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Manufacturing Performance Evaluation Tool for Malaysian Automotive Small and Medium-sized Enterprises

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Abstract: This study is aimed to develop a manufacturing performance evaluation tool for Malaysian automotive SMEs. The performance criteria were identified and adapted from literature study. A survey was conducted to Malaysia automotive SMEs in matching the criteria with the industry practices. Finally, five factors with a total of 25 dimensions are proposed as the manufacturing performance criteria. Analytical Hierarchy Process (AHP) approach was applied in developing manufacturing performance evaluation tool for Malaysian automotive SMEs. A software-based tool is subsequently developed using PHP and MySQL. Two case studies were conducted to validate the tool. The tool hopefully will enable and assist Malaysian automotive SMEs in their efforts to continually improve their manufacturing performance so as to become more effective and competitive. The tool could also identify the strengths and weaknesses that indicate where and how improvements need to be made. It provides the direction to practice continuous improvement towards achieving excellence.

Keywords: Automotive suppliers, competitive, evaluation tool, manufacturing performance, small and medium-sized enterprises

INTRODUCTION

The globalization of markets, growing inter-diffusion of economies, and increased inter-dependence of economic agents are reshaping national and

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international competitive environment and economic performance (Ghobadian and Gallear, 1996). To be competitive, all companies have to re-examine and modify their competitive strategies. Small and medium sized enterprises (SMEs) can not be separated from these pressures. They have to pay more attention to the changes in manufacturing performance system including the measures used. They need to have a set of manufacturing performance measure to gauge their level of achievement.

Hudson, Smart and Bourne (2001) suggested that there are numerous barriers to strategic performance measurement system implementation in SMEs. The failure of the implementation was attributed primarily to the development process being: too resource intensive and too strategically oriented. This is due to limited resources and a dynamic style strategy of SMEs. These issues are acutely problematic because developing a strategic performance measurement system is necessarily long term and it explicitly requires the resulting measures to be strategically focused. These differences of SME's characteristics indicate a need to asses their performance measurement differently.

The manufacturing performance measurement literatures have shown the financial measures such as profits and return on investment were criticized by many authors because of their many shortcomings. They are short-term rather than long-term focus, measuring the past rather than future (McNair, Lynch and Cross, 1990). Financial measures tend to be obsolete and easily manipulated by managers (Jusoh and Parnell, 2008). To deal with those criticisms then non financial measures such as quality, delivery, time, and flexibility have been suggested as better performance measures. Non-financial measures are timelier than financial ones, very measurable and precise, meaningful to the workforce so aiding continual improvement, consistent with company goals and strategies, they change and vary over time as market needs change, and so tend to be flexible (Medori and Steeple, 2000). This study focused only on the non-financial manufacturing performance measures. In performance measurement, numerous non-financial measures can be used by organizations. The problem is which of the measures from the ones that are available in an organization should be used (Medori and Steeple, 2000). It usually depends on the characteristics of the organization and the nature of its business industry and environment.

In the performance measurement literature, there are also different models or approaches on analytical techniques and quantification of performance. Oztayşi and Uçal (2009) summarized the most frequently used analytical models in the literature. They are Cognitive Maps, Regression Analysis, Artificial Neural Networks (ANNs), Analytical Hierarchy Process (AHP), Multi Attribute Utility Theory (MAUT), and Simple Multi Attribute Rating Technique (SMART) and Data Envelopment Analysis (DEA). These techniques usually used to determine the importance of indicators or define tradeoffs between indicators and definition of relationship between the indicators (Abu-Suleiman, 2006). Of those techniques, the AHP is the most popular tool for multiple criteria decision-making. AHP has been extensively used for selection process such as comparing the overall performance of manufacturing departments (Rangone, 1996), determining measures for business performance (Cheng and Li, 2001), manufacturing supply chain (Wang, Huang and Dismukes, 2005), benchmarking logistics performance (Chan, Chan, Lau and Ip, 2006), and vendor evaluation and selection (Haq and Kannan, 2006). As cited in Muralidharan, Anantharaman and Desmukh (2001), in addition to simplicity, ease of use, and flexibility, its ability to handle complex and ill-structured problems has led to AHP's power and popularity as a decision-making tool (Vargas, 1990; Wedley, 1990). Many researchers have realized that AHP is an important method and can be applied to various areas of manufacturing (Wang et al., 2005).

AHP can elicit biased opinions of decision makers in weighting. Cheng and Li (2001) underlined two advantages of AHP: it adopts a pair-wise comparison process by comparing two objects at one time to formulate a judgment as to their relative weight; and it employs the consistency test that can screen out inconsistent responses. Inconsistency refers to a lack of transitivity of preferences (Saaty, 2008).

This paper proposes a manufacturing performance evaluation tool for Malaysian automotive SMEs. The tool is developed using the Analytical Hierarchy Process (AHP) methodology for analysis through pair-wise comparison to calculate the relative weights of manufacturing performance factors and dimensions. The company score was obtained both for overall and individual factors. The companies then were ranked based on their score. A software-based tool was subsequently developed for computerization using PHP and MySQL. Finally, two case studies have been conducted to validate the tool.

CHARACTERISTICS OF SMEs

Small and Medium-sized Enterprises (SMEs) play a very important role to support the economy and the growth of any nation. Some advanced economies are successful because SMEs form a fundamental part of the economy, comprising over 98% of total establishments and contributing to over 65% of employment as well as over 50% of the gross domestic product. SMEs can provide a major contribution to the economy and as a basis in the development of new industries. Table 1 shows a summary of SMEs development and growth. From the table, it can be concluded that SMEs play a major and crucial role in supporting the economic well being and competitiveness of a nation to meet the international and globalization challenges.

SMEs are often the supplier of goods and services to large organizations which demand high quality of product supplies from them. The lack of product and service quality would adversely affect the competitive ability of the larger companies. In addition, they provide varieties to products and services offered to the consumers because they can flourish in a small or specialized market that is uneconomic for large firms. SMEs can also provide competition and break down monopolies by large companies. The combination of competition and cooperation between SMEs and large companies can result in a high quality, responsive and dynamic industrial system (Deros, Yusof and Salleh, 2006).

SMEs have their own unique characteristics that differentiate them from larger companies. Hudson et al. (2001) concluded the general characteristics of SMEs as personalized management, with little devolution of authority; severe resource limitations in terms of management and manpower, as well as finance; reliance on a small number of customers, and operating in limited markets; flat, flexible structures; high innovatory potential; reactive, fire-fighting mentality; and informal, and dynamic strategies.

Table 1: SMEs development and growth

Country (Year)	Total establishment (%)	Total workforce (%)	Contribution to GDP (%)
Malaysia (2005)	99.2	56.4	32.0
Japan (2004)	99.7	71.0	55.3
Chinese Taipei	98.0	76.9	40.0
(2005)	99.8	86.5	49.4
Korea (2003)	90.6	69.0	38.9
Thailand (2002)	90.0	45.0	25.0
Singapore (2004)	99.7	79.0	49.0
Germany (2003)	99.0	75.0	56.0
China (2004)	99.6	70.0	32.0
Philippines (2003)			

Source: SME Annual Report, National SME Development Council, 2006

Dangayach and Deshmukh (2001) underlined flexibility, quick decision making, favorable capital output ratio, and cooperation from employee as the strengths of SMEs, while the weaknesses are lack of technical superiority, of infrastructural facilities and of financial resources. A wide literature exist, according to which SMEs perform worse than large companies, due to a lack of human and financial resources that keeps them from adopting new technological solutions and innovative managerial practices, necessary to improve their overall performances (Grando and Belvedere, 2006).

The specific characteristics of Small and Medium-sized Enterprises (SMEs) indicate a need to assess manufacturing performance differently.

MALAYSIAN AUTOMOTIVE SMEs

The automotive industry is one of the most important and strategic industry in the Malaysian manufacturing sector. It is an important industrial driver of industrial development, design, marketing, the provider of technological capability and generator of inter-industry linkages, because it brings together various components, which are manufactured by suppliers in other industries (Chin and Saman, 2004). The Malaysian automotive market is dominated by the two main national car manufacturers, Perusahaan Automobil Nasional (PROTON) and

Perusahaan Automobil Kedua (PERODUA). Both manufacturers have many suppliers in supporting their production and most of them are SMEs.

Currently, the awareness of Malaysian government in developing SMEs sector has shown a major improvement as compared to several years ago. The change is in the main due to SMEs has become a major sector in stimulating economic growth in the new millennium and the era of globalization (Ab Rahman et al., 2009). The importance of SMEs in the local manufacturing sector has become significant as demonstrated by their contribution to the Gross Domestic Production (GDP). The contribution of SMEs to national GDP is very obvious in Malaysia. In 2005, SMEs contributed 32% towards the GDP in Malaysia (NSDC, 2006). SMEs have also provided significant contribution towards the economic performance of a country and are considered to be one of the main sources of new jobs. In Malaysia, 99.2% of total enterprises in 2005 consist of SMEs and 56.4% of manufacturing employment is in small and medium sized companies with less than 150 employees (NSDC, 2006).

In order to survive this competing environment, Malaysian automotive SMEs have to pay greater attention to their manufacturing performance. It is highly needed to evaluate manufacturing performance for Malaysian automotive SMEs.

DEVELOPMENT OF MANUFACTURING PERFORMANCE EVALUATION TOOL

This section presents the stages of the manufacturing performance evaluation tool for Malaysian automotive SMEs. The Analytic Hierarchy Process (AHP) methodology was applied in the developing the tool. The stages are follows:

Stage 1: Define the Criteria

The first step of the tool development involves defining the criteria of manufacturing performance evaluation. The manufacturing performance measures were identified and adapted from the literature study. Then, a survey was conducted to Malaysian automotive SMEs in order to match with the measures which are practiced in industry. Through the survey, the measures were modified. After some revisions, finally five factors with a total of 25 dimensions have been proposed as manufacturing performance measures (Amrina and Yusof, 2009). The proposed measures are used as manufacturing performance criteria as shown in Table 2.

Table 2: The manufacturing performance criteria

Quality	Delivery	Cost	Time	Labor
Reliability Durability Scrap and rework Defects Customer complaint Conformance to specification Reject rate	On time delivery Due date adherence Portion of delivery promises met Schedule attainment Delivery speed Delivery lead time	Material cost Overhead cost Inventories cost Setup cost Labor cost Unit cost	Manufacturing lead time Setup time Process time Cycle time	Safety record Employee training

Stage 2: Construct the Hierarchy

The manufacturing performance criteria defined in stage 1 are then used in constructing a hierarchy. For 'Evaluate manufacturing performance in Malaysian automotive SMEs' to be set as the goal, the criteria for this goal are the five factors, the sub-criteria being the 25 dimensions, and the alternatives are the suppliers that intend to be benchmarked and compared. This overall hierarchy is depicted in Figure 1.

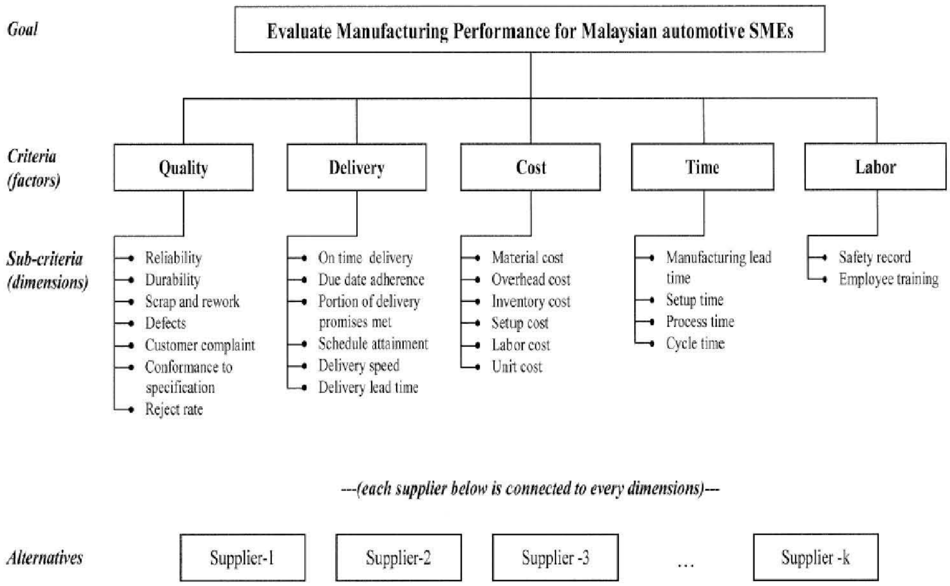

Figure 1: The hierarchy of manufacturing performance evaluation in Malaysian automotive SMEs

The goal will be to evaluate manufacturing performance for Malaysian automotive SMEs. At the first level of the hierarchy, five factors of the manufacturing performance criteria i.e. quality, delivery, cost, time, and labor, are set as the criteria. At the second level, there are a total of 25 dimensions of manufacturing performance criteria that described each factors as the sub-criteria. Finally, at the third level of the hierarchy, there are the suppliers (supplier-1 to supplier-k) that will be evaluated and compared.

Stage 3: Calculate the Relative Weight of the Criteria

Once the hierarchy has been constructed, the relative weight of the criteria and sub-criteria should be calculated. The steps are follows:

[1] Determine pair-wise comparisons between the criteria and the sub-criteria within each criterion. Saaty's scale of 1 to 9 is used to reflect these preferences as shown in Table 3.

Table 3: Scale of measurement in pair-wise comparisons

Intensity of importance	Definition	Explanation
1	Equally importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above
Reciprocals		If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*

Source: Saaty (2008)

For example, consider the relative weights calculation between the manufacturing performance criteria. The criteria consist of five elements are quality, delivery, cost, time, and labor. Pair-wise comparisons are determined to indicate how much more one element is important than other element as shown in Table 4.

Table 4: The pair-wise comparison of the criteria

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Criteria**
Quality								X										Delivery
Quality									X									Cost
Quality						X												Time
Quality				X														Labor
Delivery											X							Cost
Delivery								X										Time
Delivery						X												Labor
Cost							X											Time
Cost						X												Labor
Time								X										Labor

From the table, the importance of quality is considered equally-to-moderate over delivery, equally compared to cost, moderate-to-strong compared to time, and strong-to-very strong compared to labor.

[2] Construct the pair-wise comparisons matrix: After pair-wise comparisons, the pair-wise comparisons matrix is formed. From the comparisons in Table 4, the matrix as shown below is constructed:

$$
\begin{bmatrix}
 & Quality & Delivery & Cost & Time & Labor \\
Quality & 1 & 2 & 1 & 4 & 6 \\
Delivery & 1/2 & 1 & 1/3 & 2 & 4 \\
Cost & 1 & 3 & 1 & 3 & 4 \\
Time & 1/4 & 1/2 & 1/3 & 1 & 2 \\
Labor & 1/6 & 1/4 & 1/4 & 1/2 & 1
\end{bmatrix}
$$

All the diagonal elements of the matrix are 1 (as the elements are compared with themselves). Values of elements in the upper triangular matrix are obtained from the comparisons. The reciprocals of these values are shown in the lower triangular matrix.

[3] Construct the normalized matrix: Each column in the pair-wise matrix is then normalized by dividing the sum of the elements in the column. The result is a normalized matrix as below:

$$\begin{bmatrix} & Quality & Delivery & Cost & Time & Labor \\ Quality & 0.343 & 0.296 & 0.343 & 0.381 & 0.353 \\ Delivery & 0.171 & 0.148 & 0.114 & 0.190 & 0.235 \\ Cost & 0.343 & 0.444 & 0.343 & 0.286 & 0.235 \\ Time & 0.086 & 0.074 & 0.114 & 0.095 & 0.118 \\ Labor & 0.057 & 0.037 & 0.086 & 0.048 & 0.059 \end{bmatrix}$$

[4] Calculate the relative weight: The next step is taking the average of each row results the relative weight of each element as below:

$$\begin{bmatrix} Quality \\ Delivery \\ Cost \\ Time \\ Labor \end{bmatrix} = \begin{bmatrix} 0.343 \\ 0.172 \\ 0.330 \\ 0.097 \\ 0.057 \end{bmatrix}$$

[5] Compute the Consistency Ratio (*CR*): In order to check for consistency, multiply the pair-wise comparisons matrix with the relative weight matrix as follows:

$$\begin{bmatrix} 1 & 2 & 1 & 4 & 6 \\ 1/2 & 1 & 1/3 & 2 & 4 \\ 1 & 3 & 1 & 3 & 4 \\ 1/4 & 1/2 & 1/3 & 1 & 2 \\ 1/6 & 1/4 & 1/4 & 1/2 & 1 \end{bmatrix} \times \begin{bmatrix} 0.343 \\ 0.172 \\ 0.330 \\ 0.097 \\ 0.057 \end{bmatrix} = \begin{bmatrix} 1.750 \\ 0.877 \\ 1.710 \\ 0.574 \\ 0.289 \end{bmatrix}$$

Then divide the resultant matrix by the relative weight matrix:

$$\begin{bmatrix} 1.750 \\ 0.877 \\ 1.710 \\ 0.574 \\ 0.289 \end{bmatrix} \div \begin{bmatrix} 0.343 \\ 0.172 \\ 0.330 \\ 0.097 \\ 0.057 \end{bmatrix} = \begin{bmatrix} 5.101 \\ 5.104 \\ 5.179 \\ 5.894 \\ 5.041 \end{bmatrix}$$

After that, taking the average of the final matrix and the result λ_{max} is 5.264. The Consistency Index (*CI*) is then computed for a matrix of size n according to the formula:

$$CI = \frac{(\lambda \max - n)}{(n-1)} \quad (1)$$

Finally, Consistency Ratio (CR) is then calculated using the formula:

$$CR = \frac{CI}{RI} \tag{2}$$

where RI is a known random consistency index for the matrix size n. Table 5 shows the value of the random consistency index (RI). A CR value of less than 0.1 is acceptable (Saaty, 2008).

Table 5: Random consistency index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Source: Saaty (2008)

The Consistency Index (CI) of the five elements is calculated as below, where Random Consistency Index (RI) for the five factors (n = 5) is 1.11 (see Table 5).

$$CI = \frac{(\lambda \max - n)}{(n-1)} = \frac{(5.264 - 5)}{(5-1)} = 0.066$$

$$CR = \frac{CI}{RI} = \frac{0.066}{1.11} = 0.059$$

Since Consistency Ratio (CR) = 0.059 (less than 0.1), thus the decision-making is consistent over the pair-wise comparisons.

Stage 4: Rate the Sub-criteria

Having determined the relative weights of the criteria, the next step is to rate all the manufacturing performance sub-criteria. For this purpose, a guideline was assigned. The value of the measures range from 0 (representing lowest value) to 100 (representing highest value). The guideline rates the measures from the best performance to worst performance. For instance, reliability value is given 85, so reliability rating is 85. For other dimensions, if defect value is given 12, hence defect rating is 88 (obtained from 100 minus 12). Table 6 shows an example of rating calculation for quality.

Table 6: Result of the quality rating

No	Quality Dimensions	Value	Rating
1	Reliability	85	85
2	Durability	82	82
3	Scrap and rework	12	88
4	Defects	8	92
5	Customer complaint	15	85
6	Conformance to specification	87	87
7	Reject rate	5	95

Stage 5: Compute the Score of the Suppliers

The ratings of the sub-criteria are combined with the relative weights of the sub-criteria to give a score of the suppliers. The score is calculated for individual criterion score and as well as for the overall score. The individual criterion score of a supplier is given by the sum of product of the supplier's manufacturing performance ratings and the relative weight of sub-criteria.

$$CS_{ik} = \sum_{j=1}^{N} w_{ij} R_{ijk} \tag{3}$$

where:

CS_{ik} = individual criterion score of i^{th} criterion for k^{th} supplier,
w_{ij} = relative weight of j^{th} sub-criterion belonging to i^{th} criterion,
R_{ijk} = rating sub-criteria of k^{th} supplier for j^{th} sub-criterion of i^{th} criterion,
N = total number of sub-criteria belonging to i^{th} criterion.

For example, the individual score of quality for company-1 is calculated using Equation 3 as follows:

$$\begin{aligned} CS_{11} &= (0.299 \times 85) + (0.196 \times 82) + (0.122 \times 88) + (0.071 \times 92) \\ &\quad + (0.074 \times 85) + (0.094 \times 87) + (0.145 \times 95) \\ &= 86.998 \end{aligned}$$

The overall score of a supplier is given by the sum of the product of the manufacturing performance rating of the supplier in each criterion and the relative weight of the respective criterion:

$$S_k = \sum_{i=1}^{M} \sum_{j=1}^{N_i} W_i w_{ij} R_{ijk} \tag{4}$$

where:

S_k = overall score of k^{th} supplier,
W_i = relative weight of i^{th} criterion,
w_{ij} = relative weight of j^{th} sub-criterion belonging to i^{th} criterion,
R_{ijk} = rating criteria of k^{th} supplier for j^{th} sub-criterion of i^{th} criterion,
M = total number of criteria,
N_i = total number of sub-criteria belonging to i^{th} criterion.

The individual criterion score and the overall score of suppliers is presented by final result. For example, results of the individual criterion scores of three suppliers comparison is shown in Table 7. These scores are then used to rank the manufacturing performance of each company relative to others.

Table 7: The individual criterion scores of suppliers

Factors	Company-1	Company-2	Company-3
Quality	86.998	83.342	88.852
Delivery	89.858	83.312	78.775
Cost	79.680	73.240	79.852
Time	85.073	77.992	85.846
Labor	82.044	79.772	80.962

From the results, the suppliers can know their current performance involving their strengths and weaknesses. The scores give sufficient information to indicate where improvements are to be done by the suppliers. They must establish actions to be taken and help the suppliers in continuous improvement.

Stage 6: Rank the Suppliers Based on the Score

The individual criterion score and the overall score of suppliers in the product are then ranked in descending order. By using previous example, the ranking of companies can be shown as in Table 8. The result shows a supplier's performance compared with the others. The supplier with the highest score could be regarded as the best practice.

Table 8: The ranking quality score of suppliers

Supplier Name	Supplier Score	Supplier Ranking
Supplier-1	84.519	1
Supplier-3	83.288	2
Supplier-2	79.602	3

DEVELOPMENT OF THE SOFTWARE-BASED TOOL

While the proposed tool provides a systematic approach for quantitative assessment of suppliers, it is not entirely automated. Thus for that purpose, a software-based tool was subsequently developed. All the stages of the software development use the same sequence of the stages of manufacturing performance evaluation tool for Malaysian automotive SMEs as described previously.

The software-based tool comprises a set of programs and databases developed using PHP and MySQL. PHP (Hypertext Pre-Processor) is a server-side web programming language widely used for web development. PHP is a particularly useful programming language because it allows for advanced programming and is easy to integrate with web pages. PHP has many advantages; it is fast, stable, secure, easy to use and open source (Gosselin, 2006). Besides, PHP interfaces very well with MySQL, a popular type of online database. MySQL is a relational database management system (RDBMS) which has more than 11 million installations. MySQL is very commonly used in conjunction with PHP scripts to create powerful and dynamic server-side applications (Welling and Thomson, 2005).

In order to test the software, a web page called "Manufacturing Performance" has been created on the local host (http://localhost/audit/). Initially, the companies can register themselves as users of the site by providing unique login names and passwords for authentication purposes in the register page as shown in Figure 2.

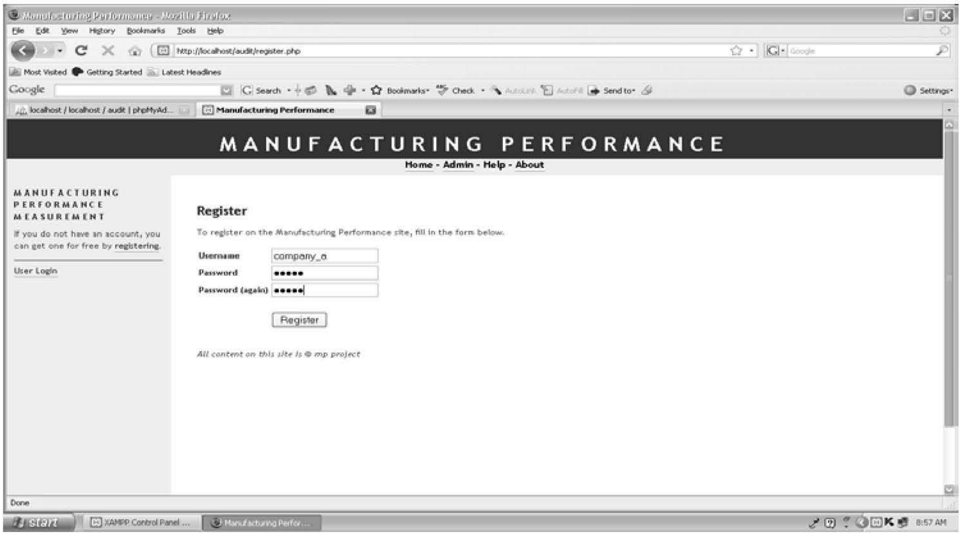

Figure 2: User register page

A registered company can log into the site. The first step of users is filling the company information form. The next is to determine the values of manufacturing performance measures. For instance, Company A entering values of the measures in the form as shown in Figure 3.

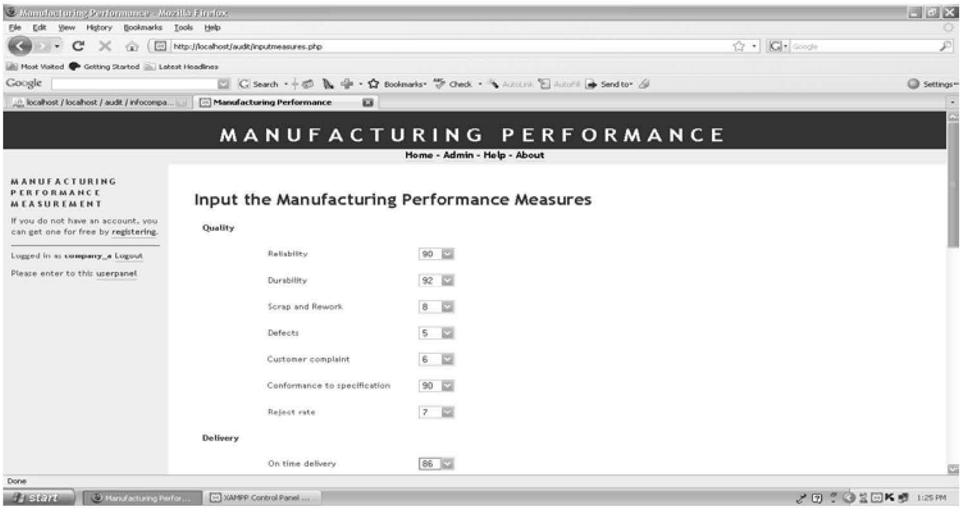

Figure 3: Input values of measures page

Relative weights of the measures should be calculated to obtain the company score. Admin must determine the weight by using pair-wise comparison form. It is conducted between the factors and the dimensions within each factor. After that, relative weights of the measures will compute. The results consist of the relative weights of the manufacturing performance criteria and consistency ratio of the pair-wise comparisons as presented in Figure 4. The results show which factors or dimensions are regarded as more important relative to others.

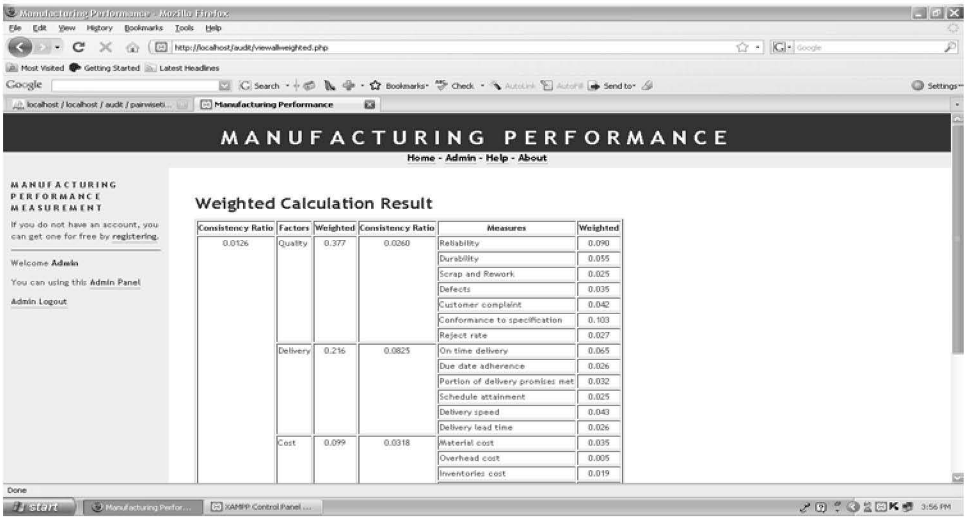

Figure 4: Relative weights of measures

Finally, the score of all the suppliers are calculated giving the overall score and the individual factor score as shown in Figure 5.

Company Name	Company_A	Company_B	Company_C	Company_D	Company_E	Company_F	Company_G	Company_H	Company_I	Company_J
Overall Score	89.556	88.481	86.637	86.653	79.513	86.482	84.366	89.538	87.828	87.443
Reliability	7.410	7.176	6.396	6.864	5.850	6.084	6.708	7.020	6.084	8.100
Durability	4.320	4.128	3.744	4.080	3.360	3.600	3.696	4.416	4.080	4.840
Scrap and Rework	2.090	2.024	1.936	1.980	1.870	2.024	1.980	2.090	2.046	2.250
Defect	2.790	2.790	2.700	2.640	2.580	2.700	2.640	2.790	2.760	3.220
Customer complaint	3.404	3.515	3.478	3.145	3.108	3.404	3.256	3.478	3.330	3.780
Conformance to specification	7.920	8.100	7.200	7.380	7.200	7.200	7.380	8.550	7.920	9.270
Reject rate	2.232	2.280	2.208	2.256	1.920	2.112	2.208	2.280	2.256	2.511
On time delivery	5.246	5.246	5.185	5.612	4.758	5.795	5.002	5.612	5.490	5.280
Due date adherence	2.040	2.112	2.064	2.280	1.800	2.208	1.920	2.160	2.112	2.028
Portion of delivery promises met	2.610	2.610	2.552	2.755	2.320	2.668	2.436	2.726	2.668	2.635
Schedule attainment	2.632	2.520	2.520	2.520	2.128	2.632	2.324	2.660	2.660	2.250
Delivery speed	3.680	3.480	3.600	3.680	3.000	3.840	3.200	3.720	3.680	3.526
Delivery lead time	1.674	1.692	1.656	1.674	1.584	1.710	1.548	1.692	1.674	1.720
Material cost	2.560	2.400	2.624	2.688	2.400	2.720	2.624	2.688	2.624	2.800

Figure 5: The companies score

The results also present the average score of the suppliers being compared. From the results, the companies can know their current performance involving their strengths and weaknesses. Strengths have to sustained and improved, while weaknesses have to be converted into the strengths. The scores give sufficient information to indicate where improvements have to be done by the companies. They must establish actions to be taken and helps companies in continuous improvement.

The companies are then compared and ranked based on their scores as shown in Figure 6. The results can be used as basis data to conduct benchmarking. Chen (2002) suggested the benchmarking process is generally based on a competitive basis and is the value of some parameters used as a reference point in comparisons. The benchmarking process is generally based on a basis value of some parameters which is used as a reference point in comparison (Chen, 2002). It could be used to compare the performance within one company (internally) or among different companies in an industry (externally). Establish performance benchmarks as the beginning of the process in achieving and sustaining manufacturing excellence.

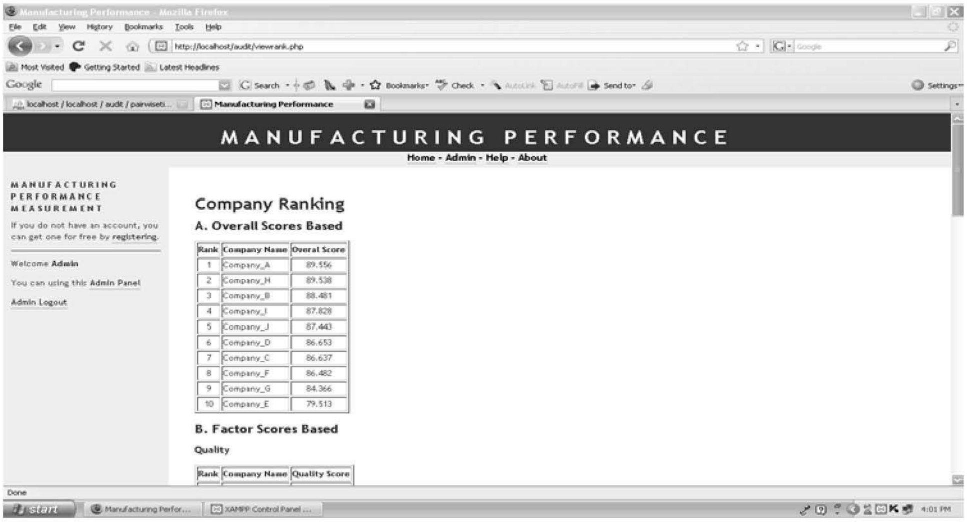

Figure 6: Ranking of companies

VALIDATION OF THE MANUFACTURING PERFORMANCE EVALUATION TOOL

The manufacturing performance evaluation tool was empirically tested and validated at two Malaysian automotive SMEs. After presentation of the tool, both companies gave positive comments on the tool. They said that it is simple, easy to use and well understood, and very useful. Both companies agreed that the tool is suitable methodology for SMEs to assess manufacturing performance. In addition, they perceived the tool as implementable and uncomplicated, which can easily be used in real working environment. Other positive comments raised are the tool could give an effective way of presenting the overall manufacturing performance and it is a simple methodology for assessing manufacturing performance in SMEs.

The companies concluded that the tool has given a common understanding of the need to improve and where improvement should be focused. It can help in determining target to be achieved that will drive the companies to practice continuous improvement. Beside that, the tool can be used as a base for conducting the benchmarking process.

Both companies agreed that top management must give their full commitment, not only in providing sufficient resources but they must also be committed to implement the recommendations made in order to become excel in manufacturing. Besides, it is also need an understanding of the implementation process by all company employees in continually improvement. The companies also suggested that with some modifications to the tool can be made applicable to other types and sizes of industries.

They also gave comments of the use of AHP methodology in the tool that can minimize subjectivity in determining weights of the measures. Since every criterion is considered in turn, a consensus choice of decision alternative can be achieved. The AHP also enables the company to assign different weights depending on their requirements or importance to the measures. This helps the company to overcome some issues related to the change of performance measures. It can be concluded that AHP methodology is very flexible that changing of relative weight is allowed at any time and new alternatives can be added as necessary. Different companies may have their own goals and operational strategies, so the values of relative weights may be different. The use of AHP enables companies to enter their own pair-wise comparison to reflect their own management strategies so that the outcome can provide a best solution meeting their existing and future business strategies.

From the case studies, it can be concluded that the tool is appropriate and suitable to SMEs in assessing manufacturing performance. The tool can be used in self-assessment and benchmarking to ensure continuous improvement. For the self-assessment, the tool shows how the existing performance involves the strengths and weaknesses so that indicate where improvements need to be made. It also can be used as a base to conduct benchmarking by comparing the performance internally or externally. It is hoped the tool would be of benefit to SMEs in their efforts to become more effective, competitive, and excellent.

DISCUSSION AND CONCLUSIONS

A quantitative, multi-attribute decision tool for evaluating the manufacturing performance in Malaysian automotive SMEs has been developed. The tool applies the Analytic Hierarchy Process (AHP) methodology. The hierarchy was constructed based on five criteria and 25 sub-criteria of manufacturing performance measures for Malaysian automotive SMEs. Relative weights of the measures were assigned by pair-wise comparisons. Values of the measures were rated using the rating guideline. The company score has been computed to evaluate suppliers against the measures. Finally, the company rank was determined based on the score.

This tool enables managers to understand their existing level and the performance gap with the best-in-class company. Competitive advantage and disadvantage can also be identified to indicate the direction of improvement. It also provides managers to select the best practice that can be learnt from the industry leader. The decision will be the most suitable option selected to improve the existing problem and for continuous improvement.

The software-based tool was subsequently developed for computerization purpose. The methodology of the manufacturing performance evaluation tool is used in designing the software. It is a web based-software developed using PHP and MySQL. The software is entirely automated to conduct stages of manufacturing performance evaluation tool for Malaysian automotive SMEs.

Finally, the manufacturing performance evaluation tool for Malaysian automotive SMEs was tested and validated at two Malaysian automotive SMEs. From the case studies, the tool is found to be an appropriate and suitable tool to them in assessing manufacturing performance. The tool can be used to evaluate performance internally and externally. The tool is able to identify the strengths and weaknesses, and can indicate where improvements need to be made. In benchmarking, the tool can be used as a base to compare the performance and select the best practices. The tool can assist Malaysian automotive SMEs in their efforts to continually improve their manufacturing performances so as to become efficient and effective.

Although the research was limited to Malaysian automotive SMEs, the insights obtained will have similar implications for other industries and other countries. Finally, it is hope the tool would be of benefit to the Malaysian automotive SMEs in their pursuit towards enhancing their business competitiveness and excellence.

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