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A Simple Multi-Criteria Selection Model to Set Boundary Sample for Auto Parts

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Abstract. Decision making when faced with several alternatives is not simple. At an automobile manufacturer, the review boundary sample activity for reducing cost and maintaining the best quality for customers is complex; it requires criteria-based judgments, e.g., defect ratio and claimed history of customers' parts. We propose a decision support system for this multiple criteria selection problem. We apply Analytic Hierarchy Process (AHP) techniques, which enable this problem to be solved without an optimizer. In our work, questionnaires were used to survey quality control engineers and to determine weights of criteria. With this system, an automobile manufacturer can collect data and use it to consider selection alternatives. Even a new or an inexperienced engineer can use this system to identify the best selection and ensure objective selection.

Keywords: Analytic Hierarchy Process, Boundary Sample, Multiple Criteria Decision Making.

1. Introduction

Because an automobile manufacturer needs to maintain a goal of "Customers Come First," it must ensure that its suppliers provide products with the highest quality. However, the manufacturer does not have explicit knowledge of suppliers' capability; suppliers cannot control the quality of parts or defect outflow to the manufacturer. Some suppliers resort to scrapping and repairing part in order to deliver parts in good conditions to the manufacturer; this scrapping may result in higher costs to suppliers, even though the parts may not be unacceptably defective.

"Boundary Sample" is defined as the defective limit of a vehicle's parts specified by the manufacturer to ensure suppliers make proper judgments on the quality of their parts, when screening parts are consigned to the manufacturer. However, the company does not set boundary samples for all vehicles' parts. The company has three conditions for setting the boundary sample: when suppliers cannot control the process, when an identified defective part clearly does not meet the standard, and finally, when the parts are in areas visible to customers.

The manufacturer, in the interests of customer satisfaction, always sets stricter boundary samples than required. The manufacturer has three main standards for quality control. The complete Vehicle Inspection Standard (CVIS) is used to control vehicle quality at the automobile manufacturer, by reference to Japanese fitting standards; the Shipping Quality Audit (SQA) is for controlling vehicle quality, by reference to customer satisfaction. Generally, the CVIS must exercise stricter control than the SQA. Finally, the Approval Inspection Standard (ATIS) controls parts quality for suppliers, by reference to drawings. If a part is shown in the CVIS or a drawing, the manufacturer would not set a boundary sample. On the other hand, if the defective part is not shown in the CVIS or drawing, the company would set boundary samples based on the more strict SQA, to ensure the highest quality for customers.

The Quality Control (QC) department therefore needs to “Review Boundary Samples” to counteract this issue, by using multiple criteria in making decisions, e.g., defect ratio, benefit-cost analysis, supplier’s history, extent of defects and acceptable defects based on the SQA. Suppliers provide the manufacturer with various data and dimensional defects or financial benefits in Baht/vehicle.

As a result, the manufacturer needs to create a decision support system (DSS) to enable objective judgments which take into account several selections or alternatives, in order to provide the best selection. Suppliers’ data and the SQA’s constraints will be included in this system through the Analytic Hierarchy Process (AHP) framework. Our proposed decision support system will produce a selection with the best criteria. We are in the process of implementing our framework in Microsoft Excel because it is one of the most widely-used management tools that enable easy data collection and manipulation. Furthermore, this decision support system is ideal for efficient judgment of boundary samples by engineers with limited skill or experience.

2. Literature Survey

Bhutta and Huq describe AHP as an excellent approach that can be used in a multifactor decision-making environment, especially when subjective and/or intuitive considerations have to be incorporated. AHP provides a structured approach for determining scores and weights for multiple criteria, and then standardizing them, so that they can be compared and used for making decisions.

Dickson study the vendor selection decisions. He lists at least 50 distinct factors (characteristics of vendor performance) from the purchasing literature that are presented by various authors as being meaningful to consider in the vendor selection decisions. Dickson summarizes the findings of Dickson’s study regarding the importance of 23 criteria for vendor selection.

Lee, Ha, and Kim state that the supplier selection and management system (SSMS) can use the AHP model to calculate the weights of both tangible and intangible criteria for supplier selection, and to rank the suppliers’ performance. The weights of the criteria derived from the AHP analysis are applied to select the key criteria for reinforcing the quality of each part.

Narasimhan suggests using AHP for the supplier selection activity, as it is a decision-making method for prioritizing alternatives when multiple criteria must be considered. AHP also offers a methodology to rank alternative courses of action based on the decision maker’s judgments concerning the importance of the criteria, and the extent to which they are met by each alternative.

In addition, Ragsdale suggests that AHP provides a more structured approach for determining the scores and weights for the multi-criteria scoring model. Sometimes, a decision maker finds it difficult to subjectively determine the criterion scores and weights needed in the multi-criteria scoring model

3. Empirical Results

Firstly, we need to discuss our questionnaire design for the criteria ranking (Section 3.1), extent of defects (Section 3.2) and other criteria (Section 3.3).

3.1. The Criteria Ranking

We consider five quality criteria: extent of defect, defect ratio, benefits, claimed history data and customer complaint history data. We then prepare a questionnaire for a pair-wise comparison matrix. We design the extent of defect questionnaire to find acceptable dimensions smaller than the standard of SQA. We find that the extent of defect criteria is difficult to establish, and the experience from survey takers are needed. However, we are able to design questionnaires for other quality criteria. This includes the numerical data of acceptable defect ratios, sufficient benefits, the acceptable number of customer complaint cases and the acceptable number of claimed part cases when we accept the dimension of defect presented by suppliers.

The remaining criteria simply require an opinion and a sense of judgment; for example, we separate the extent of defect criteria in the questionnaire design with weight scores which are proportional to job positions (the more senior the positions, the higher the weights), e.g., engineer's weight equals to "1", chief engineer's weight equals to "1.5" and higher than assistant manager's weight equals to "2". The remaining criteria questionnaire is combined in another set of questions.

3.2. Design of Extent-of-Defect Questionnaire

Generally, Quality Control Engineers approve suppliers' proposals concerning the extent of defects by referring to the SQA; however, few engineers have sufficient understandings to properly judge the optimal position of defects in the SQA. Inexperienced engineers need to be supported by assistant managers with greater skills. We create a decision support system to enable correct judgment in minimum time and with limited skill and experience. We design the dimension-of-defect questionnaire in a pair-wise comparison matrix case for one part at a time. However, we find it impractical for survey takers to answer all the questions that come from suppliers' proposal. The scope of the defect questionnaire was therefore redesigned and distributed to eighteen qualified engineers in the Quality Control Department for setting the grade of suppliers who present the extent of defect for establishing boundary samples. The grade of A to E represents "surely acceptable", "acceptable", "may be acceptable", "need support from leader" and "not acceptable" opinion. "Surely acceptable" and "not acceptable" grade questionnaires are designed for minimum and maximum extent of defect. Remaining grades of suppliers are calculated from an average dimension from minimum to maximum values.

We do not categorize all grades of suppliers because answering questionnaires is a demanding task for survey takers. Both types of questionnaires have 44 questions with 6 multiple choices; each question is classified by the zone of defect and the type of auto parts following the SQA. Each choice is designed by according to the dimension of defect in the SQA. Then a pair-wise comparison in AHP is created using scales of 1, 3, 5, 7 and 9, representing from "equally preferred" that means two suppliers present their extent of defects and are given the same grade of suppliers; "moderately preferred" represents the difference of 1 grade, "strongly preferred" 2 grades, "very strongly preferred" 3 grades and "extremely preferred" 4 grades (See the complete detail in [6]). For example, the supplier K presents the extent of defects and results in grade A, whereas the supplier L presents his and receives grade E. Therefore, the AHP score is "9" because they differ by 4 grades. The empirical results of minimum and maximum dimension of defect questionnaire are shown in Figures 1 and 2.

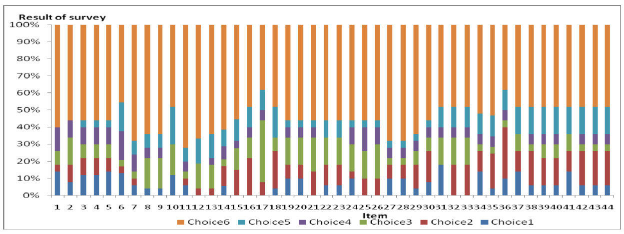

Fig. 1: The result of the survey in "surely acceptable" questionnaire (minimum dimension of defect).

The result of the survey in "surely acceptable" questionnaire shows the same pattern as in Figure 1 in that the minimum dimension of defect for each item should be the sixth choice, which would not be accepted or 0 (zero).

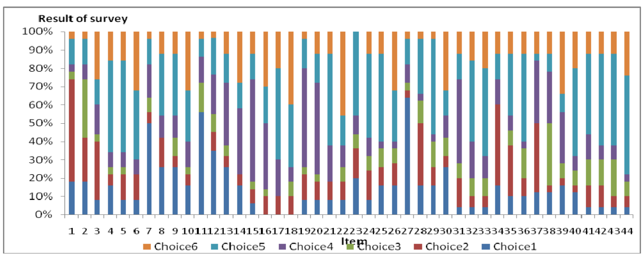

Fig. 2: The result of the survey in "not acceptable" questionnaire (maximum dimension of defect).

The result of the survey in “not acceptable” questionnaire shows that the maximum dimension of defect depends on the zone of defects and type of parts. Some zones of defects and type of parts are more critical and visible that small dimension of defect is required. Some zones of defect and type of parts are less critical and less visible that more dimension of defect should be acceptable.

3.3. The Other Criteria Questionnaire Design

The remaining criteria questionnaire are on benefits, defect ratio, claimed history data and customer complaint history data are answered by twenty-eight Quality Control Engineers using the same concept with extent-of-defect questionnaire. The questionnaire is graded by using A to E, ranging from “surely acceptable”, “acceptable”, “may be acceptable”, “need support from leaders” and “not acceptable”. We design the questionnaire so that survey takers can decide to accept conditions by themselves for “surely acceptable” (grade A). Survey takers can accept a condition after requesting one item of information for “acceptable” (grade B); survey takers can accept a condition after requesting more than one item of information for “may be accept” (grade C); survey takers need support from leaders to accept conditions for “need support from leaders” (grade D), and survey takers cannot accept condition for “not acceptable” (grade E). Then a pair-wise comparison in AHP is creating the same concept with the extent-of-defect questionnaire (see the complete detail in [6]). The empirical result of other criteria questionnaire is shown in Tables 1-4.

Table 1: The result of surveys in benefits criteria

Grade	Benefits (Percent of cost reduction)
A	80% and up
B	51% – 60%
C	41% – 50%
D	21% – 30%
E	0% – 10%

Table 2: The result of surveys in defect ratio criteria

Grade	Defect Ratio
A	80% and up
B	31% – 40%
C	21% - 30%
D	11% - 20%
E	0% – 10%

Table 3: The results of customer complaint cases in the last 8 months

Grade	# of customer complaint cases
A	0 case
B	1 case
C	2 – 3 cases
D	4 – 5 cases
E	7 cases up

Table 4: The result of survey for part claimed cases in 8 months

Grade	# of part claimed cases
A	1 – 10 cases
B	11 - 20 cases

C	21 - 30 cases
D	31 - 40 cases
E	80 cases up

The result of a survey of the remaining criteria shows that grade A of benefits criteria should reduce cost by more than 80%. That means if supplier presents cost reduction of more than 80%, almost all engineers will accept this condition by themselves. Grade B of defect ratio criteria is 31% to 40%; almost all engineers will accept this condition after requesting one item of information. Grade C of customer complaint criteria is 2 to 3 cases; if customer complaint history of supplier is 2 to 3 cases in 8 months, almost all of engineers will accept the supplier's proposal after requesting more than one item of information. Grade D on part claimed criteria are 31 to 40 cases; if part claimed history of the suppliers is 31 to 40 cases in 8 months, almost all engineers will accept the supplier's proposal with support from leaders. Almost all of engineers do not accept Grade E.

4. Conclusion and Future Work

In this study, we propose the AHP framework for the multi-criteria selection problem. Suppliers' data and SQA's constraints are integrated into our decision support system for determining if the boundary sample proposed by suppliers should be accepted. We plan to implement this tool on Excel for actual use.

5. Acknowledgement

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