Improvement of Automotive Part Supplier Performance Evaluation

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Abstract. This research investigates the problem of the part supplier performance evaluation in a major Japanese automotive plant in Thailand. Its current evaluation scheme is based on experiences and self-opinion of the evaluators. As a result, many poor performance suppliers are still considered as good suppliers and allow to supply parts to the plant without further improvement obligation. To alleviate this problem, the brainstorming session among stakeholders and evaluators are formally conducted. The result of which is the appropriate evaluation criteria and sub-criteria. The analytical hierarchy process is also used to find suitable weights for each criteria and sub-criteria. The results show that a newly developed evaluation method is significantly better than the previous one in segregating between good and poor suppliers.

1. Introduction
Nowadays, the business competition has become increasingly intensified in Thailand especially in the automotive industry which has grown and developed rapidly. One car consists of numerous different parts, which can be provided by various suppliers. This leads to high competition among automotive part suppliers who supply the same or similar parts to the automotive manufacturer. These suppliers are striving to gain a higher market share. To achieve the goal as such, they must pass several stringent criteria set by the automotive manufacturer. The case study company is a leading Japanese automotive assembly plant in Thailand. Currently, 243 suppliers pass the supplier selection process of the company. Therefore, they must have their operational processes evaluated on a monthly basis by several departments of the company, i.e. production, sales, and quality control departments. The evaluation process is not only conducted to assess the current performance of the suppliers, but also to further develop and improve the quality of the supplied parts. Furthermore, helping suppliers to reach the world class standard can mitigate potential future risks and problems that might affect the company, such as late orders and damaged goods, high turnover time and high part inspection time. As a consequence of the part supplier performance evaluation, the company can select the suppliers who can operate in line with its current competitive strategy. The overall supplier evaluation policy of the company weights equally in terms of delivery and quality of the parts supplied. Thus, the weight of part delivery has been set to 40\%, the quality to 40\% and the price to 20\%. This weighting scheme forces the supplier to deliver high quality parts and also to be aware of the total lead time to ensure an on-time delivery. The part control department is responsible for the part supplier performance evaluation. A total of 12 evaluators have to evaluate 203 suppliers. These evaluators apply the same
criteria in the part delivery performance measurement. It was found that the evaluation results are different based on their experience and self-opinion. As a result, the outcome of the evaluation may not reflect the actual delivery performance of the suppliers. In addition, the weights using in the evaluation criteria are not suitable. This study aims to improve the part delivery evaluation criteria to ensure the standardized evaluation process so that the results are trustworthy. The analytic hierarchy process (AHP) technique is applied to find suitable criteria and its associated weight. The measurement system analysis (MSA) is also exercised to calibrate the accuracy of the evaluators.

2. Literature Review
Due to the fact that the quality and performance of suppliers can affect the company, the part supplier performance evaluations are very important to any kind of business. Many researchers have studied and presented types and criteria which are different from each other, depending on the type of business and the strategy of the company.

2.1 Performance Evaluations
Evaluations are processes of gathering information from measurements and using evaluator opinion to determine the suitable scores through comparing the results to the standard. Supplier evaluations aim to reduce the risk when ordering goods, which assures that the supplier can meet customer needs and the results of the evaluation will be used to determine future purchase orders [1]. Evaluations help to choose efficient suppliers and avoid those who do not provide high quality products. The evaluations always ensure confidence with suppliers who pass all the criteria so that they maintain responsibility and succeed in filling customer needs [2]. Part supplier performance evaluations have diverse issues in determining the criteria. The primary three criteria are price, quality and lead time [3].

2.2 Multi-Criteria Decision Making (MCDM) Overview
MCDM is a method of balancing variables in the evaluation to produce the best outcome based on multiple criteria and their respective weights. To do this, finding clear methods and realistic weights can help the determination of the most effective and efficient supplier based on multiple criteria, not just only cost. Nowadays, there are many ways to deal with decision issues, which each has its own specialty. These can be used differently, depending on situation, appropriateness and specialization of the evaluator [4]. AHP is one of the most effective ways to deal with the complicated issues which are made easier to understand through simulation of human linguistics [5]. There are several ways to deal with determination issues by using MCDM, depending on the researchers, such as procurement and best supplier selection [6], location selection [7], environment risk assessment [8] and health care system [9].

2.3 Analytic Hierarchy Process
AHP was developed in 1970 by Thomas L. Saaty [10]. AHP is a technique that converts the feelings and opinions of evaluators into numerical data. A standard weighting of criteria is created based on the results of evaluations. AHP is a primary way to determine MCDM and is an effective and convenient process for creating a standard weight. AHP helps to determine the best suppliers based on evaluations. It can also be used to help with complicated multi-criteria decisions by comparing methods [11]. The primary technique of AHP involves presenting issue of hierarchy determination and comparing criteria through a statistical matrix. These results are then evaluated and the criteria are ranked and weighted. To obtain the best result, according to the study, the AHP technique is applied in many decision making situations, such as supplier performance evaluations [12, 13], supplier selection [14, 15], etc. The main benefits of AHP are that the results are formulated into numerical data, ranking criteria is simplified, and evaluation bias and opinion is reduced. AHP consists of three steps as follows: (1) Establishing the hierarchical structure, (2) Constructing the pairwise comparison matrix and (3) Calculating the consistency. More detail can be seen in [16]
3. Case Study
This study employs the example occurring in the automotive assembly plant. The company currently faces with the problem of part supplier performance evaluation. Top management found that the results of the evaluations were ineffective enough to reflect the actual part supplier performance. The reasons come from inappropriate weights being used in the evaluation criteria and non-standardized self-opinion of the evaluators. To analyse this problem, this research divided the suppliers into 3 groups depending on the importance of the supplied parts. AHP was then applied to these groups to specify the appropriate weights of the criteria. These criteria are further used to improve the delivery performance of the suppliers. Through doing this, a new standardized weights can be determined so that trustworthy and consistency results can be achieved.

4. AHP Implementation
AHP is a reliable and suitable method for decision procedures and help decision-makers to assess the criteria’s weights and chosen the best alternative [17]. It helps to determine the best supplier (alternative) based on both qualitative and quantitative evaluations. It can also be used to help in complicated multi-criteria decisions. The main benefits of AHP are that its result is shown in a numerical format, ranking criteria is simplified, and evaluation bias and opinion are reduced; therefore, AHP was chosen to strive for suitable criteria and its associated weight to help improve the part delivery evaluation criteria to ensure the standardized and trustworthy evaluation process.

Due to the high number of purchased parts, the suppliers are classified into three groups, according to the importance of their supplied parts.

Group A (48 suppliers): These suppliers produce large and specialized parts such as engines, cushions and doors. These suppliers are difficult to replace, and their supplied parts are not regularly kept in stock. In addition, these suppliers always show on-time delivery performance.

Group B (130 suppliers): These supplies produce unspecialized parts such as headlights, brake lights, batteries and radios. These suppliers can be replaced easily. In addition, these suppliers send parts to the company according to the given cycle time.

Group C (25 suppliers): These suppliers produce small parts, which are ordered once a week, depending on the needs of the company. These parts are constantly kept in stock, which include the parts like screw, nut, bolt, tape and clip.

In each group, AHP is applied to specify the main criteria and their associated weights to be used in the part delivery performance evaluation so that the aforementioned problem can be effectively resolved. The steps can be described as follows.

4.1 Primary Criteria Selection
Numerous delivery problems and criteria for part delivery performance evaluation used in the automotive industry were collected. 3 main stakeholders as well as 12 evaluators were invited to participate in the brainstorming meeting. The criteria which deemed to be the most influences to the delivery performance and had the goal of improving delivery performance were selected. The results of the primary criteria selection in the part delivery evaluation consisted of 5 factors (on-time delivery, delivery cooperation, delivery part accuracy, package and delivery's documentation).

4.2 Sub-criteria selection
After the primary criteria were selected, once again the sub-criteria were chosen through stakeholder brainstorming. After brainstorming, the stakeholders vote to conclude the selected sub-criteria. It is noted that the sub-criteria must be related to the primary criteria. The results can then be exemplified as shown in Table 1.
Table 1. Results of selected sub-criteria

| Criteria               | Sub Criteria                                                                 |
|------------------------|-----------------------------------------------------------------------------|
| A. On - time delivery  | A.1 Line stop                                                              |
|                        | A.2 Pending Car (not complete)                                              |
|                        | A.3 Change production schedule                                             |
|                        | A.4 Not on time delivery but not effect to production line                  |
| B. Delivery cooperation | B.1 ASN confirm                                                            |
|                        | B.2 Information such as delivery delay information                         |
|                        | B.3 Delivery performance during emergency order                            |
|                        | B.4 Delivery flexibility                                                   |
|                        | B.5 Follow the rule of the factory                                         |
|                        | B.6 Reply countermeasure ,Car Report and Survey                             |
| C. Delivery part accuracy | C.1 Part Short delivery quantity                                            |
|                        | C.2 Part Over delivery quantity                                             |
|                        | C.3 Part NG (damage, wrong parts, mixing Parts)                             |
| D. Package             | D.1 Size standard                                                           |
|                        | D.2 No damage                                                              |
|                        | D.3 Cleaning                                                               |
|                        | D.4 Safety                                                                 |
|                        | D.5 Easy for receiving check                                               |
|                        | D.6 Enough to use for requirement                                          |
| E. Delivery's Documentation | E.1 Delivery documents must complete (part tag, delivery tag& delivery note) |
|                        | E.2 Part Tag and delivery tag base on document standard                     |
|                        | E.3 Delivery note must easy for receiving check                            |

4.3 Analytic Hierarchical Process

After the relevant primary and sub-criteria were selected, the next step is to apply AHP to determine suitable weights for them. The process can be explained as follows.

4.3.1 Establishing a Hierarchical Structure

Following the criteria identification, the hierarchical structure (Figure 1.) can be established by creating a hierarchy chart, in which the highest factor is the goal. In this case, the goal was the delivery performance of part suppliers. One level lower the goal is the primary criteria used in determining the best supplier [18], which includes 5 factors (i.e. on-time delivery, delivery cooperation, delivery part accuracy, package and delivery's documentation). The sub-criteria located under the primary criteria consisted of 22 sub-factors (Table 1).
Figure 1. AHP based hierarchical model to evaluate delivery performance of suppliers.

Establishing a hierarchical structure shows the complicated relationships between the main criteria and sub-criteria. Creating the hierarchical structure leads to the ability to evaluate the comparison criteria within the same factor, which can affect the solution.

4.3.2 Ranking the Priority
This step is the most important step in the selection process because it ranks the importance of the evaluation criteria, which, if chosen incorrectly, will greatly affect the outcome. In this step, the details of factors are gathered and compared each factor in part supplier performance evaluations. The weight of each factor is then analysed with evaluator brainstorming results through scoring and evaluator comment. The scores are the outcome of comparing the importance of each factor in pairs. These pairwise comparisons proceed from the top of the hierarchical structure, starting with primary criteria and then moving through the sub-criteria.

In AHP, scores of 1-9 (Table2) are given based on importance of the pair of the factors to get satisfaction into the numbers, applying numerical values to non-numerical opinion.

Table 2. Measurement scales of AHP

| Verbal judgment or Preference     | Numerical rating |
|-----------------------------------|------------------|
| Extremely preferred               | 9                |
| Very strongly preferred           | 7                |
| Strongly preferred                | 5                |
| Moderately preferred 3            | 3                |
| Equally preferred 1               | 1                |
| Intermediate values between two adjacent judgments (when compromise is needed) | 2, 4, 6 and 8 |
Once the comparison result is obtained, a pairwise comparison matrix is created to compile the priority ranking of each criteria. In the 2nd level of the hierarchy, 5 critical factors dimensions are identified, i.e. delivery cooperation, delivery part accuracy, package and delivery's documentation. The decision first builds the pairwise comparison matrix for 5 factors (n=5) using intensity scales (1-9). The comparison judgment table (Table 3) shows the pairwise comparison matrix.

| Table 3. Pairwise comparison matrix (criteria) |
|----------------------------------------------|
| Factor        | On Time | Cooperate | Accuracy | Package | Document |
| On Time       | 1       | 5         | 3        | 7       | 7        |
| Cooperate     | 1/5     | 1         | 1/3      | 5       | 3        |
| Accuracy      | 1/3     | 3         | 1        | 3       | 5        |
| Package       | 1/7     | 1/5       | 1/3      | 1       | 1        |
| Document      | 1/7     | 1/3       | 1/5      | 1       | 1        |
| Total         | 1.819   | 9.533     | 4.867    | 17      | 17       |

From the pairwise comparison matrix, the next step is to calculate the priority or weight of the elements in the matrix by summing up the values in each column. Each value is then divided by the total of the column. The result of priority or weight of factors are shown in Table 4 (A). In Table 4 (A), the sum of each column must equal to 1 or 100%.

| Table 4. (A) Priority matrix          |
|---------------------------------------|
| Factor                        | On Time | Cooperate | Accuracy | Package | Document |
| On Time                       | 0.550   | 0.524     | 0.616    | 0.412   | 0.412    |
| Cooperate                     | 0.110   | 0.105     | 0.068    | 0.294   | 0.176    |
| Accuracy                      | 0.183   | 0.315     | 0.205    | 0.176   | 0.294    |
| Package                       | 0.079   | 0.021     | 0.068    | 0.059   | 0.059    |
| Document                      | 0.079   | 0.035     | 0.041    | 0.059   | 0.059    |
| Total                         | 1       | 1         | 1        | 1       | 1        |

The weight in Table IV (B) is the average of all factors in each row, for example the factor “Cooperate” weight is the sum of row factor cooperate (0.754) divided by the number of factors (n=5) giving the value of 0.151. From the analytical results (Table 5(B)), On-time delivery (0.503) is the most important criterion whereas other criteria obtain their weights as delivery part accuracy (0.235), delivery cooperate (0.151), package (0.057) and delivery's documentation (0.054).

4.3.3 Consistency Analysis

This step investigates the comparison results regarding their consistency relativity through calculating the consistency ratio (CR). CR can be calculated by dividing the Consistency Index (CI) by the Random Consistency Index (RI), which can be obtained from the matrix found above. If CR is less than or equal to 0.1, then the consistency is acceptable. If the CR greater than 0.1, then the consistency is unacceptable and the subjective judgment must be redone. The measure in Table 5 is calculated by summing the value of each row and then divide it by the identical weight.
Table 5. The value of each row

| Factor     | Measure |
|------------|---------|
| On Time    | 5.453   |
| Cooperate  | 5.164   |
| Accuracy   | 5.53    |
| Package    | 5.108   |
| Document   | 5.154   |
| Total      | 26.409  |

The $\lambda_{\text{max}}$ value is the total in Table V. divided the number of factors.

$$\lambda_{\text{max}} = \frac{26.409}{5} = 5.282$$ (3)

To find the Consistency Ratio (CR), the random index (RI) when $n = 5$ is 1.12.

$$\text{CR} = \frac{\lambda_{\text{max}} - n}{(n-1) \text{RI}}$$
$$= \frac{5.282 - 5}{(5-1) (1.12)}$$
$$= 0.06 < 0.1$$

CR = 0.06 < 0.1, meaning the consistency is acceptable.

In the next level (3rd level) of decision making, the weights of the sub-criteria nested under the primary criteria have to be determined. The steps are similar to those explained previously. The result is shown in Table 6.

Table 6. Ranking of overall weight Criteria and Sub-Criteria

| Criteria          | Weight | Rank | Sub-Criteria                             | Weight | Rank |
|-------------------|--------|------|------------------------------------------|--------|------|
| A. On-time delivery| 0.503  | 1    | A.1 Line stop                            | 0.592  | 1    |
|                   |        |      | A.2 Pending Car (not complete)           | 0.237  | 2    |
|                   |        |      | A.3 Change production schedule           | 0.126  | 3    |
|                   |        |      | A.4 Not on time delivery but not effect to production line | 0.045 | 4    |
| B. Delivery cooperate | 0.151 | 3    | B.1 Advance confirm order               | 0.19   | 2    |
|                   |        |      | B.2 Information such as delivery delay information | 0.328 | 1    |
|                   |        |      | B.3 Delivery performance during emergency order | 0.182 | 3    |
|                   |        |      | B.4 Delivery flexibility                 | 0.128  | 4    |
|                   |        |      | B.5 Follow the rule of the factory       | 0.096  | 5    |
|                   |        |      | B.6 Reply Countermeasure , Car Report and Survey | 0.076 | 6    |
| C. Delivery part accuracy | 0.235 | 2    | C.1 Part Short delivery quantity       | 0.488  | 1    |
|                   |        |      | C.2 Part Over delivery quantity          | 0.064  | 3    |
|                   |        |      | C.3 Part NG (damage, wrong parts and mixing Parts) | 0.448 | 2    |
| D. Package        | 0.057  | 4    | D.1 Size standard                       | 0.164  | 3    |
|                   |        |      | D.2 No damage                           | 0.173  | 2    |
|                   |        |      | D.3 Cleaning                            | 0.053  | 6    |
| Criteria          | Weight | Rank | Sub-Criteria                                       | Weight | Rank |
|-------------------|--------|------|----------------------------------------------------|--------|------|
|                   |        |      | D.4 Safety                                        | 0.412  | 1    |
|                   |        |      | D.5 Easy for receiving check                       | 0.050  | 5    |
|                   |        |      | D.6 Enough to use for requirement                  | 0.148  | 4    |
| E. Delivery's document | 0.054  | 5    | E.1 Delivery documents must complete                | 0.480  | 1    |
|                   |        |      | E.2 Part tag and delivery tag Base on document standard | 0.405  | 2    |
|                   |        |      | E.3 Delivery note must easy for receiving check     | 0.115  | 3    |

After determining the weights for all criteria and sub-criteria in the delivery performance evaluation, these weights are set as a new evaluation standard. A formal training conducted by an in-house expert is provided to all evaluators so that the same evaluation baseline will be implemented in the company. To ensure that all evaluators understand and apply the given guideline correctly, the attribute MSA is conducted on each evaluator. As shown in Table 7, the percentage of repeatability and accuracy are equal to 100% meaning that all evaluators are competent to evaluate the delivery performance of the suppliers under the same standard.

| No. of Evaluator | Before Training | After Training |
|------------------|-----------------|----------------|
|                  | Appraiser Score (%) | Attribute Score (%) | Appraiser Score (%) | Attribute Score (%) |
| 1                | 100             | 98             | 100              | 100             |
| 2                | 85              | 70             | 100              | 100             |
| 3                | 100             | 94             | 100              | 100             |
| 4                | 93              | 68             | 100              | 100             |
| 5                | 100             | 96             | 100              | 100             |
| 6                | 100             | 96             | 100              | 100             |
| 7                | 96              | 73             | 100              | 100             |
| 8                | 100             | 97             | 100              | 100             |
| 9                | 96              | 73             | 100              | 100             |
| 10               | 98              | 72             | 100              | 100             |
| 11               | 100             | 92             | 100              | 100             |
| 12               | 87              | 79             | 100              | 100             |

**Table 7. Attribute MSA**

| No. of Evaluator | Before Training | After Training |
|------------------|-----------------|----------------|
|                  | Appraiser Score (%) | Attribute Score (%) | Appraiser Score (%) | Attribute Score (%) |
| 1                | 100             | 98             | 100              | 100             |
| 2                | 85              | 70             | 100              | 100             |
| 3                | 100             | 94             | 100              | 100             |
| 4                | 93              | 68             | 100              | 100             |
| 5                | 100             | 96             | 100              | 100             |
| 6                | 100             | 96             | 100              | 100             |
| 7                | 96              | 73             | 100              | 100             |
| 8                | 100             | 97             | 100              | 100             |
| 9                | 96              | 73             | 100              | 100             |
| 10               | 98              | 72             | 100              | 100             |
| 11               | 100             | 92             | 100              | 100             |
| 12               | 87              | 79             | 100              | 100             |

**Repeatability = 61%**

**Accuracy = 61%**

**Repeatability = 100%**

**Accuracy = 100%**

The test performance of 12 evaluators before training is shown in Figure 2. The overall effective repeatability and accuracy are equal to 61% and 61%, respectively. It was clear that all evaluator were failed by the testing criteria of the MSA which were set as 100%. Therefore, the company had to send all evaluators to the training program about the measurement for supplier evaluation. After completing the training course, the attribute MSA was re-conducted to these evaluators again and the testing results showed that all of them passed the given standard (Figure 3).
5. Conclusion
Due to the competitive nature within the automotive industry, suppliers must develop their performances to meet the customer satisfaction criteria. Maintaining general quality, including capital, is necessary to help companies succeed and the best way for a company to do so is to use the best suppliers. The best suppliers will have the highest quality, best on-time delivery rate and facilitate the production process of the customer. Therefore, most customer companies give the highest priority to the suppliers and use part supplier performance evaluations.

In this study, the current evaluation results are ineffective to screen out between good and poor performance suppliers. The main reasons come from inappropriate criteria and their weightings are utilized. Therefore, the new criteria are established based on the experts in industry and the in-house evaluators. AHP is applied to find suitable weights for the primary and sub-criteria. The result shows that after the standard procedure is set and the evaluators are properly trained, the outputs of the part delivery supplier evaluation are much more accurate and trustworthy. After improving the criteria for delivery evaluation by using the AHP method and implementing the standardized method for evaluated supplier delivery performance, the evaluation results are much more trustworthy, reliable and easy-to-use for the evaluators.

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