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RANKING OF CRITERIA FOR ORDER ALLOCATION IN A RUBBER GLOVE MANUFACTURING FACTORY USING ANALYTIC HIERARCHY PROCESS (AHP)

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ABSTRACT

Malaysia is the world's leading producer of rubber gloves, among over 150 manufacturers worldwide. Based on current practice among the manufacturer of rubber gloves, there is no fixed guideline in planning for the orders based on various criteria as each criterion has its importance, and the orders are planned based on the real-time situation. Therefore, in this study, the criteria to be considered for order allocation to factories and their importance were determined using Analytical Hierarchical Process (AHP) technique. Six criteria, namely quality, cost, lead time, capacity, special requirement, and regulation compliance, were identified based on the literature search of past studies in the field and supported by the expert's opinion. Later, the experts ranked the importance of each criterion using a specifically designed questionnaire employing the AHP method. The pairwise comparison matrix was consistent with a consistency ratio (CR) value of 0.0495. Thus, the six criteria by ranking top to bottom with respective weightage are quality (25.81%), cost (21.7%), lead time (20.73%), regulation compliance (16.86%), special requirement (7.86%), and capacity (7.04%). In summary, the objectives of this research have been successfully met, according to the findings, and the criteria ranking can be used as a guideline by rubber glove manufacturers in planning for order allocation.

Keywords: AHP method, allocation criteria, glove industry, order allocation.

INTRODUCTION

Malaysia is the world's leading producer of rubber gloves, among over 150 manufacturers worldwide. In the last 25 years, rubber glove manufacturing has grown rapidly. Malaysian companies have developed the technologies needed to construct state-of-the-art manufacturing facilities with advanced automation in the 2010s. For 2021, the global demand for rubber gloves was 420 billion, with 67% or approximately 281 billion gloves produced by Malaysia (Malaysian Rubber Glove Manufacturers Association, 2021). According to Malaysian Rubber Glove Manufacturers Association (MARGMA) president Dr. Supramaniam Shanmugam, glove demand will be 10% to 15% greater in 2022 and 2023 than before Covid-19 (Salim, 2022). The driver for this growth is product innovation, automation, engineering, recycling of wastewater, harnessing new energy sources, and research and development are the key sustenance for the growth of the glove business in Malaysia (Malaysian Rubber Glove Manufacturers Association, 2020).

Order allocation is defined as allocating physical product items from inventory to shipping orders and completing each shipping order from the proper fulfillment factory (Lavanpriya et al., 2022). The importance of order allocation strives to lower capital costs, ensure delivery punctuality, and meet the buyer's quality criteria (Molinè & Coves, 2013). In the rubber glove industry, there are various criteria considered when planning for order productions, such as lead time, cost efficiency, product specification requirement, food handling compliance, country regulations compliance, and available capacity (Khemiri et al., 2017; Meena et al., 2022; Nguyen, 2021). Moreover, order allocation is critical in building a competitive advantage and ensuring long-term development for the manufacturer. As a result, a systematic order allocation procedure for identifying and prioritizing important criteria and evaluating tradeoffs between technical, economic, and performance factors is required (Sultana et al., 2015).

Common practices of rubber glove manufacturers are to overview each criterion and plan for the customer's order based on orders matched with existing dipping, followed by changing formulations to dip other products. Meanwhile, some manufacturers are able to do their planning in a very flexible way to boost their utilization rate by committing all the orders regardless of the criteria considered. However, there is no fixed guideline for the orders based on various criteria. Each criterion is essential, and the orders are planned based on real-time situations. Thus, this study aims to identify the criteria for order allocation and rank them according to their importance as the method of setting guidelines for a better order allocation approach.

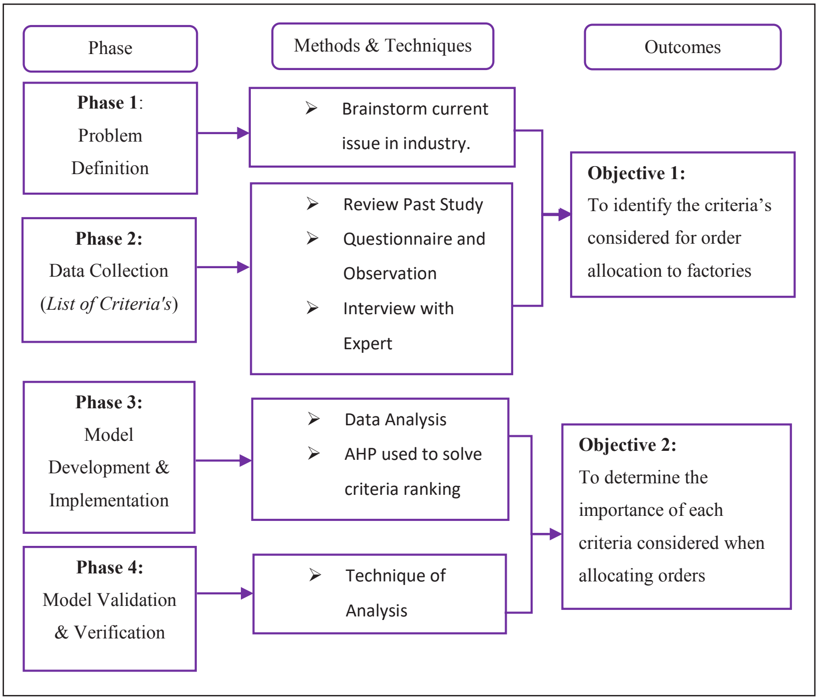
On top of that, this study focuses on Malaysian rubber glove manufacturers' decisions when allocating orders to the factory, especially disposable rubber gloves, which can be utilized by several industries such as food processing, healthcare, chemical, automotive, and others. Besides, this study only focuses on the criteria considered by planners from the respective manufacturer when allocating orders to their factories. Through this study, the researcher determined the criteria considered by planners when allocating each order to factories by priority and helpful to work out the guidelines for order allocation while ensuring the high priority criteria are prioritized every time of order allocation.

METHODOLOGY

This section discusses the research design, method of collecting data, and ranking of criteria for order allocation at the Rubber Glove Manufacturing Factories. Figure 1 presents the research design, which consists of four phases to achieve the objectives of this research. The expected outcome for Phase 1 and Phase 2 is to identify order allocation criteria in Rubber Glove Manufacturing Factories. In contrast, Phases 3 and 4 are expected to analyze the priority of each criterion by ranking the criteria using the Analytical Hierarchical Process (AHP) technique.

Figure 1

Flowchart of Research Design



For order allocation based on multi-criteria, multi-criteria decision-making (MCDM) simulates the decision-making process in an uncertain environment (You et al., 2020). According to the review, AHP is the most widely used MCDM technique for evaluating criteria (Omair et al., 2021). AHP is a mathematical approach that uses a pairwise comparison scheme to assign weights to numerous alternatives. The approach has been used in various decision-making situations, including order allocation, research and development, project selection, supplier selection, and alternative evaluation (Singh, 2014). Meanwhile, Bellman and Zadeh (1970) stated AHP is a more effective method for dealing with the ambiguity of human decision-making.

As Alegoz and Yapicioglu (2019) reported, criteria and alternatives for order allocation are gathered, and judgments are translated into crisp or fuzzy values. Following the conversion, data is subjected to one or more MCDM approaches, such as AHP, Analytic Network Process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Multicriteria Optimization and Compromise Solution (VIKOR), or fuzzy variants of these techniques, to determine the relative relevance of each criterion. This research has been guided by a few other researchers, such as Arikan (2013), Singh (2014), Kazemi et al., (2014), and Afzali et al., (2016) for identifying techniques for order allocation approaches.

From past study reviews, six criteria, quality, cost, lead time, capacity, special requirement, and regulation compliance, were identified. Targeted respondents, known as experts, are selected using a purposive sampling technique and distributed questionnaire to get their responses on preference level for each criterion. On the other hand, Rogers & Lopez (2002) and Hallowell & Gambatese (2010) stated that experts were required to meet at least two of the following criteria (within the field of research under consideration): authorship, conference presenter, member or chair of the committee, employed in profession for at least five years, and working in a higher position. Thus, the targeted experts for this study are six respondents who are well-versed in order allocation criteria and have experience in this field for more than five years. Subsequently, interviews with experts were conducted to justify their opinion.

The AHP approach was applied to achieve the second objective of this study. The steps to proceed AHP technique are to identify the unstructured issue, establish an AHP based on criteria, pairwise comparison, calculate relative weights, check the CR, and lastly, calculate the overall score. For this study, six criteria were finalized for ranking, as tabulated in Table 1 with the descriptions.

Table 1

Criteria and Description

Criteria	Description
Quality	To prioritize allocation to top quality factories based on the record of passing rate by the factory or any return shipment history to gain customer confidence and stay competitive in the business

(continued)

Criteria	Description
Cost	The production cost of the manufacturing factory is to be compared with the respective selling price of the order received to ensure a positive margin gained
Lead Time	Production lead time to complete the order production. A shorter lead time manufacturing factory is prioritized to ensure fast delivery of gloves to a customer
Capacity	Manufacturing factory with available balance capacity for the month to balance the utilization, maintain shorter lead time, and meet the shipment as per requested by the customer
Special Requirement	The capability of committing to special packing and special product specification as an added value and competitiveness among other competitors
Regulation Compliance	Capable of complying with food handling methods related to country regulations or certification required for shipments to certain countries

Table 2

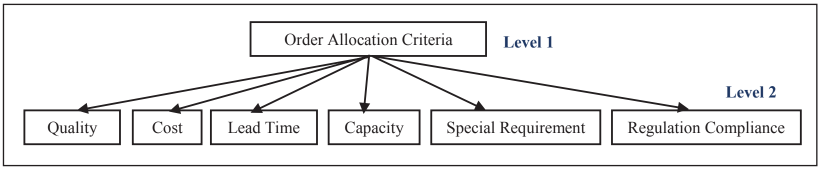
Top Criteria Considered in Order Allocation Problem

Criteria	**Author**
Quality	(Khemiri et al., 2017), (Ting & Cho, 2008), (Weber et al., 1991), (Sultana et al., 2015), (Singh, 2014)
Cost	(Khemiri et al., 2017), (Ting & Cho, 2008), (Weber et al.,1991), (Sultana et al., 2015), (Arikan, 2013), (Singh, 2014)
Lead Time / Delivery	(Khemiri et al.,2017), (Ting & Cho, 2008), (Weber et al., 1991), (Sultana et al., 2015), (Arikan, 2013), (Singh, 2014)
Capacity	(Khemiri et al., 2017), (Weber et al., 1991), (Bhutta & Huq, 2002), (Singh, 2014)
Special Requirement	(Weber et al., 1991), (Sultana et al., 2015), (Singh, 2014)
Regulation compliance / Geographical regulation	(Khemiri et al.,2017), (Weber et al., 1991), (Singh, 2014)

Correspondingly, Figure 2 presents the hierarchy of order allocation criteria, consisting of six developed criteria. The hierarchy has been divided into two levels: level one refers to the overall goal, and level two refers to the criteria contributing to the achievement of the overall goal.

Figure 2

Hierarchy of Order Allocation Criteria



Consequently, a pairwise comparison matrix was obtained by assigning the matrix's preference level scale for each element. The preference level scale for pairwise comparison was adapted from Saaty's (1980) recommendation. Responses from respondents will be converted into a pairwise matrix using Geometric Mean. It enables decision-makers to calculate weights or priorities for ratio scales for multiple respondents' preferences into a single pairwise matrix since Geometric Mean indicates the central tendency or usual value of a group of numbers using the product of their values. Therefore, the values for each element in matrix *A* are obtained by Equations 1 and 2.

$$a_{ii} = 1 \begin{bmatrix} diagonal\ will\ always\ be\ 1\ as\ each\ criteria\ is\ equally \\ important\ with\ itself \end{bmatrix} \quad (1)$$

$$a_{ij} = \frac{1}{a_{ji}},\ where\ a_{ij} > 0, \quad (2)$$

where element *i* has a number assigned to it when compared to element j, and j has the reciprocal value of *i*.

The next step is to compute a normalized pairwise matrix where the sum of each criteria column will be calculated, followed by all the elements in the column divided by the sum of the column. From the normalized pairwise matrix, criteria weights are computed by averaging all the elements in the row. The formula for each criterion weight is shown in Equation 3.

$$Criteria\ i\ weights = \frac{a_{i1}+a_{i2}+a_{i3}+a_{i4}+a_{i5}+a_{i6}}{n}, \quad (3)$$

where

i is the number of rows,

n is the number of criteria.

From the above equation, we have obtained the criteria weight of each criterion. Subsequently, consistency is calculated to check the accuracy of the calculated criteria weight using the Unnormalized Pairwise Matrix. Consequently, the weighted sum value is obtained by calculating the sum of each value in the row, followed by the ratio of the weighted sum value and criteria weights for each row and the average ratio. The formula to calculate the ratio and average of the ratio, λ_{max} is shown in Equations 4 and 5.

$$Ratio\ of\ weighted\ sum\ and\ criteria\ weights\ of\ i^{th}\ row = \frac{Weighted\ sum}{criteria\ weight} \quad (4)$$

$$\lambda_{max} = Average\ of\ Ratio\ of\ weighted\ sum\ and\ criteria\ weight. \quad (5)$$

After calculating relative weights, the consistency index (CI) and CR were computed. In contrast, the formula for calculating CI and CR is shown in Equations 6 and 7. Note that the CR indicates how consistent our responses are. A larger number indicates that the output is not as consistent as it should be, whereas a smaller number indicates that the output is more consistent. If the CR value is less than 0.1, the decision-maker can conclude that the level of consistency is reasonable and acceptable. Meanwhile, severe inconsistencies were clearly present when CR was more than 0.1. Random Index (RI) is derived from Saaty (1980), which indicates the immediate capacity of the number of alternatives or systems being assessed.

$$CI = \frac{\lambda_{max} - n}{\boldsymbol{n-1}} \quad (6)$$

; where *n* refers to the number of criteria

$$Consistency\ Ratio = \frac{Consistency\ Index\ (CI)}{Random\ Index\ (RI)}. \quad (7)$$

After obtaining the CR, the researcher proceeded with the decision-making process using criteria weights value for further calculation. From the criteria weightage, the researcher ranked the criteria based on high-weighted criteria as more important than the low-weighted criteria and least important to consider when planning for order allocation.

Lastly, the criteria of order allocation were validated from past studies and verified by the expertise from glove manufacturing factories based on the importance and contribution of each criterion for order allocation planning.

RESULTS AND DISCUSSION

The data obtained from the questionnaire was utilized to identify the weight for all pairwise comparison matrices computed. The experts' feedback from the interview session will justify the result. For the demographic background of the respondents, five aspects were analyzed such as gender, age group, educational background, working experience, and working position.

As the criteria for order allocation in Rubber Glove Manufacturing Factories were identified through past studies, it was included in the questionnaire. Respondents were required to rank the criteria based on their preference level by comparing them. As there are six target respondents for this research, their responses are guided to follow the preference scale as shown in Table 3 for each criterion compared with another criterion. The responses are combined using Geometric Mean. Meanwhile, Table 4 displays the compilation of the individual preference matrix into the overall preference matrix.

Table 3

Preference Level Scale

Scale	Preference
1	Equally Preferred
3	Moderately Preferred
5	Strongly Preferred
7	Very Strongly Preferred
9	Extreme Strongly Preferred
2,4,6, and 8	Intermediate values

Table 4

All Responses and Geometric Mean Calculation

n	(C1, C2)	(C1,C3)	(C1, C4)	(C1, C5)	(C1, C6)	(C2, C3)	(C2, C4)	(C2,C5)	(C2, C6)	(C3,C4)	(C3, C5)	(C3, C6)	(C4,C5)	(C4, C6)	(C5, C6)
1	1/7	1/7	7	7	7	7	7	7	7	7	7	7	7	7	7
2	7	1/7	7	1/7	1/7	1/7	7	1/7	1/7	7	1/7	1/7	1/7	1/7	1/7
3	1/7	5	8	8	8	3	8	9	9	6	8	8	1/3	1/3	1
4	7	5	8	5	1	3	1	4	1	1	1	1	3	1	1
5	7	1/5	7	8	3	1/7	7	1	1/7	7	8	7	4	1/3	1
6	1/5	7	7	5	1/6	4	5	6	1/8	1/6	6	1/5	4	1/8	1/8
Geo-mean	1.06	0.95	7.32	3.42	1.26	1.31	4.89	2.45	0.74	2.65	2.70	1.50	1.59	0.49	0.71

n = Respondent

Next, Initial Pairwise Comparison Matrix was tabulated from Table 4, as presented in Table 5.

Table 5

Initial Pairwise Matrix from Geometric Mean

Criteria	Quality	Cost	Lead Time	Capacity	Special Requirement	Regulation Compliance
Quality, C1	1.00	1.06	0.95	7.32	3.42	1.26
Cost, C2	0.95	1.00	1.31	4.89	2.45	0.74
Lead Time, C3	1.06	0.76	1.00	2.65	2.70	1.50
Capacity, C4	0.14	0.20	0.38	1.00	1.59	0.49
Special Requirement, C5	0.29	0.41	0.37	0.63	1.00	0.71
Regulation Compliance, C6	0.79	1.36	0.67	2.04	1.41	1.00

From the initial pairwise matrix shown in Table 5, normalized pairwise matrix and criteria weights were obtained by dividing each element from the column with column sum from the initial pairwise comparison matrix. The purpose of tabulating a normalized pairwise comparison matrix is to verify the data's consistency. Weightage is obtained by dividing the row sum by the number of criteria. This is to show the weightage of each criterion from respondents' feedback based on their preference level. Subsequently, consistency verification was carried out, and an average of the ratio of weighted sum and criteria weights were obtained, which equals 6.3070. In contrast, CI is computed where the value obtained is 0.0614. Thereafter, CR is calculated, where the value obtained is 0.0495. By referring to RI in Table 6 below, the CR value is within the range compared to the number of criteria analyzed. Moreover, as CR = 0.0495, less than 0.1, matrices are reasonably consistent. With this, the researcher decided to rank the criteria based on weightage.

Table 6

Random Index (RI)

Random Index (RI)														
n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Therefore, ranking criteria based on criteria weights demonstrate the priority to consider when planning for order allocation, as shown in

Table 7 and Figure 3 below. The top 3 criteria are quality (25.81%), cost (21.70%), and lead time (20.73%), which are basics of order allocation planning and contribute about 68%.

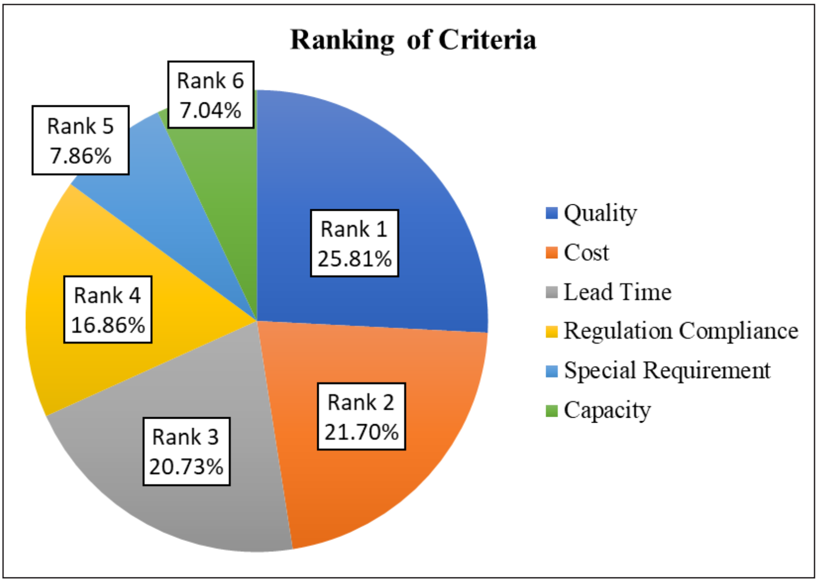
Table 7

Ranking of Criteria

Criteria	Criteria Weight
Quality	25.81%
Cost	21.70%
Lead Time	20.73%
Capacity	7.04%
Special Requirement	7.86%
Regulation Compliance	16.86%

Figure 3

Ranking of Criteria



CONCLUSION

The main purpose of this research is to make good planning using proper guidelines in allocation for Rubber Glove Manufacturing

Factories. The objectives of this research have been successfully met, according to the summary of findings from the preceding chapter. By completing this research, the researcher identified the criteria for order allocation and ranked the criteria by the level of importance. According to the findings, the essential criteria for allocating orders are quality, cost, lead time, capacity, special requirements, and regulation compliance. Besides, there are several limitations encountered for this research, such as the period of conducting this study is short, causing a limited number of respondents to be targeted. Correspondingly, most of the data are confidential, which makes it unable to be disclosed in this study, such as the manufacturer's name where experts were targeted and shared their company practice. On the other hand, this research will be advantageous to all rubber glove manufacturers, provided they have at least two factories to plan for order allocation. At the same time, the findings from this study can be used worldwide as the criteria considered are not restricted.

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