

# Integration of ANP and QFD for Sustainable Supplier Selection in the Chemical Industry Supply Chain

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## Abstract

In response to global demands for sustainable business practices, chemical industry companies such as PT XYZ are required to implement procurement strategies that are not only efficient but also environmentally and socially responsible. This study aims to analyze the strategic role of the supply chain in supporting sustainable supplier selection, identify and prioritize sustainability criteria in the transportation supplier selection process, and develop a comprehensive decision-making approach by integrating the Analytic Network Process (ANP) and Quality Function Deployment (QFD) methods. The ANP method was applied to address the complexity of interdependent relationships among criteria, resulting in the highest priorities being placed on Green Transportation, Financial Capability, and Social Responsibility. Subsequently, the ANP results were integrated into the QFD method to translate customer sustainability requirements into supplier technical characteristics. The findings from the House of Quality indicate that the top-priority technical requirement is the use of environmentally friendly transport vehicles supported by alternative fuel infrastructure.

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## INTRODUCTION

In recent decades, the issue of sustainability has become a major concern in various industrial sectors. Companies are no longer only required to pursue financial profits, but are also required to contribute to preserving the environment and providing a positive social impact on society. In this context, the supply chain plays a strategic role in determining the success of implementing sustainability practices. Supplier selection is one of the most critical decisions in supply chain management because suppliers not only act as providers of goods or services, but also as strategic partners who can influence a company's sustainability performance.

Furthermore, multinational companies have now established globally applicable sustainability-based Key Performance Indicators (KPIs). These KPIs serve as mandatory measurement standards for all business units, including those in Indonesia, to ensure that the entire company supply chain operates in accordance with the principles of sustainable supply chain management. One important aspect of sustainability KPIs is environmental contribution. In the supplier selection process, companies are now required to evaluate the extent to which suppliers are able to reduce the environmental impact of their operations.

In Indonesia, this policy is clearly outlined in Presidential Regulation No. 12 of 2021 concerning Government Procurement of Goods and Services, which mandates that environmental aspects must be taken into consideration in the procurement of goods and services. This regulation is in line with global initiatives such as Sustainable Public Procurement (SPP) developed by the United Nations Environment Programme (UNEP, 2017). With this regulation in place, companies are encouraged to integrate sustainability aspects into the procurement process, making the selection of suppliers an important instrument for achieving sustainable development goals. Within this framework, the Supply Chain Department, particularly Procurement, plays a very important role.

PT XYZ is a company engaged in the petrochemical sector and located in the Cilegon industrial area, Banten Province. Currently, PT XYZ has a production capacity of up to 120,000 tonnes per year, making it one of the major players in the national petrochemical industry. Of this total capacity, approximately 90 per cent of its production is destined for the export market, demonstrating that PT XYZ has a strong business orientation towards the global market. Within PT XYZ's operational environment, responsibility for the procurement of goods and services falls under the authority of the Procurement Division. This division plays a strategic role in ensuring the smooth supply of materials and services that support the production process and other operational activities.

To address this complexity, a decision-making method is required that is capable of taking into account the interdependencies between elements. Analytic Network Process (ANP) is a method developed by Thomas L. Furthermore, as a strategic step to improve sustainable procurement systems in the future, the Quality Function Deployment (QFD) method is used. The integration of ANP and QFD results in a comprehensive and adaptive approach to supporting sustainable supplier selection. ANP is used to objectively measure and prioritise sustainability elements, while QFD is used as a strategic design tool to ensure that these requirements are truly internalised in the procurement system and policies. In this way, companies can build long-term collaborations with suppliers who are not only competent but also aligned with the company's future sustainability vision.

## RESEARCH METHOD

The approach used was a case study with qualitative research methods. This method is exploratory in nature, not rigidly structured, and uses a limited number of subjects selected purposefully in order to explore meanings, perceptions, and dynamics that occur more intensively. In the research process, a combination of quantitative and qualitative data was used to gain a more comprehensive understanding of the issue. Quantitative data was obtained through figures from the questionnaire results, while qualitative data came from the opinions of experts, both through interviews and questionnaires.

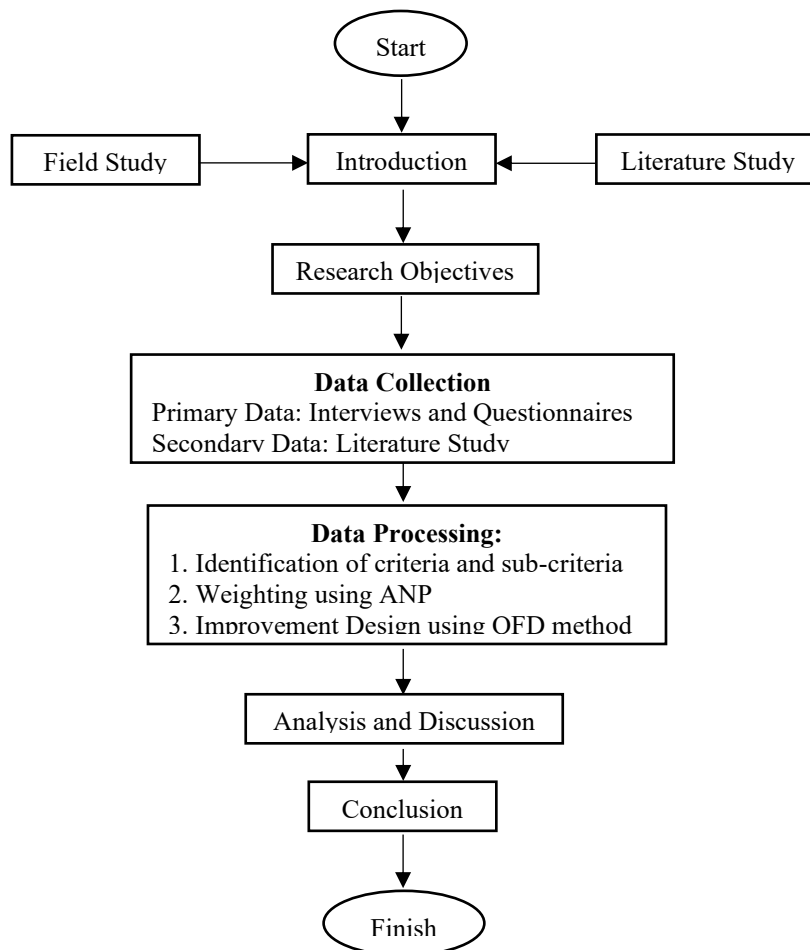


Figure 1. Flowchart of Research Stages

Data processing was carried out using the ANP (Analytical Network Process) method, as in previous studies the ANP method has been applied in various fields and has made a significant contribution. The ANP model design process requires criteria and sub-criteria, which are then assessed according to their respective weights. The final stage of the Analytic Network Process (ANP) method is to obtain the criteria with the highest weight and determine the supplier that best meets the characteristics of a green supplier based on the overall weight analysis results. The detailed stages of applying the Quality Function Deployment (QFD) method in this study began with the use of the results of the Analytic Network Process (ANP) analysis to determine customer needs with the highest priority weight as the basis for preparing QFD. Next, customer requirements were identified, which became the basis for designing a strategy for improving services and a sustainable procurement system. The next step is to calculate the weighted score for each technical requirement, which is obtained by multiplying the weight of customer needs by the value of the relationship in the House of Quality, thereby obtaining the priority of technical characteristics that need to be developed first. Based on the results of these calculations, an analysis and determination of the priority of service strategy or procurement system development is carried out, focusing on environmentally friendly and low-emission transportation aspects, in accordance with the customer needs that have been identified previously.

## RESULTS AND DISCUSSION

### Identification of Relationships Between Subcriteria using ANP

The Analytic Network Process (ANP) method was used to identify and analyse the relationships between subcriteria in the selection of sustainable suppliers. This method is an extension of the Analytic Hierarchy Process (AHP) that allows for feedback and dependence between elements in a decision network. The identification process began with the preparation of a pairwise comparison questionnaire, designed to evaluate the extent to which one subcriterion influences or is influenced by other subcriteria in an interconnected context.

This questionnaire was distributed to three experts who are competent in the fields of procurement and supply chain.

**Table 1.** List of Experts

<b>Division</b>	<b>Length of Service</b>
<i>Manager Supply Chain</i>	> 15 Years
<i>Manager Procurement</i>	> 15 Years
<i>Procurement Staff</i>	> 10 Years

The paired comparison data obtained from the three experts was then processed using Super Decisions software to form an ANP network structure, consisting of clusters and nodes (subcriteria). Next, inner dependence (relationships within a cluster) and outer dependence (relationships between clusters) analyses were performed to compile an unweighted supermatrix. This matrix was then normalised into a weighted supermatrix and further processed into a limit supermatrix to obtain the global weight or final priority of each sub-criterion. Using this approach, a comprehensive and realistic picture was obtained of the reciprocal influence between sub-criteria that affect the decision to select a sustainable supplier.

### Data Processing with Analytic Network Process (ANP)

#### *Development of Analytic Network Process (ANP) Network Model*

Figure 2 shows the hierarchical decision-making model for selecting sustainable suppliers at PT. XYZ. After developing the hierarchical decision-making model, an ANP network model was developed based on the interrelationships between sub-criteria.

#### *Pairwise Comparisons*

Pairwise comparisons aim to compare two elements in pairs to determine the preference between them. The pairwise comparison questionnaire is formed after compiling the Analytic Network Process (ANP) structure in Super Decisions software.

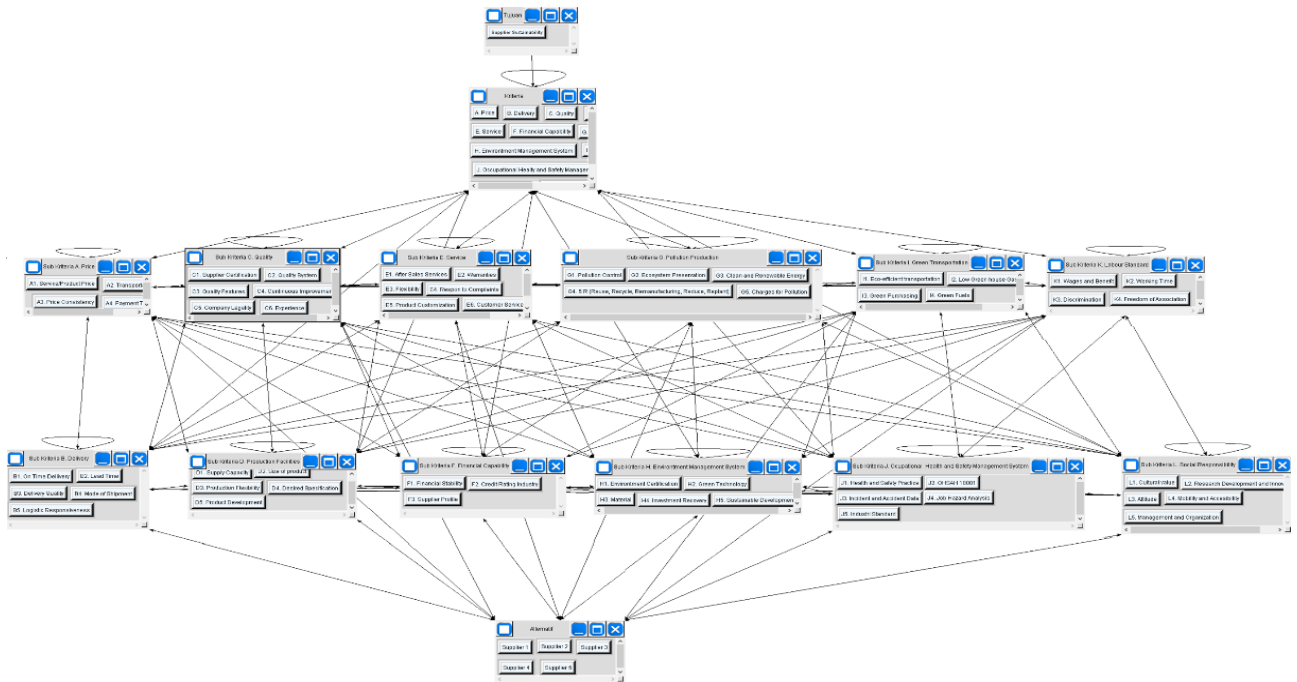


Figure 2. Analytic Network Process (ANP) Structure

**Results of Pairwise Comparisons of Criteria and Objectives**

Pairwise comparisons involve 12 criteria, requiring 66 pairwise comparisons to evaluate the relative preferences or priorities between each pair of criteria. Figure 2 shows an example of the results of pairwise comparisons of the price criterion, where a value of 3 indicates that the price criterion is slightly more important or influential than the services criterion. In addition, Figure 2 shows that the inconsistency value is 0.09950, which is less than 0.1, indicating that the experts are consistent in their answers.

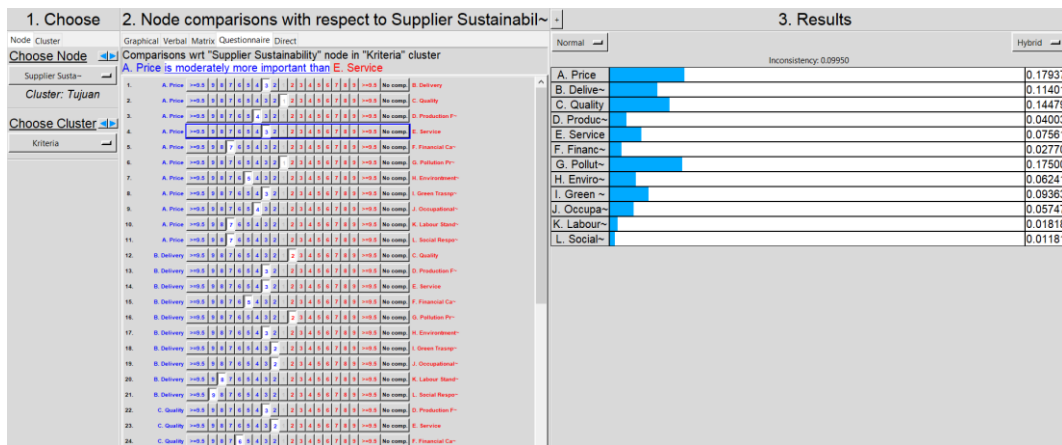


Figure 3. Results of ANP data processing comparing criteria against objectives (Source: processed data, 2025)

**Priority Results**

The results show that the criterion with the highest weight is Green Transportation (I) with a weight of 0.11057, ranking first out of all twelve main criteria. This indicates that environmentally friendly transportation is a major consideration in supplier selection, in line with the company's commitment to reducing emissions and improving energy efficiency.

The Financial Capability (F) criterion ranks second (0.09632), indicating that the financial condition of suppliers remains an important consideration to ensure operational continuity and stability. This is followed by Social Responsibility (L) in third place (0.09315), indicating the company's attention to the social and governance aspects of suppliers.

Table 2. Priority Results of Subcriteria for Criteria

Criteria	Weight	Rank	Sub criteria	Local		Global
				Weight	Rank	
A. Price	0.08044	8	A1. Service/Product Price	0.28004	1	6
			A2. Transportation Cost	0.22198	4	18
			A3. Price Consistency	0.27174	2	7
			A4. Payment Term	0.22624	3	16
B. Delivery	0.0814	6	B1. On Time Delivery	0.17777	5	41
			B2. Lead Time	0.18998	4	33
			B3. Delivery Quality	0.22797	1	15
			B4. Mode of Shipment	0.20355	2	26
			B5. Logistic Responsiveness	0.20073	3	27
C. Quality	0.08698	4	C1. <i>Supplier Certification</i>	0.16673	4	48
			C2. Quality System	0.13867	6	53
			C3. Quality Features	0.1674	3	47
			C4. Continuous Improvement	0.15206	5	52
			C5. Company Legality	0.20682	1	25
			C6. Experience	0.16832	2	46
D. Production Facilities and Capacity	0.07529	10	D1. Supply Capacity	0.19052	3	32
			D2. Size of product	0.17193	4	45
			D3. Production Flexibility	0.13804	5	54
			D4. Desired Specification	0.2577	1	9
			D5. Product Development	0.24181	2	12
E. Service	0.07774	9	E1. After Sales Services	0.13433	4	55
			E2. Warranties	0.10666	7	58
			E3. Flexibility	0.17716	1	43
			E4. Respon to Complaints	0.16331	2	49
			E5. Product Customization	0.15971	3	51
			E6. Customer Services 24 hours	0.13133	5	56
			E7. GPS availability	0.1275	6	57
F. Financial Capability	0.09632	2	F1. Financial Stability	0.38155	1	1
			F2. Credit Rating Industry	0.23905	3	13
			F3. <i>Supplier Profile</i>	0.3794	2	2
G. Pollution Production	0.08395	5	G1. Pollution Control	0.19923	3	28
			G2. Ecosystem Preservation	0.21171	2	23
			G3. Clean and Renewable Energy	0.21615	1	20
			G4. 5 R (Reuse, Recycle, Remanufacturing, Reduce, Replant)	0.17551	5	44
			G5. Charges for Pollution	0.1974	4	30
H. Environment Management System	0.06936	11	H1. Environment <i>Certification</i>	0.21522	2	21
			H2. Green Technology	0.16249	5	50
			H3. Material	0.18728	4	36
			H4. Investment Recovery	0.21433	3	22
			H5. Sustainable Development	0.22067	1	19
I. Green Transportation	0.11057	1	I1. Eco-efficient transportation	0.3015	1	4
			I2. Low Green house Gas Emission	0.18843	4	34
			I3. Green Purchasing	0.22828	3	14
			I4. Green Fuels	0.28179	2	5
J. Occupational Healthy and Safety Management Systems	0.08084	7	J1. Health and Safety Practice	0.187	4	37
			J2. OHSAH 18001	0.18481	5	39
			J3. Incident and Accident Data	0.21015	2	24
			J4. Job Hazard Analysis	0.19256	3	31
			J5. Industri Standard	0.22548	1	17
K. Labour Standard	0.06394	12	K1. Wages and Benefit	0.31474	1	3
			K2. Working Time	0.18494	4	38
			K3. Discrimination	0.24443	3	11
			K4. Freedom of Association	0.25589	2	10
L. Social Responsibility	0.09315	3	L1. Cultural value	0.17947	4	40
			L2. Research Development and Innovation	0.1772	5	42
			L3. Attitude	0.19767	2	29
			L4. Mobility and Accessibility	0.1874	3	35
			L5. Management and Organization	0.25826	1	8

**Table 3.** Results of supplier alternative weighting

<b>Alternative</b>	<b>Normalized By Cluster</b>	<b>Ranking</b>
<i>Supplier 1</i>	0.19342	4
<i>Supplier 2</i>	0.14127	5
<i>Supplier 3</i>	0.2354	1
<i>Supplier 4</i>	0.22367	2
<i>Supplier 5</i>	0.20624	3

Based on the results of calculating the priority weight of alternative suppliers using the Analytic Network Process (ANP) method, the ranking of each supplier was obtained, namely supplier 3 obtained the highest weight value of 0.2354 and ranked first, indicating that this supplier was assessed as the best alternative based on all sustainability criteria that had been analysed. Supplier 3 most likely demonstrates superior performance in aspects such as financial capability, transport efficiency, and fulfilment of environmental and social criteria.

### **Data Processing Using Quality Function Deployment (QFD)**

After obtaining the priority results for sustainability criteria through the Analytic Network Process (ANP) method, the next step in this study was to apply the Quality Function Deployment (QFD) method to translate these sustainability requirements into technical characteristics for suppliers. QFD is a systematic approach used to integrate customer requirements (in this case, the company/Procurement Division) into technical elements that can be implemented by suppliers. The main tool in QFD is the House of Quality (HOQ), which represents the relationship between sustainability requirements and the technical capabilities required from transportation suppliers.

#### **Identification of Customer Requirements**

Based on the results of previous processing using the Analytic Network Process (ANP) method, the customer importance rating weights for each sustainability requirement related to green transportation aspects were obtained. There are four main requirements identified, namely:

- a. Eco-efficient transportation with the highest weight of 0.3015, indicating that transportation efficiency is the company's top priority in ensuring energy-efficient and sustainable logistics distribution processes.
- b. Green Fuels ranks second with a weight of 0.28179, reflecting the importance of using environmentally friendly fuels by transport suppliers to reduce dependence on fossil fuels and support carbon emission reduction.
- c. Green Purchasing has a weight of 0.22828, emphasizing the importance of integrating sustainability principles into the process of purchasing and procuring goods and services from suppliers with environmental commitments.
- d. Low Greenhouse Gas Emissions has a weight of 0.18843, which remains significant in demonstrating the company's expectations for suppliers to have systems or technologies capable of reducing greenhouse gas emissions during the transportation process.

These weights are then used in the technical priority calculation stage in the House of Quality (HOQ) matrix, which will be linked to the supplier's technical characteristics (Technical Requirements). The customer importance rating values obtained from ANP provide a strong basis for companies in designing procurement strategies that are able to meet sustainability needs in a measurable and systematic manner.

**Table 4.** Customer importance rating values obtained from ANP

<b>Customer importance rating</b>	<b>Customer Requirements - (What's) ↓</b>
0.3015	I1. Eco-efficient transportation
0.18843	I2. Low Green house Gas Emission
0.22828	I3. Green Purchasing
0.28179	I4. Green Fuels

#### **Identification of Technical Requirements (TR)**

In the process of mapping Customer Requirements (CR) to Technical Requirements (TR) using the Quality Function Deployment (QFD) method, ten supplier technical characteristics (TR) have been identified that

represent the technical capabilities required to meet the company's sustainability needs, particularly in terms of environmentally friendly transportation. These technical characteristics reflect the technical dimensions that can be measured and assessed in the supplier evaluation process. These ten technical characteristics form the basis of the House of Quality matrix and will subsequently be linked to Customer Requirements to calculate their priority. The results of this QFD processing will provide concrete technical recommendations for PT XYZ in selecting transportation suppliers capable of responding to sustainability challenges.

**Table 5.** Technical Requirements for Green Transportation

No.	Technical requirements
1	Vehicle type (EV)
2	Vehicle type (hybrid)
3	Route optimisation
4	Compliance with environmental certification
5	Use of environmentally friendly fuel
6	Digital monitoring and reporting of emissions
7	Fuel consumption and monitoring system
8	Online Procurement / Paperless Procurement
9	Integrated Digital Ordering & Payment System
10	Transport Vehicles with Supporting Infrastructure for Environmentally Friendly Fuel

**Relationship between Customer Requirements and Technical Requirements**

The matrix of relationships between Customer Requirements (CR) and Technical Requirements (TR) in the Quality Function Deployment (QFD) method shows how key customer needs are translated into measurable and implementable technical aspects for suppliers. This relationship is assessed using a numerical scale, where 9 indicates a strong relationship, 3 indicates a moderate relationship, and 1 indicates a weak relationship between each CR and TR.

**Table 6.** Matrix of relationships between CR and TR in the QFD method

Technical Requirements (How's) →	Jenis Kendaraan (EV)	Jenis Kendaraan (hybrid)	Optimalisasi Rute	Kepatuhan Terhadap Sertifikasi Lingkungan	Penggunaan Bahan Bakar Ramah Lingkungan	Pemantauan dan Pelaporan Emisi Secara Digital	Sistem monitoring dan konsumsi BBM	Pengadaan Secara Online / Paperless Procurement	Sistem Pemesanan & Pembayaran Terintegrasi Secara Digital	Kendaraan pengangkut disertai Infrastruktur Pendukung Bahan Bakar Ramah Lingkungan
Customer Requirements (What's) ↓										
11. Eco-efficient transportation	9	9	3	3	3	9	9	1	1	9
12. Low Green house Gas Emission	9	9	3	3	3	9	9	1	1	9
13. Green Purchasing	1	1	1	1	1	0	1	9	9	1
14. Green Fuels	1	1	1	1	9	9	3	1	1	9

**Company Targets**

**Table 7.** Company Targets

No.	Technical Requirement	Company Targets
1	Vehicle Type (EV)	Average energy consumption per 1 kWh for 5 km per vehicle
2	Vehicle Type (hybrid)	Deliveries within a radius of <100 km using hybrid vehicles
3	Route Optimization	Implementation of route management software across the entire fleet
4	Compliance with Environmental Certification	ISO certification (ISO 14001, etc.).
5	Use of Environmentally Friendly Fuel	Fossil fuel restriction policy in operations
6	Digital Emission Monitoring and Reporting	Vehicles are roadworthy according to their vehicle inspection validity period
7	Fuel consumption monitoring system	Main fleet uses an integrated real-time monitoring system
8	Online Procurement / Paperless Procurement	Procurement process is carried out digitally without physical documents
9	Integrated Digital Ordering & Payment System	Provides digital payment options and e-invoicing
10	Transport vehicles accompanied by environmentally friendly fuel support infrastructure	Cooperation with SPBG, SPKLU or alternative fuel filling facility partners, as well as the procurement of new units using environmentally friendly vehicles



The most important sub-criteria that emerged include Financial Stability, Supplier Profile, Eco-efficient Transportation, and Wages and Benefits. This reflects that supplier selection is not only based on cost or technical considerations, but also on sustainability values that support environmental and social integration in the supply chain.

3. Application of the ANP Method

The Analytic Network Process (ANP) method is used to identify and prioritize supplier selection criteria by considering the interdependencies between elements. ANP helps to overcome the complexity of decision-making, resulting in more objective priority weights that are in line with the actual conditions of sustainability in the supply chain.

4. Application of the QFD Method

The Quality Function Deployment (QFD) method is used to translate customer sustainability requirements (CR) into supplier technical characteristics (TR). From the results of the House of Quality, technical aspects such as transport vehicles accompanied by environmentally friendly fuel infrastructure, digital emission monitoring and reporting, and fuel consumption monitoring systems are ranked highest in priority. These findings provide direction for continuous improvement in the procurement and supply chain management systems, emphasizing collaboration with suppliers who are able to meet environmentally friendly technical requirements.

## Suggestions

In this study due to the limited research time available, here are some suggestions and research developments that can be carried out in the future:

1. Strengthening the Role of the Supply Chain in Sustainability

PT XYZ is advised to continue strengthening the role of the supply chain as the main driver in the implementation of sustainability. This can be done by formulating procurement policies that are more proactive towards environmental and social aspects, as well as involving all elements in the supply chain to collaborate in evaluating supplier performance on a regular basis and based on sustainability indicators.

2. Utilisation of Priority Sustainability Criteria Results

Companies should use the priority results from the ANP method as a reference in formulating supplier selection strategies. Criteria such as green transportation, financial capability, and social responsibility need to be made mandatory elements in the evaluation and selection of partners. This step will help companies build long-term partnerships with suppliers that are aligned with their sustainability vision.

3. Integration of the ANP Method in Decision-Making Systems

It is recommended that the ANP method be integrated into decision-making management systems in the field of procurement more broadly. By considering the interrelationships between evaluation elements, this approach can result in a more comprehensive and accurate supplier selection process.

4. Sustainable Implementation of QFD Results

The results of Quality Functional Deployment (QFD) show that technical requirements in the form of transport vehicles accompanied by environmentally friendly fuel support infrastructure are a top priority. Future implementation of this aspect can be carried out through several strategic steps. One of them is to encourage selected suppliers to collaborate with clean energy infrastructure providers such as SPBG (Gas Fuel Filling Stations) and SPKLU (Public Electric Vehicle Charging Stations) to ensure the availability of environmentally friendly fuel at important operational points. In addition, companies can also encourage the procurement of new electric or hybrid logistics vehicles and strengthen digital emission monitoring systems to support transparency and efficiency in sustainable supply chain management.

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