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It is our great pleasure to welcome you to the 2011 IEEE International Conference on Industrial Engineering and Engineering Management. After having it in Hong Kong in 2009 and Macau in 2010, the IEEM conference is back in Singapore where it started.

As in the past years, we have received many submissions and each paper was sent to 3-4 reviewers. The rigorous review process has helped to maintain a high standard for this conference We would like to thank the technical program committee members and the author-reviewers for their help in the review process.

IEEM conference is truly an international event with about 50 countries/regions represented each time. We also have three prominent keynote speakers and a meet-the-editors panel for participants to discuss publication and research issues.

The conference is grateful to all authors for your interests and contributions. The supports from Singapore Management University, National University of Singapore and Nanyang Technological University are also greatly appreciated.

Finally, we wish all the participants a fruitful conference. To those overseas, we hope that you enjoy your stay in Singapore.

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Key Performance Indicators for Sustainable Manufacturing Evaluation in Automotive Companies

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Abstract - **The automotive industry is regarded as one of the most important and strategic industry in manufacturing sector. It is the largest manufacturing enterprise in the world and one of the most resource intensive industries of all major industrial system. However, its products and processes are a significant source of environmental impact. Thus, there is a need to evaluate sustainable manufacturing performance in this industry. This paper proposes a set of initial key performance indicators (KPIs) for sustainable manufacturing evaluation believed to be appropriate to automotive companies, consisting of three factors divided into nine dimensions and a total of 41 sub-dimensions. A survey will be conducted to confirm the adaptability of the initial KPIs with the industry practices. Future research will focus on developing an evaluation tool to assess sustainable manufacturing performance in automotive companies.**

Keywords - **Automotive, key performance indicators, manufacturing performance, sustainable manufacturing**

I. INTRODUCTION

Sustainability has becoming an increasingly important issue amongst companies around the world. It is a critical and timely topic [1], a major concern internationally over the last decade [2], a major competitive factor for many manufacturing companies [3], and an important concept to survive the competitive environment [4]. Increasing concerns to sustainability have forced manufacturing companies to consider sustainability into their strategies and activities.

In response to the growing sustainability concerns, manufacturing companies have to formulate measures to evaluate sustainable manufacturing performance, aiming at integration of sustainability aspects. Generally, sustainability is evaluated by environment, social, and economic; known as the three pillars of sustainability.

Although literature on sustainability is abundant and growing, very few studies have actually integrated sustainability into manufacturing performance. Sustainability has been integrated into manufacturing management areas such as product development ([2], [5]), supply chain management ([6], [7]), lean manufacturing [8], and supplier evaluation and selection [9].

In this research, attempt is made to integrate sustainability into manufacturing performance by incorporating manufacturing performance indicators with sustainable manufacturing indicators. As a result, a set of initial Key Performance Indicators (KPIs) for sustainable manufacturing evaluation is proposed. This study focused on automotive industries. The automotive industry has regarded as one of the most important and strategic industry in manufacturing sector and the use of sustainable manufacturing in this industry is very important. This paper culminates in a discussion of the development of a questionnaire to meet the purpose of this study, which is to investigate sustainable manufacturing evaluation KPIs relevant to automotive companies.

II. LITERATURE REVIEW

A. Manufacturing Performance

Manufacturing performance is critical to the success of many firms. Superior performance leads to the competitiveness. In order to stay competitive, manufacturing companies must regularly evaluate their performance. Thus, it is vital for manufacturing companies to identify and ensure good performance in the global competition.

Performance evaluation can be used in guiding organizational change and development [10] and to describe and review the historical performance as well as to set performance targets for the future [11]. Performance indicators do not simply describe what has happened; they influence what will happen, as they provide information for decision maker to make decisions which may affect the future competitive position of the organization [12]. The role of manufacturing performance indicators is to reflect the current state of manufacturing situation, to monitor and control operational efficiency, to drive improvement programme, and to gauge the effectiveness of manufacturing decisions [13]. Four of the most commonly cited indicators to evaluate manufacturing performance are quality, cost, delivery, and flexibility [14].

A literature review was carried out in an attempt to determine indicators commonly used in manufacturing performance evaluation based on those four indicators. A summary of the indicators reviewed is presented in Table I. It can be seen that quality, cost, delivery, and flexibility are most commonly used indicators of manufacturing performance evaluation. It is believed that these indicators are important and relevant and therefore will be used for further development in this research.

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TABLE I
SUMMARY OF MP INDICATORS USED BY AUTHORS

Literature	MP Indicators used									
	1	2	3	4	5	6	7	8	9	10
[15]	*	*	*	*						
[16]	*			*						
[17]	*		*	*	*	*				
[18]	*		*		*	*				
[19]	*	*	*	*	*					
[14]	*			*	*	*	*			
[20]	*	*	*	*	*					
[21]	*	*	*	*	*			*		
[22]	*	*	*							
[23]	*		*			*	*		*	
[24]	*	*		*				*		
[25]	*	*	*	*						
[26]	*		*			*	*			
[27]	*	*		*	*					
[28]	*	*	*	*			*			
[29]	*	*	*	*						
[30]	*	*	*		*	*				
[31]	*					*	*		*	*
[32]	*	*	*	*				*		
[33]	*	*	*			*				
[7]	*	*	*	*						
[34]	*	*	*	*						
[35]	*	*	*	*	*	*				
[36]	*	*	*	*	*		*			
[37]	*	*		*						

Note: 1= Quality, 2= Cost, 3= Delivery, 4= Flexibility, 5= Time, 6= Labor, 7= Customer satisfaction, 8= Dependability, 9= Efficiency, 10= Innovation

B. Sustainable Manufacturing

The US Department of Commerce [38] define sustainable manufacturing as the creation of manufactured products that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound. According to OECD, the general principle of sustainable manufacturing is to reduce the intensity of materials use, energy consumption, emissions, and the creation of unwanted by-products while maintaining, or improving, the value of products to society and to organizations [39].

Sustainable manufacturing is currently a very important issue for governments and industries worldwide [40]. Achieving sustainability in manufacturing activities have been recognized as a critical need due to diminishing non-renewable resources, stricter regulations related to environment and occupational safety, and increasing consumer preference for environmentally-friendly products [41]. It was suggested that sustainable manufacturing must respond to environmental, economical, and social challenges [42].

A review on the sustainable manufacturing indicators was conducted and is summarized based on the triple bottom line of sustainability in Table II. It can be concluded that environmental performance is regarded as the most important indicator in evaluating sustainable manufacturing performance. All the studies considered environmental performance as sustainable manufacturing measure. Social performance is used in the following consideration and lastly, economic performance is used in a low level. The social and economic performance received the least attention in the existing sustainable manufacturing performance measures.

Table II shows studies which have considered all the three factors of environmental, social, and economic performance in evaluating sustainable manufacturing are in a low level. Most studies only focused on the environmental factor alone. However, for an effective sustainable manufacturing evaluation, all the three factors should be considered in the same equal level.

TABLE II
COMPARISON OF SOME PREVIOUS KPI STUDIES

Author	Sustainability factors considered			Final instrument
	Environmental	Social	Economic	
[43]	*	*	*	22 indicators
[44]	*	*	*	32 indicators
[45]	*	*		12 indicators
[46]	*	*	*	34 indicators
[47]	*		*	21 indicators
[48]	*	*		24 indicators
[49]	*			6 indicators
[7]	*		*	16 indicators
[50]	*	*	*	26 indicators
[51]	*	*	*	22 indicators
[52]	*	*		20 indicators
[53]	*	*	*	44 indicators
[41]	*	*	*	40 indicators
[54]	*	*	*	28 indicators
[55]	*	*	*	32 indicators
[8]	*	*		30 indicators

III. THE INITIAL KPI

Based on a review on previous studies of the manufacturing performance indicators and the sustainable manufacturing indicators, the authors have developed a set of initial KPIs for sustainable manufacturing evaluation in automotive companies.

The initial KPIs have been constructed from the integration of manufacturing performance indicators and sustainable manufacturing indicators. The initial KPIs have adopted the triple bottom line of sustainability consisting of environmental, economic, and social performance factors. Four manufacturing performance indicators of quality, cost, delivery, and flexibility are incorporated into the initial KPIs as economic performance dimensions. The other dimensions are derived from the literature.

Finally, the initial KPIs consist of three factors of environmental, economic, and social performance and further divided into nine dimensions. A total of 41 sub-dimensions was then adopted and modified from relevant literature as shown in Table III.

TABLE III
INITIAL KPI OF SUSTAINABLE MANUFACTURING EVALUATION

Environmental performance	
1. Emissions	(1) Air emission
	(2) Water emission
	(3) Land emission
2. Resource utilization	(4) Energy utilization
	(5) Water utilization
	(6) Fuel consumption
	(7) Land used
3. Waste	(8) Solid waste
	(9) Hazardous waste
	(10) Waste water
Economic performance	
4. Quality	(11) Product reliability
	(12) Product durability
	(13) Conformance to specification
	(14) Customer complaint
	(15) Scrap and rework
	(16) Reject rate
5. Cost	(17) Material cost
	(18) Setup cost
	(19) Overhead cost
	(20) Inventory cost
	(21) Unit cost
	(22) Labor cost
6. Delivery	(23) On time delivery
	(24) Delivery lead time
	(25) Delivery speed
	(26) Cycle time
	(27) Due date adherence
	(28) Schedule attainment
7. Flexibility	(29) Volume flexibility
	(30) Product flexibility
	(31) Process flexibility
	(32) Technology flexibility
	(33) New product development
Social performance	
8. Employee	(34) Training and development
	(35) Occupational health and safety
	(36) Turnover rate
	(37) Job satisfaction
	(38) Community satisfaction
9. Supplier	(39) Supplier certification
	(40) Supplier commitment
	(41) Supplier initiative

IV. PILOT STUDY

In order to investigate these KPIs of sustainable manufacturing in automotive companies, a questionnaire was developed. The questionnaire was divided into three main sections: (i) background information; (ii) perception of sustainable manufacturing; and (iii) perceived importance of the initial KPIs. The first section was intended to obtain some basic information, such as business size, types of certification gained, and experience in automotive industry as well as on sustainable manufacturing initiative. The second section on sustainable manufacturing perception provides the drivers, barriers, and benefits on which respondents were asked to rank their level of agreement. In the last section, respondents were asked to rank their level importance of the initial KPIs. These results will be used to develop a set of KPIs in evaluating sustainable manufacturing.

A pilot study was conducted to validate and improve the questionnaire, in terms of the questions and statements content, wording, sequence, and also potential participant interest. A total of 16 forms were distributed to two groups of sustainable manufacturing experts: practitioners in automotive industry and professionals (academics and consultants). Nine responses were received, thus giving a 56 % response rate.

The comments were generally concerned on questions and statements wording. For the initial KPIs, some terms was edited and corrected, for example, “water emission” was changed to “water pollution”, “land emission” was changed to “land contamination”, and “due date adherence” was changed to “due date compliance”. One sub-element of cost element (i.e. unit cost) was removed, and rework cost was added as a new sub-element. In this way, the questionnaire was greatly improved. The questions and statements were corrected and improved in order to make them more clearly and accurate.

In short, the questionnaire was validated through pilot study and provided improvement opportunities for the researchers before conducting the full survey. The survey will be conducted to Malaysian automotive companies which manufacture parts and accessories for motor vehicles and their engines listed in Federation of Malaysian Manufacturers (FMM) Directory.

V. CONCLUSION

The automotive companies are under intense pressure to reduce environmental impacts of their products and operations. For sustainability, they should try to aim at a balance amongst economic development, environmental protection and social equity. It is a big challenge for the automotive companies, particularly Malaysia, to give serious attention on sustainability.

Although sustainability issues have been widely growing for many years, only few studies have been conducted on incorporating sustainability into manufacturing performance. There is yet to be a standard set sustainable manufacturing performance indicators. Although some studies have investigated indicators for sustainable manufacturing, only few have considered the triple bottom line of sustainability on the same equal level.

This study tries to integrate sustainability with manufacturing performance and has incorporated them into sustainable manufacturing indicators. As a result, a set of initial KPIs for sustainable manufacturing evaluation in automotive companies was proposed.

A questionnaire has been developed to be used as the instrument for investigating the KPIs in industry. It was piloted using sustainable manufacturing experts and practitioners in automotive industry. The questionnaire was validated and improved upon before being used in the main survey, which is the next stage of this research. Future research will focus on investigation of the KPIs for sustainable manufacturing evaluation and provide a basis for developing a sustainable manufacturing evaluation tool that will be useful for the automotive companies.

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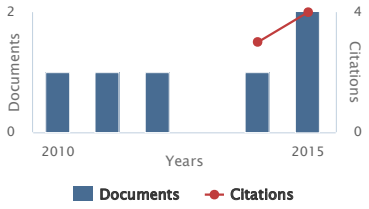

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