International Journal of
Economics Development Research, Volume 5(4), 2024
pp. 3491-3506

Selection Analysis of Secondary Pharmaceutical Industry Contract Manufacturers with Fuzzy Analytical Hierarchy Process (FAHP) Method

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Abstract:

This study aims to analyze the selection of contract manufacturer in secondary pharmaceutical industry using Fuzzy AHP. This study employs a quantitative approach using statistical analysis to assess the validity and reliability of the data then subsequently mapped into a matrix model. The Fuzzy AHP is applied to conquer the ambiguity and vagueness of personal knowledge. Six criteria were identified named quality, cost, service performance, compliance, delivery, and operational. The evaluation is conducted by a committee of five decision makers that include purchasing manager, toll manufacturing manager, production manager, quality assurance manager, and quality control manager of the industry. The results revealed that quality is the most important criteria in determining the selection of contract manufacturers in secondary pharmaceutical industry, followed by cost, compliance, delivery, operational and service performance. According to the results, contract manufacturer 2 was chosen to be the best to outsource operational activities of the industry. The results show that the proposed method could provide promising results in decision making process more appropriately. The proposed evaluation criteria provide a reference for pharmaceutical industry practices in the selection of contract manufacturers using Fuzzy AHP.
Keywords: *Contract Manufacturing, Pharmaceutical Industry, MCDM, FAHP.*

Submitted: 22 May 2024, Accepted: 16 August, Published: 9 October 2024

1. Introduction

The pharmaceutical industry is in the second-leading position among all profitable industries globally (Liao et al., 2021). Pharmaceutical companies play an important role in the manufacturing industry that supports health services in Indonesia (Ricardianto et al., 2022). The number of pharmaceutical companies is increasing every day due to rapid population growth and global demand for their services (Modibbo et al., 2022). Currently, there are 230 pharmaceutical industries in Indonesia, all of which are growing year by year (Arief et al., 2022).

The pharmaceutical sector is characterized as a blend of procedures, tasks, and associations involved in the creation, innovation, and manufacture of drugs (Ishizaka & Labib, 2011). Elekidis & Georgiadis (2022) divide pharmaceutical production into two major subsectors. The primary pharmaceutical industry is responsible for the

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production of the required active pharmaceutical ingredients (Silva & Mattos, 2019). The secondary pharmaceutical industry transforms active pharmaceutical ingredients into final products like tablets, capsules, injections, and more (Elekidis & Georgiadis, 2022). Typically, most contract manufacturers focus on secondary manufacturing (Elekidis & Georgiadis, 2022).

Among health products, pharmaceuticals account for 20%–30% of global health expenditure (Rekabi et al., 2023). The production and distribution of these products in an appropriate and timely manner is an issue that governments must consider in all circumstances (Nazari-Shirkouhi et al., 2023). Managing and selecting pharmaceutical raw materials and supplies for healthcare have a significant impact on the quality and form of patient care and account for a large portion of supply chain costs (Khan et al., 2023).

For this reason, companies are making massive efforts to increase profit margins by allocating available resources more efficiently among competing activities and thereby reducing various costs (Elekidis & Georgiadis, 2022). A growing trend is for companies to try partnerships with other companies by providing strategic alliances with other suppliers to engage in competitive advantage outsourcing (Barak & Javanmard, 2020). So companies have started to focus on their main activities and buy other activities through outsourcing, along with globalisation and increased competition (Cebi et al., 2023).

Suppliers are an important component of the supply chain because their performance has an indirect and significant impact on customer satisfaction (Khan, et al., 2023). Poorly performing suppliers negatively affect a company's position in the market by slowing down workflow, creating quality problems, increasing costs, delaying product delivery, and reducing customer satisfaction (Cebi et al., 2023).

Therefore, selecting the most appropriate partner for the manufacturing system is considered a time-consuming and resource-intensive issue in daily operations that can affect the operational success of the company (Barak & Javanmard, 2020). Supplier selection is the process by which companies identify, evaluate, and contract with suppliers (Kayani et al., 2023). Several aspects play an important role in choosing an outsourcing partner (Nila & Roy, 2023). In the supplier selection problem, companies must consider quantitative criteria such as product prices and qualitative criteria such as vendor reputation (Astanti et al., 2020).

Researchers have approached partner selection with multiple conflicting quantitative and qualitative criteria as a multiple decision-making (MCDM) problem (Barak & Javanmard, 2020). People commonly apply multi-criteria decision-making methods (MCDM) to solve various real-life problems that involve multiple criteria and alternatives (Orji & Ojadi, 2021). MCDM methods aim to guide decision-makers in finding the most desirable solution to their problems (Manik, 2023).

Although there are many MCDM techniques, the Analytical Hierarchy Process (AHP) is the most applicable method for decision-making problems (Manik, 2023).

However, pairwise comparison, the core of AHP, introduces imprecision as it requires expert judgement (Liu et al., 2020). The fuzzy analytic hierarchy process (Fuzzy-AHP) offers interval judgements through triangular fuzzy numbers (TFN), which get rid of the lack of clarity and specificity in personal knowledge (Abdullah et al., 2021). Numerous researchers have conducted studies on supplier selection. The Fuzzy Analytic Hierarchy Process (F-AHP) and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (F-TOPSIS) were used by Chen & Hung (2010) to choose suppliers in the pharmaceutical industry. We selected three executive members to evaluate five criteria and assess three supplier alternatives.

Forghani et al. (2018) did research on how to choose suppliers in the pharmaceutical industry. They used three different methods: Principal Component Analysis (PCA), Technique for Order Performance by Similarity to Ideal Solution based on the concept of Z numbers (Z-TOPSIS), and Mixed Integer Linear Programming (MILP). The study selected business managers from 34 pharmaceutical industries to evaluate 24 criteria, which led to the identification of 4 main criteria (product quality, product price, documentation of past records, and customer relationship management) for assessing 4 supplier alternatives. Şahin et al. (2019) used the healthcare industry, especially hospitals, to research supplier selection using the Analytic Hierarchy Process (AHP) method. This study selected 15 academics to evaluate six existing criteria and assess 16 alternatives.

Cebi et al. (2023) examined supplier selection in the pharmaceutical industry utilizing the Decomposed Fuzzy Analytic Hierarchy Process (DF-AHP) method. The research team selected three experts to evaluate four key criteria. Nazari-Shirkouhi et al. (2023) conducted supplier selection research in the pharmaceutical industry sector using the Z-Number Data Envelopment Analysis (Z-DEA) and Artificial Neural Network (ANN) methods. They selected experts to evaluate eight existing criteria and assess 36 supplier alternatives.

Nila & Roy (2023), focusing on the food industry, used the Logarithmic Percentage Change-Driven Objective Weighting (LOPCOW), Full Consistency Method (FUCOM), and Dombi Bonferroni (DOBI) methods. A total of six decision-makers collaborated to score 15 criteria to assess six supplier alternatives.

Based on the background of previous research and the motivation of the researcher, this study analyses the criteria and sub-criteria in the selection of secondary pharmaceutical industry contract manufacturers. The analysis aims to identify the priority factors that influence the selection of contract manufacturers and identify the selected contract manufacturers that are most suitable for the needs of the secondary pharmaceutical industry.

2. Theoretical Background

Operations Management

Heizer et al. (2020) define operations management (MO) as a set of activities that add value by converting inputs into outputs to produce goods and services. The MO functional area includes all activities and processes required to convert inputs into services and products (Sancha et al., 2023).

During the manufacturing process, resources serve as inputs and transform into products or semi-finished products (Ricardianto et al., 2022). MO activities in production encompass determining the production of raw materials, monitoring quality standards, reducing waste, and managing consumer demand (Iqbal et al., 2020). In manufacturing, the goal of MO is to successfully deliver products between the supply and demand sides of the supply chain with available logistics services (Zaalouk et al., 2023).

Supply Chain Management

Supply chain management is the process of managing the flow of materials, information, and operations as products move from the source (i.e., raw material suppliers) to the customer (i.e., end users) (Zaalouk et al., 2023). Supply chain management is a critical component of any manufacturing operation (Kayani et al., 2023).

Supply chain management can be defined as the phenomenon of managing and controlling the process of transforming raw materials into valuable products that can create value for the organization and increase productivity (Iqbal et al., 2020). The supply chain includes suppliers, manufacturers, service providers, distributors, wholesalers, and retailers who provide goods and services to end customers (Heizer et al., 2020). These stakeholders have a significant impact on the operational and financial performance of the supply chain (Liang et al., 2024).

The goal of supply chain management is to reduce costs, reduce risk uncertainty, and improve operations in the supply chain to gain the best competitive advantage and benefits for end customers (Heizer et al., 2020; Zaalouk et al., 2023).

Supplier Selection

Supplier selection is one of the most important activities for most companies and has a major impact on the efficiency and effectiveness of the entire supply chain (Forghani et al., 2018). Supplier selection is an important step in the procurement process, where procurement managers select the best suppliers for the services or raw materials they want to buy (Abdulla et al., 2023). In supply chain management activities, supplier selection decisions are one of the strategic decisions faced by operations managers and procurement managers in order to remain competitive (Karsak & Dursun, 2015).

Supplier Selection Methods
To ensure a structured means of decision-making, we need formal methods (Liu et al., 2020). Decision theory provides a comprehensive theoretical framework that includes decision-making processes, criteria, types, and approaches (Demir et al., 2024). Decision-making refers to the process of choosing an optimal plan after analysing, evaluating, and assessing various factors affecting the achievement of a goal based on the treatment of certain information and practical experience, which uses certain means, techniques, and methods to achieve a specific goal (Jin et al., 2023).

There are various criteria and techniques to assist decision-makers in selecting the right supplier from the many available suppliers to supply goods and services (Modibbo et al., 2022). This empowers the decision-maker to decide on the most optimal solution given the preferences, priorities, and context of the situation under consideration (Demir et al., 2024). Experts play a major role in decision-making issues and provide important information (Nazari-Shirkouhi et al., 2023).

Pharmaceutical Industry
Public health recognizes the pharmaceutical industry as one of the most significant industries (Nazari-Shirkouhi et al., 2023). The pharmaceutical industry is a highly regulated industry because it produces medicines that directly affect human life (Arief et al., 2022). The pharmaceutical industry is a major asset to the economies of developed countries; it is one of the largest employers in high-tech industries and indirectly generates three to four times more jobs (Marques et al., 2020).

The main goal of the pharmaceutical industry, although it strives for profit, is to build the necessary support for the healthcare system by providing essential medicines at the right time and place (Kumar et al., 2018). The activities of the pharmaceutical industry depend on a large number of suppliers (Nazari-Shirkouhi et al., 2023).

3. Methodology

The research design in this study uses a quantitative approach or method, which seeks to measure data and apply some form of measurement and statistical analysis. This research aims to obtain identification results for several key criteria in the selection process of secondary pharmaceutical industry contract manufacturers. Based on these objectives, this research utilises the Fuzzy Analytical Hierarchy Process (FAHP) method to obtain decision values for making choices based on the criteria used. The criteria processed by the FAHP method are factors that align with the company's needs and significantly influence its decision-making.

This study utilizes the results of interviews as primary data to determine contract manufacturer criteria that align with company policies. Additionally, it references criteria and sub-criteria from several literature studies. Secondary data used comes from company records or project activities, company data recaps, references from journal publications, and other reference literature that is in accordance with the research topic.

4. Empirical Findings/Result and Discussion

Consistency Analysis

The fuzzy AHP method is based on pairwise comparisons that decision-makers use to establish preferences between alternatives for different criteria. The procedure for developing pairwise comparisons in the fuzzy AHP method is when the researcher obtains verbal preferences from the decision-maker using the preference scale. However, when decision-makers have to make many comparisons, they may lose track of previous responses. As the fuzzy AHP method relies on the decision-maker's preference responses, it is important that the responses are valid and consistent. In other words, the preferences expressed in one set of pairwise comparisons should align with those in other sets.

A consistency index (CI) can be calculated to measure the level of inconsistency in pairwise comparisons. If the CI value is equal to zero, then the decision maker provides highly consistent pairwise comparison results. However, decision makers cannot be completely consistent, so an acceptable level of consistency is required. The pairwise comparison matrix is considered consistent if the consistency ratio value is smaller than 0.1 (Liu et al., 2020). We evaluate the consistency of pairwise comparisons across the entire pairwise comparison matrix to confirm the consistency of the fuzzy AHP method as a whole.

The degree of consistency of pairwise comparisons in the decision criteria matrix in this study was determined by computation through the application http://FuzzyMCDM.upol.cz/FuzzyAHP. This application was created by Pavel Holecek (Palacky University in Olomouc). It is a web application that allows to evaluate alternatives by the classical AHP method or its version suitable for fuzzy environments. In addition to solving classical (fuzzy) multi-criteria decision-making problems, the application can also be used for group decision-making and risk decision-making.

Criterion Level Consistency Value

Analysis of the consistency value at the criterion level uses data on the value of pairwise comparisons of predetermined criteria. The analysis results show a consistency value of less than 0.1, specifically 0.056, leading to the conclusion that the pairwise comparison value in the pairwise comparison matrix between criteria is consistent.

Consistency Value of Quality Subcriteria Level

Analysis of the consistency value at the quality subcriteria level uses data on the value of pairwise comparisons of predetermined quality subcriteria. The analysis results show a consistency value of less than 0.1, specifically 0.045, indicating the consistency of the pairwise comparison value in the quality subcriteria pairwise comparison matrix.

The level of consistency between the cost and price subcriteria

We use data on the value of pairwise comparisons of the cost / price subcriteria to analyze the consistency value at the cost / price subcriteria level. The analysis results show a consistency value of less than 0.1, specifically 0.058, indicating the consistency of the pairwise comparison value in the pairwise comparison matrix between the cost and price subcriteria.

Service Performance Subcriteria Level Consistency Value

To look at the consistency value at the level of service performance subcriteria, data on the values of pairwise comparisons of set service performance subcriteria is used. The analysis concludes that the pairwise comparison value in the pairwise comparison matrix between service performance subcriteria is consistent, as the consistency value is less than 0.1, specifically 0.069.

Consistency Value of Compliance Subcriteria Level

The value of pairwise comparisons of predetermined compliance subcriteria is used to figure out the consistency value at the compliance subcriteria level. The analysis results show a consistency value of less than 0.1, specifically 0.068, indicating the consistency of the pairwise comparison value in the compliance subcriteria pairwise comparison matrix.

Consistency Value of Delivery Subcriteria Level

Analysis of the consistency value at the delivery subcriteria level uses data on the value of pairwise comparisons of predetermined delivery subcriteria. The analysis concludes that the pairwise comparison value in the pairwise comparison matrix between delivery subcriteria is consistent, as the consistency value is less than 0.1, specifically 0.042.

Consistency Value of Operational Subcriteria Level

Data on the value of pairwise comparisons of operational sub-criteria determine the consistency value at the operational sub-criteria level. The analysis concludes that the value of pairwise comparisons in the pairwise comparison matrix between operational sub-criteria is consistent, as the consistency value is less than 0.1, specifically 0.059.

Consistency Value of Contract Manufacturer Alternative Level

Analysis of the consistency value at the alternative level of contract producers uses data on pairwise comparisons of alternative contract producers against each predetermined sub-criteria. The analysis concludes that the pairwise comparison value in the pairwise comparison matrix between alternative contract producers is consistent, as the consistency value of all the data is less than 0.1. Table 1 summarizes the analysis of the consistency value of the alternative level of contract producers based on 26 sub-criteria.

Table 1. Contract Manufacturer Alternative Level Consistency Values

Contract Producer Alternatives on Each Sub Criteria	Consistency Values	Contract Producer Alternatives on Each Sub Criteria	Consistency Values
Product Quality	0,099	No Intellectual Property Infringement	0,046
Quality Control Procedures and Processes	0,045	Industry Trade Rule Compliance	0,060
Continuous Improvement Program	0,057	Risk Management System	0,060
Contaminated Medicine	0,079	EH&S Compliance	0,067
Number of Defective Items	0,095	Complete Product Delivery	0,028
Service/Production Cost	0,076	No Damaged Product Delivery	0,096
Product Price	0,042	Delivery Flexibility	0,074
Payment Terms	0,064	Cost-Effective Delivery	0,049
Raw Material and Packing Material Supply Cost	0,037	On-time Delivery	0,031
Shipping Cost	0,049	Standardization of Production Procedures	0,063
After-sales Service/Warranty	0,063	Storage Space	0,037
Response to Change	0,028	Unmet Demand	0,046
Drug Production Regulatory Compliance	0,063	Inventory Management	0,067

Sensitivity Analysis

Sensitivity Value Quality Criteria Level

Based on data processing, the weight of the quality criteria is 0.353, resulting in the final weight value of alternative contract producers 1 of 0.238; the final weight value of alternative contract producers 2 of 0.343; and the final weight value of alternative contract producers 3 of 0.419.

If the weight of the quality criteria is reduced to 0.005, then the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.283; contract producer 2 is the second priority with a weight value of 0.235; and contract producer 1 has a weight value of 0.134.

The data reveals that the order of alternative contract manufacturers remains unchanged if we lower the weight of the quality criteria to 0.100, with contract manufacturer 3 maintaining the top priority with a weight value of 0.320, contract manufacturer 2 in second priority with a weight value of 0.265, and contract manufacturer 1 with a weight value of 0.163.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the quality criteria to 0.500, with contract manufacturer 3 maintaining the top priority with a weight value of 0.476, contract manufacturer 2 in second priority with a weight value of 0.389, and contract manufacturer 1 with a weight value of 0.282.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the quality criteria to 0.700, with contract manufacturer 3 maintaining the top priority with a weight value of 0.554, contract manufacturer 2 in second priority with a weight value of 0.451, and contract manufacturer 1 with a weight value of 0.342.

If the weight of the quality criteria is increased to 0.999, then the data shows that the order of alternative contract manufacturers does not change, with contract manufacturer 3 remaining the top priority with a weight value of 0.671, contract manufacturer 2 in second priority with a weight value of 0.544, and contract manufacturer 1 with a weight value of 0.431.

Based on the overall results of the sensitivity analysis of the quality criteria, it can be concluded that the weight assessment has a strong final decision because providing changes for sensitivity testing on the weight value of the criteria ranging from a value of 0.005 to a value of 0.999 does not change the alternative decision of the contract manufacturer. This condition also confirms the perfect value strength of the test data, as the respondents' input weights, particularly for the quality criteria, exhibit a high level of validity and accurately describe the results of the pairwise comparison matrix.

Cost/Price Criteria Level Sensitivity Value
Based on the previous data processing, the weight of the cost/price criterion is 0.271, resulting in the final weight value of alternative contract producers 1 of 0.238; the final weight value of alternative contract producers 2 of 0.343; and the final weight value of alternative contract producers 3 of 0.419.

The data reveals that the order of alternative contract producers remains unchanged if we reduce the weight of the cost/price criteria to 0.005, with contract producer 3 maintaining the top priority with a weight value of 0.302, contract producer 2 coming in second with a weight value of 0.247, and contract producer 1 with a weight value of 0.185.

Reducing the weight of the cost/price criterion to 0.100 does not alter the order of alternative contract manufacturers. Contract manufacturer 3 maintains the top priority with a weight value of 0.343, followed by contract manufacturer 2 with a weight value of 0.282, and contract manufacturer 1 with a weight value of 0.204.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the cost/price criteria to 0.500, with contract manufacturer 3 maintaining the top priority with a weight value of 0.519, contract manufacturer 2 in second priority with a weight value of 0.426, and contract manufacturer 1 with a weight value of 0.283.

The data indicates that the order of alternative contract manufacturers remains unchanged when we increase the weight of the cost/price criterion to 0.700, with contract manufacturer 3 maintaining the top priority with a weight value of 0.607, contract manufacturer 2 in second priority with a weight value of 0.498, and contract manufacturer 1 with a weight value of 0.323.

The data indicates that the order of alternative contract manufacturers remains unchanged when we increase the weight of the cost/price criterion to 0.999, with contract manufacturer 3 maintaining the top priority with a weight value of 0.519, contract manufacturer 2 in second priority with a weight value of 0.426, and contract manufacturer 1 with a weight value of 0.283.

The overall results of the sensitivity analysis of the cost/price criteria show that the weight assessment makes a strong final decision. This is because changing the sensitivity testing on the weight value of criteria between 0.005 and 0.999 does not change the decision of alternative contract producers. This condition also leads to the conclusion that the test data is of perfect value strength. This is because the respondents' weights, especially for the cost/price criteria, are highly valid and can accurately describe the pairwise comparison matrix results.

Service Performance Criteria Level Sensitivity Value

Based on the previous data processing, the weight of the service performance criteria is 0.055, resulting in the final weight value of the alternative contract manufacturer 1 of 0.238; the final weight value of the alternative contract manufacturer 2 of 0.343; and the final weight value of the alternative contract manufacturer 3 of 0.419.

The data reveals that the order of alternative contract manufacturers remains unchanged if we reduce the weight of the service performance criteria to 0.005, with contract manufacturer 3 maintaining the top priority with a weight value of 0.403, contract manufacturer 2 coming in second with a weight value of 0.321, and contract manufacturer 1 with a weight value of 0.226.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the service performance criteria to 0.100, with contract manufacturer 3 maintaining the top priority with a weight value of 0.433, contract manufacturer 2 in second priority with a weight value of 0.363, and contract manufacturer 1 with a weight value of 0.249.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the service performance criteria to 0.500, with contract manufacturer 3 maintaining the top priority with a weight value of 0.562, contract manufacturer 2 in second priority with a weight value of 0.539, and contract manufacturer 1 with a weight value of 0.344.

The data indicates that the order of alternative contract manufacturers remains unchanged if we increase the weight of the service performance criteria to 0.700, with contract manufacturer 3 maintaining the top priority with a weight value of 0.627, contract manufacturer 2 in second priority with a weight value of 0.627, and contract manufacturer 1 with a weight value of 0.392.

When we increase the weight of the service performance criteria to 0.999, the data reveals a change in the order of alternative contract manufacturers. Contract manufacturer 2 holds the top priority with a weight value of 0.758, followed by contract manufacturer 3 with a weight value of 0.724, and contract manufacturer 1 with a weight value of 0.463.

Based on the overall results of the sensitivity analysis of the service performance criteria, we can say that the weight assessment makes a strong final decision. This is because changing the weight value of the criteria from 0.005 to 0.700 does not affect the other decisions made by contract manufacturers. Although there is a change in the weight value of the criterion at a value of 0.999, there is a change in the priority of alternative contract producers. This is due to the greatest weight value of contract producer 2 among other alternatives. This condition also leads to the conclusion that the test data is of perfect value strength. This is because the respondents' weights, especially on service performance criteria, are highly valid and can accurately describe the pairwise comparison matrix results.

Compliance Criteria Level Sensitivity Value

Based on the previous data processing, the weight of the compliance criteria is 0.113, resulting in the final weight value of the alternative contract producer 1 of 0.238; the final weight value of the alternative contract producer 2 of 0.343; and the final weight value of the alternative contract producer 3 of 0.419.

The data reveals that the order of alternative contract producers remains unchanged if we lower the weight of the compliance criteria to 0.005, with contract producer 3 maintaining the top priority with a weight value of 0.366, contract producer 2 in second place with a weight value of 0.310, and contract producer 1 with a weight value of 0.216.

If the weight of the compliance criterion is increased to 0.500, the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.606; contract producer 2 is the second priority with a weight value of 0.465; and contract producer 1 has a weight value of 0.317.

If the weight of the compliance criterion is increased to 0.700, then the data shows that the alternative order of contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.703; contract producer 2 is the second priority with a weight value of 0.527; and contract producer 1 has a weight value of 0.357.

If the weight of the compliance criteria is increased to 0.999, the data shows that the order of alternative contract manufacturers does not change, where contract manufacturer 3 remains the top priority with a weight value of 0.847; contract manufacturer 2 is the second priority with a weight value of 0.621; and contract manufacturer 1 has a weight value of 0.418.

The overall results of the sensitivity analysis of the compliance criteria show that the weight assessment makes a strong final decision. This is because changing the sensitivity testing on the weight value of criteria between 0.005 and 0.999 does not affect the other decisions made by contract producers. The test data used also meets this condition, which means it has perfect value strength. This is because the respondents' input weights, especially those related to compliance criteria, are very valid and can accurately describe the results of the pairwise comparison matrix.

Delivery Criteria Level Sensitivity Value
Based on the previous data processing, the weight of the delivery criterion is 0.113, resulting in the final weight value of alternative contract producers 1 of 0.238; the final weight value of alternative contract producers 2 of 0.343; and the final weight value of alternative contract producers 3 of 0.419.

If the weight of the compliance criteria is lowered to 0.005, then the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.375; contract producer 2 is the second priority with a weight value of 0.301; and contract producer 1 has a weight value of 0.217.

If the weight of the compliance criteria is increased to 0.500, the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.577; contract producer 2 is the second priority with a weight value of 0.495; and contract producer 1 has a weight value of 0.315.

If the weight of the compliance criterion is increased to 0.700, then the data shows that the alternative order of contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.658, contract producer 2 is the second priority with a weight value of 0.573, and contract producer 1 has a weight value of 0.355.

If the weight of the compliance criteria is increased to 0.999, the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.780; contract producer 2 is the second priority with a weight value of 0.690; and contract producer 1 has a weight value of 0.414.

The overall results of the sensitivity analysis of the delivery criteria show that the weight assessment makes a strong final decision. This is because changing the weight value of the criteria from 0.005 to 0.999 does not affect the contract manufacturer's other decision. This condition also proves that the test data has perfect value strength because the respondents' input weights, especially for the delivery criteria, are very valid and match the results of the pairwise comparison matrix.

Operational Criteria Level Sensitivity Value
Based on the previous data processing, the weight of the operational criteria is 0.096, resulting in the final weight value of alternative contract producers 1 of 0.238; the final weight value of alternative contract producers 2 of 0.343; and the final weight value of alternative contract producers 3 of 0.419.

If the weight of the compliance criteria is lowered to 0.005, then the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.378; contract producer 2 is the second priority with a weight value of 0.313; and contract producer 1 has a weight value of 0.218.

If the weight of the compliance criterion is increased to 0.500, then the data shows that the alternative order of contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.600, contract producer 2 is the second priority with a weight value of 0.478, and contract producer 1 has a weight value of 0.325.

If the weight of the compliance criterion is increased to 0.700, the data shows that the order of alternative contract producers does not change, where contract producer 3 remains the top priority with a weight value of 0.690; contract producer 2 is the second priority with a weight value of 0.545; and contract producer 1 has a weight value of 0.369.

If the weight of the compliance criteria is increased to 0.999, then the data shows that the order of alternative contract producers does not change, with contract producer 3 remaining the top priority with a weight value of 0.825, contract producer 2 in second priority with a weight value of 0.645, and contract producer 1 with a weight value of 0.433.

The overall results of the sensitivity analysis of operational criteria show that the weight assessment makes a strong final decision. This is because changing the weight value of criteria from 0.005 to 0.999 does not affect the other decisions made by contract producers. This condition also confirms the perfect value strength of the test data, as the input weights from respondents, particularly those on operational criteria, exhibit a high level of validity and accurately describe the results of the pairwise comparison matrix.

5. Conclusions

This study aims to determine the best contract manufacturer in the secondary pharmaceutical industry of PT XYZ by using the fuzzy AHP method. Based on the analysis, there are six main criteria and twenty-six sub-criteria that influence the selection of contract manufacturers, with quality criteria as the most influential, followed by cost/price, compliance, delivery, operational, and service performance. We selected Contract Manufacturer 3 as the best, assigning the highest weights to quality, cost/price, and compliance criteria. The results of this study show the importance of quality, cost, and operations in the selection of contract manufacturers. Companies can improve relationships with contract manufacturers to ensure high-quality products, while for contract manufacturers, focusing on these criteria can improve performance and customer satisfaction. We expect the implementation of the fuzzy AHP method to enhance the company's competitiveness and performance, while also ensuring an efficient and effective supply chain.

This study has several limitations, including the limited number of respondents (5 respondents), which may affect the results of the study; subjective assessments from respondents due to differences in knowledge and experience; research conducted in only one company (PT. XYZ), so that the results may not be generally applicable to all secondary pharmaceutical companies; and PT. XYZ's company policy, which may be different from other companies in the same industry. We recommend conducting future research in several secondary pharmaceutical companies with a larger number of respondents to obtain more general results, and developing an end-to-end approach that includes the selection of raw material suppliers and logistics companies. More advanced methods, such as fuzzy goal programming or genetic algorithms, can also be considered.

Recommendation

Author recommend secondary pharmaceutical companies to use the fuzzy AHP method to objectively evaluate the performance of contract manufacturers, create customizable manual calculation templates using Microsoft Excel, and increase collaboration with contract manufacturers in quality and operations to produce high-quality and safe products. Therefore, we anticipate that this research will significantly enhance the performance and competitiveness of companies in the secondary pharmaceutical industry.

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