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## Sustainable Maintenance Performance Measures: a pilot survey in Malaysian Automotive Companies

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### Abstract

For sustainability to be realized the automotive companies need to cascade down their strategies to all business functions, including maintenance. Maintenance objectives at the operational level shall be aligned with business strategies at the corporate level by defining key performance measures at each level. This paper developed the initial framework for measuring sustainable maintenance performance (SMP) where 15 measures at the corporate level, 20 measures at the tactical level and 43 measures at the functional level, are identified. In sequence, this paper established the importance level of these measures through a pilot survey in Malaysian automotive companies. The findings of this study are concluded by recommending all proposed measures as important. The total of lubricants consumption has been considered as the most crucial measure at the functional level, while learning and growth is the most vital perspective, and furthermore, social factor is becoming a more important in measuring SMP.

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### 1. Introduction

Nowadays, sustainability has become a critical issue in the automotive companies. The scarcity of natural resources and the implementation of environmental regulations have forced automotive companies to take sustainability initiatives [1, 2]. Similarly, the Malaysian Ministry of International Trade Industry has announced the new National Automotive Policy (NAP) on January 20, 2014. Amongst the objectives of NAP are [3]: *promote a competitive and sustainable domestic automotive industry including the national automotive companies; promote increase in value-added activities in a sustainable manner.* In trying to address this issue, Malaysian automotive companies need to incorporate sustainability initiatives into their business strategies.

Maintenance as a business function has also a crucial part in achieving the status of a sustainable company [4]. Hence, maintenance objectives have to be aligned to the company objectives in terms of sustainability initiatives.

This paper proposes the concept of a sustainable maintenance management (SMM). The SMM can be defined as all required processes for ensuring the acceptable assets condition by eliminating negative environmental impact, prudent in using resources, concern for the safety of employees and stakeholders, while at the same time economically sound.

SMM process has to be measured, monitored and improved in order to become a sustainable automotive company [5]. To do that, SMM need to develop an appropriate measurement framework. Many authors have developed maintenance measurement frameworks but most of them concentrated at the functional or machine level without considering its relation to the company objectives [6].

In order to address the shortcomings, this research is developing a new SMP measurement framework which are aligned to or directly derived from company objectives, in terms of three pillars of sustainability; economic, environmental and social in a balanced manner. The SMP

measurement framework enables clear alignment between maintenance function and corporate objectives by defining objectives and key performance measures at each organizational level; corporate, tactical and functional [7]. Therefore, maintenance people at functional level can perform their maintenance daily activities and improve their value created aligned to their company objectives in becoming a sustainable company.

## 2. Maintenance performance measurement reviews

The literature review was conducted in order to find perspectives that commonly used for maintenance management of the assets and facilities in manufacturing companies. Outcome and value created by the maintenance process shall be measured, monitored and improved in using a proper maintenance performance measurement system (MPMS) [5]. In fact, some of researchers have developed MPMS from specific viewpoints rather than holistic. Several researchers attempted to focus more on financial contribution [8, 9, 10, 11]. On the other hand, some researchers also tried to consider financial and non-financial measures in developing MPMS [12, 13, 14].

Moreover, Parida argued that in developing MPMS, it is important to ensure alignment between maintenance activities and organization objectives [5]. Thus, different MPMS need to be developed in line with the Balanced Scorecard (BSC). BCS is a balanced approach which considers financial and non-financial aspects in term of customer, internal processes, and learning and growth at the equal level. BSC enables all employees to know organization's strategy which allows employees to contribute at enhancing organization's performance. Many authors have adopted BSC approach for measuring organizational performance which includes the field of maintenance performance [1, 5, 7, 15, 16, 17].

Currently, sustainability issues affect all aspects of the organization's operation and maintenance management. It requires the sustainability perspective to be embedded into MPMS. In anticipating this emerging issue, some authors have been forced to take sustainability perspectives i.e. economic, environmental and societal instead of solely considering the BSC perspectives [5, 7, 16, 17].

To become more eco-efficient and more sustainable, there is a need to balance three factors of sustainability at developing MPMS. Some authors have constructed SMP measurement system which considered three sustainability perspectives [18, 19].

On the other hand, several researchers have considered specific sustainability perspectives in developing MPMS. Raouf [20] introduced some indicators for MPMS which related to economic and environmental performance.

In contrast, some authors [21, 22, 23] have applied economic and social as a crucial factor in maintenance management. Besides that, Pintelon and Muchiri [23] developed indicators with a strong emphasis on safety factor that is categorized into reactive and proactive indicators.

A summary of the overall studies related to SMP measurement is presented in Table 1.

Table 1. Summary of maintenance performance measurement perspectives in manufacturing companies used by authors [modified from 24]

Authors (Year)	Economic		Social				Environmental
	Cost Effectiveness	Quality	Productivity	Learning and growth	Health and safety	Employee satisfaction	
Tsang et al. (1999)	x		x	x			x
Kutucuoglu et al. (2001)	x	x		x			x
Swanson (2001)	x	x					
Liyanage and Kumar (2003)	x	x	x		x	x	x
Cholasuke et al. (2004)	x			x		x	
Raouf (2004)	x	x	x	x			
Mather (2005)	x	x	x	x	x		x
Alsyouf (2006)	x		x	x	x		x
Parida and Chattopadhyay (2007)	x	x	x	x	x	x	x
Aoudia et al. (2008)	x			x		x	x
Duffuaa and Haroun (2009)	x	x					
Kodali et al. (2009)	x	x	x		x	x	
Liyanage et al. (2009)	x					x	x
Mirghani (2009)	x						
Pintelon and Muchiri (2009)					x		
Raouf (2009)	x		x				x
Chinese and Ghirardo (2010)	x	x			x		
Muchiri et al. (2011)	x	x	x				
Parida (2012)	x	x	x	x	x	x	x
Ajukumar and Gandhi (2013)			x		x		x

One of the main issues on SMP measurement in manufacturing companies is the lack of linkage between maintenance as a support function and corporate objectives. In order to bridge this shortcoming, some authors suggested that the MPMS need to be aligned with the corporate objectives by defining measures at each organizational level; corporate, tactical and functional [4, 5, 6, 7, 10, 14, 17].

## 3. A framework of sustainable maintenance performance measurement systems for automotive companies

Based on the review on previous studies of maintenance performance and SMP, this paper proposed a SMP

measurement framework for automotive companies which consist of eight perspectives. These perspectives have been chosen which considered maintenance management perspectives and incorporated sustainability issues in balanced manner. This framework also adopted BSC approach to ensure maintenance as a support function performs their daily activities is in line with the corporate objectives.

In order to make clear the alignment between corporate objectives and day to day maintenance activities, SMP measures is defined at each level; corporate, tactical and functional as stipulated in previous literatures. Based on previous authors, only Parida has developed detailed indicators for all three levels. Therefore, some of measures developed by Parida where chosen as the measures for developing the initial framework of SMP measurement systems. However, sustainability measures by Parida were not comprehensive from the environmental measures point of view. Thus, the authors incorporated other measures developed by previous authors in order to ensure the framework is balanced, holistic and sustainable.

Finally, the initial framework of SMP measurement systems for automotive companies proposed as many as 78 measures that have been categorized into eight perspectives as demonstrated in Table 2. At the same time, these measures broken down into three levels; 15 measures at the corporate, 20 measures at the tactical and 43 measures at the functional. These measures were adopted and modified based on relevant literatures [4, 7, 5, 9, 10, 14, 17, 19, 20, 21, 23, 25, 26, 27].

#### 4. Research methodology

In order to validate and to know the measures that commonly used in measuring SMP in automotive companies, authors have selected the method of survey as the methodology conducted in this research.

This research is developing a questionnaire as an instrument through extensive literature reviews. As the initial phase, the questionnaire was sent to 15 experts who are either practitioners or academicians to check for the content validity. Five responses of local experts and three responses of international experts have been received through email and direct interviews. The preliminary questionnaire was modified based on comments from these eight experts in terms of content, wording, sequence, respondent interest, time consuming, flow and continuity.

Parida, an author who had previously developed maintenance performance measures in three hierarchies [9], suggested valuable comments especially in the naming of measures. Thus, the names of the measures were modified to be consistent with the industry terminology.

It is in the second phase where the pilot survey was conducted. The aims of this pilot survey are to test survey administration procedures; to test procedures for handling non-respondents, missing data and data cleaning; assessing measurement quality [28].

#### 5. Results and Discussions

The population of automotive companies which are listed in Malaysia Automotive Institute is 185. A validated questionnaire was sent to 20 respondents and return rate is 100%. The questionnaire comprised of three main sections. The first section of the questionnaire was intended to obtain the characteristics of respondent. The second section was aimed to obtain the background of company in terms of general information, maintenance management and SMM. The third section requested the respondents to indicate the importance level score of each measure. A five point Likert-type scale was used where 1 = not important at all, 2 = not important, 3 = neutral, 4 = important, 5 = very important.

The number of employees determines the size of company so that they can be categorized into small, medium and large. The respondents in this pilot survey were mainly amongst medium companies (70%) which having 51 to 150 full time employees [29].

The next questions revealed maintenance management issues and implementation in automotive companies. 50% of the respondent companies stated that maintenance management issues are important to their company's performance. Furthermore, 75% of the respondent companies have implemented maintenance management systems in delivering their daily activities for 5 to 10 years. Similarly, 80% of the respondent companies applied Total Productive Maintenance (TPM) concept. These data indicate that most of the respondent companies have considered maintenance management as a critical business function to enhance company's performance [30].

Lastly, the respondent companies were asked about SMM. 60% respondent companies stated that awareness of the concept SMM systems amongst the employees is at moderate level. Similarly, 60% respondent companies considered SMM issues is neutral to improve company's performance. These facts indicate that SMM systems have not been considered as a crucial part in Malaysian automotive companies. This is supported by evidence that 65% of the respondent companies only attempt to implement the SMM systems between 1 to 5 years. Thus, the Malaysian automotive companies need to initiate incorporating SMM issues in their business strategies aligned National Automotive Policy 2014 in responding the global competitive pressure.

##### 5.1. Reliability and validity test

Reliability test is an assessment of the consistency between multiple measurements of a variable. The commonly used measure of reliability is internal consistency. The internal consistency expressed on the basis of Cronbach's alpha coefficient, with values of 0.60 – 0.70 is deemed as the lower limit acceptability [31]. The summary of reliability is given in Table 3. The alpha value of sustainability factors exceeded the minimum reliability standard. It can be concluded that all measures are consistent in their measurement.

Table 2. The proposed measures of sustainable maintenance performance measurement systems

Position level	Level 1/ Corporate	Level 2/ Tactical	Level 3/ Functional
<b>Economic Performance Measures</b>			
Cost effectiveness perspective	Return on eco-friendly maintenance investment and innovation Computerized maintenance management system Manufacturing budget Maintenance budget	Production cost/ unit Preventive maintenance cost  Corrective maintenance cost	Direct material Direct maintenance labor Overhead cost Direct material Direct maintenance labor Overhead cost
Quality perspective	Maintenance cost/ unit Overall plant effectiveness	Overall department effectiveness	Overall equipment effectiveness Availability Performance rate Quality rate Mean time between failures Number of breakdown
Productivity perspective	Maintenance efficiency	Preventive maintenance task Corrective maintenance task	Maintenance program achievement Quality for maintenance task (rework) Response time for maintenance Start up after shutdown Mean time to repair
<b>Environmental Performance Measures</b>			
Environmental perspective	Resources saving      Environmental illegal cases	Total of spare parts used  Total of lubricants consumption  Total of water consumption  Total of land used Total of energy consumption  Water pollution Land contamination  Air pollution	Original spare parts used Recycled spare parts used Re-purposed spare parts used Remanufactured spare parts used Original oils consumption Synthetic oils consumption Vegetable oils consumption Fresh water consumption Recycled water consumption  Non-renewable energy consumption Renewable energy consumption Total of bio-degradable components used Total of bio-degradable lubricants consumption Total of bio-degradable cleanser consumption Total of hazardous waste Total of greenhouse gas emission
<b>Social Performance Measures</b>			
Learning and growth perspective	Skill improvement related to sustainable maintenance practices Number of innovation carried out related to sustainable maintenance	Training topics  Innovation suggested	Training hours per employee  Small group meetings/ team work
Health and safety perspective	Lost time injury rate  Health and safety illegal cases	Recordable injury rate  Physical working environment	Safety attitude Toxic spare parts Toxic lubricants Toxic cleanser Workplace noise level Lighting and ventilation
Employee satisfaction perspective	Employee turn-over rate	Employee satisfaction rate	Employee complaints
Stakeholders satisfaction perspective	Stakeholders - company partnership in terms of sustainable maintenance practice	Stakeholders satisfaction rate	Stakeholders complaints

Validity, as well as reliability, is an important measure of a survey instrument's accuracy. Validity is the degree to which a measure accurately represents what it is supposed to [31]. In this study, a content validity test of the questionnaire was conducted through a theoretical review and expert's validation. First, the developed questionnaire was based on previous frameworks. In the next stage, the questionnaire has

been sent to 15 experts either practitioners or academicians. Based on comments received from 8 experts, the questionnaire was improved and validated. Therefore, the instrument developed for this study could be considered that it has content validity.

Table 3. Reliability test

Sustainability Factors	Number of items	Alpha value
Economic	30	0.878
Environmental	26	0.698
Social	22	0.713

5.2. Importance level of SMP measures

This section aims to rank the importance level of SMP measures. The respondents were asked to indicate the importance level of each measure using a five point Likert scale ranging from 1 = not important at all to 5 = very important. The mean importance score of each measure is presented in Table 4.

Table 4. The importance level of sustainable maintenance measures

Measures	Mean	Rank
Total of lubricants consumption	4.85	1
Overall plant effectiveness	4.85	2
Stakeholders - company partnership in terms of sustainable maintenance practice	4.75	3

From the results obtained, the most important sustainable maintenance measures were the total of lubricants consumption, followed by overall plant effectiveness, and stakeholders – company partnership in terms of sustainable maintenance practices. These top measures are categorized in perspectives of environmental, quality, and stakeholder’s satisfaction perspective.

From the results that is presented in Table 4, the mean of importance value for the perspectives and the factors of SMP were then summarized and analyzed. The mean of importance level of eight perspectives SMP measures is presented in Figure 1.

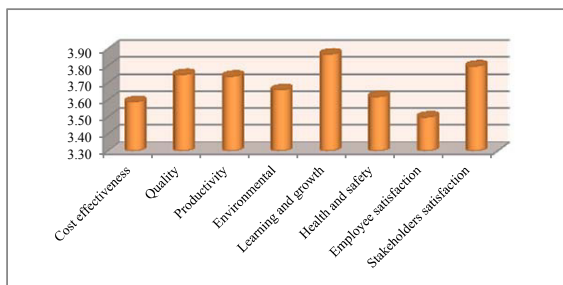


Figure 1 . The mean of importance values for the perspectives

Figure 1 shows learning and growth, and stakeholder’s satisfaction were regarded as the two most important perspectives in measuring SMP for automotive companies with importance percentage of 77.4% and 76, respectively. In contrast, employee satisfaction and cost effectiveness were considered as the least important perspectives with percentage of 70% and 71.8%, but these values can still be considered as high values.

The three of six measures in learning and growth perspective, skill improvement related to sustainable maintenance practices; training topics and training hours have quiet high importance scores 4.74; 4.20 and 4.00. Thus, this perspective considered as the most crucial perspective in SMP measurement for automotive companies. Learning and growth related to how we can maintain to be innovative and use sustainable asset management as an area of growth [7]. In fact, the concept of SMP is relatively new at automotive companies in Malaysia. So, the companies need to educate this new concept to all employees at the entire organization levels. Therefore, learning and growth process is to be shown as the effective way in order to deliver this SMP concept and in turn improvement of SMP will be achieved [32].

The mean of importance level for each factor of SMP measures is illustrated in Figure 2.

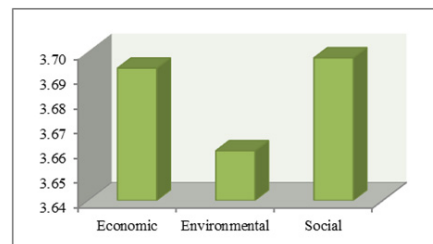


Figure 2. The mean of importance values for the main factors

The results show that social factor is considered as the most crucial factor in measuring SMP with an importance value of 3.70 and importance percentage is 73.95%. This followed by economic and environmental factor with importance percentage of 73.87% and 73.2%, respectively. These results are in line with the results of importance level for the perspectives where the two most important perspectives are under social factor. Furthermore, these results also revealed that the social factor is becoming more important in measuring SMP at automotive companies in Malaysia [33].

Based on the pilot survey results, all the measures have been recommended as the SMP measures for automotive companies as their importance level are 3 or greater.

6. Conclusions

The automotive companies need to adopt sustainability initiatives in their business strategies to respond the global competition pressures. Subsequently, these sustainability business strategies have to be cascaded down to all business functions, including maintenance function. Maintenance objectives at the functional level need to have clear alignment with the business strategies at the corporate level. However, there is evidence that indicate lack of linkage between maintenance objectives and overall business strategies.

Due to this phenomenon, this research has developed a preliminary framework of SMP in order to solve this problem. A pilot survey was conducted to validate this framework before running the full survey. The pilot survey results



suggested that all measures are important in measuring SMP for automotive companies. Thus, all the proposed 78 measures that have been categorized into three hierarchies and eight perspectives are suitable to go for further research. Authors believe that the measures will be useful in developing a SMP measurement system for automotive companies.

In the next stage, a full survey will be carried out to automotive companies in order to validate the preliminary framework of SMP measurement systems.

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