SUSTAINABLE SUPPLIER EVALUATION AND SELECTION USING ANALYTICAL HIERARCHY PROCESS (AHP)

BY

NATTAPONG PRASERTCHAI

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Member and Advisor

(Associate Professor Pisal Yenradee, D.Eng.)

Member

(Associate Professor Jirachai Buddhakulsomsiri, Ph.D.)

Director

(Professor Pruettha Nanakorn, D.Eng.)

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Author	Nattapong Prasertchai
Degree	Master of Engineering (Logistics and Supply Chain Systems Engineering)
Faculty/University	Sirindhorn International Institute of Technology Thammasat University
Advisor	Associate Professor Pisal Yenradee, D.Eng.
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ABSTRACT

Analytic Hierarchy Process (AHP) is a decision-making tool used to prioritize alternatives based on multiple criteria. Sustainability criteria typically include environmental, social, and economic aspects. Sustainable. In each criteria contain sub-criteria, for economic sub-criteria consists of price, quality, service, and delivery. Environment sub-criteria consist of environmental management, green design, and resource consumption. Social sub-criteria consist of social responsibility, health and safety and human right. This research paper proposes AHP (Analytical Hierarchy Process) method to select best supplier from 3 different suppliers based on sustainability criteria. Sustainable AHP is a valuable tool for organizations that aim to make sustainable decisions and reduce their environmental impact.

Keywords: Analytical hierarchy process (AHP), Sustainable supplier selection, Sustainability, Triple bottom line (TBL)

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LIST OF SYMBOLS/ABBREVIATIONS

Symbols/Abbreviations	**Terms**
SIIT	Sirindhorn International Institute of Technology
TU	Thammasat University
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

CHAPTER 1
INTRODUCTION

Nowadays, sustainability has become one of the most important topics in many organizations such as safety, health, service, and manufacturing. Sustainable development brings the advantage into the present without negatively affect the future to achieve the goals (WCED, 1987). In order to increase performance and advantage of business while concern sustainability issue, sustainable supplier selection is the important decision to support sustainable supply chain that considers environmental, economic, and social criteria (Sunil Luthra, 2017). The sustainable development is one of the most important strategies for business in recent years (Benn et al., 2014).

Selecting sustainable suppliers plays a crucial role in meeting the social, environmental, and economic goals of a sustainable supply chain. To achieve this objective, the research paper proposes utilizing the Analytical Hierarchy Process (AHP) as a multi-criteria decision-making technique to assess and choose sustainable suppliers in the supply chain. AHP is leveraged to identify the criteria for selecting sustainable suppliers to ensure sustainability in the supply chain.

1.1 Problem Statement

As the climate change, resource limited and poverty issue became the attention, sustainability become one of the topics to concern that made many companies have to consider sustainability issues in their supply chain management operations (Merve Er, 2016). The finding shows that managers interested in economic dimension of sustainability more than others two dimensions which lack of interest in environmental and social dimension (Yuanzhu Zhan, 2021)

1.2 Research Objective

- To understand and identify evaluation criteria for sustainable supplier selection
- To identify the weight of the criteria for sustainable supplier selection and evaluation.
- To select the supplier to satisfy sustainable criteria.

1.3 Overview of this proposal

This research paper is divided into five parts, first introduction, second literature review which include 2 categories, third the methodology includes 2 methods, fourth performance and result, and fifth is the conclusion.

CHAPTER 2
LITERATURE REVIEW

This chapter presents the related literature review to this independent study, the research papers are divided into two categories. First is sustainable supplier selection, second, AHP (Analytic Hierarchy Process). The last is the research gap.

2.1 Sustainable supplier selection

One of the most popular methods of evaluating and selecting supplier are AHP and TOPSIS also using with Fuzzy logic (Fuzzy AHP or Fuzzy TOPSIS). A review of the literature on sustainable supplier selection found that the AHP (Analytic Hierarchy Process) is widely utilized for evaluating the triple bottom line, which comprises three assessment criteria: economic, environmental, and social.

In (Sunil Luthra, 2016) paper, they proposed a framework for assessing sustainable supplier selection using an integrated analytic hierarchy process (AHP), VIKOR, multi-objective optimization and A compromise approach. First, 22 selection criteria and three aspects (economic, ecological, social) for sustainable supplier selection was determined using the literature and the brainstorming by the experts.

In (Mohamed Marzouk, 2021), (Mani.Va, 2014), and (Mohammad Chavosh Nejad, 2021) papers, they suggest using the Analytic Hierarchy Process (AHP) to select suppliers based on social sustainability, which involves obtaining the weightage of social sustainability criteria. Meanwhile, Mohamed Marzouk utilizes both the AHP and the Similarity to the Ideal Solution (TOPSIS) methods. TOPSIS is applied to assess suppliers based on various identified attributes.

Fuzzy logic is also applied in (S. Gold, 2015) and (Krishnendu Shaw, 2012) papers. The papers put forth a comprehensive method for choosing a sustainable supplier in a supply chain. This approach employs the fuzzy-AHP technique to evaluate the significance of various criteria such as cost, flexibility, quality, among others.

In (Swati Kwatra, 2021) paper, they proposed to demonstrates the use of methods that involve various related stakeholders and estimate the importance weight if various parameters that impact sustainable development at the local level.

In (Ernesto Mastrocinque, 2020) paper, their objective is to offer a TBL-based (triple bottom line) multi-criteria decision-making model for the supply chain in the renewable energy sector. This model incorporates three criteria - economic, environmental, and social - and employs the AHP (analytic hierarchy process) technique.

Table 2.1 A Summary of sustainable supplier selection research papers (keyword: sustainability AHP)

Research Paper	Description	Method					
		AHP	TOPSIS	VIKOR	Fuzzy TOPSIS	Fuzzy AHP	Dempster-Shafer
(Sunil Luthra, Kannan Govindan, Devika Kannan, Sachin Kumar Mangla, Chandra Prakash Garg, 2016)	Sustainable supplier selection and evalutation	X		X			
(Mohamed Marzouk, Marwa Sabbah, 2021)	Social sustainability approach for selecting supplier	X	X				
(S. Gold, A. Awasthi, 2015)	Sustainable supplier selection	X				X	
(Krishnendu Shaw, Ravi Shankar, Surendra S. Yadav, Lakshman S. Thakur, 2012)	Supplier selection using fuzzy AHP and fuzzu multi-objective programming for low carbon supply chain	X				X	
(Mani.Va, RajatAgarwala, Vinay Sharmaa, 2014)	Supplier selection using social sustainability in India	X					
(Mohammad Chavosh Nejad, Saeed Mansour, Azita Karamipour, 2021)	Social sustainability of technology management process: A case study in banking industry	X					
(Swati Kwatra, Archna Kumar , Sumit Sharma , Prateek Sharma, 2021)	Prioritizing sustainability issues using AHP: A case study of Goa, India	X					
(Ernesto Mastrocinque, F.Javier Ramirez, Andrés Honrubia-Escribano, Duc T. Pham, 2020)	AHP for sustainable supply chain in renewable energy sector	X					
(Anjali Awasthi, Satyaveer S. Chauhan, 2011)	Using AHP and Dempster -Shafer theory for evaluating sustainable transport solutions	X					X

2.2 AHP (Analytic Hierarchy Process) research

The AHP is a highly effective technique used in multi-criteria decision-making, and is commonly employed in research on categorical methods. AHP facilitates the integration of both qualitative and quantitative data in decision-making problems, while also offering an easy-to-understand process. (Ozcan Kilincci ,2011). AHP has been widely applied to use in supplier selection. It used to match and compare method to prioritize and weight the alternative solutions to the problem. AHP is an abstract conceptualization to weights criteria by using numbers instead of concrete values.

In (Francisco Rodrigues Lima Junior, 2014) and (Mohd. Nazim, 2022) paper present a comparative analysis of Fuzzy TOPSIS and Fuzzy AHP that applied in decision making. According to the findings of this study, both TOPSIS and AHP methods are suitable for selecting suppliers. However, the comparative results indicate that the Fuzzy TOPSIS approach is more appropriate for supplier selection than Fuzzy AHP. This is attributed to the variations in alternatives and criteria.

In (Ozcan Kilincci, 2011) paper, they propose a FEAHP (Fuzzy extended analytical hierarchy process) method using analysis method to determine priority of criteria to select the best supplier for washing machine company. The highest priority weights were determined to select the best supplier in this study, by calculating the priority weights of criteria using Macros in MS Excel. Also in (Milind Jaiwant Sakhardande, 2022) proposed the technique for solving large matrix problems in Fuzzy AHP. De Ding introduces the use of Fuzzy AHP to assess the green building characteristics and examine its applicability in the planning of green building projects.

There was a paper that uses AHP method to solve the problem with danger. In (Sandeep Panchal, 2022) paper proposed to prepare landslide hazard along national highway 5 in India by using AHP model. The route is damaged due to the heavy rain in rainy season. The criteria are divided into sub-criteria such as slop, fault density, geology, curvature and etc.

In (Yusuf Tansel Ic, 2022) paper proposes to using AHP with VIKOR method for developing a financial performance measurement model. Also, this paper presents a comparative analysis of model with TOPSIS and MOORA methods.

Table 2.2 A Summary of AHP research paper (keyword: AHP)

Research Paper	Description	Method					
		AHP	TOPSIS	VIKOR	Fuzzy TOPSIS	Fuzzy AHP	Dempster-Shafer
(Francisco Rodrigues Lima Junior, Lauro Osiro, Luiz Cesar Ribeiro Carpinetti, 2014)	A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection	X	X		X	X	
(Ozcan Kilincci, Suzan Aslı Onal, 2011)	Fuzzy AHP approach for supplier selection in a washing machine company	X				X	
(Ireneusz Miciula, Joanna Nowakowska-Grunt, 2019)	Using the AHP method to select an energy supplier for household in Poland	X					
(Mohd. Nazim, Chaudhary Wali Mohammad, Mohd. Sadiq, 2022)	A comparison between fuzzy AHP and fuzzy TOPSIS methods to software requirements selection	X	X		X	X	
(Milind Jaiwant Sakhardande, Rajesh Suresh Prabhu Gaonkar, 2022)	On solving large data matrix problems in Fuzzy AHP	X				X	
(Giuseppe Bruno, Emilio Esposito, Andrea Genovese, Renato Passaro, 2012)	AHP-based approaches for supplier evaluation : Problems and perspectives	X					
(Sandeep Panchal, Amit Kr. Shrivastava, 2022)	Landslide hazard assessment using analytic hierarchy process (AHP): A case study of National Highway 5 in India	X					
(Yusuf Tansel , Beril Çelik, Sevcan Kavak, Büşra Baki, 2022)	An integrated AHP-modified VIKOR model for financial performance modeling in retail and wholesale trade companies	X	X	X			
De Ding, Jiayan Wu, Shengwei Zhu, Yu Mu, Yongyang Li, 2021)	Research on AHP-based fuzzy evaluation of urban green building planning	X				X	

2.3 Research gaps

Selecting suppliers is important part of achieving sustainability in supply chains. Nevertheless, numerous organizations concentrate exclusively on economic factors such as price, delivery, quality, and flexibility. However, sustainable supplier evaluation has more complex evaluation criteria than normal supplier evaluation. Sustainable supply chain must consider 3 criteria which are economic, environmental, and social. This study used 3 evaluation criteria for sustainable supplier selection as economic, social and environmental dimensions by collecting evaluation criteria from literature review where sustainability criteria were used in selection and evaluation of supplier as shown in table 2.3.

Table 2.3 Sustainable supplier selection and evaluation criteria with source

Sustainability dimensions	Evaluation Criteria	(Sunil Luthra, Kannan Govindan, Devika Kannan, Sachin Kumar Mangla, Chandra Prakash Garg, 2016)	(Mohamed Marzouk, Marwa Sabbah, 2021)	(S. Gold, A. Awasthi, 2015)	(Krishnendu Shaw, Ravi Shankar, Surendra S. Yadav, Lakshman S. Thakur, 2012)	(Mani.Va, RajatAgarwala, Vinay Sharmaa, 2014)	(Mohammad Chavosh Nejad, Saeed Mansour, Azita Karamipour, 2021)	(Swati Kwatra, Archna Kumar, Sumit Sharma, Prateek Sharma, 2021)	(Ernesto Mastrocinque, F.Javier Ramírez, Andrés Honrubia-Escribano, Duc T. Pham, 2020)	(Anjali Awasthi, Satyaveer S. Chauhan, 2011)
Economic	Price	X		X	X				X	
	Delivery	X			X					
	Quality	X		X	X				X	
	Service						X			
	Flexibility	X		X						
	Technological & Innovation	X		X					X	
	Financial	X								
Environmental	Environmental Management System	X		X	X			X	X	X
	Green Design	X			X				X	
	Waste & Pollution Management	X		X	X			X	X	X
	Environmental Cost	X						X		X
	Energy & Resource Consumption			X						X
Social	Social Responsibility		X	X		X	X		X	
	Health and Safety	X	X			X	X	X		X
	Human resource Management						X		X	X
	The right of stakeholders	X	X						X	
	Human rights	X		X		X	X			

CHAPTER 3
METHODOLOGY

This research used a method of studying and reviewing research papers that related to sustainability in supplier evaluation and selection with multi-criteria decision-making method using the AHP (Analytical Hierarchy Process), which has steps and methods as picture of proposed framework below.

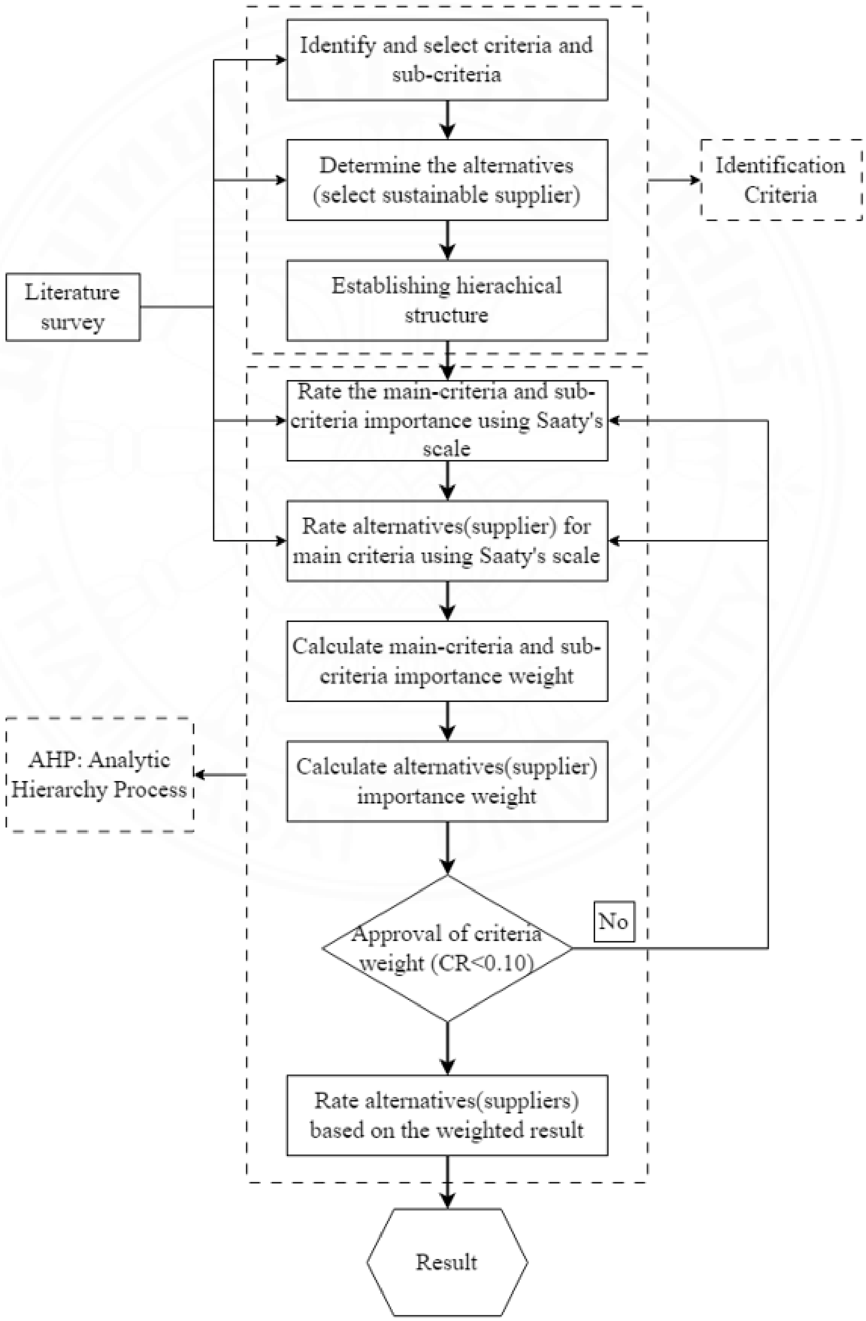

Figure 3.1 Flow Chart of proposed framework

3.1 Identification of evaluation criteria

Evaluation criteria for selection of sustainable supplier were based on TBL (Triple Bottom Line) economic, environmental and social criteria. Then, sub criteria from table 3 that we obtained from summarized of sustainability literature review were used for selection criteria analysis. In this research paper, economic criteria consist of four sub criteria which is price, quality, delivery and flexibility. Environment criteria consist of three sub criteria which is environmental management, green design and resource consumption and finally, social criteria consist of three sub criteria which is social responsibility, health and safety, and last is human right as shown in below table.

Table 3.1 Criteria table

Main criteria	Sub-criteria
Economic	Price
	Quality
	Service
	Delivery
Environment	Environmental Management
	Green Design
	Resource Consumption
Social	Social Responsibility
	Health and Safety
	Human right

This research paper creating a hierarchical chart by using AHP technique to analyze and comparing 5 examples of supplier in sustainable terms. The hierarchical chart consists of 3 criteria with sub criteria for each main criteria as picture below.

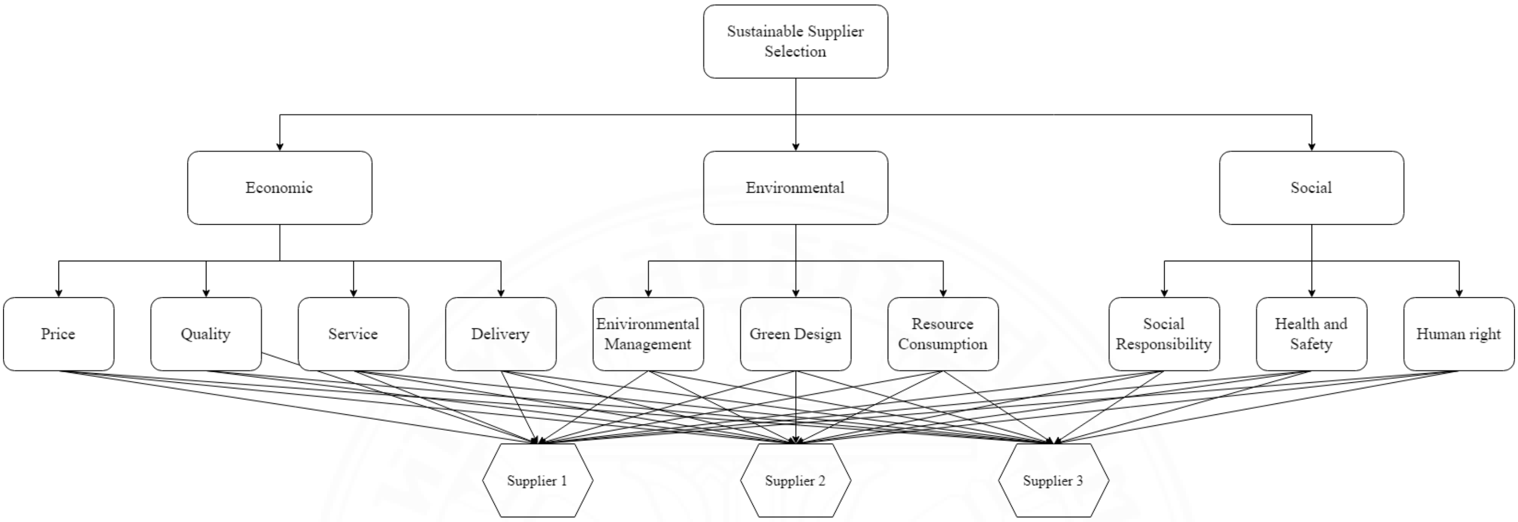

Figure 3.2 Hierarchical chart

3.2 AHP: Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a decision-making methodology developed by Thomas Saaty in the 1970s. AHP is a mathematical framework that helps people make complex decisions by breaking them down into smaller, more manageable pieces.

The AHP model involves three parts:

1. Decomposition: This involves breaking down the complex decision into smaller, more manageable pieces. For example, if you are trying to decide which car to buy, you may break down the decision into criteria such as price, fuel efficiency, safety, reliability, and design.
2. Prioritization: Once you have identified the criteria, you need to prioritize them in order of importance. This is done by pairwise comparisons, where each criterion is compared to every other criterion to determine their relative importance. The pairwise comparisons are done using a scale, usually from 1 to 9, where 1 means that the two criteria are equally important, and 9 means that one criterion is much more important than the other.

3. Synthesis: In this final step, the AHP model calculates a weighted average of the criteria, based on their relative importance. This weighted average is used to determine the overall ranking of the options being considered.

AHP has been widely used in a variety of fields, including business, engineering, and environmental science. Its versatility and ability to handle complex decision-making problems make it a valuable tool for decision-makers who want to ensure that their decisions are well-informed and based on sound criteria.

AHP is a procedure that used to solve multi-criterion decision making problems. AHP has been applied to use in supplier selection. Also, it used to match and compare method to prioritize and weight the alternative solutions to the problem. AHP can do the process by following 4 steps (Ozcan Kilincci, 2011).

1) Creating a hierarchical chart. In this study, consideration of the evaluation criteria is divided into main and sub-criteria. The hierarchical chat is divided into layers where first is objective layer, select and evaluation sustainable supplier, second, this layer is the layer that contains the main criteria, for the third, this layer contains sub-criteria and the fourth is the layer that contains the choice of sustainable supplier.

2) Comparative the importance of evaluation criteria. This second step make pairwise comparison between sustainable supplier selection criteria by create a relation matrix and collecting data using Saaty's scale as follow:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (3.1)$$

a_{ij} is represent as point of pairwise comparison that collect data from nine-point scale. According to table below.

Table 3.2 Saaty's scale table

AHP scale for pairwise comparison	
Importance scale	Importance description
1	Equally importance
3	Weak importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance

After that, we calculate weight of evaluation criteria by using geometric mean as formula below:

$$V_i = (\Pi_{j=1}^{n} a_{ij})^{1/n} \tag{3.2}$$

Where V_i = geometric mean

3) Determine normalized weight for sustainable supplier selection criteria. Normalized weights based on ranking of criteria that they have made by using formula below:

$$w_i = \frac{V_i}{\sum_{i=1}^{n} V_i} \tag{3.3}$$

$$\sum_{i=1}^{n} w_i = 1 \tag{3.4}$$

Where

w_i = weight of each criteria

V_i = geometric mean

n = number of criteria

4) Evaluate the consistency ratio (CR). CR (consistency ratio) can identify consistencies of criteria weight, evaluate consistency, and selection and ranking. This paper calculates the CR (consistency ratio) to see the condition that consistency ratio less than or equal to 0.1 mean weighting is reliable but if consistency ratio more than 0.1, mean unreliable and have to redo the pairwise comparison. The consistency ratio is calculated to see the consistency of pairwise comparisons for reliability by using formula below:

$$\lambda_{max} = \sum_{i=1}^{n} a_{ij} w_i \tag{3.5}$$

$$CI = (\lambda_{max} - 1)/(n - 1) \tag{3.6}$$

$$CI = CI/RI \tag{3.7}$$

Where
n = number of criteria
λ_{max} = Eigenvalues
CR = Consistency ratio
CI = Consistency Index
RI = Random Consistency Index ;Random Consistency Index is depend on size of the matrix between 1 x 1 and 15 x 15 which shown in table below:

Table 3.3 Random Consistency Index table

N	1	2	3	4	5	6	7	8	9	10
R.I.	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

N	11	12	13	14	15
R.I.	1.51	1.48	1.56	1.57	1.59

CHAPTER 4
PERFORMANCE AND RESULT

This is the case of sustainable supplier selection by using Analytical Hierarchy Process (AHP). A company would like to choose suppliers to order supplies by considering sustainable issues. There are 3 suppliers that company interested in. Therefore, in order to decide which suppliers is the best sustainable supplier. A company use Analytic Hierarchical Process techniques to decide which supplier have the best sustainability performance by considering 3 main criteria which is economic, environment and social. And also using sub-criteria of each criteria for help in decision-making.

4.1 Normalize weight of criteria

To do the decision-making, this research paper creating a hierarchical chart from literature review as shown in *figure 2* and create a pairwise-comparison matrix of criteria using saaty's scale rating from literature review as shown in table below.

Table 4.1 Main criteria's pairwise comparison matrix

Criteria	Economic	Environment	Social
Economic	1	1	2
Environment	1	1	3
Social	1/2	1/3	1

In this matrix, the values represent the relative importance of each main criteria compared to the others which are economic, environment and social. The diagonal elements(blue hightlight) are always 1 since a criterion is always equally important to itself. Consistency ratio is calculated CR = 0.02 which is ≤ 0.1 that mean reliable.

Note: As assign 3 in economic row and social column which mean econimic is weakly importance than social according to Table 3.2.

Table 3.2 Saaty's scale table

AHP scale for pairwise comparison	
Importance scale	Importance description
1	Equally importance
3	Weak importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance

Table 4.2 Economic sub-criteria's pairwise comparison matrix

Criteria	Price	Quality	Delivery	Flexibility
Price	1	3	7	7
Quality	1/3	1	3	7
Delivery	1/7	1/3	1	7
Flexibility	1/7	1/7	1/3	1

In this matrix, the values represent the relative importance of each economic sub-criteria compared to the others which are price, quality, delivery, and flexibility. The diagonal elements(blue hightlight) are always 1 since a criterion is always equally important to itself. Consistency ratio is calculated CR = 0.09 which is ≤ 0.1 that mean reliable.

Table 4.3 Environment sub-criteria's pairwise comparison matrix

Criteria	Resource consumption	Environmental management	Green Design
Resource consumption	1	3	7
Environmental management	1/3	1	5
Green Design	1/7	1/5	1

In this matrix, the values represent the relative importance of each environment sub-criteria compared to the others which are resource consumption, environmental management, and green design. The diagonal elements(blue hightlight) are always 1 since a criterion is always equally important to itself. Consistency ratio is calculated CR = 0.08 which is ≤ 0.1 that mean reliable.

Table 4.4 Social sub-criteria's pairwise comparison matrix

Criteria	Health and Safety	Social responsibility	Human right
Health and Safety	1	3	3
Social responsibility	1/3	1	1
Human right	1/3	1	1

In this matrix, the values represent the relative importance of each social sub-criteria compared to the others which are health and safety, social responsibility, and human right. The diagonal elements(blue hightlight) are always 1 since a criterion is always equally important to itself. Consistency ratio is calculated CR = 0.00 which is ≤ 0.1 that mean reliable.

Table 4.5 Normalized weight of criteria

Criteria	Average weight of main-criteria	Average weight of sub-criteria
Economic	**0.387**	
-Cost		0.574
-Quality		0.271
-Service		0.104
-Delivery		0.051
Environment	**0.443**	
-Resource consumption		0.643
-Environment management		0.283
-Green design		0.074
Social	**0.170**	
-Health and safety		0.600
-Social responsibility		0.200
-Human right		0.200

According to table above, we normalized weight of main-criteria based on pairwise comparison matrix above and found that the most highly important main-criteria is Environment (0.443) followed by Economic (0.387) and the lowest important criteria is Social (0.170).

For economic dimension, the most important economic sub-criteria is Cost (0.574), Quality (0.271), Service (0.104), and Delivery (0.051) respectively. For environment dimension, the most important economic sub-criteria is Resource consumption (0.643), Environment management (0.283), and Green design (0.074) respectively. For social dimension, the most important economic sub-criteria is Health and safety (0.600), Social responsibility (0.200), and Human right (0.200) respectively.

4.2 Normalize weight of supplier(alternative)

Company have to collecting data for decide which supplier have the best sustainability performance by considering 3 main-criteria which is economic, environment and social where sub-criteria that more specific criteria are considered to make up the number for main-criteria. Company collecting data and rating supplier using Saaty's scale in sub-criteria dimension. This can be done through a pairwise comparison process, where each sub-criteria is compared to every other sub-criteria and given a relative score or rating based on their relative importance.

The data is collected for rating the score as shown in table below.

Table 4.6 Economic data

Economic	Sub-criteria	Measurement	S1	S2	S3
	Cost	(Baht/unit)	7	9	10
	Quality	(%defect)	0.5	1	3
	Service	(Response time days)	7	3	1
	Delivery	(Lead time days)	2	3	6

Table 4.7 Environment data

Environment	Sub-criteria	Measurement	S1	S2	S3
	Resource Consumption	(Energy consumption)	30000KWh	20000KWh	10000KWh
	Environmental management	(Strategies)	Bad	Good	Excellent
	Green design	(Design)	Slightly Bad	Good	Excellent

Noted: reason of qualitative data are provided below. (Excellent is better than Good)

From table above, some data are quantitative data that can measured by number and some data are qualitative data that can not measured by number. So, some data will be provided as qualitive data from observed and recored as shown below:

Environmental management: Supplier 1 don't have any strategies for sustaunability management. They never promote conservation and environmental awareness in their local community. Supplier 2 has some strategies for environmental management. They has environmental management initiatives, including waste reduction, energy efficiency, and water conservation. Supplier 3 put a lot of investments in environmental management. Their targets is to reduce their carbon footprint, water consumption, and waste generation. They also have partnerships with environmental organizations and invested in renewable energy projects. They have achieved several industry awards and recognitions for their sustainability efforts.

Green design: Supplier 1 minimize packaging waste but didn't use recyclable materials. Supplier 2 designs and manufactures eco-friendly furniture using sustainable materials such as bamboo, reclaimed wood, and recycled plastic. Supplier 3 is focus on sustainable design. They have developed innovative green solutions that reduce energy consumption, water usage, and waste generation. They have won several awards for their sustainable designs.

Table 4.8 Social data

Social	Sub-criteria	Measurement	S1	S2	S3
	Health and Safety	(Employee Service)	Good	Bad	Excellent
	Social responsibility	(Contribute to society)	Good	Bad	Excellent
	Human right	(Employee Service)	Good	Slightly Bad	Excellent

Noted: reason of qualitative datas are provided below. (Excellent is better than Good)

Health and Safety: Supplier 1 places a high priority on health and safety. They also train their staff on practices and provide protective gear such as gloves and masks. Supplier 2 have a lot of complaining from employee because they provide only few regular training and safe work practices. Supplier 3 have a strong emphasis on health and safety. They have implemented a range of measures to protect their workers, including the use of personal protective equipment, regular safety training, and safety protocols.

Social responsibility: Supplier 1 invest a portion of their profits in community development projects such as education and healthcare. Supplier 2 didn't do any of projects for community to show the responsibility for social. Supplier 3 have social responsibility program to support their employees, customers, and the communities where they operate. They also have non-profit organizations to support social causes such as poverty reduction.

Human right: Supplier 1 pay their workers a fair wage and provide safe working conditions. They also have a strict policy against child labor and ensure that all workers are of legal working age. Supplier 2 pay their workers a fair wage but they not provide comprehensive safe working conditions as much. Supplier 3 have a comprehensive human rights policy that covers all aspects of their operations, including labor rights, environmental protection, and community engagement.They have achieved several recognitions for their human rights practices, including inclusion in the Human Rights Campaign Corporate Equality Index.

After collecting data, we can create pairwise comparison matrices for AHP (Analytic Hierarchy Process) comparing sub-criteria dimension of three different suppliers (1, 2, and 3) as shown in table below:

Table 4.9 Economic Performance of supplier's pairwise comparison matrix

Cost	Supplier1	Supplier2	Supplier3
Supplier1	1	5	7
Supplier2	1/5	1	3
Supplier3	1/7	1/3	1

CR=0.1

Quality	Supplier1	Supplier2	Supplier3
Supplier1	1	3	7
Supplier2	1/3	1	5
Supplier3	1/7	1/5	1

CR=0.08

Service	Supplier1	Supplier2	Supplier3
Supplier1	1	1/3	1/5
Supplier2	3	1	1/3
Supplier3	5	3	1

CR=0.05

Delivery	Supplier1	Supplier2	Supplier3
Supplier1	1	5	5
Supplier2	1/5	1	1
Supplier3	1/5	1	1

CR=0.00

In these matrix, the values represent the relative economic sub-criteria performance of each supplier compared to the others. The diagonal elements(blue hightlight) are always 1 since a company is always equally important to itself. Every martrices of economic sub-criteria are calculated consistency ratio which is $\leq$ 0.1 that mean reliable.

Table 4.10 Environment Performance of supplier's pairwise comparison matrix

Resource Consumption	Supplier1	Supplier2	Supplier3
Supplier1	1	1/6	1/9
Supplier2	6	1	1/3
Supplier3	9	3	1

CR=0.07

Environment Management	Supplier1	Supplier2	Supplier3
Supplier1	1	1/7	1/9
Supplier2	7	1	1/2
Supplier3	9	2	1

CR=0.03

Green Design	Supplier1	Supplier2	Supplier3
Supplier1	1	1/5	1/7
Supplier2	5	1	1/3
Supplier3	7	3	1

CR=0.08

In these matrix, the values represent the relative environment sub-criteria performance of each supplier compared to the others. The diagonal elements(blue hightlight) are always 1 since a company is always equally important to itself. Every martrices of environmental sub-criteria are calculated consistency ratio which is ≤ 0.1 that mean reliable.

Table 4.11 Social Performance of supplier's pairwise comparison matrix

Health and Safety	Supplier1	Supplier2	Supplier3
Supplier1	1	6	1/3
Supplier2	1/6	1	1/9
Supplier3	3	9	1

CR=0.07

Social Responsibility	Supplier1	Supplier2	Supplier3
Supplier1	1	6	1/3
Supplier2	1/6	1	1/9
Supplier3	3	9	1

CR=0.07

Human right	Supplier1	Supplier2	Supplier3
Supplier1	1	5	1/3
Supplier2	1/5	1	1/9
Supplier3	3	9	1

CR=0.04

In these matrix, the values represent the relative social sub-criteria performance of each supplier compared to the others. The diagonal elements(blue hightlight) are always 1 since a company is always equally important to itself. Every martrices of social sub-criteria are calculated consistency ratio which is ≤ 0.1 that mean reliable.

Table 4.12 Normalized weight of criteria and alternatives

Criteria	Average weight of main-criteria	Average weight of sub-criteria	Supplier 1	Supplier 2	Supplier 3
Economic	**0.387**				
-Cost		0.574	0.724	0.193	0.083
-Quality		0.271	0.643	0.283	0.074
-Service		0.104	0.106	0.26	0.633
-Delivery		0.051	0.714	0.143	0.143
Environment	**0.443**				
-Resource consumption		0.643	0.06	0.282	0.658
-Environment management		0.283	0.058	0.347	0.595
-Green design		0.074	0.074	0.283	0.643
Social	**0.170**				
-Health and safety		0.600	0.282	0.06	0.658
-Social responsibility		0.200	0.282	0.06	0.658
-Human right		0.200	0.267	0.064	0.669

According to table above, we normalized weight importance of each supplier in sub-criteria dimension based on pairwise comparison matrix (in *table 4.2.4 - 4.2.6)* and found the result as shown in the yellow columns.

Table 4.13 Weight score of economic dimensions

Economic					Weighted score of economic		
	Weight	S1	S2	S3	S1	S2	S3
Cost	0.574	0.724	0.193	0.083	0.416	0.111	0.048
Quality	0.271	0.643	0.283	0.074	0.174	0.077	0.020
Service	0.104	0.106	0.26	0.633	0.011	0.027	0.066
Delivery	0.051	0.714	0.143	0.143	0.036	0.007	0.007
				SUM=	0.637	0.222	0.141

Table 4.14 Weight score of environment dimensions

Environment					Weighted score of Environment		
	Weight	S1	S2	S3	S1	S2	S3
Resource Consumption	0.643	0.06	0.282	0.658	0.039	0.181	0.423
Environmental Management	0.283	0.058	0.347	0.595	0.016	0.098	0.168
Green Design	0.074	0.074	0.283	0.643	0.005	0.021	0.048
				SUM=	0.060	0.300	0.639

Table 4.15 Weight score of social dimensions

Social					Weighted score of Social		
	Weight	S1	S2	S3	S1	S2	S3
Health and Safety	0.6	0.282	0.06	0.658	0.169	0.036	0.395
Social Responsibility	0.2	0.282	0.06	0.658	0.056	0.012	0.132
Human right	0.2	0.267	0.064	0.669	0.053	0.013	0.134
				SUM=	0.279	0.061	0.660

From table 4.13, the weighted score can be calculated from sub-criteria's weight(green column) multiplied by normalized weight of alternatives(yellow column) under that criterion.

Ex. Weight score of Health and Safety for Supplier 1 => 0.6 * 0.282 = 0.169

Then find the sum value of all criterion in each supplier(pink column) to get the weight score of Social dimension for each supplier.

Ex. Supplier 1 => 0.169 + 0.056 + 0.053 = 0.279

Table 4.16 Normalized weight of alternatives

	Supplier1	Supplier2	Supplier3
Economic	0.637	0.222	0.141
Environment	0.060	0.300	0.639
Social	0.279	0.061	0.660

According to table above, this is the result of normalized weight of alternatives based on weight score calculation tables (table 4.12 - 4.16).

4.3 Rank alternative (based on total weighted standardized value)

Table 4.17 Compute the total weighted standardized value of each

		Weight Score			Weighted standardized decision		
Criteria	**Weight**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Economic	0.387	0.637	0.222	0.141	0.247	0.086	0.054
Environment	0.443	0.060	0.300	0.639	0.027	0.133	0.283
Social	0.170	0.279	0.061	0.660	0.047	0.010	0.112
				AHP Result = sum(each column)	**0.321**	**0.220**	**0.450**
				Rank suppliers using AHP	**2**	**3**	**1**

From table 4.17, the weighted standardized can be calculated from criteria's weight(green column) multiplied by normalized weight of alternatives(yellow column) under that criterion.

Ex. Economic dimension for supplier 1 => 0.387 * 0.637 = 0.247

Then find the sum value of all criterion in each supplier(pink column) to see the result for ranking supplier.

Ex. Supplier 1 => 0.247 + 0.027 + 0.047 = **0.321**

Table 4.18 Alternative ranking

Alternative	Weighted standardized decision	Rank
Supplier3	**0.450**	**1**
Supplier1	0.321	2
Supplier2	0.229	3

The result is shown *in table 4.3.2* that **Supplier3** is the most efficiency sustainable supplier compare to the others which corresponds to that supplier3 have the most normalized weight in environment dimension(0.639) and also have high value of the normalized weight in social dimension(0.435) but less value in economic dimension(0.141). **Supplier1** has the most economic weight(0.637) but still have less weight score than **Supplier3** because of lack in environment weight(0.060).

CHAPTER 5
CONCLUSION

In conclusion, This research paper provides a model about supplier selection for sustainability using AHP (Analytic Hierarchy Process). The Analytic Hierarchy Process (AHP) is a powerful tool for sustainable supplier selection, allowing organizations to prioritize criteria and alternatives based on their sustainability goals. By using a structured approach to evaluate suppliers on multiple criteria, including economic, environmental , and social, the AHP (Analytic Hierarchy Process) enables decision-makers to make more informed and sustainable choices. The sustainable supplier selection process using AHP (Analytic Hierarchy Process) is not only beneficial for the environment and society, but it can also lead to cost savings and increased profitability for organizations. Suppliers who demonstrate sustainable practices are often more efficient and innovative, leading to better quality products and services. In summary, the sustainable supplier selection process using AHP (Analytic Hierarchy Process) is a powerful approach that can help organizations achieve their sustainability goals, while also promoting innovation and efficiency. With careful planning and execution, the AHP (Analytic Hierarchy Process) can be an effective tool for selecting suppliers that align with an organization's values and goals.

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BIOGRAPHY

Name	Nattapong Prasertchai
Education	2016: Bachelor of Engineering (Industrial Engineering)
	Sirindhorn International Institute of Technology
	Thammasat University