Green Supplier Selection Using Fuzzy Approach of AHP and VIKOR – A Case Study in an Indonesian Pharmaceutical Company

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Abstract

Pharmaceutical Industry in Indonesia has grown significantly due to the COVID-19 pandemic. The industry is now becoming one of the country's priority sectors, with one of the key development practices is to achieve Green Industry Standards. This study aims to design a Green Supplier Selection Model by incorporating the economic and green characteristics for Active Pharmaceutical Ingredients (API) Suppliers. Analytic Hierarchy Process (AHP) Method is used to weigh the criteria with a Fuzzy approach and VIKOR Method to rank the suppliers based on the weighted economic and green criteria. This research results in the ranking of 6 suppliers for 2 different APIs. With the proposed model, pharmaceutical manufacturers can have a better understanding of the capabilities that a green supplier must possess for the purpose of selecting the most suitable green supplier.

Keywords
Green Supplier Selection, Pharmaceutical Industry, Fuzzy Analytic Hierarchy Process, VIKOR

1. Introduction
The pharmaceutical industry is one of the main contributor to the growth of Indonesian industries (Ministry of Industry Indonesia 2019). Despite the COVID-19 pandemic, the Indonesian pharmaceutical sector has been growing steadily with a growth of 14% since 2009 (BPS 2020). Additionally, the chemical, pharmaceutical and traditional medicine sector grew by 14.96%, this was due to the increasing production of drugs, multivitamins and supplements to meet domestic demand for the COVID-19 outbreak (BPS 2020). The significant growth contributes to the pharmaceutical industry to be one of the country's priority (Ministry of Industry Indonesia 2019).

The level of competition in industries now require companies to increase their innovation for them to survive the global competition (Dachyar and Novita 2016). The purchasing process is very important for the company, therefore an increase should be taken into account for companies to meet the increasing demand and to be able to remain competitive (Dachyar and Praharani 2016).

Due to the increasing government regulations and greater public awareness of environmental issues such as global warming, air pollution, the use of hazardous chemicals, and climate change, companies are starting to realize the importance of implementing green practices into their daily operations. In Indonesia, the number of companies that have reached the Green Industry increases every year (Ministry of Industry Indonesia 2019).

Consumer company's supply chain typically produces much higher environmental costs than its own operations, accounting for more than 80% of greenhouse gas emissions and more than 90% of the effect on air, soil, water, biodiversity and geological resources (McKinsey 2016). Thus, by concentrating on their supply chains, customer businesses may substantially reduce their environmental costs.

Supplier assessment and selection are crucial operational activities for the success of sustainable supply chain operations and are among the most important environmental protection issues (F. 2015). Because of its long-term impact on the environment, green supplier selection is one of the most critical stages of supply chain management and environmental practices must be emphasized (Kannan et al. 2014).

Supplier selection requires the consideration of various qualitative and quantitative criteria (Toloo 2014). In order to manage the purchasing function correctly, it is important to reach the right suppliers. The performance and aggregate environmental impact of a company depends on the environmental performance of all supply chain partners (Yook et al. 2018). Therefore, an environmentally friendly supplier evaluation system is needed for companies to determine the suitability of suppliers as partners in an environmentally friendly supply chain.

This study aims to select the most suitable green suppliers for 6 API suppliers for Ascorbic Acid and Hydroxychloroquine for an Indonesian pharmaceutical company. 19 subcriteria under 5 main criteria for green supplier selection are considered according to the literature review. Firstly, the criteria were weighted according to the judgments of 5 decision makers via Fuzzy AHP. After that, the VIKOR method was used to rank alternatives from the best to the worst.

2. Literature Review

2.1 Green Purchasing

Eco-friendly purchasing emphasizes reducing the waste generated, material substitution through the source of raw materials from the environment, minimizing hazardous waste, and so on. Supplier involvement and support is essential to achieve these goals. The environmental performance of a company is not only related to environmentally friendly efforts from within the company but is also influenced by the environmental performance of suppliers (Büyüközkan and Ifi 2012). Therefore, more and more companies are managing the environmental performance of their suppliers to ensure that the materials and equipment supplied by them are environmentally friendly and produced using processes that also respect environmental principles.

Supplier selection is crucial and considered as a strategic way in the management of an adequate supply chain (Ramadhani et al. 2018). Companies generally expect their suppliers to adopt environmentally friendly practices through compliance with local regulations and develop production designs that are environmentally friendly and efficient (Tseng et al. 2016). There are two ways that companies can do to involve environmental factors in their suppliers (Tachizawa et al. 2015). The first is to monitor their environmental performance. This can be done in various ways (Lamming dan Hampson 1996; Lloyd 1994), namely through the Supplier Environment Questionnaire; Supplier Environmental Audits and Assessments; Supplier selection model design; Include environmental criteria in contracts; Require suppliers to carry out Environmental Certification independently; etc. Then the second is to proactively collaborate with them on environmentally friendly practices and processes. Collaboration can include providing resources to suppliers such as materials, standards, or technology; jointly develop products that are more environmentally friendly; collaborating on packaging reduction and recycling and helping them implement sustainable production processes.

2.2 Fuzzy Approach

In the matter of supplier selection, parameters are typically not known in absolute basis, so that decision makers can face high uncertainty (Hashim et al. 2017). This difficulty then broadens the importance of using a fuzzy approach to deal with conditions where information is not known with certainty. The deterministic model is less suitable for solving problems in this situation in order to get an effective solution (Hashim et al. 2017). In addition, in some cases, it is difficult for decision makers to clarify requirements in detail, adding to the uncertainty on the part of the supplier. Additionally, the costs of various things can differ from different regions. Therefore, the high degree of uncertainty arising from incomplete information should be considered with extreme caution during the selection procedure. In addition, it is very difficult for decision makers to determine demand, cost and quality in advance because the values of these parameters change over time and do not remain the same. Considering this situation, fuzzy variables is used to describe uncertain, imprecise or ambiguous information in the problem.

2.3 Integration of Fuzzy AHP and VIKOR

The AHP method introduced by Saaty shows how to determine the priority of the alternatives and the relative importance of the criteria in the MCDM problem (Saaty 1980). Through AHP, the importance of several criteria is obtained from the pairwise comparison process. To solve this problem, many researchers combine fuzzy theory with AHP to overcome uncertainty. The main advantage obtained from AHP and fuzzy AHP is a pairwise comparison that is more realistic and based on logic (Mohammady and Amid 2010). Researchers typically use the triangular fuzzy numbers as a membership function because it is easy to use by decision makers in assessing. Triangular fuzzy numbers

are also mathematically easy to apply and represent a rational rationale for measuring vague knowledge on most decision-making problems (Mardani et al. 2015). The triangular fuzzy number shows the equal relative strength of each pair of elements in the AHP hierarchy. The use of AHP in decision making is also due to the hierarchical structure of AHP using detailed information so that the results obtained for the criteria weights are stronger than the use of other methods (Forghani et al. 2018)

VIKOR has the advantage of providing ranking procedures for positive and negative attributes when used in decision making (Zeng 2013). The VIKOR method can be used in the scope of supplier selection because it produces compromise solutions. The compromise solution formed by the VIKOR method can produce more than one main alternative making it suitable for use in the scope of supplier selection. In making an alternative assessment, the VIKOR method needs to be combined with the AHP method because the AHP method is used to determine the weight of the criteria's importance to the objective and the best alternative decision cannot be determined based on the weight of the criteria alone. Meanwhile, the VIKOR method can be used to rank alternatives based on the weight of the criteria obtained from the AHP method calculation and to determine the best alternative which has opposite criteria (Mohammady and Amid 2010). By combining the two methods, the assessment can be done more simply because the VIKOR method does not require pairwise comparisons for each of the alternatives being assessed.

3. Methods

This research was conducted for 2 categories of raw materials, namely Ascorbic Acid and Hydroxychloeroquine. The research methodology starts from collecting criteria in the literature review. Furthermore, the criteria will be validated by experts and carried out to form a questionnaire. The questionnaire will be distributed to experts to obtain data. Data from the questionnaire were processed by Fuzzy AHP to get the final weighting and VIKOR for ranking the supplier. After the data is processed, the next step is to evaluate and draw conclusions.

4. Data Collection

Literature study is conducted for the initial stage to determine the criteria for green supplier selection and 26 subcriteria were obtained for 5 different criteria. Criteria reduction is done by pharmaceutical purhcasing experts to assess the relevance of the subcriteria to the pharmaceutical industry. The criteria assessment is done by distributing questionnaires using a Likert 1-5 scale questionnaire where 1 represents very unrelated and 5 represents very related. The experts' judgements resulted in 5 criteria and 19 subcriteria as seen on Table 1.

Table 1. Results of Criteria and Subcriteria Reduction

No	Criteria	Subcriteria
1	Environmental Performance	Environmental Certificates
2		Regulatory Compliance
3		Top-Management Commitment
4		Waste Management
5		Emission Control
6	Product Quality	Product Quality
7		Packaging Quality
8		Defect History
9	Price	Product Price
10		Payment System
11		Discount
12	Service	After Sales Service
13		Delivery
14		Mutual Trust
15		Flexibility
16	Management	Financial Stability
17		Geographical Location
18		Company Reputation
19		Production Capacity

5. Results and Discussion

5.1 Weighting of Criteria and Subcriteria with Fuzzy AHP Method

In this step, pairwise comparisons are used with the fuzzy approach using the 5 scale Triangular Fuzzy Number (TFN) range (See Table 2).

Table 2. Triangular Fuzzy Number (Ayhan 2013)

Scale	Description	Triangular Fuzzy	Triangular fuzzy reciprocal
1	Equal	1,1,1	1,1,1
3	Weak	2,3,4	1/4, 1/3, 1/2
5	Fair	4,5,6	1/6, 1/5, 1/4
7	Strong	6,7,8	1/8, 1/7, 1/6
9	Absolute	9,9,9	1/9, 1/9, 1/9

After assessing and calculating each of the criteria and sub-criteria, the results for each of the local and global weight are obtained (See Table 3). The multiplication of the local weight values for the criteria and sub-criteria will give the global weight for each sub-criterion

Table 3. Weighting Results for each Criteria and Subcriteria

NO	Criteria	C Weight	Rank	Sub-criteria	Local Weight	Global Weight	Global Rank
1	Environment	0,067	5	Environmental Certificates	0,206	0,014	15
2				Regulatory Compliance	0,149	0,01	19
3				Staff Environmental Training	0,176	0,012	18
4				Top-Management Commitment	0,278	0,019	14
5				Green Product	0,19	0,013	17
6	Quality	0,330	1	Waste Management	0,534	0,176	1
7				Emission Control	0,178	0,059	8
8				Recycle and Reuse	0,287	0,095	3
9	Price	0,297	2	Green Energy Consumption	0,397	0,118	2
10				Green Reputation	0,301	0,09	5
11				Green Collaboration	0,302	0,09	4
12	Service	0,228	3	Product Quality	0,122	0,028	10
13				Packaging Quality	0,348	0,079	6
14	Management	0,078	4	Defect History	0,201	0,046	9
15				Product Price	0,329	0,075	7
16				Payment System	0,239	0,019	13
17				Discount	0,171	0,013	16
18				After Sales Service	0,281	0,022	12
19				Delivery	0,31	0,024	11
14				Defect History	0,201	0,046	9

It is found that the criteria that get the highest weight is the Quality criterion followed by the Price, Service, Management, and Environmental Performance. For the Environmental Performance criterion, it is found that the most important subcriteria is the Waste Management followed by Environmental Certifications, Emission Control, Top-management Commitment, and Regulatory Compliance. Waste Management is proven to be the most important because in the context of Pharmaceutical Industry, the API can be dangerous for both the environment and human, therefore the treatment of such chemicals should be prioritized (Devesh and Dayaram 2015). While Environmental Certifications, such as ISO 14001, can be important because certified companies will get pressure to develop an environmental performance system to measure and evaluate the effectiveness of programs related to their environmental management (Nurkhaeriyah et al. 2019), therefore leading to the overall environmental performance of the company.

The next stage is to calculate the consistency of the expert's judgment. To control the results of the methods used, each consistency ratio of the AHP hierarchical matrices must be taken into account. CR or consistency ratio is used to estimate the consistency of the pairwise comparison matrix. The CR value must be less than or equal to 0.1 because this indicates that pairwise comparisons are acceptable because the elements contained in the matrix have been grouped homogeneously and the relationships between the criteria justify each other logically (Saaty 1980). In the fuzzy approach, the CRm (middle limit) and CRg (upper and lower limit) calculations are used. The results of CRm and CRg calculations performed for each criterion and sub-criteria show a number below 0.1 (See Table 4).

Table 4. Fuzzy AHP Consistency Test Results

Indicators	CRm	CRg
Criteria	0,023	0,067
Environmental Subcriteria	0,033	0,094
Quality Subcriteria	0,027	0,071
Price Subcriteria	0,004	0,009
Service Subcriteria	0,033	0,098
Management Subcriteria	0,013	0,040

According to (Saaty 1980), consistency ratio of 0.1 or less is considered acceptable for each matrix. Thus, all weighting values at this AHP fuzzy stage can be said to be consistent and can be used for research materials.

5.2 Supplier Assessment using the VIKOR Method

Supplier assessment is carried out on the basis of the weights that have been obtained from data processing in the previous stage. The data used in this step is the expert assessment using a 5-point Likert scale. Assessment was carried out separately for 2 categories, Ascorbic Acid and Hydroxychloroquine.

The data from the experts' assessments are then processed using the VIKOR method. The calculation of the Q_i parameters tells us which is the order in distance modes between the optimal value and different alternatives of each supplier (Pérez-Velázquez et al., 2020).

In the case of the Ascorbic Acid Suppliers, it is found that the supplier with smallest VIKOR Index is A3 (See Table 5). Which shows that the most suitable Ascorbic Acid Supplier for the company according to the combined criteria is A3 (Q=0,000), followed by A1 (Q=0,841) and A2 (Q=1,000).

Table 5. S, R, and Q Results for Ascorbic Acid Suppliers

	Si	Ri	Qi	Rank
A1	0,437	0,104	0,841	2
A2	0,472	0,118	1,000	3
A3	0,312	0,090	0,000	1

As for the Hydroxychloroquine Suppliers, it is found that the supplier with smallest VIKOR Index is H3 (See Table 6). Which shows that the best supplier for Hydroxychloroquine is H3, followed by H2 and H1.

Table 6. S, R, and Q Results for Hydroxychloroquine Suppliers

	Si	Ri	Qi	Rank
H1	0,495	0,095	0,592	3
H2	0,345	0,118	0,548	2
H3	0,329	0,090	0,000	1

After obtaining the VIKOR Index value, the chosen alternative must be able to meet the two VIKOR requirements to ensure that the chosen solution is the best solution. The best alternative (with the smallest VIKOR or Q index value) must meet 2 conditions, namely:
Condition 1. Acceptable advantage: Q(a") - Q(a') > DQ ; DQ = 1/(J-1)
- Ascorbic Acid:
D1= 1/(3-1)=0,5
Q(A1) – Q(A3) = 0,841-0,000=0,841
Therefore, Condition (1) is fulfilled since 0,841≥ 0.5
- Hydroxychloroquine
D1= 1/(3-1)=0,5
Q(H2)-Q(H3)= 0,548-0,000 =0,548
Therefore, Condition (1) is fulfilled since 0,548 ≥ 0.5

Condition 2. Acceptable stability in decision making: Alternative A′ must also be the best ranked by S or/and R
- Ascorbic Acid
Q(A3) corresponds to the lowest value in S_i =0,312 and Ri = 0.090
Therefore, Condition (2) is fulfilled

- Hydroxychloroquine
Q(H3) corresponds to the lowest value in S_i =0,329 and R_i = 0.090
Therefore, Condition (2) is fulfilled

After the calculation of the conditions, the results show that A3 and H3 suppliers meet both conditions, so through this study it can be concluded that the supplier company A3 (Ascorbic Acid) and H3 (Hydroxychloroquine) are chosen as the most ideal suppliers for the company.

5.3 Sensitivity Analysis

The sensitivity analysis is carried out by increasing and decreasing the weight of the decision-making strategy (v) carried out by the VIKOR method. Although in general, the recommended value of v is 0.5, but the alternative final ranking and the decisions obtained depend on this value (Tavakkoli-Moghaddam et al. 2011). Under these different scenarios, the VIKOR step is used to observe changes in the outcome of the alternatives. Sensitivity analysis is also used because the assessment of the decision-making strategy used will affect the stability of the data processing results. Information on the stability of the results obtained can be obtained by conducting a sensitivity analysis.

The ranking index for each alternative is obtained through a linear combination of proximity to a positive ideal value and a negative ideal value. The value of this index is very dependent on the value of v, so a sensitivity analysis is carried out to measure the impact on the results and decisions obtained (Tavakkoli-Moghaddam et al. 2011). This sensitivity analysis was performed by increasing and decreasing the value of v by 10% at each stage.

- Ascorbic Acid Suppliers
In a condition where the value of v = 0.5, the highest rank of ascorbic acid supplier is A3, with the next rank being A1 and then A2. Each of the v value is calculated and the compromise solutions for each of the scenarios are obtained (See Table 7).

Table 7. Sensitivity Results for Ascorbic Acid Supplier

No	*V*	Q A1	Q A2	Q A3	Compromise Solution
1	0,1	0,841	1,000	0,000	A3
2	0,2	0,791	1,000	0,000	A3
3	0,3	0,741	1,000	0,000	A3
4	0,4	0,691	1,000	0,000	A3
5	0,5	0,640	1,000	0,000	A3
6	0,6	0,590	1,000	0,000	A3
7	0,7	0,540	1,000	0,000	A3
8	0,8	0,490	1,000	0,000	A3
9	0,9	0,440	1,000	0,000	A3
10	1	0,390	1,000	0,000	A3

The effect of the v value to the scenarios of Ascorbic Acid Suppliers changes along with the different decision-making strategies (See Figure 1).

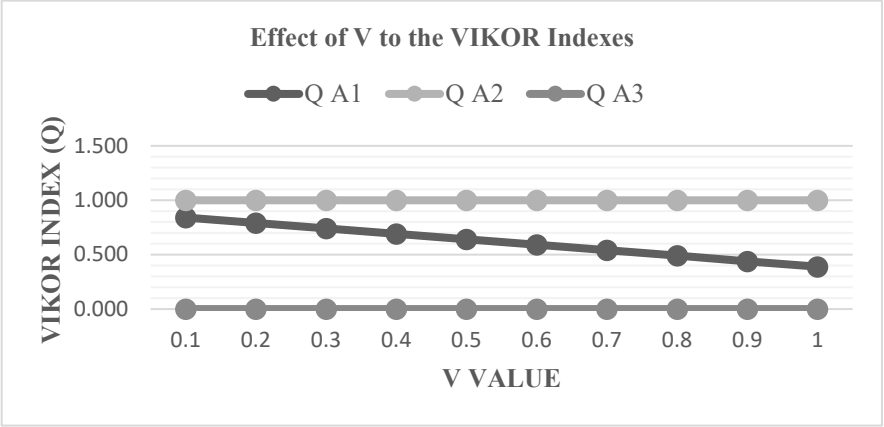

Figure 1. The Effect of V to the VIKOR Indexes (Ascorbic Acid)

It can be seen that changes in decision-making strategies, namely for decision-making scenarios based on veto, consensus, and voting, have no effect to the selection of ascorbic acid suppliers. This also means that A3 is absolutely better than A1 because the difference in the vikor index is equal to 1 (the maximum value)

2. Hydroxychloroquine Suppliers
In a condition where the value of v = 0.5, the highest ranking for hydroxychloroquine supplier is H3, with the next rank being H2 and then H1. Each of the v value is calculated and the compromise solutions for each of the scenarios are obtained (See Table 8).

Table 8. Sensitivity Results for Hydroxychloroquine Suppliers

No	*V*	Q A1	Q A2	Q A3	Compromise Solution
1	0,1	0,666	0,910	0,000	H3
2	0,2	0,648	0,819	0,000	H3
3	0,3	0,629	0,729	0,000	H3
4	0,4	0,611	0,638	0,000	H3
5	0,5	0,592	0,548	0,000	H3
6	0,6	0,574	0,457	0,000	H3
7	0,7	0,555	0,367	0,000	H3
8	0,8	0,537	0,276	0,000	H3
9	0,9	0,518	0,186	0,000	H3, H2
10	1	0,500	0,095	0,000	H3, H2

The effect of the v value to the scenarios of Hydroxychloroquine Suppliers changes along with the different decision-making strategies (See Figure 2).

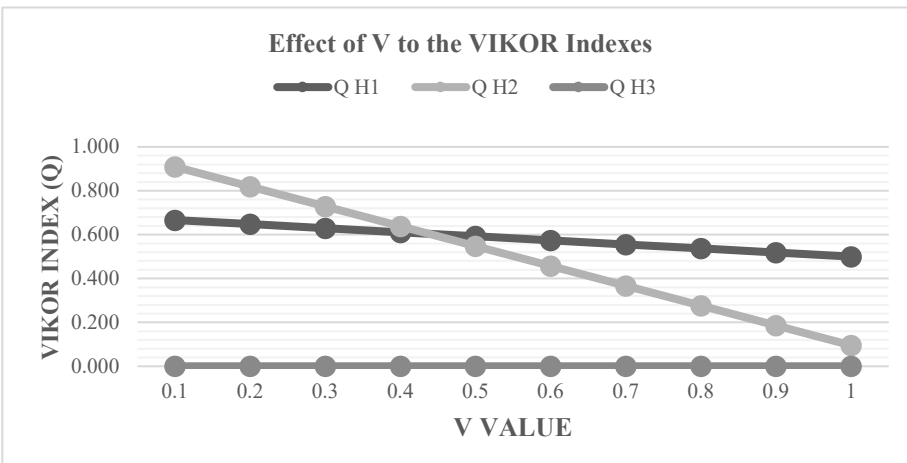

Figure 2. The Effect of V to the VIKOR Indexes (Hydroxychloroquine)

The value or weight of the decision-making strategy v> 0.5 is used if the decision is based on majority vote, the value of v = 0.5 is used if the decision is based on consensus and the value of v <0.5 is used if the decision is based on veto.

The value or weight of the decision-making strategy has no effect on the company's ranking of ascorbic acid suppliers. However, this has an effect on the ranking of hydroxychloroquine supplier companies. When the value of v = 0 to 0.4, the supplier companies H2 and H1 are in positions 2 and 3. However, when the value of v> 0.4 (when decision making leads to consensus and veto strategies), the supplier ranking changes to H1 in a position second and H2 are in third position.

This change then yields a different compromise solution. Based on Table 8, when the value of v is converted into an absolute voting system (value of v = 1), the compromise solution obtained is that the supplier companies H3 and H2 are in the same level or position. This means that the company can choose one of the two companies to be the best green supplier if the decision-making strategy is voting (each person has the same voting weight).

6. Conclusion

Evaluating suppliers is an important part of implementing the green purchasing practice for a business. The selection of green suppliers in the Indonesian pharmaceutical industry is studied in this paper. The framework of a green supplier selection method for is presented. In order to assess the suppliers, 5 criteria and 19 subcriteria are chosen based on literature review and expert judgments. Applying the framework to an Indonesian pharmaceutical company's green suppliers, by using the fuzzy AHP method and the VIKOR method, the results are obtained for 6 API of Ascorbic Acid and Hydroxychloroquine suppliers. And it is found that the main influential criteria are Quality, followed by Price, Service, Management, and Environmental Performance. In addition, for Environmental criteria, the most fundamental subcriteria is Waste Management, followed by Environmental Certifications, Emission Control, Management Commitment, and Regulatory Compliance. The framework affects the selection of suppliers in the company. It is found that the most suitable green suppliers are those that have realized the green criteria to its full potential. In Indonesia, companies have gradually realized the importance of environmental protection. Yet, few companies still do not realize the importance of the practice. The alternatives that are similar to the positive-ideal solution were chosen as the best alternative, but far from the negative-ideal solution. Finally, it is found that alternative A3 (Ascorbic Acid) and H3 (Hydroxychloroquine) is the best selection and that alternative H2 (Hydroxychloroquine) can also be included in the company's selection of green suppliers if the decision-making strategy were to be done by voting. Manufacturers of pharmaceutical or related industries may use or tailor the proposed model based on their own needs, to evaluate or select the most suitable green suppliers. For future studies, the areas of application might be extended to apply to other sectors.

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