUSTAINABLE MANUFACTURING SMES

The conceptual model summarized from literature review is shown in Figure 1. The index for evaluating degree of sustainability shown in Figure 1 will be explained in details in later section. From the conceptual model, wastage is the result of inefficient production process that contributes to reduce outputs. The sources of wastage come from underutilized inputs such as labour, energy, raw materials and other manufacturing resources from production process.

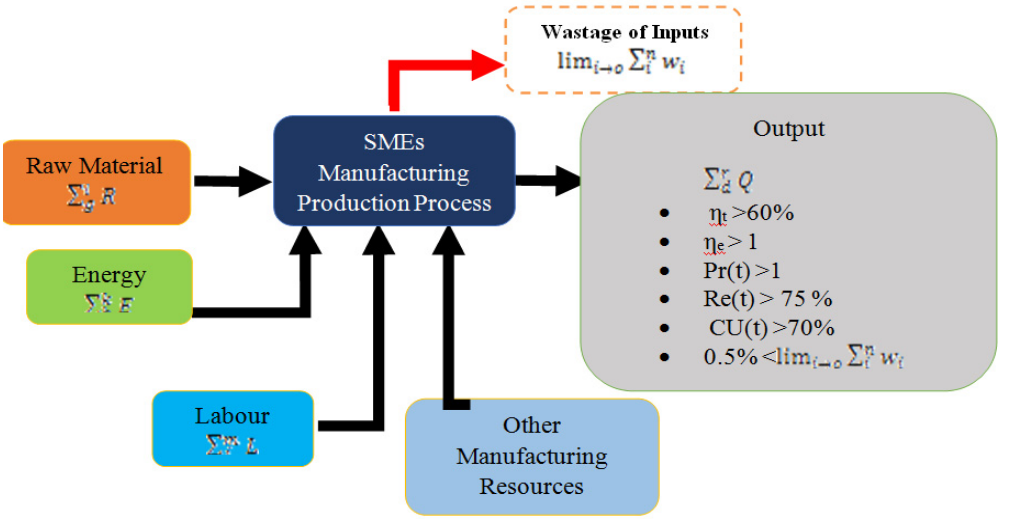

Figure 1: Conceptual Model of Sustainability for Manufacturing SMEs

where η_p = Technical Efficiency
η_e = Economic Efficiency
Pr(t) = Manufacturing Productivity
CU(t) = Capacity Utilization
Re(t) = Plant Production Machineries Reliability
G(Q) = Output growth contributed by inputs

2.1 Mathematical Representation of the Conceptual Model

The mathematical expression to represents conceptual model from Figure 1 is shown in Equation (1).

$$\sum_d^r Q = K\,[Input\left(\sum_j^m L\,.\sum_h^k E\,.\sum_g^l R\,.\sum_f^p MR\right) - Wastage(\sum W_L\,.\sum W_R\,.\sum W_E\,.\sum W_{MR})] \quad (2.1)$$

where,
Q = outputs
K = input transformation factors with respect to wastage
L = labour
E = energy
MR = other manufacturing resources
W = wastage with respect to inputs

2.2 Indicators for Achieving Sustainability

Table 1 presents a summary of performance models for manufacturing SMEs to achieve sustainability.

Table 1**:** Sustainability Indicators

Parameters	**Manufacturing SMEs Performance Models**	**Sustainability Indicators**	**References**
Technical Efficiency (η_t)	$\eta_{t=}\frac{\text{Output}}{\text{Input}}$	$\eta_t > 60\%$	(Chen et al., 2014; Islam et al., 2015)
Economic Efficiency (η_e)	$\eta_{e=}\frac{\text{Value of Output}}{\text{Production Cost}}$	$\eta_e > 1$	(Chen et al., 2014; Egilmez et al., 2013; Farrell, 1996; Islam et al., 2015)
Productivity [Pr(t)]	$\Pr = \beta\frac{\sum R}{\alpha\sum X_i}$ R = Revenue of products; X_i = Input Costs B = Constant depends on the potentials manufacturing process variables; α = dimensionless coefficient	Pr > 1	(Houseman, 2007; Shahidul & Shazali, 2011)
Plant Operating Reliability [Re(t)]	$\text{Re}(t) = \int_0^t f(t)dt = 1 - e^{\alpha t}$ α = failure rate of machine, t = failure time	Re > 75%	(Das, Lashkari, & Sengupta, 2007; Shahidul et al., 2015)
Capacity Utilization [CU(t)]	$CU = \frac{\text{Actual Capacity},Q_A}{\text{Potential Capacity},Q_P}$	CU > 70%	(Cigolini & Grando, 2009; Shahidul et al., 2015)
Wastage (W)	$\sum W = \sum I - \sum Q$ $\sum I$ = Inputs used in process; $\sum Q$ = Production Output	0.5%< $\sum W$ <1.5%	(Allwood et al., 2008; Bi, 2011; Shahidul et al., 2013)
Production Output Growth	$\sum G(Q) = \alpha \sum G(\text{Inputs})$ Where α = factor efficiency parameters	G(Q) > 1	(Elaswad et al., 2015)

3. PRACTICAL IMPLICATIONS AND SCENARIO ANALYSIS

Developed models would have practical implications in Malaysian manufacturing SMEs and society. The expected implications are:

- The model would be useful for decision makers and other relevant stakeholders in formulating operating strategy for optimizing the input usage and reducing wastage of inputs as part of green manufacturing program.
- The model would serve as a holistic approach towards better understanding of sustainability and green manufacturing.
- The indicators provided in the models would serve as measuring tools for engineering managers to evaluate degree of sustainability for manufacturing SMEs.

The literature review findings of this study indicate that higher percentage of wastage has higher degree of negative impacts on economic and environment. The industrial wastage has two options; either is disposes off, or could be recycled to produce products. The classification of industrial wastage is shown below (Heilala et al., 2008; Iris & Cebeci, 2014; Yen Ting, Yee Shee, & Sze Choong, 2017):

- Input wastes - Inputs used in production process such as energy, water, raw materials, and labour hours being consumed in excess to produce outputs.
- Pollutants - Material wastes, discarded scraps or pollutants that being discharged into the environment such as wastewater, air emissions and solid wastes.
- Hazardous wastes - By product or hazardous substances that being used during production process or presence in outputs. This waste can cause serious effects on human health or environment.

Dispose of wastage has a negative impact on environment. On the other hand, recycling of wastage will contribute to increase economic performance of manufacturing. Therefore, waste has to be recycled attaining both economic and environmental sustainability (Jovane et al., 2008). However, waste management programs in current manufacturing industries is limited especially SMEs due the fact that limited information, resources, technical expertise and experience in managing waste (Yen Ting et al., 2017) Moreover, emphasis are being placed on producing main products rather than waste management which has less operational importance. Many did not realize that waste could be managed strategically turn into valuable resources which add sustainable value to the industry (Simpson, 2012).

It was found that the waste concept from sustainable manufacturing is different from lean manufacturing. Lean manufacturing focused on minimizing waste to reduce time and cost for achieving only economic sustainability. Apart from that, sustainable manufacturing focus on minimizing the negative impact on environment without compromising economic performance (Heilala et al., 2008). All in all, concept of manufacturing sustainability is more superior and more

challenging for the industry to implement. For SMEs to accomplish sustainability, high level of production performance such as higher level of capacity utilization could contribute to reduce resource wastage.

3.1 Comparisons with Past Research

The difference between this study and past research is that past research focused on general discussions about new requirements for sustainable manufacturing. In addition, the mathematical model to capture data and effective implementation measure for SMEs is limited. On the other hand, this study introduces a practical starting point for engineering managers towards formulating strategy to capture real time operations and production data for sustainability development in the manufacturing SMEs. Sustainability and productivity growth of manufacturing SMEs could be achieved by reducing non-value added inputs and maximizing output (Shahidul & Shazali, 2011). This is due to wastage or underutilized capacity creates productivity gap that acts as non-value added input which contributes to reduce production performance. This scenario is in line with findings of other researchers: Shahidul et al. (2013) reported that capacity utilization and wastage is negatively associated. They found that low level of machinery maintenance and skills of machine operators could cause failures to achieve higher performance of machinery. This scenario contributes to increase waste such as rejection of products, increases exhaust gases of machineries with unburned fuel. Likewise, Egilmez et al. (2013) found that about 90% of total manufacturing SMEs in US are actually inefficient, and significant improvements in their performance are required to reduce industrial waste. They concluded that manufacturing SMEs should focus on reducing direct and indirect overall energy consumption to increase their environmental sustainability. Heilala et al. (2008) also reported that underutilized production machinery (idle operating hour in production) uses a lot of energy even though it is not producing any product, and the actual machining only required 14.8% of the total energy. Al-Najjar (1996) stated that maintenance activities are essential in eliminating potential problems at early stage for ensuring good quality and reliability of products and processes as the internal and external failures costs could be 10-15 per cent of turnover.

3.2 Significance of Capacity Utilization to Manufacturing SMEs

Capacity Utilization (CU) is a performance indicator of manufacturing industries that discusses the strength management capability (Shahidul et al., 2013). The unused capacity, known as the Capacity Gap (CG), is the non-value added input which contributes to the reduced growth of the manufacturing enterprise (Penrose, 2009). The capacity of labour and machinery are at the core of the performing manufacturing process. They are the potential determinants of manufacturing SMEs growth. The efficient use of these inputs contributes to achieving the targeted growth of the enterprises (Lee, Houssein, & Shahidul, 2016). On this note, manufacturing SMEs must pay attention to CU because

capacity management is concerned with the matching of the production resource capacity on which product demands are placed. In this regard, capacity planning involves and attributes the facilities, equipment, labour, and other relevant logistics engaged in the long-term production activities, such as the process time and set-up time of the machinery, the product defective rate, and the maintenance down time, which are the determinants of CU (Kumru, 2011). CU also depends on the operations management capability of manufacturing SMEs (e.g., designing the shop floor, deploying people and machines efficiently, smoothing out the product workflow, and managing the working environment) (Grando & Turco, 2005).

The optimization of the production cycle time and CU is positively associated with SME growth because it contributes to reducing the production cost. In this case, the multi-objective capacity planning methodology could be useful (Iwata, Taji, & Tamura, 2003). The production facility layout design and SME growth has a link as the efficient facility layout contributes to increase CU (Grando & Turco, 2005). The maintenance of machinery, its CU, and SME growth are closely linked. Relationships among these three parameters have been determined. The availability of machinery for production is associated with the degree of maintenance (Dhouib, Gharbi, & Ben, 2012; Lee et al., 2016; Suliman & Jawad, 2012).

4. CONCLUSION AND RECOMMENDATIONS FOR FUTURE STUDY

This study has addressed sustainability by developing a model for manufacturing SMEs to serve as guideline for engineering managers to achieve sustainability. Finding of this study indicates that wastage of inputs or underutilized capacity creates productivity gap that acts as barrier to growth and achieving sustainability. The findings of this study would be useful for policy makers, further research for academicians, government agencies and other relevant stakeholders in formulating strategy to reduce wastage for achieving sustainability. In conclusion, this work would bring the formulation of indicators for manufacturing SMEs sustainability development which is limited in published papers. In this aspect, this paper will definitely add new knowledge in the stock of present manufacturing domain. Ultimately, this study would be served as foundation for further research in manufacturing SMEs sustainability including research in SMEs plant operations capacity optimization to reveal and reduce its capacity gap.

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