ANALYZING CRITICAL SUCCESSFUL FACTORS OF VINFAST IN SELECTING GREEN SUPPLIERS

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Hoa Lac, April, 2021

Authors of the thesis

EXECUTIVE SUMMARY

Increased environmental consciousness has made it essential for businesses to choose suppliers based on sustainable and green factors. This thesis proposes Multi-Criteria Decision Making (MCDM) models, including Fuzzy Analytical Hierarchy Process (FAHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for data processing and to provide assessment and selection of green and sustainable suppliers in the automotive industry.

Methods that could be applicable to studies on other topics and used in this analysis to identify a supplier selection approach for the producer. In particular, this study uses FAHP to determine the weights of proposed criteria. The FTOPSIS is employed to rank the suppliers.

This study is outlined by the fact that VinFast describes the value of social sustainability and the automotive sector in Vietnam. This thesis is a piece of extensive knowledge of GSCM and sustainable supplier selection. Following analyzing results highlights short-term and long-term recommendations from donations of customers to increase collaboration between sustainability businesses.

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ABBREVIATIONS AND ACRONYMS LIST

Abbreviation	Full explanation
SC	*Supply Chain*
SCM	*Supply Chain Management*
GSCM	*Green Supply Chain Management*
SSS	*Sustainable Supplier Selection*
SSCM	*Sustainable Supply Chain Management*
MCDM	*Multi-criteria decision making*
AHP	*Analytical Hierarchy Process*
FAHP	*Fuzzy Analytical Hierarchy Process*
DEMATEL	*Decision-making trial and evaluation laboratory*
TOPSIS	*Technique for Order Preference by Similarity to the Ideal Solution*
FTOPSIS	*Fuzzy Technique for Order Preference by Similarity to the Ideal Solution*
Eq.	*Equation*
PIS	*Positive Ideal Solution*
NIS	*Negative Ideal Solution*
GMO	*Genetically Modified Organism*
CSR	*Corporate Social Responsibility*

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

1.1.1. Topic background

1.1.1.1 A brief to the automotive industry

Recently, by serving the population's transportation needs, the automobile industry occupies a significant role in supporting the national economy and being an economic sector with huge profits through the manufacture of goods with outstanding value.

In order to have such a brilliant automotive industry as it is today, the industry has gone through a long embryonic period where the first major foundation was the invention of various types of engines. In 1887, German scientist Nicolai successfully invented the 4-wheel engine and successfully assembled its first car. It can be said that the invention of the automobile is the indispensable crystallization of a period of blossoming inventions in the first scientific and technical revolution of humanity. Because from the 13th-century, the English Franciscan friar Roger Bacon identified that cars could be made to move with unbelievable speed without animals. After that, the automobile gained the attention of many scientists. They have continuously improved in both form and quality, from primitive, bulky and ugly early cars to be lighter, smaller and more luxurious. Subsequently, the automobile became popular, with the outstanding advantages of high travel speed, maneuverability, effortlessness and a multitude of other conveniences. As a result, the car has become an indispensable and useful means for the people of industrialized countries and an important industrial product in all countries around the world. Therefore, according to the history of the world automotive industry, in the first year of the 20th century, there were 621 factories manufacturing cars and motorcycles worldwide, of which 112 were in the UK, 11 in Italy, 35 in Germany, 167 in France, 215 in the US and 11 other countries. However, the milestone marking the official birth of the automobile industry must be in 1910 when Henry Ford- founder of the famous Ford Motor Corporation began to organize mass production of cars on a large scale.

After the Second World War, the modern science and technology revolution exploded, the automobile and automobile industry also developed great progress. The scientific and technical achievements that have been applied such as new materials, electronic engineering, cybernetics, etc have fundamentally changed the automobile and the automotive industry both science and technology as well as socioeconomic scale.

Automotive total production in the world from 2000 to present has increased steadily and stably improved over the years, focusing on 3 major industrial countries China, the US and Japan (from Figure 1.1). In addition, OICA's 2019 statistics also showed that the total world car output is approximately 92 million units, of which the Chinese market accounts for 27 percent.

Ranking	Country	2019	2018	2017	2016	2015	2014	2012	2010	2005	2000
	World	**91,786,861**	**95,634,593**	**97,302,534**	**95,057,929**	**90,780,583**	**89,747,430**	**84,141,209**	**77,629,127**	**66,482,439**	**58,374,162**
1	**China**	**25,720,665**	27,809,196	29,015,434	28,118,794	24,503,326	23,722,890	19,271,808	18,264,761	5,717,619	2,069,069
2	**United States**	**10,880,019**	11,314,705	11,189,985	12,198,137	12,100,095	11,660,699	10,335,765	7,743,093	11,946,653	12,799,857
3	**Japan**	**9,684,298**	9,728,528	9,693,746	9,204,590	9,278,321	9,774,558	9,943,077	9,628,920	10,799,659	10,140,796
4	**Germany**	**4,661,328**	5,120,409	5,645,581	5,746,808	6,033,164	5,907,548	5,649,260	5,905,985	5,757,710	5,526,615
5	**India**	**4,516,017**	5,174,645	4,782,896	4,519,341	4,160,585	3,840,160	4,174,713	3,557,073	1,638,674	801,360
6	Mexico	3,986,794	4,100,770	4,137,544	4,519,341	4,029,463	4,664,779	4,002,508	3,981,728	3,583,076	3,099,522
7	South Korea	3,950,617	4,028,834	4,134,913	4,228,509	4,555,957	4,524,932	4,561,766	4,271,741	3,699,350	3,114,998
8	Brazil	2,944,988	2,879,809	2,699,672	2,156,356	2,429,463	3,146,306	3,402,508	3,381,728	2,530,840	1,681,527
9	Spain	2,822,355	2,819,565	2,848,335	2,885,922	2,733,201	2,402,978	1,979,179	2,387,900	2,752,500	3,032,874
10	France	2,202,460	2,270,000	2,227,000	2,082,000	1,972,000	1,817,000	1,967,765	2,229,421	3,549,008	3,348,361
11	Thailand	2,013,710	2,167,694	1,988,823	1,944,417	1,915,420	1,880,007	2,429,142	1,644,513	1,122,712	411,721
12	Canada	1,916,585	2,020,840	2,199,789	2,370,271	2,283,474	2,393,890	2,463,364	2,068,189	2,687,892	2,961,636
13	Russia	1,719,784	1,767,674	1,551,293	1,303,989	1,384,399	1,886,646	2,233,103	1,403,244	1,354,504	1,205,581
14	Turkey	1,461,244	1,550,150	1,695,731	1,485,927	1,358,796	1,170,445	1,072,978	1,094,557	879,452	430,947
15	Czech Republic	1,433,963	1,442,884	1,419,993	1,349,896	1,303,603	1,251,220	1,178,995	1,076,384	602,237	455,492
16	United Kingdom	1,381,405	1,604,328	1,749,385	1,816,622	1,682,156	1,598,879	1,576,945	1,393,463	1,803,109	1,813,894
17	Indonesia	1,286,848	1,343,714	1,216,615	1,177,389	1,098,780	1,298,523	1,052,895	702,508	500,710	379,300
18	Slovakia	1,100,000	1,090,000	1,001,520	1,040,000	1,035,503	993,000	926,555	561,933	218,349	181,783

Table 1.1. Automotive total production in the world from 2000 to 2019

Currently, the automotive industry has been growing continually. According to OICA data in 2017, TOYOTA was recognized as the largest car company in the world, Volkswagen Group took the second place; 3rd place to Hyundai.

In terms of revenue, Volkswagen, Toyota and General Motors topped the list of major automobile makers in 2015, while the automotive supplier industry was dominated by Bosch, Continental, Denso and Magna.

In general, the world auto industry has always played a crucial role in all fields since its invention. It meets the increasing people's demands to travel and goods rotation and makes a great contribution to the socio-economic development of each country in particular and the world economy in general. In addition, the automotive industry is the biggest customer of many neighboring industries such as metals, chemicals, mechanics, electronics, etc, and creates job opportunities for countless workers in these industries.

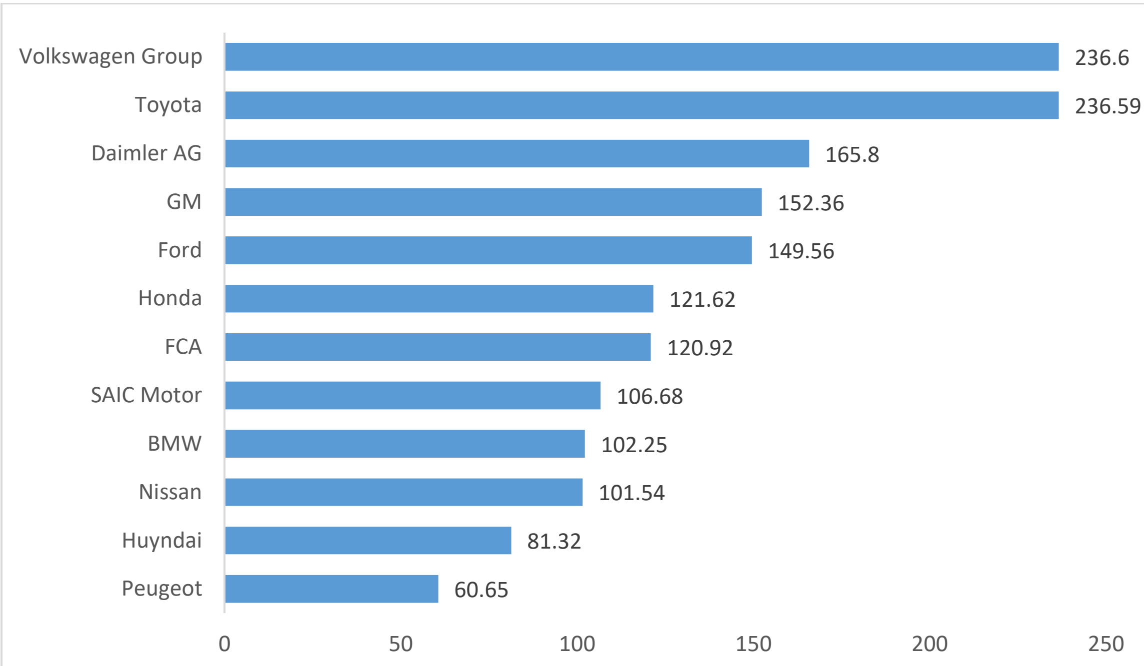


Chart 1.1. Leading motor vehicle manufacturers based on revenues in 2015 by Statista

RANK	GROUP	COUNTRY	VEHICALES
1	Toyota	Japan	10,466,051
2	Volkswagen Group	Germany	10,382,334
3	Hyundai / Kia	South Korea	7,218,391
4	General Motors	United States	6,856,880
5	Ford	United States	6,386,818
6	Nissan	Japan	5,769,277
7	Honda	Japan	5,235,842
8	FCA	Italy / United States	4,600,847
9	Renault	France	4,153,589
10	Groupe PSA	France	3,649,742
11	Suzuki	Japan	3,302,336
12	SAIC	China	2,866,913
13	Daimler	Germany	2,549,142
14	BMW	Germany	2,505,741
15	Geely	China	1,950,382

Table 1.2. Largest manufacturers by production volume in 2017 (source: OICA 2017)

According to the Industrial Research Department, there are 7.3 million employees in the auto industry, accounting for 11.3% of the 64.4 million employees in Japan. The automobile industry consumes 70% of natural rubber; 67% lead; 64% cast iron; 50% synthetic rubber; 40% of machine tools; 25% glass; 20% of semiconductor materials; 18% aluminium; 12% steel and some huge fuel and oil. This shows that the development of the automobile industry will motivate and entice the development of many other industries.

Finally, another important role of the world auto industry is accelerating globalization through the internationalization of the world's auto giants and the promotion of public transfers technology from developed countries to less developed countries.

1.1.1.2 Automotive industry in Vietnam and some specific countries

- ***<u>Chinese automotive industry</u>***

China is currently the largest automobile consumption market in the world since 2009 (OICA 2009 report). Besides famous foreign models, China also has domestic cars which are very popular in this country such as SAIC Motor, Dongfeng, FAW and Changan Automobile. They are the four pillars of the Chinese automobile industry and help China to actualize the domestic auto dream.

In the early 1950s, under the strong support of the Soviet Union, Chinese auto industry was initially licensed and put into operation. During the 30 years of its establishment, this industry had a small output, increased slightly and steadily with no more than 100-200 thousand units per year. The Chinese auto industry began to make significant strides in the early 1990s and exceeded one million units for the first time in 1992. 10 years later, China produced over two million units. It can be said that the golden period of the automobile market in this country has developed rapidly since China joined the World Trade Organization in 2001. From 2002 to 2007, national automobiles rose by an average of 21 percent, equivalent to one million vehicles per year. By 2009, China had officially usurped the United States and became the biggest automobile manufacturer in the world in terms of volume with approximately 14 million cars produced. In 2010, both sales and production reached 18 million units, with 13.76 million passenger cars delivered. This was the largest number in this country's history since joining the industry. In 2014, total vehicle production in China reached 23.720 million units, accounting for 26% of global car production.

In 2019, according to OICA statistics, Chinese car production accounts for 27 percent of the total world car production with approximately 26 million units. Thus, the Ministry of Public Security found that since its establishment to the half of 2019, China has produced about 250 million cars, making the auto industry the mainstay contributing to China's GDP.

- ***Automotive industry in the US***

Referring to the auto industry, it is impossible not to remember the person who made the American legend - Henry Ford. He was the founder of the American car industry and also the first to create the world auto industry. When he founded the Ford Group in 1901, he made millions of people's dreams about cars come true. With the release of cars at a price that everyone can own, Henry Ford was the first to mass-produce cars on a large scale and since then, the American domestic automobile industry in particular and the world auto industry in general has prepared for a development process at breakneck speed. Like many other industries in the US, the American automobile industry was established and developed mainly based on large capitalists with giant corporations such as General Motor, Ford, Chrysler, etc. The US automotive industry has developed in the direction of the free market, almost without the US Government participation (except for policies to encourage trade, investment and competition).

Until now, the US automotive industry still asserted its position through global market share. During the past century from 2010, the American automaker has always occupied the number one position in all aspects, headed by General Motor and second place belongs to Ford. Until 2010, when the Chinese automobile industry developed rapidly, the US had to retreat to cede the highest position to China. However, it has still maintained its performance and steadily developed, grown slightly over the years and reached second place just following China. The rapid development of the American automobile industry is associated with the strong growth and the internationalization of giant automobile corporations taking place throughout the countries of the world. By 2020, the US Market size value reached 79.2 billion dollars, revenue forecast in 25 is estimated 86.2 billion dollars.

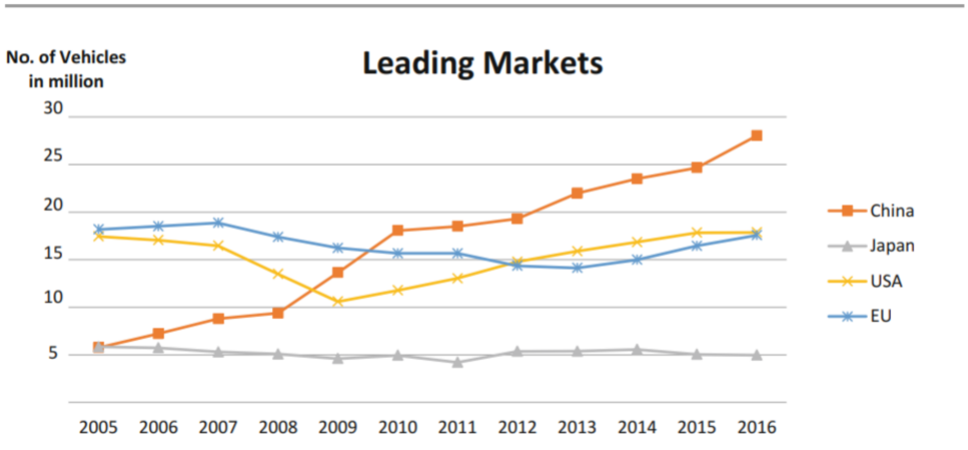


Chart 1.2. Leading Markets (Source: Möller, D. P. F., & Haas, R. E. (2019)

- ***Japanese Automotive industry***

Japan is currently one of the most developed countries in the world, in which the automobile industry plays a crucial role. During the period of miraculous development in the decade from 1960 to 1970, Japan annually produced over 10 million cars of all kinds and exported about 70 percent of the car produced. Some Japanese car manufacturers such as Nissan, Toyota, Mitsubishi, Honda, etc are very famous all over the world. The growth of the automotive accessories industry has been an important factor in the Japanese automotive industry's growth.

45 years ago, the country's auto parts industry started out with small output and simple technology, not even at the international level. Facing that fact, the Japanese Government has set out legal policies to support the domestic accessories manufacturing industry's development. The support measures have been maintained for nearly 20 years and have strongly promoted the growth and modernization of the parts industry in particular and the Japanese automobile industry in general. A few years after that, Japan had 11 car manufacturers.

In 1952, Nissan transferred technology from Austin, England; 1953 Isuzu with Hillman of England; Hino with Renault of France, etc. Meanwhile, accessories manufacturers in the development and selection process have gradually accumulated in the form of systematization or converted to production by themselves. In 1963, automotive imports were liberalized, but at that time, the automakers have gained international competitiveness. Development was then governed by American automobile industry policy, which is the largest export market. For fear of losing the market share, the Japanese manufacturers have flocked to technical development independent that met the demand of the US government. In 1973 the oil crisis broke out, low fuel-using vehicles were welcomed in the domestic market and as a result this strategy succeeded in expanding in the US market.

Overall, the Japanese automobile industry's success based on protective policies that manifested in the form of regulations banning car imports in 1963 and tariff regulations. In the context of banning foreign capital from entering the auto market until 1971, manufacturers still reached two goals: import substitution and foreign currency collection. At the same time, this success was due to the indirect favors enjoyed by industrial policy towards other industries in the country; in addition, the automakers know-how to take advantage of changes in international conditions.

By 2018, Japan is recognized as the 3rd largest automobile market in the world, with a total output of 9.7 million (according to OICA in **Chart 1.1**).

- ***Vietnamese Automotive industry***

In the 1990s, the Vietnamese automobile industry was formed by the Government's permission for foreign-invested enterprises to manufacture and assemble cars in Vietnam. Before the 1990s, Vietnam mainly imported cars from socialist countries without any enterprises investing in assembling and manufacturing cars. Major Vietnamese mechanical enterprises primarily only repair and fix cars.

The automobile industry can be considered as a measure of the country's economic development, at the same time, it is also a major contributor to every countries' GDP in the world. A few years ago, this industry was considered as a "luxury" to Vietnam, however, nowadays beside the rapid development, Vietnamese automobile industry is booming strongly. Currently, Vietnamese automotive industry not only holds an important position in promoting the development of national economy by meeting the needs of transportation, contributing to the development of production and business, it is also an economic sector that brings in very high profits with the help of production of outstanding value products, which greatly contributes to the GDP of the country. In Vietnam, the Automotive industry also accounts for 3 percent of the country's GDP. For this reason, this one always gets special attention and treatment from the government. Trade agreements have always had exceptions for the automotive industry to protect the industry from competitive pressure of other countries worldwide.

The automobile manufacturing and assembling industry in Vietnam currently consists of 2 blocks. The first one is foreign invested enterprises. The total investment capital of 14 FDI enterprises is 920 million USD, production capacity is 220,000 vehicles per year. They manufacture mainly passenger cars, utility vehicles and trucks. The second sector includes domestic firms. Up to now, more than 30 enterprises are investing in manufacturing and assembling cars with a total capital of about 2,500 billion VND. Domestic enterprises mainly produce buses, passenger cars, small and heavy trucks, and specialized vehicles.

In the present circumstances, Vietnam has signed a total of 15 free trade agreements with countries and blocks, of which 13 ones have already been valid. A prominent thing about the signed agreements is that two industries such as automotive and steel are always treated extremely special and often on tax exemption list. Vietnam is considered a fertile land for car manufacturers. While the car market in neighboring countries gradually became saturated as a result of the automotive demand stimulus policy a few years ago, Vietnamese people started to rush to buy cars by the law of supply and demand when the country's economy developed significantly.

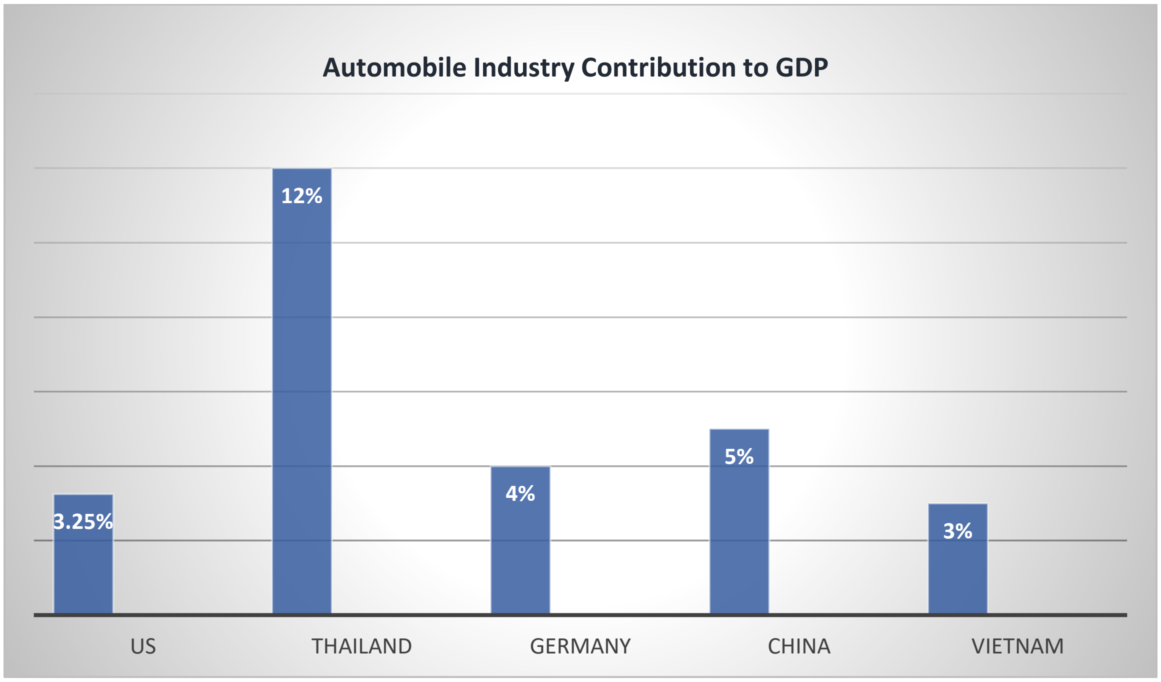


Chart 1.3. Automobile Industry Contribution to GDP (Source: Eurostat, CTS)

The achieved figures	Total revenue in 2018: **$ 10.3 billion**
	Growth from 2014 to 2018: **23.7%**
	Number of domestically produced cars in 2018: **263,170 Units**
	Estimated growth 2019-2023: **10.5 - 15%**

Source: Vietinbank report

This trend is expected to continue for a long time, plus the roadmap to join the Asean Economic Community makes automakers strive to compete in the Vietnamese market, a market previously considered to be the most expensive in the world because of tax and investment policies. Moreover, even luxury car manufacturers participate enthusiastically in this race. As an inevitable result, Vietnamese automotive market has become diverse in terms of models, segments and also customers. That situation makes the auto market a fierce battle than ever. Automakers try to come up with competitive strategies to gain a foothold in the market that is seen as becoming increasingly grumpy.

According to a VAMA report in early 2020, Toyota, Honda, Ford and Thaco currently account for 77 percent of the auto market share in Vietnam. In which, accounting for the highest market share is a domestic company - Thaco with 34.3 percent, the second is Toyota with 23.8 percent, Honda and Ford hold 10.2 percent and 8.7 percent of the domestic vehicle market respectively. The rest are other brands such as VinFast, Mitsubishi, etc.

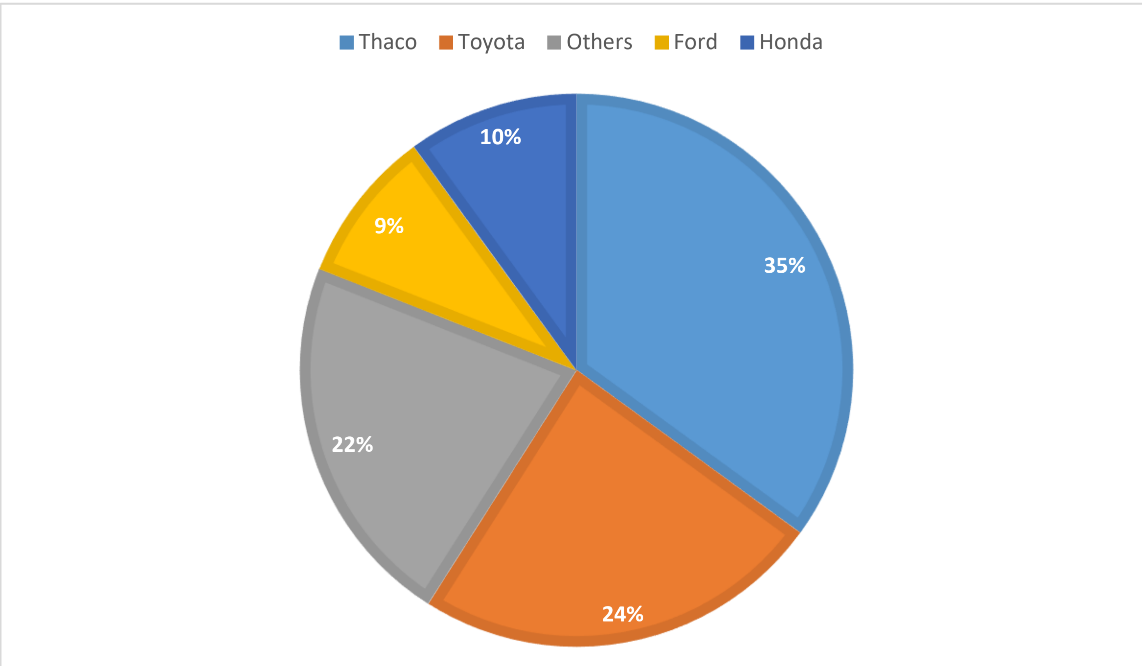


Chart 1.4. Vietnamese Automobile Market Share

1.1.2. Practical problem

1.1.2.1. Environmental problems affected the economy

The explosive industrial revolution has dramatically changed society and people's lives around the world. Industrial development has rapidly increased various factories, modern means of transport, and many items in everyday life. Besides the convenience and modernity that they bring to human life, they have inadvertently caused more serious environmental pollution, such as climate change leading to terrible natural disasters, global warming, etc. Therefore, environmental protection has become an incredibly urgent issue and also the anxiety of the whole world today.

In an economy increasingly focusing on environmental protection, companies and enterprises aim to create added value and aim to be sustainable development with consideration in terms of environment and public health. Over the past few years, companies worldwide have been working to perfect their supply chains by building eco-friendly supply chains- Green Supply Chain. Not only protecting the environment, but the green supply chain is also a development that brings a competitive advantage for companies in expanding markets and increasing profits.

In general, Green supply chain is the chain that operates efficiently, ensures both environmental friendliness and efficient use of natural ecological resources, for instance: product design, sourcing, and raw materials selection, operating procedure of manufacturing, delivering products to customers, and recycling management. Besides the environment's efficiency, GSC also brings positive effects on both the economy and society. For the economy, GSC helps improve production processes, reduce material costs, create competitive advantages, increase flexibility and linkages with partners. In addition, for society, GSC helps protect human health, reduce bad impacts from industrial waste, reduce bad effects on the community and demonstrate social responsibility per business.

1.1.2.2 Overview of green supply chain management

- ***<u>Green supply chain</u>***

In recent years, the phrase "green supply chain" has been mentioned more and more. Concerning these concerns, there have been several other words, such as "sustainable supply chain", "sustainable green supply chain", "environmental supply chain", "ecological supply chain", etc. The sustainable green application can be defined as using environmentally friendly inputs and turning the by-products into something that can be improved or recycled in the current environment. This enables the outputs and by-products to be reused at the end of their life cycle, thus creating a sustainable supply chain. Penfield suggested that a sustainable supply chain's whole idea is to reduce costs and be environmentally friendly (Penfield, 2008). Narasimhan & Carter defined green supply chain management concerning the use of methods that reduce materials in addition to recycling, processing, and reusing (Narasimhan, 1998). Godfrey (1998) considered green supply chain governance as the practice of continuously monitoring the environmental impacts of a chain and improving its results (Dawei *et al.*, 2015). Beamon emphasized the importance of collaboration with a company and the definition of green supply chain governance is the use of supply chains between a central company and a collaborative firm to support organizations (Beamon, 1999). Sarkis also defined green supply chain management as a combination of an environmental firm's operations and recovery logistics, which emphasizes the importance of the latter (Sarkis, 2003). Johnny defines green supply chain management as the process of adding 'green' elements to existing supply chains, and creating a recalled supply chain as the act of radically rebuilding systems (Ho, 2009). This includes the pursuit of efficiency and supply chain innovation in terms of costs, returns, and the environment. Although there are many different concepts that are presented depending on the perspective of each study, all the results have the common feature that the green supply chain must ensure two problems: cost, cost minimization and more environmentally friendly.

- ***Green supply chain management***

Although still being a new topic in the world, there has been a lot of research focusing on green supply chain management and its importance for businesses and applications. practice and practical analysis in many businesses. In 1996, Robert Handfield at the Manufacturing Research Group at Michigan State University used the concept of green supply chain management for the first time. Handfield initially gave a basic idea of the environmental impacts of optimizing the use of resources in the manufacturing industry's supply chain, particularly the home appliance industry. Accordingly, green supply chain is the process of specifying environmental criteria or concerns about an organization's purchasing decisions and long-term supplier relationships (Dawei *et al.,* 2015).

Green supply chain is expanding in the purchasing of raw materials for production and input of the business. Enterprises need to improve the long-term in green supply chain management, particularly in establishing supplier partnerships to be able to control raw materials. Supply chain greening is playing a significant role in all sectors, especially for high-tech electronics, fast-moving consumer goods, original product manufacturers (OEMs), etc. Green supply chain management combines supply chain management practices and environmental indicators to form purchasing decisions and long-term relationships with suppliers. It also focuses on minimizing waste of all business activities to save energy and prevent the hazardous effects of materials on the environment. Not only that, green supply chain management is also identified as the direction of combining logistics with business strategy and environmental issues in collaborative efforts to maximize business performance and efficiency towards the desired results. The distribution of goods always has high risks of harmful impacts on the environment, so businesses that desire an effectively organized green supply chain need to organize the distribution network and logistics well.

In specific terms, the concept of supply chain management is defined as: a green supply chain management system should include purchasing, inbound logistics, manufacturing, distribution and reversed logistics (Sarkis, 2003). In this concept, Sarkis has expanded the idea of green supply chain management more wholly and extensively. Green supply chain management needs to incorporate environmental ideas into the normal supply chain management process. The above research theories have shown that green supply chain management is consistent and covers many stages of the product life cycle, from the production of raw materials, to the design, manufacturing and distribution stages, the consumers' use, along with the handling of product problems at the end of the life cycle. In other words, green supply chain management can be said to be a modern governance model in the overall supply chain management, in which environmental effects and impacts are concerned. Like normal supply chains, green supply chain management is concerned with purchasing, operation, production, distribution, logistics, etc. However, the nature of the goals and the achieved values have fundamental differences. First of all, the supply chain's target value is often aimed at economic values from efficient management, operating costs, warehousing, reduced production costs, and distributed goods. Approaches to the environment are often available in the supply chain, but in the first place thanks to the efficiency in reducing the use of resources.

- ***<u>Green supplier and Green supplier selection</u>***

In the enterprise's core business activities, supply chain in general, and GSC in particular, suppliers have an extremely significant role. They ensure to supply materials, raw materials, goods, etc with sufficient quantity, quality, stability, accuracy, etc to meet production and business requirements with low cost and on time. Aside from the final consumer, suppliers are known as all the enterprises in the supply chain. Ting and Cho demonstrated that suppliers are also the SC's entire source. The precondition and basis of SC cooperation is effective supplier management 2009 (Ting and Cho, 2008).

For the green industry, Hoek considered that GSM has improved and practiced based on supplier management and it minimized environmental risks and also environmental management obstacles for businesses (Van Hoek, 1999). In addition, green suppliers helped minimize life cycle cost to provide consumers goods that are more environmentally-friendly, safer, and less expensive.

In view of all the above, suppliers have become a crucial part of green supply chains and positively affect the development of green supply chain management (Hsu *et al.*, 2013). Green supplier management in this study will concentrate on how enterprises select green suppliers and how green suppliers are developed.

According to all the reasons below, selecting and grouping the most suitable suppliers and managing them is a prerequisite, playing a substantial responsibility in SCM, contributing to production and business organizations' success. Selecting suitable green suppliers and managing them is the basis for organizations to reduce input costs, improve goods quality and services provided to customers, and improve their competitiveness in the market. To choose suitable green suppliers, many economic and environmental standards need to be considered in the evaluation process. Consequently, the topic of supplier selection has been broadly researched over the past several decades by a series of famous researchers such as Feng et al. (2011). Dickson (1966), Johnson et al. (1995), Patton (1996) Yahya and Kingsman (1999), etc. (Dawei *et al.*, 2015). The primary criteria were specified through those research, including green competency, environmental efficiency, suppliers' green image, and net life-cycle cost. With a view to addressing all of the criteria and difficulties in selecting green suppliers, various multi-criteria decision-making (MCDM) techniques have continually progressed over the years.

1.1.2.3. "Green" economy trend in the world and Vietnam

The environmental issue is the concern of the whole world, so in recent decades, the world has continuously applied and favored the green and sustainable economic development to create an economy that both satisfies the need for economic growth and addresses environmental challenges.

In the world, there are several common approaches to describe the Green Economy. A green economy is an intelligent, sustainable, and equitable economy (European Commission, 2011). Green Economic Coalition (2012) defined a green economy as an economy that creates a better quality of life for everyone within the earth's ecological limits. ICC has considered a green economy from business perspective and thought that a green economy is one where economic growth and environmental responsibility go hand in hand and mutually support each other, and at the same time supporting the social development process (ICC, 2012). UNDESA synthesized many countries' definitions and pointed out the common point that the green economy should aim to reduce the negative impacts of economic activities on the environment and society (UNDESA, 2012).

The United Nations Environment Program has introduced the concept of a green economy as one that brings human well-being and social justice, while significantly reducing environmental risks and ecological degradation. This is considered the most accurate and complete explanation of the green economy. Accordingly, a green economy is simply one with low emissions, efficient use and saving of natural resources, ensuring social equity. In GE, the growth in income and employment through public and private investments in the economy reduces carbon emissions, reduces environmental pollution, and efficiently uses energy and resources efficiently, also preventing biodiversity and ecosystems' service degradation.

Green supply chain concept is associated with green economy. Along with the current conditions of globalization, green supply chain and green supply chain management are considered as a direct and effective mechanism to solve environmental problems in the global value chain. Utilizing the purchasing power and consumption behaviour of governments, large enterprises and communities, green supply chain management is the market mechanism to reduce pollution and increase energy efficiency and natural resources. When combined with national, regional and global legal sanctions, it can lead to a green shift in industries.

The Green Public Procurement is an essential element to promote green supply chains. In the current free-market system, demand has a significant influence on supply choices. Due to the special concern of worldwide buyers about the environment as well as green products, businesses must gradually change towards greening their products if they do not want to lose market share. Therefore, green procurement is an effective market-oriented tool to develop environmentally friendly products and services, thereby gradually greening the supply chain. Therefore, in most countries' or region's supply chain greening strategies, the role of green public procurement is highly valued.

With the trends of green economic development and green shopping, at present, many countries around the world have made great strides in the development of green economic models, specifically Asian countries such as Korea, Japan, China, etc; in Europe: Germany, UK, France, Netherlands, etc have pioneered green growth and green procurement and supply.

- ***US green development trend***

The US Government has enacted laws and regulations to guide the development of green supply chains. These focused on pollution and traffic control, food preservation and consumer health protection. Since then, corresponding monitoring systems were also set up and promoted market preferences to guide businesses’ behaviour in order to environmental protection, specifically tax incentives to influence enterprises' financial decisions, thereby increasing the efficiency of using available energy resources and adopting renewable energy sources. The US government will subsidize the enterprises that lead the use of renewable energy in the supply chain. In addition, laws and regulations requiring and encouraging firms to report environmental impacts related to supply chains have also been enacted. The most compelling evidence is the Toxics Release Inventory requirement that requires companies to report the amount of chemical toxins they release during their operations. Moreover, the US government also implemented a reporting system on environmental information. All US companies or enterprises doing business in the US have to report relevant financial and corporate governance issues in standard format published by the Securities and Exchange Commission. What's more, the US Government has also stepped up the implementation of voluntary programs to reduce the environmental impact of the supply chain. They encouraged enterprises to implement voluntary programs in order to reduce the environmental impact of supply chain. The government-sponsored volunteer programs to encourage businesses to join the green value chain and orient these businesses towards sustainable activities. These things are instructive and where businesses share profitable operating experiences, for instance, the SmartWay program that started in 2004. This is a partnership program between the government and the logistics industries to reduce fuel use by means of efficiency.

Top US firms are also very interested in establishing partnerships with suppliers that pay attention to the supply process's environmental issues. Suppliers are ultimately selected based on compliance with laws and regulations and through other very thorough analysis. And when they become partners, leading businesses will orient, support and help these suppliers. For example, environmental workshops and delivery of environmental training are often held.

- ***Green procurement trend to develop green supply in the European Union***

The European Community has enacted policies related to the GPP quite early. In fact, public procurement accounts for about 19.9% of the EU's total national income (Renda *et al.*, 2012). Therefore, promoting "green" criteria in public procurement is extremely important in encouraging markets to produce and exchange greener products. In addition, developing green public procurement widely is also a goal in the Europe 2020 strategy to move towards a resource-efficient Europe. EU member states assume that when applying the GPP they will be able to have benefits not only in terms of environment, society and health, but also economic and political benefits.

Besides, promoting GPP also means promoting the development of environmentally friendly technologies. Recognizing such benefits, the European Union has emphasized the importance of the GPP since 2001 with the issuance of a statement explaining Community legislation applied to public procurement and capacity to integrate environmental issues into public procurement. This was the first statement explaining the incorporation of environmental issues into the public procurement process. Later in 2004, two important public procurement guidelines were adopted, including detailed items related to environmental issues such as the use of technology that meets environmental requirements, and using eco-labels, establishing social and environmental conditions in the enforcement of sales contracts, requiring economic actors to meet mandatory environmental demand, requiring economic entities when implementing contracts must comply with environmental management criteria and apply bonus criteria based on environmental characteristics.

Following that, in 2008, the European Commission went on to issue the announcement of Public Procurement for a Better Environment as part of the Action Plan on Sustainable Consumption and Production and Sustainable Sector Policy. With this announcement, the European Commission developed common GPP standards for several product and service groups and invited agencies to incorporate these standards into their procurement procedures, thereby purchasing greener products and services. Specifically, 10 selected product groups included clean products and services, construction, electricity, catering services and food products; office equipment, copy and graphic paper, textile, transport and furniture. Recently, the number of products and services with green criteria has been expanded to 20, including: gardening products and services; insulation products; floor covering equipment, wall panels; street lights and traffic lights; mobile phone; indoor lighting, sewage infrastructure and sanitary water taps. Each product group has its own core and comprehensive standards. The core standard is the standard that applies to all contracting agencies in Europe to address critical environmental issues at the lowest costs of verification and incidental costs. Comprehensive standards are intended for those agencies that want to buy the best products for the environment. These standards will incur higher verification costs than products with the same function.

In summary, the European Union considered sustainable development a long-term development strategy, so GPP will continue to be encouraged in the next time. Until now, the most important change in the European Union has been the introduction of common GPP standards for countries. Lastly, the support from policy and legal frameworks are also important factors in accelerating the green public procurement process in Europe.

- ***Korean green development trend***

Korea pays a lot of attention to green growth and development, and this country early had a relatively legal basis on this issue. In fact, since 1992, Korea has established Korea's eco-label. In 1994, the "Regulation on environmentally friendly technology development and support" was born and initially encouraged GPP. More importantly, the Green Product Promotion Regulation to promote the purchase of eco-friendly products was enacted in 2004 and has been valid since 2005. This regulation requires state agencies to submit effective annual plans and records to green public procurement to the Ministry of Environment. Furthermore, the Korean law allows the Ministry of the Environment to design "Guidelines for the procurement of environmentally friendly products". This guide oriented public agencies to prepare and create strategic procurement plans and initiatives and have annual reports on these strategies. At the same time, it directed the public authorities to set up a list of products that meet the standards and have the Korean eco-label, the energy-saving stamp or the recycling mark. Since 2005, the application of the Green Procurement Law has increased the amount of green public procurement in Korea from 255 million USD in 2004 to 850 million USD in 2006. By 2010, this figure was estimated at 1400 million USD, accounting for 80 % of total government procurement (Ho, Dickinson and Chan, 2010).

- ***<u>Vietnamese Green development trend</u>***

Vietnam is one of the few countries heavily affected by climate change and has suffered many negative impacts from natural disasters and epidemics. DARA International pointed out that climate change can cost Vietnam about $15 billion per year, equivalent to about 5% of GDP. If Vietnam does not have a timely response, climate change damage will be estimated to reach 11% of GDP by 2030 (Scott, Hall and Gössling, 2019).

Recognizing the impacts of climate change on people's lives, Vietnam has had many green economic development policies over the past few years. The Party's XII Congress reaffirmed the goal of rapid and sustainable development, green economic development, ensuring rapid and sustainable development on the basis of macroeconomic stability and continuously improving productivity and quality, efficiency and competitiveness, harmoniously developing between breadth and depth, focusing on deep development; developing knowledge economy, green economy. Economic development must be closely gone with social and cultural development, environmental protection, and proactive response to climate change, ensuring national defense and security and maintaining peace and stability in order to build the country.

1.1.3. Company background

1.1.3.1 Vingroup joint stock company

Vingroup - Joint Stock Company, formerly known as Technocom Group, was established in Ukraine in 1993 by young Vietnamese people. The company initially produced the dried foods and achieved great success with the Mivina instant noodles brand.

In the early years of the 21st century, Technocom always appeared in the ranking of Top 100 largest enterprises in Ukraine. Since 2000, Technocom - Vingroup has returned to Vietnam to invest with the desire to contribute to enrich the country. With a long-term vision and a sustainable development perspective, Vingroup has focused on investing in tourism and real estate with two original strategic brands- Vinpearl and Vincom. Vincom has become a top 1 brand in real estate with unceasing efforts with a series of high-end commercial centres, offices, apartments in big cities, and leading smart urban, luxury eco-urban trends in Vietnam. Along with Vincom, Vinpearl has also become the tourism industry leader with a chain of hotels, resorts, villas, amusement parks, etc.

In January 2012, Vinpearl Joint Stock Company merged into Vincom Joint Stock Company and officially operated under the Group model with the name of Vingroup. After establishment, Vingroup restructured and focused on growing with many brand groups such as Vinhomes (luxury serviced villas and apartments) in the spirit of sustainable and professional development. Vincom (High-class commercial centers), Vinpearl (Hotel, Tourism), Vinpearl Land (Entertainment), Vinmec (Medical), Vinschool (Education), VinCommerce (Retail business: VinMart, VinPro, Adayroi, VinDS, etc), VinEco (Agriculture), Almaz (International Culinary and Conference Center), etc.

At the end of 2019, Vingroup announced a consolidated financial report with huge total assets of approximately 408,572 billion VND and annual net revenue reached 100.3 trillion VND (According to Statista)

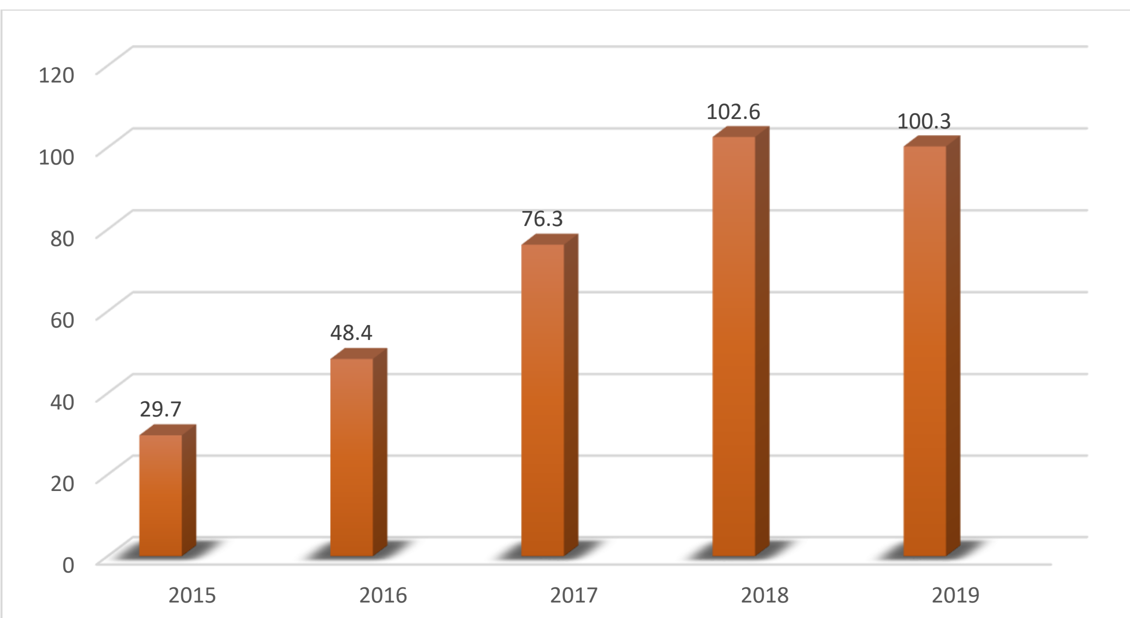


Chart 1.5: VinGroup JSC annual net revenue from 2015 to 2019.Source: Statista

With the dream to bring to the market international standards products and services and completely new experiences of modern lifestyle, in any field, Vingroup also proves its pioneering role and orients consumer trends. Efforts and hard work from the first steps, Vingroup has created miracles to honour Vietnamese brands and also brought sustainable and dynamic development strategy with the potential for international integration to reach the regional level. At present, Vingroup is proud of being one of the leading private economic groups in Vietnam.

1.1.3.2 VinFast Manufacturing and Trading Co., Ltd

In 2017, VinFast Manufacturing and Trading Limited Liability Company was established as a Vingroup Joint Stock Company subsidiary. This is also the 7th core business of Vingroup with the head office located in Hanoi and the CEO is Mr. Pham Nhat Vuong. The birth of VinFast not only contributed to making the Vietnamese car dreams come true, but also opened Vingroup's era of development-based technology and knowledge and participated in promoting Vietnamese automotive industry. VinFast's goal is to become the leading car manufacturer in Southeast Asia with a design capacity of production complex up to 500,000 vehicles per year by 2025. VinFast's main product is internal combustion, electric motor-using cars, and eco-friendly electric motorcycles.

From the initial expectation of most Vietnamese customers for Vietnamese-branded cars with quality and cheaper price. On 2nd September 2017, Vinfast’s factory was officially constructed. The manufacturing factory located in Hai Phong owns an area of 335 hectares, includes 5 main workshops. From the first day of launching the product, Vinfast has realized its ambition to manufacture Vietnamese branded cars.

In January 2018, VinFast signed a contract to buy intellectual property rights from BMW, thereby completing the value chain led by VinFast and famous global brands such as Pininfarina (design), BMW (technology, engineering, manufacturing methods), Magna Steyr, and AVL (automotive engineering and manufacturing consulting), Siemens (plant design, management, and operation), Bosch (automotive components and technology), etc.

One year after its debut, Vinfast appeared first time at the Paris Motor Show 2018. This is one of the main milestones of Vinfast to bring the Vietnamese car brand abroad and attract the attention of Vietnamese auto fans

One of the important goals that VinFast aimed is to export to expand the market as well as to generate profits in scale, contributing to reduce the company's economic pressures. VinFast's export targets are enormous markets, including Europe, China and ASEAN. VinFast has prepared carefully by quietly establishing subsidiaries and representative offices in Germany, China, and Korea since August 2018.

Up to now, Vinfast has launched 4 lines of gasoline cars: Fadil, LUX A2.0, LUX SA2.0, President, in which Vinfast's largest internal market share is Vinfast Fadil. In early 2021, Vinfast also launched 3 lines of electric cars: VF31, VF32, VF33. This is a crucial milestone that affirms VinFast's vision of becoming a global electric automotive brand and bringing Vietnam to a new position on the world automotive industry map.

According to the latest VAMA report, in the terrible effect of the Covid-19 epidemic, VinFast still achieved impressive successes with record sales of nearly 30,000 cars in Vietnam after less than 18 months officially launched the market with only 3 models (excluding VinFast President due to the limited edition only producing 500 units). The above figure confirmed the Vietnamese car brand's position, especially when compared with many other famous international brands.

With the mission of bringing Vietnamese people better living standards, Vingroup desires to build a proud, stylish, and classy automotive brand with ambitions to go beyond the domestic market and catch the global one.

1.2. RESEARCH OBJECTIVES

The main purpose of this study is to analyze and select green suppliers for VinFast. To achieve the set purpose, this research implements all the following objectives:

- Analyzing the current state of the automotive market and green supply trends in the world in general and in Vietnam in particular;
- Revising overview of studies related to standards and evaluating models, and green supplier classifications;
- Presenting general overview of Fuzzy Set Theory and MCDM models, specifically FAHP, and FTOPSIS;
- Developing specific hybrid MCDM model to classify a group of green suppliers;
- Applying the proposed model of integrating FAHP and FTOPSIS to assess green suppliers for VinFast, thereby giving some suggestions and implications.

1.3. RESEARCH QUESTIONS

To achieve set purpose, this study answers the following questions:

- ***What set of criteria affects VinFast's green supplier selection?***
- ***How do proposed criteria influence VinFast's green supplier selection?***

1.4. RESEARCH SCOPE

In this study, we will concentrate on groups of criteria that affect VinFast's green supplier selection. Our research method to collect data is direct interview, which focuses on a group of professionals, business and economic specialists, and VinFast's high-level staff.

- Type of survey: Direct interview with automotive specialists
- Number of respondents expected: 12 experts
- Respondents: 12 experts from Technical and Customer Service, Commercial Vehicles Service Division, Toyota Motor Vietnam Co., Ltd.; Body Development Division, Ford Vietnam Limited; Vehicle Production Engineering Group Production Engineering Department, Honda Vietnam Company Quality Technology Section; Hyundai Vietnam Ltd.; Production Control Management Division, Isuzu Viet Nam Co., Ltd.; Management Department, Suzuki Vietnam Co., Ltd.; Manufacturing department, Kia Motors Vietnam Parts Quality Control Section; Porsche Vietnam Body Development Division Engineering Development Engineer; Mercedes-Benz Vietnam Ltd Automotive Asia Limited (Audi Vietnam); THACO passenger Car Distribution Co., Ltd (BMW Distributor in Vietnam); VinFast Commercial and services trading limited liability company.

1.5. METHODOLOGY AND DATA REVIEW

In this research, multiple methods were applied to collect and analyse data. The primary research was implemented on the basis of quantitative research, which is gathered through direct interview and then analyzed by FAHP, and FAHP methods determines weights of criteria, and FTOPSIS method evaluates green suppliers. Secondary research was conducted through online references (news, VinFast's official website, research articles, books, etc), consultation with economic experts, and Vinfast's internal data.

1.6. CONCLUSION

This thesis gives an introduction to the research topic and provides background information related to our research. It focuses on introducing topic background, company background, and giving an overview of the practical problem of green supply chain in Vietnam. To investigate this problem, the research subject, research scope, and proposed research questions are identified.

1.7. THESIS OUTLINE

The rest part of the thesis (excluding the abstract, appendix, reference, list of tables and figure, abbreviations and acronyms list) is laid out as follows:

- **Chapter 1: Introduction**

Chapter 1 briefly provides basic information about the background, objective, and research question as well as the methodology.

- **Chapter 2: Literature review**

Chapter 2 presents relevant theories that are the basis to develop research questions. Different methods to evaluate and choose a green provider are presented briefly

- **Chapter 3: Methodology**

Chapter 3 presents research methods such as qualitative, quantitative, and observational studies. Data collection and analysis methods are clarified in this chapter.

- **Chapter 4: Empirical Case Analyses of VinFast**

Chapter 4 analyses and applies the model and methods proposed in Chapter 3 to evaluate and group green suppliers for VinFast.

- **Chapter 5: Conclusions and Implications**

Final chapter answers the research questions by summarizing the findings and suggest recommendations for VinFast company to choose suitable green suppliers. Limitations and implications of this study are also reminded for applying our results in future research.

CHAPTER 2: LITERATURE REVIEW

This chapter provides an overview of the automotive industry around the world and Vietnam, reviews the perspectives on the literature and related models used in the process of selecting sustainable green suppliers. Also, the literature gap is stated.

2.1. OVERVIEW OF THE AUTOMOTIVE INDUSTRY

Automated cars are now becoming an essential driving force for passenger change. According to the latest statistical data, despite the decline of the automotive industry in ASEAN countries was influenced and failed in 2020 by the 19 deadly viruses of COVID, the large market in the automotive sector indicates signs of recovery. Specifically, On the 26th of February, Toyota announced a 4% improvement in production to 741,704 units (Roberts, 2021). In 2021 SUVs began "with a success story" in Europe as a result of JATO Dynamics, which announced that the sector accounted for 44 % of all new passenger car registrations in January for 27 markets, the largest share ever registered for SUVs (Roberts, 2021). Through in January 2021, the demand for a new vehicle in the Thai industry dell unexpectedly by 23% compared with that reported a year earlier, the wholesale data collected by the Federation of Thai Industries and Malaysia's new-vehicle market decreased by almost 24 % in January 2021 in the same month of the previous year, based on registration data released by the Malaysian Automotive Association (Roberts, 2021).

In recent years, the automotive industry has drawn many emerging economies, including Vietnam. Instead of importing only automobiles in the 1900s, car manufacturing was strongly encouraged by the government’s policy but it is still under market pressure from countries that are strong on exports such as China where is among the biggest automotive markets in the world, India, and some ASEAN countries (An, 2019). Due to the automotive sector's contributions, the national GDP is 3% (Bank, 2019). In January 2021, Vietnam's market for new vehicles started to recover significantly with more than 60% of sales rising in the same month last year (Team, 2021). In the first month of 2021, Vietnam's VinFast sales of cars rose compared to May 2020. (Marklines.com, 2021). Advanced Science and technology application significantly from foreign countries combined domestically assembled production lines, VinFast is proud to be a sustainable business in the automotive industry in Vietnam.

2.2. GREEN SUPPLY CHAIN MANAGEMENT

2.2.1. Definition of supply chain

To grasp supply chain meaning, it is important to provide a general understanding of what the supply chain framework is like. Nowadays, there are many accepted definitions for supply chains. A supply chain is a set of firms that pass materials forward. Normally, several independent firms are involved in manufacturing a product and placing it in the hands of the end-user in a supply chain—raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain (Londe and Masters, 1994). Another concept of supply chain refers to the network of entities that are engaged, across upstream and downstream linkages, in the various processes and operations that generate value in the form of goods and services provided to the ultimate customer (Behrenbeck, Thonemann and Merschmann, 2007).

Therefore, a supply chain includes a variety of individual organizations, each of which contributes value to the commodity or product service. In definition, a supply chain stops until the commodity hits the end buyer. The supply chain is characterized by its links—companies and consumers—and by the multidirectional movements of goods, resources, knowledge, and capital. If every connection in the chain is badly managed, the whole chain is adversely affected. Thus, a smooth process and sophisticated supply chains are critical to potential success in the global marketplace.

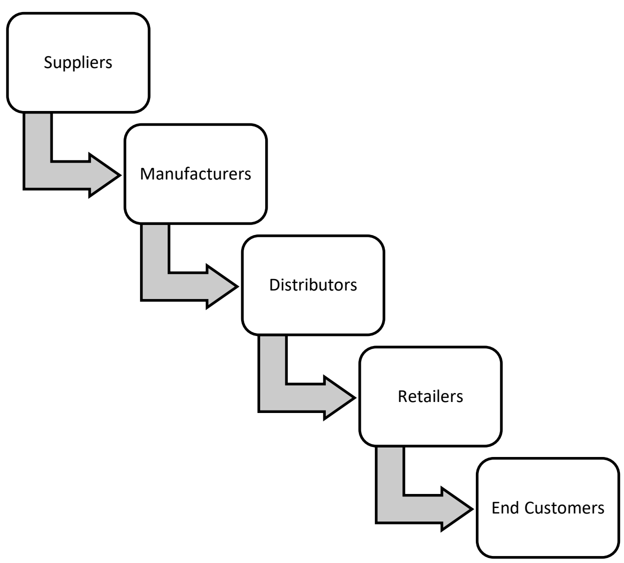


Figure 2.1. Supply Chain Process

2.2.2. Green supply chain management

Supply chain management (SCM) is associated with almost all activities of the business: from planning and organizing the production process, purchasing, finished goods from raw materials, managing logistics to coordination with partners, suppliers, intermediaries, service providers and clients. In recent years, this word became popular and a hot subject of analysis. Despite the emergence of several theories on SCM, almost some authors define supply chain management as a system that covers activities of the business from organizing raw materials to distributing to customers. According to study of (Giunipero, 2008), SCM is the group that adds value from the initial raw materials to the end customer along with the production process. In the early 1990s, research in SCM focused on reducing transaction costs in purchaser/supplier interaction (Giunipero, 2008). Thus, the authors agree that the SCM deals with absolute sales operation excellence, representing a modern process of managing the business and its relationships with other members of the supply chain.

Besides SCM, in the era of globalization and digital technology transformation, Green Supply Chain Management (GSCM) has become a hot term because it is related to the environment in which people are increasingly interested, especially businesses that tend to develop sustainably. Moreover, consumers are demanding green products in today's world because consumers are now more conscious regarding environmental issues (Zhang, 2019). And the eco-friendly concept has become a vital part of productivity. According to (Achillas & Bochtis, 2018), GSCM includes planning, executing, monitoring, and controlling the practice. The GSCM is a strategy that combines environmental concerns with supply chain techniques to make a company more productive and environmentally sustainable. That is the reason why a competitive edge and sector’s competitiveness appears when a company has a good strategy in GSCM.

2.3. SUSTAINABLE SUPPLIER SELECTION

2.3.1. Sustainability Term and Misconceptions

In the globalized world, being under pressure from public awareness and the political leaders and stakeholders, firms recognized greening and sustainability in Supply Chain Management (SCM) operations is a way to thrive and reap the business benefits. The “sustainable” terminology has become a topic of concern and research in business areas such as manufacturing, health care, energy, etc. and also grown up a misconception for most people to determine its exact meaning in “environmental sustainability”. Popular misconception sentiment in favor of the dominant detriment to the process of development is simply destruction to the environment. However, economic and social aspects are substantial in sustainable supplier selection also known informally as profits, planet, and people. The triad idea that social, economic and environmental sustainability are interlinked has become very popular in recent years (Purvis, Mao and Robinson, 2019). The ‘social' viewpoint concerns itself with the “continued fulfilment of essential human needs”, the ‘ecological' focuses mostly on “sustained productivity and functioning of ecosystems” as well as the “protection of genetic capital and the conservation of biological diversity”, and the “elusive” ‘economic' concept entails addressing “the constraints that a sustainable environment must impose on economic growth” (Brown *et al.*, 1987). Thus, sustainability is more than just going green and being eco-friendly. It is the development that fulfils the present needs and future generations requirements without negatively affecting the environment and affects the entire production chain from which the raw materials are obtained, to the processes inside the factory, to the use of the product or service and the future recyclability per se.

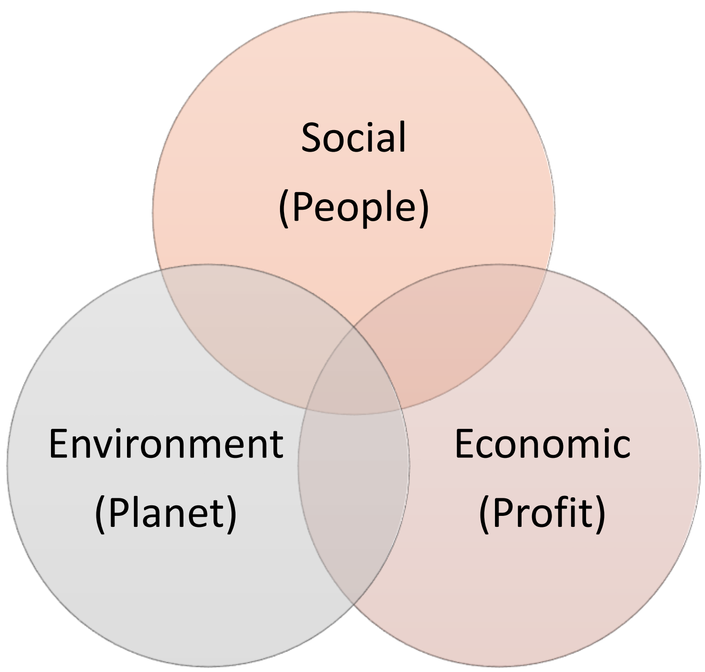


Figure 2.2. Proposed Sustainability Pillars

2.3.2. Sustainable Supplier Selection Process

Generally, there are distinct stages in the supplier selection process. The progress proceeds from identifying needs and specifications. Next, criteria are defined. After that, administrators or decision-makers identify a group of qualified suppliers. Finally, evaluation and final selection are performed (Zimmer, Fröhling and Schultmann, 2016).

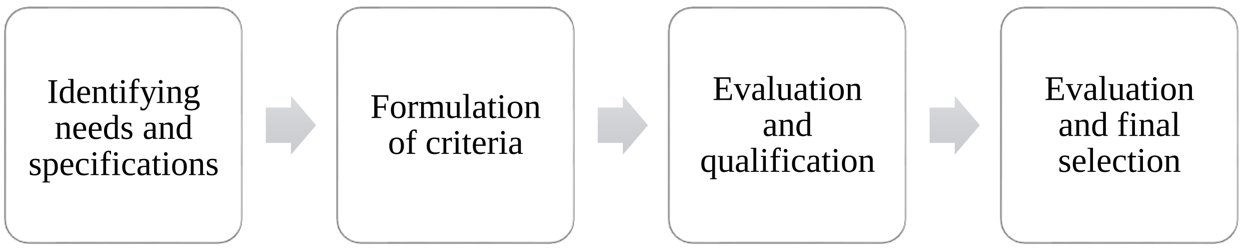


Figure 2.3. Sustainable supplier selection process

2.3.3. Sustainable Supplier Selection Problem

Supplier selection is one of the most critical strategic challenges used by modern businesses, even though one problem is the question of which criteria should be included in the selection problem, the second problem is which method should be used and the requirement of their documented examples. The selection process is a complex and multi-dimensional problem because you have a mix of qualitative and quantitative factors, but you also have to consider how sustainable it is.

Considering the financial success of a business, SSS has a tremendous impact. Also, a great proportion of data and statistics on suppliers' sustainability is subjected to specialist assessments and personal beliefs. Correspondingly, various SSS criteria diversify in relation to industry, corporate procedure, and scale of the focal company. Another problematic aspect of this conceptualization is that it requires theoretical advancement; there are no initial frameworks upon which it originates, and it is scarcely adopted at face value. Nonetheless, SSS criteria still transform over the years, based on the business aspects of politics, economy, society, and environment.

2.3.4. Proposed Criteria for Evaluating Sustainable Supplier

Determining criteria is crucial for effective sustainable supplier selection. Supplier evaluation must be the first phase in choosing suitable suppliers and is critical to the success of supply chain operations. A variety of studies have been published about the criteria for choosing sustainable suppliers. After reviewing Internet-based journal articles, the authors summarize some of the sustainability criteria used by experts in the reviewed articles. In the present circumstances, Vietnam has signed a total of 15 free trade agreements with countries and blocks, of which 13 ones have already been valid. A prominent thing about the signed agreements is that two industries such as automotive and steel are always treated extremely special.

Vietnam is considered a fertile land for car manufacturers. While the car market in neighboring countries gradually became saturated as a result of the automotive demand stimulus policy a few years ago, Vietnamese people started to rush to buy cars by the law of supply and demand when the country's economy developed significantly.

Criteria		Previous Research
Economic (C1)	Staff training (C11)	(Liao, Fu and Wu, 2016)
	Delivery (C12)	(Liao, Fu and Wu, 2016)
	Service level (C13)	(Bali, Kose and Gumus, 2013); (Lee *et al.*, 2009)
	Quality (C14)	(Lee *et al.*, 2009); (Guo *et al.*, 2017)
	Cost (C15)	(Sevkli *et al.*, 2007)
	Technology (C16)	(Wang Chen *et al.*, 2016)
	Flexibility (C17)	(Wang Chen *et al.*, 2016)
	Financial capability(C18)	(Wang Chen *et al.*, 2016)
	Culture (C19)	(Wang Chen *et al.*, 2016)
	Innovativeness (C110)	(Wang Chen *et al.*, 2016)

	Relationship (C111)	(Wang Chen *et al.*, 2016)
Environmental (C2)	Green products (C21)	(Bali, Kose and Gumus, 2013);(Lee *et al.*, 2009)
	Green image (C22)	(Bali, Kose and Gumus, 2013);(Lee *et al.*, 2009)
	Eco-design(C23)	(Wang Chen *et al.*, 2016)
	Management commitment(C24)	(Wang Chen *et al.*, 2016)
	Green technology(C25)	(Wang Chen *et al.*, 2016)s
	Pollution control(C26)	(Zhang, 2019) ; (Lee *et al.*, 2009)
	Recycle(C27)	(Zhang, 2019);(King *et al.*, 2006)
	Re-manufacturing(C28)	(Zhang, 2019); (King *et al.*, 2006)
	Environmental management system (C29)	(Yildiz, 2019); (Lee *et al.*, 2009); (Guo *et al.*, 2017)
	Resource consumption(C210)	(Guo *et al.*, 2017)
Social (C3)	Human resource management (C31)	(Er and Firat, 2016)
	Corporate social responsibility (C32)	(Er and Firat, 2016)
	Health and safety (C33)	(Er and Firat, 2016)
	Human right issues (C34)	(Er and Firat, 2016)
	Relationship with stakeholders (C35)	(Er and Firat, 2016)

Table 2.1. Sustainability Criteria Used in the Reviewed Articles

- The following are definitions and Sub-criteria for Table 2.1, listed respectively.

- **Staff training (C11):** It refers to the obtainability of expert activities and training programs.
- **Delivery (C12):** Includes lead time and order fulfilment rate. Lead time is the time between placing a materials order and receiving materials. The order fulfilment rate is the actual quantity received/order size. Besides, the supplier has proficiency in on-time delivery, low transportation cost, and use of green fuel.
- **Service level (C13):** Includes customer service and social service. Customer service indicates performance in terms of reliability, responsiveness, assurance and satisfaction. Social service indicates performance in terms of social services.
- **Quality (C14):** Includes defect rate and rejection rate based on the certification of products. The defect rate is the percentage of defective products. The rejection rate is the percentage of rejected products. Besides, it includes ISO 9001 implementation.
- **Cost (C15):** Includes product cost and transportation cost. Production cost that determines the final price of the product, including processing cost, maintenance cost, warranty cost, etc. Transportation cost is from the supplier to the manufacturer.
- **Technology (C16):** Communication and e-commerce systems, the capability of research development and innovation, and production facilities and capacity.
- **Flexibility (C17):** Product volume changes, short setup time, conflict resolution, using flexible machines, the demand that can be profitably sustained, and time or cost required to add new products to the existing production operation.
- **Financial capability (C18):** Financial position, economic stability, and price strategy
- **Culture (C19):** Communication openness, vendor’s image, and mutual trust
- **Innovativeness (C110):** Communication openness, vendor’s image, and mutual trust
- **Relationship (C111):** Long term relationship, relationship closeness, communication openness, and reputation for integrity.
- **Green products (C21):** The supplier consumes less energy, uses most of the natural materials.
- **Green image (C22):** The supplier shows the importance of environmental and social responsibility. It also represents the ratio of green customers to total customers and social responsibility.
- **Eco-design (C23):** Design for resource efficiency, design of products for reuse, recycle, and recovery of material, design for reduction, or elimination of hazardous materials.
- **Management commitment (C24):** The commitment of senior managers to support and improve green supply chain management initiatives.

- **Green technology (C25):** The application of environmental science to conserve the natural environment and resources and to curb the negative impact of human involvement.
- **Pollution control (C26):** Pollution is the unit volume of air emission pollutant, wastewater, solid wastes and harmful materials releases. Thus, the suppliers need to reduce air emissions, wastewater, solid wastes, and chemical wastes that are generated in the production and transportation operations.
- **Recycle (C27):** Products can be remanufactured such that the second-life product is made up to date to the market.
- **Re-manufacturing (C28):** The process used to recycle products.
- **Environmental management system (C29):** Environmental certificates such as ISO 14000, continuous monitoring and regulatory compliance, environmental policies, green process planning, and internal control process.
- **Resource consumption (C210):** Resource consumption in terms of suppliers using up raw material, energy and water.
- **Human resource management (C31):** Effectiveness of discipline management, Effectiveness of performance management system, Effectiveness of personnel recruitment and selection, Average annual training time per employee, Annual personnel turnover.
- **Corporate and social responsibility (C32):** Responsibility to the community, Safe-guarding mechanism in CSR, Fraction of total sales invested for social projects per year, Respect for the policy.
- **Health and safety (C33):** Occupational health and safety management systems, Applications of work safety and labor health, Annual number of recordable accidents per employee.
- **Human right issues (C34):** Underage labor, Long working hours, Feminist labor issue, The interests and rights of employee, Effectiveness of compensation management, Gender diversity.
- **Relationship with stakeholders (C35):** The rights of stakeholders, Organization's openness to stakeholder involvement in decision making, relationship closeness and attitudes, Degree of strategic cooperation.

2.4. APPROACHES FOR GREEN SUPPLIER SELECTION

2.4.1. MCDM Models

Because businesses have to change their processes in the management of a green supply chain that is environmentally sustainable strives to respect green practices and technology to establish sustainability, choosing the appropriate green supplier is a complicated multi-dimensional challenge. Over the years, several (special) approaches for decision-making have been adapted to solve similar issues. From the beginning of the 1970s up to now, a large range of MCDM approaches and their extensions have been implemented. MCDM methods provide a possibility to evaluate these and other conflicting factors and to decide which alternative is the most suitable according to different criteria" (Siksnelyte-Butkiene, Zavadskas and Streimikiene, 2020). All of these MCDM approaches can be used to address a broad range of complex problems from diverse fields of study. The MCDM models allow practitioners and administrators to find the best green suppliers from the hundreds of suppliers available in short periods of time and with minimal effort.

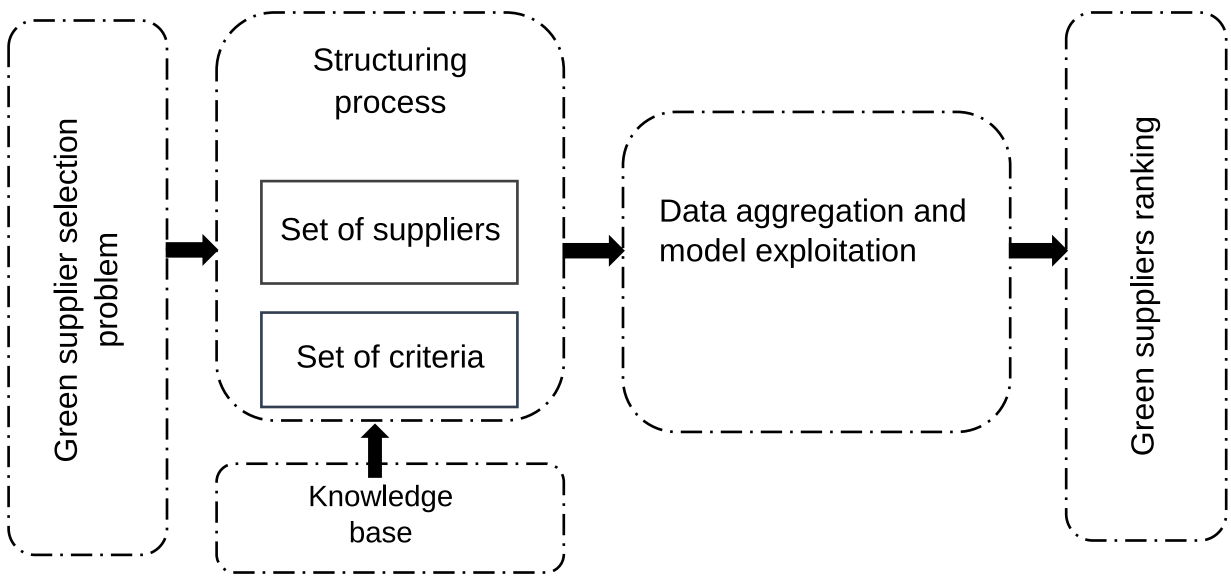


Figure 2.4. Conceptual framework for green supplier selection

However, green supplier selection may be viewed as an MCDM challenge, where a small range of alternative suppliers is assessed against several contradictory quality standards. As a result, to collect and assess data for this study without any bias and prejudices, 2 MCDM models have been chosen. They are FAHP, and TOPSIS.

The AHP is one of the MCDM models used in this study. It is a mathematical-based model that evaluates the validity of the decision-making and measurement methods. AHP would be a good decision-making approach for deciding on complicated and multiple parameters. "In this technique, rating alternatives and aggregating processes to find the most relevant alternatives are integrated. The technique is employed for ranking a set of alternatives or for the selection of the best in a set of alternatives. The ranking/selection is done with respect to an overall goal, which is broken down into a set of criteria"

(Ramanathan, 2004). This method includes determining the significance of criteria that would be associated with the ultimate target. The figures are determined by evaluating each criterion pairwise. FAHP is AHP under a fuzzy environment.

The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) is another model being used. It was developed by Hwang and Yoon (1981) and is the second most widely used and popular MCDM method after AHP (Çelikbilek and Tüysüz, 2020). " TOPSIS simplifies the decision matrix by applying vector normalization computing the weighted normalized decision matrix, determining the positive ideal solution (PIS) and negative ideal solution (NIS), calculating the separation or distance by using the n-dimensional Euclidean of each alternative from PIS and NIS, determining the relative closeness of each alternative to PIS by calculating the ranking index and finally ranking the preference order " (Çelikbilek and Tüysüz, 2020).

Many publications on selecting green suppliers and reviewing them have been released in recent years. However, supplier selection is a challenge in MCDM since there can be contradictions between qualitative and quantitative criteria. This study suggested a fuzzy MCDM model, which can evaluate the criteria of different suppliers or malfunction causes and choose the best supplier. The "fuzzy" concept will be defined in the next section.

2.4.2 Fuzzy Concepts

The magnitude of individuals' expectations for particular circumstances can be unclear, subjective and ambiguous. Simply put, if the humans' fuzziness and uncertainty making the choices are not taken into account, the consequences can be deceptive. In choosing which supplier to work with, it is understood that choices affect several individuals joining the decision-making phase (including executives, staff, and specialists).

Making more participants involved enables the selection process to be more rationale is that the group's view (prejudice) is not carrying much force. For the system to conclude a realistic final decision, it must reflect human thinking. In making decisions, decision-makers are more comfortable evaluate criteria for a certain degree of tolerance in some cases than they are deciding on a set value. As a result, one system was implemented which suggests a human-like thinking style, known as fuzzy logic.

2.4.3. Advantages and Disadvantages of MCDM Models

Every MCDM models have their advantages and disadvantages when applying in the supplier selection process. The following are listed advantages and disadvantages of several MCDM models reviewed via Internet-based published researches.

- ***Advantages:***

Differences	AHP	FAHP	DEMATEL	TOPSIS
Evaluators are able to represent the relative importance and interaction of multiple criteria in the supplier selection process (Jamil, Besar and Sim, 2013)	X			
Bias in decision making can be reduced by the flexibility and ability to check on inconsistency and able to decompose and problems into hierarchies of criteria (Jamil, Besar and Sim, 2013)	X	X		
Effectively handle both qualitative and quantitative data and easy to implement and understand (Jamil, Besar and Sim, 2013)	X	X	X	X
Effectively analyzes the mutual influences (both direct and indirect effects) among different factors and understands the complicated cause and effect relationships in the decision making problem (Si *et al.*, 2018)			X	
No tedious pairwise comparison and weights can be directly assigned by decision-makers which makes the practical application of the methodology very straightforward (Jamil, Besar and Sim, 2013)				X
TOPSIS has been proved to be one of the best methods addressing rank reversal issue, that is, the change in the ranking of the alternatives when a nonoptimal alternative is introduced (Jamil, Besar and Sim, 2013)				X
Fuzzy AHP is preferable for widely spread hierarchies, where few importance/rating pair-wise comparisons are required at lower level trees (Jamil, Besar and Sim, 2013)		X		
Can adopt linguistic variables (Jamil, Besar and Sim, 2013)		X		
Ranking results for both methods are similar which shows that when decision-makers are consistent in determining the data, two methods independently, and the ranking results will be the same and will handle fuzziness of data involved in decision making effectively (Jamil, Besar and Sim, 2013)		X		

Table 2.2. MCDM Models advantages

- ***Disadvantages***:

Differences	AHP	FAHP	DEMATEL	TOPSIS

When a problem is decomposed into subsystems, the decision problem might become very large and lengthy (Jamil, Besar and Sim, 2013)	X			
AHP's using crisp number, hence not able to reflect human thinking style (Jamil, Besar and Sim, 2013)	X			
When the number of alternatives and criteria increased, pair-wise comparison becomes cumbersome and the risk of inconsistencies grows (Jamil, Besar and Sim, 2013)		X		
Determines the ranking of alternatives based on interdependent relationships among them, but other criteria are not incorporated in the decision making problem (Si *et al.*, 2018)			X	
The relative weights of experts are not considered in aggregating personal judgments of experts into group assessments (Si *et al.*, 2018)				
Problem is not decomposed into hierarchy hence decision-maker might encounter difficulty to simplify the problem which makes the practical application of the methodology very straightforward (Jamil, Besar and Sim, 2013)				X
Does not take into account the uncertainty associated with the mapping of one's judgment to a number (Jamil, Besar and Sim, 2013)	X			
FAHP requires more complex computations than FTOPSIS which includes a pairwise comparison (Jamil, Besar and Sim, 2013)		X		
In the extended analysis of FAHP, the priority weights of criterion or alternative can be equal to zero (Jamil, Besar and Sim, 2013)		X		

Table 2.3. MCDM Models disadvantages

It can be seen from the table that their greatest constraint is that the materials from which they are attempting to produce solutions or selection algorithms are mostly meant to be tradeoffs for various goals, rather than one that is the optimum solution to the dilemma. Whilst the main advantage is their ability to specifically analyze how differing consequences can accumulate in the same decision phase.

2.5. RESEARCH GAP

A variety of research projects have been undertaken about the selection of suppliers through the use of information and communication technologies. These classical methods are commonly applied to sustainable supplier recognition and selection issues. To our understanding, there is a lack of a general approach that understands how one might be helpful to supplier selection, which can provide an organisation with several approaches, and which can simultaneously collect information.

Nevertheless, we have found that there are applications of the MCDM model approach that has been used in a wide range of areas in results in many countries. For further information about Supplier Selection in the Automotive Industry" (Jamil, Besar and Sim, 2013) looked at the efficiency of multicriteria decision-making in the automotive manufacturing company with MCDM tools aimed at selecting suppliers in Malaysia; in other study of or the article " A green supplier selection model for the high-tech industry" (Lee *et al.*, 2009) studied solution and evaluation to select the most suitable green supplier for the company; in the study: "Fuzzy Hybrid MCDM Model for Ranking the Agricultural Water Demand Management Strategies in Arid Areas" authors proposal MCDM model to solute water scarcity (Banihabib et al, 2016).

However, to our knowledge we have been not found out any of Vietnam's scholar research on the application of MCDM to green supplier selection in the automotive industry since our team has opted to use the MCDM tools to analyze multicriteria. The articles or studies we have read overlooked the analysis of the critical success of a business. That analysis concentrating on the use of models and the evaluation of their effects. Therefore, more comprehensive research is required to explore the importance of factors for the development of a corporate in the selection of sustainable suppliers. Our study will analyze some of the criteria in the VinFast case based on an integrating MCDM models of FAHP and FTOPSIS.

Even if this study might have some shortcomings, there needs to be further study and research that overcomes these limitations. The authors of this thesis proposed that future studies are critical to establishing metrics that were not only appropriate and comparable but would also investigate how to manage sensitive data.

2.6. CONCLUSION

Many theories have been proposed to explain what SCM, GSCM and sustainability supplier selection is. Sustainability is a rising issue for both focal businesses and their suppliers. And green supplier selection is essential for companies to retain their economic power. This study will examine the MCDM methods in a novel manner under the analysis of VinFast. Although the literature covers a wide variety of such theories, we will focus on selecting green suppliers based on integrated approaches that are mentioned throughout the study. After reviewing the literature, we clarified the important aspects of our topic by integrating early theories and viewpoints. In conclusion, this chapter provides solutions and an effective structure for decision-making when using methods listed in this study.

CHAPTER 3: METHODOLOGY

This chapter provides a better understanding of the methodology in this study, plus the rationale for why it was chosen.

3.1. INTRODUCTION

3.1.1 Research philosophy

Research philosophy deals with the source, nature and development of knowledge (Mark, 2009). A philosophy is composed of beliefs on the approaches to gather, analyse, and utilise data about a phenomenon. There are four major philosophies in business and management and listed below.

Realism, in philosophy, the viewpoint which accords to things that are known or perceived an existence or nature which is independent of whether anyone is thinking about or perceiving them based on a personal viewpoint.

Interpretivism determines the degree of interest one has in the research. Recognizing the gap between people is the premise of this approach.

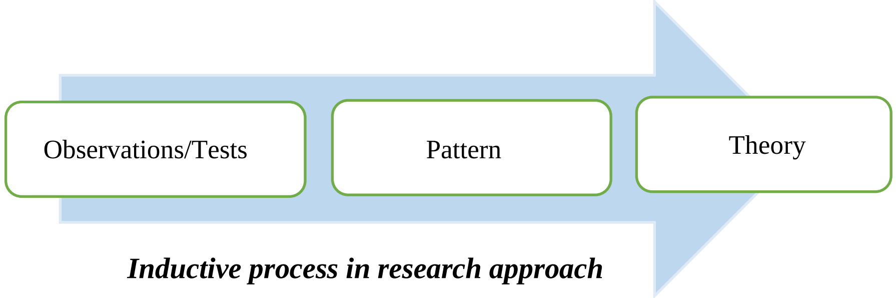
Positivism is dependent on statistical analysis based on quantifiable observations.

Pragmatism deals with similar concepts that facilitate actual actions. This is a study approach, through which understanding why issues arise and attempt to differentiate them. In the area of pragmatics, different kinds of analysis may be performed at the same time.

3.1.2. Research approaches

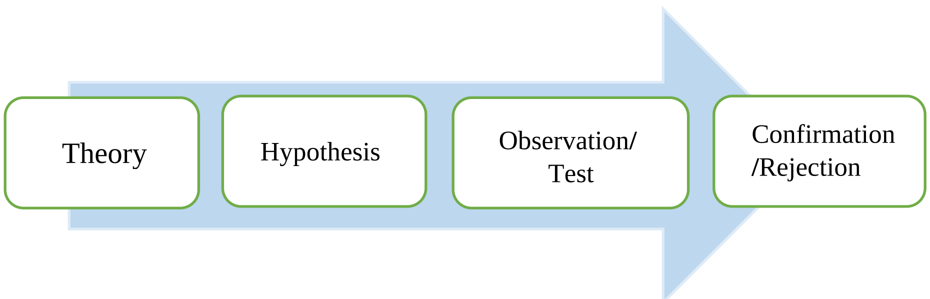
There are three types of research approaches including inductive, deductive, and abductive.

Inductive is data collected and theory developed from the data analysis. In inductive inference, known premises are used to generate untested hypotheses that of generalizability is from specific to general. Data collection is used to explore a phenomenon, identify themes and patterns, and create a conceptual framework. The theory in this research approach is theory generation and building (Saunders, 2009).



Inductive process in research approach

Deductive reasoning is generalizing from the general to the specific. The reasoning always starts with a theory and leads to a new hypothesis. Then, narrow down the results after collection to check the hypothesis. In order to reach a conclusion, it uses facts, laws, descriptions, or objects. In deductive inference, when the premises are correct, the conclusion must also be correct. Data collection is used to evaluate propositions or hypotheses related to an existing theory (Saunders, 2009).



Deductive process in research approach

Abductive is combined of inductive and deductive. is a combination of inductive and deductive. In an abductive inference, known premises are used to generate testable conclusions that of generalizability is from the interactions between the specific and the general. Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework, and test this through following data collection and so forth. The theory in this research approach is theory generation or modification, incorporating existing theory where appropriate to build a new theory or modify the existing theory (Saunders, 2009).

This research is conducted by the inductive method. In certain instances, hypotheses are relatively straightforward since the process starts with findings that serve as proof of regularities, and then, if proven, the pattern is detected; in some situations, it is hard since there is little as a shred of prior evidence, and the assumptions proceed. This is the most suitable way to assess businesses.

3.1.3. Research methods

There are two main types to collect data: qualitative and quantitative. For discriminating between the two types of data, it is essential to use numerical (numbers) data or not numeric (words) data.

Quantitative research is characterized by the results shown in the form of statistics and graphs. When conducting this kind of study, broad generalizable facts on the subject is established. These three techniques are the most often used in research: experiments, observations recorded as numbers, and surveys with closed-ended questions.

Qualitative research is expressed in words. It is used to understand concepts, thoughts or experiences. This type of research enables gathering in-depth insights on topics that are not well understood. Common methods include interviews with open-ended questions, observations described in words, and literature reviews that explore concepts and theories.

This research used quantitative and qualitative data to improve the strengths of one particular type of data and balance the limitations of its drawback.

3.2. DATA SOURCE (Primary/Secondary)

The collecting of data is a method for collecting and evaluating information on variables of interest in a systematically defined way that helps one answer questions, test hypotheses, and analyze findings (Kabir, 2016). Data collection is one of the most important stages in conducting research. The project could not be accomplished without the data collection. Numerous data collections required are hard work, patience, and clear problems. This job begins with deciding what kind of data are needed and a sample of a certain population is chosen. Then, authors have to use a certain tool to extract the data from the sample chosen.

Primary data is data originated first hand by the researcher through experiments, surveys, questionnaires, personal interviews, and etc. Then, data controlled by the supervisor to answer specific questions. Primary data sources are time-consuming even with a low response rate because of a shortage of societies or poor coordination. But it is useful for current studies as greater control and can identify the tools that will be used. These are several of the basic data sources: experiments, interviews, tests, questionnaires, observations (Kabir, 2016).

Secondary data that is already available and has been collected by someone else for a purpose other. It is usually in a different context because that is being reused. Secondary data has been collected are low cost or free, time- saving, anyone can access the data. However, it is not specific to needs and not timely. Secondary data sets analysis also enabled development scientists to effectively address important and often challenging research issues that reflect, redefine or extend key findings in the field (Greenhoot, A. F., & Dowsett, 2012).

3.3. DATA ANALYSIS

3.3.1. Fuzzy AHP method

AHP is a multi-objective decision-making method proposed by Saaty in 1980. It is a method used to determine the weights of factors through a pair comparison matrix and also based on expert opinions to make a reasonable decision. Partovi determined AHP is a decision support tool for unstructured and multi-attribute complex decisions (Partovi, 1992). Ny Dick and Hill also define this tool as a method of ranking alternatives based on decision-makers' judgment regarding the importance of standards and extending them in each alternative (Nydick and Hill, 1992).In supplier selection decisions, AHP is widely used (Nguyen *et al.*, 2020). Determination of supplier selection criteria focuses on analyzing the criteria for selecting the best supplier. In addition to the common criteria such as price, quality, delivery time, and flexibility, the factors are analysed to choose suppliers considering environmental factors, risks and logistics, etc.

However, AHP still has limitations. It is the inability to combine uncertainty and inaccuracy inherent in the mapping between perceptions and judgments of decision-makers to the exact numbers used in the method. Therefore, the FAHP method was developed to solve this problem. The fuzzy hierarchical analysis method is a synthetic extension of the AHP method (Zhu, Jing and Chang, 1999), which allows decision-makers to express approximation or almost accuracy of inputs using fuzzy numbers.

One crucial factor in the AHP model is the CR (consistency ratio). AHP measures the degree of consistency and by which decision-makers can receive the results. Therefore, before using the FAHP method to calculate the weights, the match matrices must be checked the CR. This ratio depends on the size of the matrix. Lee et al pointed out that the maximum permissible level of consistency for the 3x3 matrix is 0.05, for the 4x4 matrix it is 0.08, and for larger matrices it is 0.1 (Lee, Chen and Chang, 2008). Thus, if the CR is greater than 0.1, it is necessary to re-examine the opinions of experts to adjust the comparison matrix to ensure consistency. If the CR is less than or equal to 0.1, the survey of experts is accepted. To check these stats, Kwong's method has been researched. TFN, which were used in this work are marked as (l_{ij}, m_{ij}, u_{ij}). These parameters are sorted in ascending order from the smallest possible value, the most promising value to the highest possible one that describes a fuzzy event. A TFN, denoted as M= (l,m,u), can be defuzzified to a crisp number as follows

$$M_{-crisp} = \frac{(4\mathrm{m} + \mathrm{l} + \mathrm{u})}{6} \quad (1)$$

The extent analysis method by Chang in 1996 has been applied in this study to benefit from processing qualitative and quantitative data and comprehensibility and applicability. We also prioritize implementing the fuzzy AHP method due to the existing limitation of the AHP method mentioned above. The steps used for the Chang method are as follows:

Let assume that $X = \{x_1, x_2, \dots, x_m\}$ is a set of objects, and $U = \{u_1, u_2, \dots, u_m\}$ is a set of goals. Chang's method defined that an extended goal analysis is made for each object. Value of the extended analysis "m" for each object can be expressed by Eq. (2):

$$M_{gi}^1, M_{gi}^2, \dots M_{gi}^m \ (i = 1, 2, \dots n) \quad (2)$$

Where $M_{g,}^j \ j = 1, 2, \dots m.$, are fuzzy triangular numbers.

STEP 1: The value of the fuzzy synthetic extent with respect to the i^{th} object is defined as in Eq. (3), (4), (5), (6):

$$\mathrm{S}_i = \sum_{j=1}^{m} M_{gi}^j \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j\right]^{-1} \quad (3)$$

With

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (4)$$

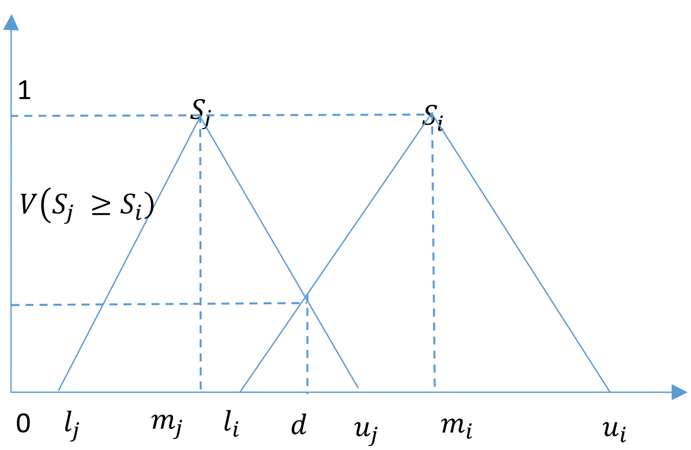
$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \quad (5)$$

Then

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (6)$$

STEP 2: The values of S_i are compared and the degree of possibility of $S_j = (l_j, m_j, u_j) \geq S_i(l_i, m_i, u_i)$ is calculated as in Eq. (7):

$$V(S_j \geq S_i) = \begin{cases} 1, & if\ m_j \geq m_i \\ 0, & if\ l_i \geq u_j \\ \dfrac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)}, & otherwise, \end{cases} \quad (7)$$



Intersection between S_j and S_i

Figure below indicates $V(S_j \geq S_i)$ for the case $m_j < l_i < u_j < m_i$ and "d" is the abscissa value of the highest intersection point between S_j and S_i

With the aim of comparison S_j and S_i, value $V(S_j \geq S_i)$ and $V(S_i \geq S_j)$ are both required.

***Step 3*:** The minimum degree of possibility $d(i)$ of $V(S_j \geq S_i)$ for $i, j = 1, 2, \dots, k$ can be calculated as in Eq. (8):

$$V(S \geq S_1, S_2, S_3, \dots, S_k) = V\,[(S \geq S_1)\ and\ (S \geq S_2)\ and\ \dots\ (S \geq S_k)] \\ = \min V(S \geq S_i) = W'(S_i) \tag{8}$$

Assume that

$$d'(A_i) = \min V(S \geq S_i),\ \text{for } i = 1, 2, \dots, k\ ;\ i \neq k$$

The weight vector is computed by Eq. (9)

$$W' = (d'(A_1), d'(A_2), \dots d'\,(A_n))^T \tag{9}$$

where $A_i (i = 1, 2, 3, \dots, n)$ contains the set of n elements.

***Step 4*:** Normalization reduces the weight vector by Eq. (10)

$$W = (d'(A_1), d'(A_2), \dots d'\,(A_n))^T = (W_1, W_2, \dots, W_n)^T \tag{10}$$

where W is a non-fuzzy number.

3.3.2. Fuzzy TOPSIS method

The Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) was introduced by Hwang & Yoon in 1981. The TOPSIS principle relates to the following idea: An option is the best if it is closest to Positive Ideal Solution (PIS) and farthest from the Negative Ideal Solution (NIS). Wang (2007) stated that the PIS includes all the best possible values of the evaluation criteria, the NIS consists of all the worst possible values. In the classical TOPSIS model, real numbers were used to evaluate the weight of criteria and rank the criteria. However, the use of real numbers in an unstable environment will cause difficulties for assessors. Therefore, the TOPSIS model incorporating fuzzy numbers was proposed to be used to overcome uncertainty and inaccuracy in the assessment. Wang et al concluded that using Fuzzy-TOPSIS evaluates efficiency in an uncertain environment and allows accurate assessment of multiple criteria at the same time.

TOPSIS method is conducted according to the following steps:

***Step 1*:** Determine the weighting of evaluation criteria. This research employs fuzzy AHP to find the fuzzy preference weights.

***Step 2*:** Construct the fuzzy performance/decision matrix and choose the appropriate linguistic variables for the alternatives with respect to criteria (Eq. (11)):

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & \cdots & C_j & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1j} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2j} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & & \vdots & \\ \tilde{x}_{i1} & \tilde{x}_{i2} & & \tilde{x}_{ij} & \cdots & \tilde{x}_{in} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & & \tilde{x}_{mj} & \vdots & \tilde{x}_{mn} \end{bmatrix} \end{array} \quad (11)$$

$i = 1, 2, \dots, m$
$j = 1,2, \dots, n$

$$\tilde{x}_{ij} = \frac{1}{K}\left(\tilde{x}_{ij}^{1} \oplus \cdots \oplus \tilde{x}_{ij}^{2} \oplus \cdots \oplus \tilde{x}_{ij}^{K}\right) \quad (12)$$

Where A_m: m^{th}alternative
C_n: n^{th} $criteria$
k: Number of expert assessments
$\widetilde{W}_j$: weight of j^{th}criteria

$$\widetilde{W} = [\widetilde{w}_1, \widetilde{w}_2, \dots, \widetilde{w}_n] \quad (13)$$

$\tilde{x}_{ij}^{K}$: is the performance rating of alternative $A_m$with respect to criterion C_n (Eq. (14))

$$\tilde{x}_{ij}^{K} = \left(\tilde{l}_{ij}^{K}, \widetilde{m}_{ij}^{K}, \tilde{u}_{ij}^{K}\right) \quad (14)$$

Step 3: Normalize the fuzzy-decision matrix.

The normalized fuzzy-decision matrix denoted by $\tilde{R}$ is calculated by Eq. (15):

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, \quad i = 1, 2, \dots, m \quad j = 1,2, \dots, n \tag{15}$$

Then, the normalization process can be performed by Eq. (16):

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right), \quad u_j^+ = max_i\{u_{ij} | i = 1, 2, \dots, m\} \tag{16}$$

OR the best aspired level u_j^+ and $i = 1, 2, \dots, m$ can be set to be equal one, otherwise the worst one is zero.

The normalized $\tilde{r}_{ij}$ is still triangular fuzzy numbers. For trapezoidal fuzzy numbers, the normalization process can be conducted in the same way.

The weighted fuzzy normalized decision matrix is calculated by matrix $\tilde{\boldsymbol{V}}$ in Eq. (17):

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}, \quad i = 1, 2, \dots, m \quad j = 1,2, \dots, n \tag{17}$$

Where $\tilde{v}_{ij} = \tilde{r}_{ij} \oplus \tilde{w}_j$

<u>Step 4</u>: Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS)

According to the weighted normalized fuzzy-decision matrix, we know that the elements $\tilde{v}_{ij}$ are normalized positive TFN and their ranges belong to the closed interval $[0,1]$. Then the two solution FPIS (A^*) and FNIS (A^-) sets are determined by Eq. (18),(19):

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_j^*, \dots, \tilde{v}_n^*) \tag{18}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_j^-, \dots, \tilde{v}_n^-) \tag{19}$$

Where $\tilde{v}_j^* = (1, 1, 1) \oplus \tilde{w}_j = (lw_j, mw_j, uw_j)$ and $\tilde{v}_j^- = (0, 0, 0);\ j = 1,2, \dots, n$

Step 5**:** Calculate the distance of each alternative from FPIS and FNIS by Eq. (20), (21):

$$\tilde{D}_i^+ = \sum_{j=1}^{n} D\left(\tilde{v}_{ij}, \tilde{v}_j^+\right), i = 1, 2, \dots, m \tag{20}$$

$$\tilde{D}_i^- = \sum_{j=1}^{n} D\left(\tilde{v}_{\mathrm{i}j}, \tilde{v}_j^-\right), j = 1,2, \dots, n \tag{21}$$

Step 6**:** Closeness coefficient measured by using Eq. (22)

$$CC_i = \frac{\tilde{D}_i^-}{\tilde{D}_i^+ + \tilde{D}_i^-} = 1 - \frac{\tilde{D}_i^+}{\tilde{D}_i^+ + \tilde{D}_i^-}, \quad i = 1, 2, \dots, m \tag{22}$$

Where, $\frac{\tilde{D}_i^-}{\tilde{D}_i^+ + \tilde{D}_i^-}$ is fuzzy satisfaction degree in i^{th} alternative and $\frac{\tilde{D}_i^+}{\tilde{D}_i^+ + \tilde{D}_i^-}$ is fuzzy gap degree in i^{th} alternative

CHAPTER 4: EMPIRICAL CASE ANALYSES OF VINFAST

4.1. Case study

In this paper, a comprehensive green supplier selection model that includes the critical economic, social and environmental dimensions for evaluating green suppliers is proposed. To find the solution in the process of selecting green supplier, the proposed approach is extended to the case of VinFast automobile manufacturing company in the Vietnamese automotive industry.

VinFast focuses on launching innovative and environmental-friendly products. VinFast, on the other hand, is now struggling with increased rivalry. Consequently, to retain customer loyalty, VinFast is therefore highly essential in selecting reliable green suppliers for the long-term cooperation in way to garner new international customers and expand their market share.

When VinFast stated theirs position and approach as a green supplier, they must assess its core competences and recognize the difference in consumer requirements. VinFast has simultaneously used the GSCM to examine environmental, social and economic aspects to satisfy consumer requirements and regulations. In addition, VinFast has invested proactively with quality control system and the climate system including ISO9001 and ISO14001.

As a key provider of automotive SC, VinFast has acquired and gained a variety of GSCM domain expertise and skills through a two-stage process of automotive components and accessories consistency verification and aggregation of all components into one product for each consumer. As a result, VinFast asks its suppliers to comply with their customers' environmental, social and economic demands. VinFast's managers and heads of divisions have agreed that commodity price, ISO quality scheme, and lead time are economic requirements, based on the agreement of a multidisciplinary body of policy makers from diverse points of view and reflecting the company's various services. Besides, environmental standards include green technology and environmental certification. Managers from various divisions, including Employee Health and Safety, Production, Quality Control and Assessment, and Purchasing, were required to make their assessments.

In fact, VinFast must collaborate with suppliers to produce green products. The most critical consumer demand drivers for green products are quality management and the potential to meet economic requirements. To meet customers’ requirements, VinFast's management team actively combines expertise to explore renewable goods such as light, lean manufacturing, and energy conservation. VinFast maintains good relationships with vendors that would profit from the purchase of goods if necessary. They also retain positive relationships with consumers, which allows VinFast to produce new products and better address the demands of customers.

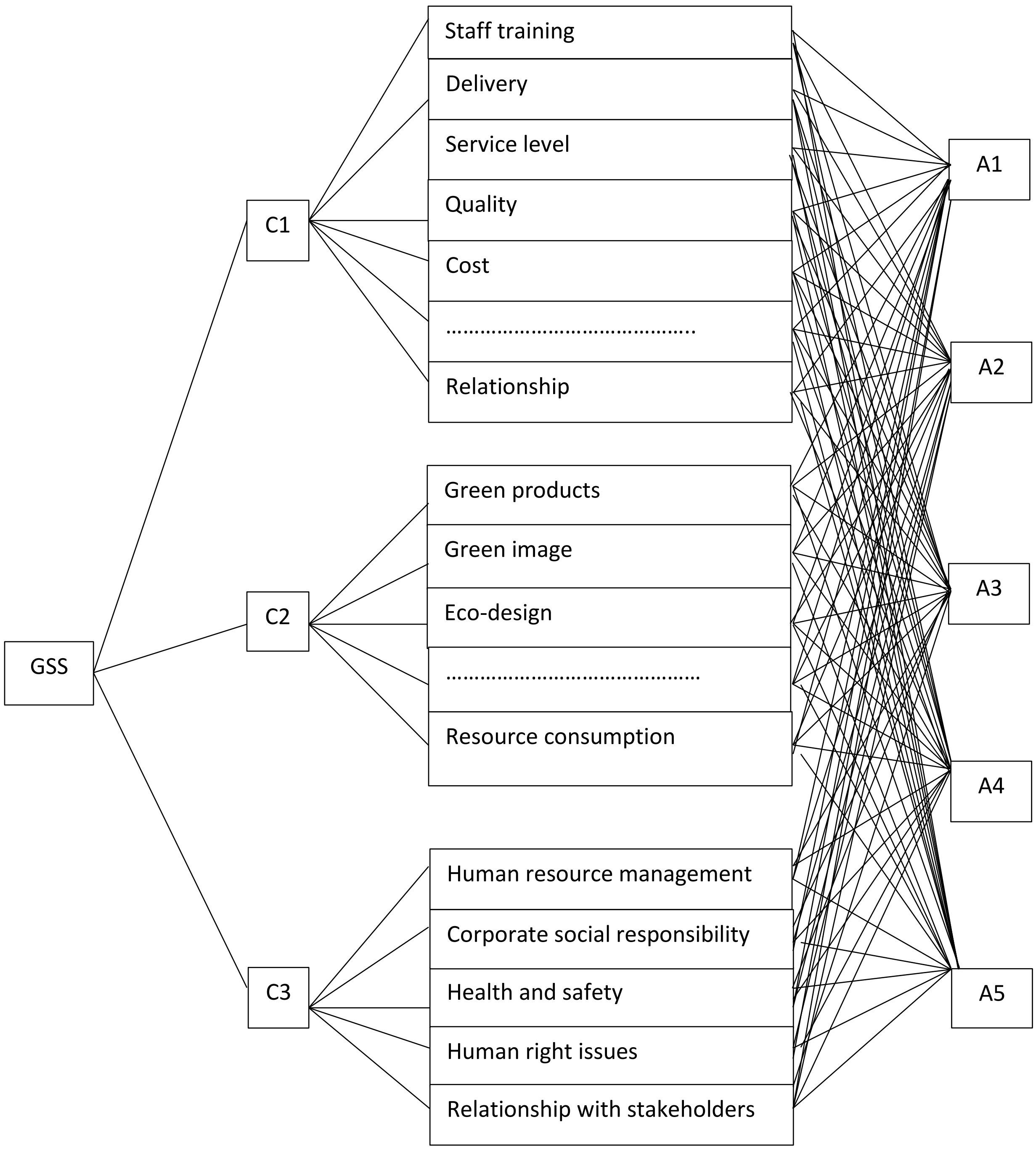


Figure 4.1. AHP hierarchy for the GSS problem

The case showed that in enterprise practice, green requirements such as the environment and sustainability do not yet play a critical role in green supplier selection procedures. Suppliers must follow certain minimum standards in order to work with focal companies in the manufacturing chain due to environmental legislation. Following that, most businesses do not use environmental standards to choose eligible vendors; instead, consumers demand that suppliers have documents such as a Certificate of Nonuse of Controlled Substances, Certificate of Nonuse of Other Controlled Substances, Material Safety Data Sheet, and Test Report of customer assigned items issued by SGS annually. Those certificates concern quality of economic criterion and pollution control of environmental criterion.

Expert	Organization	Duties	Seniority
1	VinFast Commercial and services trading limited liability company	Specialist	10
2	VinFast Commercial and services trading limited liability company	Development Engineer	15
3	VinFast Commercial and services trading limited liability company	Engineer	10
4	VinFast Commercial and services trading limited liability company	Senior Manager	8
5	VinFast Commercial and services trading limited liability company	Project Manager	10
6	VinFast Commercial and services trading limited liability company	Parts Quality Group Manager	15
7	Manufacturing department, Kia Motors Vietnam	Purchasing Manager	8
8	Parts Quality Control Section, Porsche Vietnam	Section Manager	8
9	Body Development Division Engineering Development Engineer, Mercedes-Benz Vietnam Ltd	Team Leader	
10	Automotive Asia Limited (Audi Vietnam)	Engineer	9
11	THACO passenger Car Distribution Co., Ltd (BMW Distributor in Vietnam)	Purchasing Manager	15
12	Production Control Management Division, Isuzu Viet Nam Co., Ltd.	Team Leader	15

Table 4.1 Professional backgrounds of the selected twelve experts for our survey

GSCM is implemented through mimetic and normative (competitive and benchmarking) processes, according to institutional theory. To thrive, businesses must conform with societal expectations and maintain consistency with the external world when faced with environmental conservation and authenticity isomorphism pressures. As a result, the economic, social corporate responsibility (SCR) and environmental aspects must be considered.

In this thesis, the criteria for three dimensions and the correlation between suppliers and required criteria are showed in the **Table 2.1** and **Figure 4.1** below. Five suppliers which are providing vehicle batteries for VinFast were selected to illustrate for this case study. To ensure confidentiality, authors of this thesis refer 5 suppliers as A1, A2, A3, A4, and A5.

This study data was collected by interviews with 12 experts who are the top managers and heads of departments with 8-15 years of experience in the automotive field. They were required to make their evaluation, respectively, according to their preferences for important weights of selection criteria in **Appendix** and ratings of green suppliers. The information of these experts is listed in the **Table 4.1**.

Then, an integrating Fuzzy AHP and Fuzzy TOPSIS method is presented in the **Figure 4.2**. Firstly, the fuzzy weights of proposed criteria are identified by Fuzzy AHP. Secondly, the Fuzzy TOPSIS technique is utilized to prioritize and ranking the 5 selected suppliers.

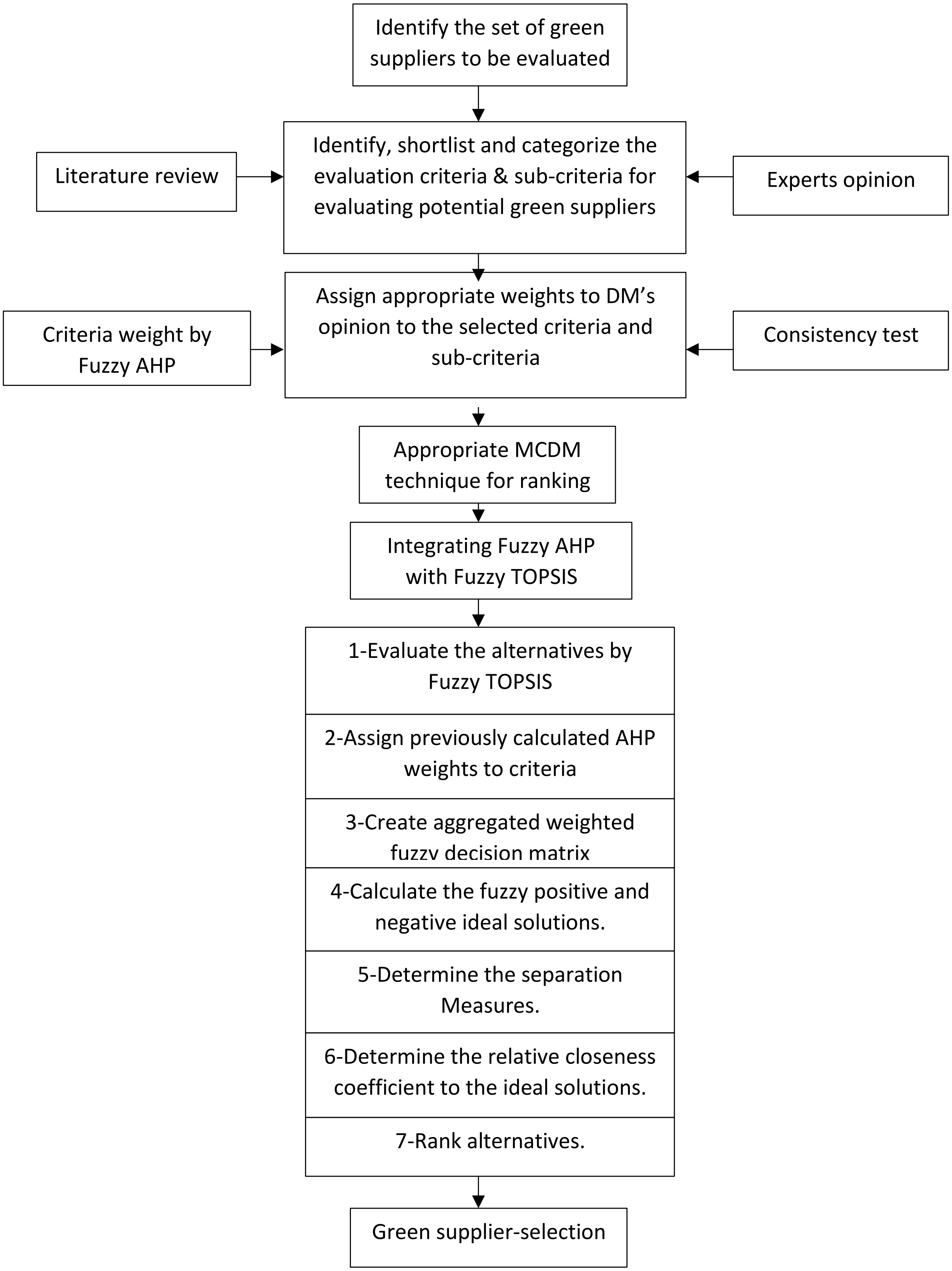


Figure 4.2. Proposed Framework of GSS Process

4.2. Fuzzy AHP for Weighting Calculation

4.2.1 Weighting Results for Main Criteria (Economic, Environmental, Social)

				Initial Comparison Matrices																
	Left Criteria is Greater									**Right Criteria Is Greater**										**Total Number of Experts**
	Perfect	**Absolute**	**Very good**	**Fairly good**	**Good**	**Preferable**	**Not bad**	**Weak advantage**	**Equal**	**Weak advantage**	**Not bad**	**Preferable**	**Good**	**Fairly good**	**Very good**	**Absolute**	**Perfect**			
C1							4	3	3	2								**C2**		**12**
C2							1	4	4	3	1							**C3**		**12**
C3						2	2	3	3	3								**C3**		**12**

Table 4.2. Initial Comparison Matrices

	Integrated Fuzzy Comparison Matrix								
	C1			C2			C3		
C1	1	1	1	1.0491	1.5280	2.0891	0.7172	1.0595	1.5280
C2	0.4787	0.6544	0.9532	1	1	1	1.0243	1.5131	2.1683
C3	0.6544	0.9439	1.3943	0.4612	0.6609	0.9763	1	1	1

Table 4.3. Integrated Fuzzy Comparison Matrix

	Fuzzy Sum of Each Row			Fuzzy Synthetic Extent			Degree of Possibility of Mi > Mj			Degree of Possibility (Mi)	normalization	weights of criteria	Ranking
C1	2.7663	3.5875	4.6171	0.2284	0.3833	0.6252		1.000	1.000	1.000	0.390	**0.390**	**1**
C2	2.5029	3.1675	4.1215	0.2067	0.3384	0.5581	0.880		1.000	0.880	0.343	**0.343**	**2**
C3	2.1156	2.6048	3.3706	0.1747	0.2783	0.4564	0.685	0.806		0.685	0.267	**0.267**	**3**
Sum	**7.3849**	**9.3598**	**12.1093**							**2.565**	**1.0000**		
										Sum			

Consistency Ratio (CRm)	0.0696	Compare with 0.1, They should be less than 0.1
Consistency Ratio (CRg)	0.1729	

Table 4.4. Results Of Fuzzy Weighting Value Of Main Criteria (Economic, Environmental, Social)

Step 1: The value of the fuzzy synthetic extent with respect to the i^{th} object is defined as in Eq. (3), (4), (5), (6) and presented in **Table 4.3** and **Table 4.4:**

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

$\sum M_1 =$ (1 + 1.0491 + 0.7172; 1 + 1.5280 + 1.0595; 1 + 2.0891 + 1.5280)

= (2.7663; 3.5875; 4.171) etc.,

$$\text{Next,} \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

S_1= (2.7663; 3.5875; 4.171) x $\left(\frac{1}{12.1093}, \frac{1}{9.3598}, \frac{1}{7.3849}\right)$ = (0.2284; 0.3833; 0.6252)

S_2 = (0.2067, 0.3384, 0.5581);

S_3 = (0.1747, 0.2783, 0.4564)

Step 2: The values of S_i are compared and the degree of possibility of $S_j = (l_j, m_j, u_j) \geq S_i(l_i, m_i, u_i)$ is calculated as in Eq. (7) and the results are shown in **Table 4.4:**

$$V(S_j \geq S_i) = \begin{cases} 1, & if\ m_j \geq m_i \\ 0, & if\ l_i \geq u_j \\ \dfrac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)}, & otherwise, \end{cases} \quad (7)$$

$V_2\ (S_2 \geq S_1) = \left(\frac{0.2067-0.6252}{(0.3384-0.5581)-(0.3833-0.2284)}\right)$ = 0.880

V_{11} (S_1 > S_2) = 1; V_{12} (S_1 >S_3) = 1; V_{21} (S_2 > S_1) = 0.880; V_{23} (S_2 > S_3) = 1; V_{31} (S_3 > S_1) = 0.685; V_{32} (S_3 > S_2) = 0.806.

Step 3: The minimum degree of possibility $d(i)$ of $V\left(S_j \geq S_i\right)$ for $i, j = 1, 2, \dots, k$ can be calculated as in Eq. (8):

$$V(S \geq S_1, S_2, S_3, \dots, S_k) = V\,[(S \geq S_1)\ and\ (S \geq S_2)\ and \dots (S \geq S_k)] \qquad (8)$$
$$= \min V(S \geq S_i) = W'(S_i)$$

The weights priority is with Consistency Ratio (CRm) = 0.0696 (less than 0.1) in **Table 4.4**:

Min V_1 (V_{11}, V_{12}) = 1; Min V_2 (V_{21}, V_{23}) = 0.880; Min V_3 (V_{31}, V_{32}) = 0.685;

W= (1, 0.880, 0.685)

W_normalize = $(0.390, 0.343, 0.267)^T$

4.2.2 Weighting Results for Sub-Criteria of Economic (C1)

$W_{sub-C1} = (0.0984, 0.1004, 0.1150, 0.1007, 0.1226, 0.0634, 0.0647, 0.0954, 0.0930, 0.0793, 0.0671)^T$

Table 1: Initial Comparison Matrices

	Left Criteria Is Greater									**Right Criteria Is Greater**										**Total Number of Experts**
	Perfect	**Absolute**	**Very good**	**Fairly good**	**Good**	**Preferable**	**Not bad**	**Weak advantage**	**Equal**	**Weak advantage**	**Not bad**	**Preferable**	**Good**	**Fairly good**	**Very good**	**Absolute**	**Perfect**			
C 11							4	3	3	2								**C1 2**		**12**
C 11							2	2	4	3	1							**C1 3**		**12**
C 11							1	2	3	4	2							**C1 4**		**12**
C 11							3	3	3	2	1							**C1 5**		**12**
C 11							4	3	3	2								**C1 6**		**12**
C 11							4	3	3	2								**C1 7**		**12**
C 11							3	3	3	2	1							**C1 8**		**12**
C 11								3	3	3	2	1						**C1 9**		**12**
C 11							3	3	3	2	1							**C1 10**		**12**
C 11								3	3	3	2	1						**C1 11**		**12**

C 12							3	3	3	2	1							**C1 3**		**12**
C 12							2	4	3	2	1							**C1 4**		**12**
C 12							3	3	3	2	1							**C1 5**		**12**
C 12							4	3	3	2								**C1 6**		**12**
C 12							4	3	3	2								**C1 7**		**12**
C 12							3	3	3	2	1							**C1 8**		**12**
C 12							3		3	2	1	2	1					**C1 9**		**12**
C 12								3	3	3	2	1						**C1 10**		**12**
C 12							5	3	3	1								**C1 11**		**12**
C 13							5	3	3	1								**C1 4**		**12**
C 13							3	3	3	2	1							**C1 5**		**12**
C 13							4	3	3	2								**C1 6**		**12**
C 13							4	3	3	2								**C1 7**		**12**
C 13								3	3	3	2	1						**C1 8**		**12**
C 13						3	3	2	1	2	1							**C1 9**		**12**
C 13						3	3	3	2	1								**C1 10**		**12**

C 13						3	3	2	1	2	1							**C1 11**		**12**
C 14						3	3	3	2	1								**C1 5**		**12**
C 14							4	3	3	2								**C1 6**		**12**
C 14							4	3	3	2								**C1 7**		**12**
C 14									3	3	3	2	1					**C1 8**		**12**
C 14							3	3	3	2	1							**C1 9**		**12**
C 14							3	3	3	2	1							**C1 10**		**12**
C 14						1	2	3	3	2	1							**C1 11**		**12**
C 15							4	3	3	2								**C1 6**		**12**
C 15							4	3	3	2								**C1 7**		**12**
C 15					3	3	2	1	3									**C1 8**		**12**
C 15					3	3	2	1	3									**C1 9**		**12**
C 15						3	3	3	1	2								**C1 10**		**12**
C 15						3	3	3	2	1								**C1 11**		**12**
C 16							4	3	3	2								**C1 7**		**12**
C 16								1	2	3	3	2	1					**C1 8**		**12**

C 16									3	3	3	2	1					**C1 9**		**12**
C 16							3	3	3	2	1							**C1 10**		**12**
C 16						1	2	3	3	2	1							**C1 11**		**12**
C 17						3	3	3	2	1								**C1 8**		**12**
C 17									3	3	3	2	1					**C1 9**		**12**
C 17								3	3	3	2	1						**C1 10**		**12**
C 17							2	4	3	2	1							**C1 11**		**12**
C 18							3	3	3	2	1							**C1 9**		**12**
C 18								3	3	3	2	1						**C1 10**		**12**
C 18							3	3	3	2	1							**C1 11**		**12**
C 19							3	3	3	2	1							**C1 10**		**12**
C 19								3	3	3	2	1						**C1 11**		**12**
C 10							3	3	3	2	1							**C1 11**		**12**

Table 4.5. Initial Comparison Matrices

Integrated Fuzzy Comparison Matrix

	C11			C12			C13			C14			C15			C16			C17			C18			C19			C110			C111		
C11	1	1	1	1.0491	1.5280	2.0891	0.7598	1.0344	1.4282	0.5830	0.8130	1.2009	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.8822	1.2723	1.7567	0.5274	0.7418	1.0699	0.8822	1.2723	1.7567	0.5274	0.7418	1.0699
C12	0.4787	0.6544	0.9532	1	1	1	0.8822	1.2723	1.7567	0.8327	1.2301	1.7151	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.8822	1.2723	1.7567	0.5811	0.7426	0.9902	0.5274	0.7418	1.0699	1.2181	1.7741	2.3450
C13	0.7002	0.9668	1.3161	0.5692	0.7859	1.1335	1	1	1	1.2181	1.7741	2.3450	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.5274	0.7418	1.0699	1.1610	1.6984	2.3971	1.4282	2.0891	2.7832	1.1610	1.6984	2.3971
C14	0.8327	1.2301	1.7151	0.5830	0.8130	1.2009	0.4264	0.5637	0.8210	1	1	1	1.4282	2.0891	2.7832	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.3539	0.4435	0.6238	0.8822	1.2723	1.7567	0.8822	1.2723	1.7567	0.9125	1.3032	1.7897
C15	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.3593	0.4787	0.7002	1	1	1	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	2.0891	2.6907	3.2313	2.0891	2.6907	3.2313	1.3032	1.9719	2.7832	1.4282	2.0891	2.7832
C16	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	1	1	1	1.0491	1.5280	2.0891	0.3539	0.4698	0.6836	0.3539	0.4435	0.6238	0.8822	1.2723	1.7567	0.9125	1.3032	1.7897

C17	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	1	1	1	1.4282	2.0891	2.7832	0.3539	0.4435	0.6238	0.5274	0.7418	1.0699	0.8327	1.2301	1.7151
C18	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	1.6031	2.2549	2.8258	0.3095	0.3717	0.4787	1.4628	2.1283	2.8258	0.3593	0.4787	0.7002	1	1	1	0.8822	1.2723	1.7567	0.5274	0.7418	1.0699	0.8822	1.2723	1.7567
C19	0.9347	1.3480	1.8961	1.0099	1.3466	1.7210	0.4172	0.5888	0.8613	0.5692	0.7859	1.1335	0.3095	0.3717	0.4787	1.6031	2.2549	2.8258	1.6031	2.2549	2.8258	0.5692	0.7859	1.1335	1	1	1	0.5274	0.7418	1.0699	0.5274	0.7418	1.0699
C110	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	0.3593	0.4787	0.7002	0.5692	0.7859	1.1335	0.3593	0.5071	0.7673	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	0.9347	1.3480	1.8961	0.5692	0.7859	1.1335	1	1	1	0.8822	1.2723	1.7567
C111	0.9347	1.3480	1.8961	0.4264	0.5637	0.8210	0.4172	0.5888	0.8613	0.5587	0.7673	1.0959	0.3593	0.4787	0.7002	0.5587	0.7673	1.0959	0.5830	0.8130	1.2009	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	0.5692	0.7859	1.1335	1	1	1

Table 4.6. Integrated Fuzzy Comparison Matrix

	Fuzzy Sum of Each Row			Fuzzy Synthetic Extent			Degree of Possibility of Mi > Mj											Degree of Possibility (Mi)	Normalization Weights	Ranking
C11	9.1916	12.7321	17.3066	0.0512	0.0955	0.1775		0.983	0.870	0.982	0.803	1.000	1.000	1.000	1.000	1.000	1.000	0.803	0.0984	5
C12	9.3827	13.0161	17.5220	0.0522	0.0977	0.1797	1.000		0.885	0.998	0.819	1.000	1.000	1.000	1.000	1.000	1.000	0.819	0.1004	4
C13	10.7455	15.0829	20.3769	0.0598	0.1132	0.2090	1.000	1.000		1.000	0.938	1.000	1.000	1.000	1.000	1.000	1.000	0.938	0.1150	2
C14	9.3994	13.0433	17.6255	0.0523	0.0979	0.1807	1.000	1.000	0.888		0.821	1.000	1.000	1.000	1.000	1.000	1.000	0.821	0.1007	3
C15	12.0749	16.3349	21.3081	0.0672	0.1226	0.2185	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.1226	1
C16	6.9449	9.2891	12.7089	0.0387	0.0697	0.1303	0.754	0.736	0.619	0.735	0.544		0.988	0.517	0.784	0.910	1.000	0.517	0.0634	11
C17	7.0141	9.4312	12.9111	0.0390	0.0708	0.1324	0.766	0.749	0.631	0.747	0.557	1.000		0.527	0.796	0.922	1.000	0.527	0.0647	10
C18	9.0995	12.4400	16.5770	0.0507	0.0933	0.1700	0.982	0.965	0.847	0.963	0.779	1.000	1.000		1.000	1.000	1.000	0.779	0.0954	6
C19	9.0705	12.2204	16.0155	0.0505	0.0917	0.1642	0.967	0.949	0.829	0.948	0.759	1.000	1.000	0.986		1.000	1.000	0.759	0.0930	7
C110	7.6817	10.4460	14.4468	0.0428	0.0784	0.1481	0.850	0.833	0.717	0.831	0.647	1.000	1.000	0.867	0.880		1.000	0.647	0.0793	8
C111	6.9112	9.2467	12.8345	0.0385	0.0694	0.1316	0.755	0.737	0.621	0.736	0.548	0.997	0.696	0.772	0.784	0.908		0.548	0.0671	9
Sum	**97.5161**	**133.2827**	**179.6330**															**8.158**	**1.0000**	
																		Sum		

Consistency Ratio (CRm)	**0.0539**	**Compare with 0.1, They should be less than 0.1**
Consistency Ratio (CRg)	**0.1470**	

Table 4.7. Results of Fuzzy Weighting Value Of Economic

4.2.3 Weighting Results for Sub-Criteria of Environment (C2):

W_{sub-C2}= $(0.1088, 0.0967, 0.1353, 0.1058, 0.1560, 0.0551, 0.0595, 0.0973, 0.1119, 0.0736)^T$

				Initial Comparison Matrices																
	Left Criteria Is Greater									Right Criteria Is Greater										Total Number of Experts
	Perfect	Absolute	Very good	Fairly good	Good	Preferable	Not bad	Weak advantage	Equal	Weak advantage	Not bad	Preferable	Good	Fairly good	Very good	Absolute	Perfect			
C 21							4	3	3	2								C2 2		12
C 21							2	2	4	3	1							C2 3		12
C 21							1	2	3	4	2							C2 4		12
C 21							3	3	3	2	1							C2 5		12
C 21							4	3	3	2								C2 6		12
C 21							4	3	3	2								C2 7		12
C 21							3	3	3	2	1							C2 8		12
C 21								3	3	3	2	1						C2 9		12
C 21							3	3	3	2	1							C2 10		12
C 22							3	3	3	2	1							C2 3		12
C 22							2	4	3	2	1							C2 4		12

C 22							3	3	3	2	1							**C2 5**		**12**
C 22							4	3	3	2								**C2 6**		**12**
C 22							4	3	3	2								**C2 7**		**12**
C 22							3	3	3	2	1							**C2 8**		**12**
C 22									3	3	3	2	1					**C2 9**		**12**
C 22								3	3	3	2	1						**C2 10**		**12**
C 23							5	3	3	1								**C2 4**		**12**
C 23							3	3	3	2	1							**C2 5**		**12**
C 23							4	3	3	2								**C2 6**		**12**
C 23							4	3	3	2								**C2 7**		**12**
C 23								3	3	3	2	1						**C2 8**		**12**
C 23					3	3	3	2	1									**C2 9**		**12**
C 23						3	3	3	2	1								**C2 10**		**12**
C 24						3	3	3	2	1								**C2 5**		**12**
C 24							4	3	3	2								**C2 6**		**12**
C 24							4	3	3	2								**C2 7**		**12**
C 24									3	3	3	2	1					**C2 8**		**12**

C 24							3	3	3	2	1							**C2 9**		**12**
C 24							3	3	3	2	1							**C2 10**		**12**
C 25							4	3	3	2								**C2 6**		**12**
C 25							4	3	3	2								**C2 7**		**12**
C 25				3	3	3	2	1										**C2 8**		**12**
C 25				3	3	3	2	1										**C2 9**		**12**
C 25						3	3	3	2	1								**C2 10**		**12**
C 26							4	3	3	2								**C2 7**		**12**
C 26									3	3	3	2	1					**C2 8**		**12**
C 26									3	3	3	2	1					**C2 9**		**12**
C 26							3	3	3	2	1							**C2 10**		**12**
C 27						3	3	3	2	1								**C2 8**		**12**
C 27									3	3	3	2	1					**C2 9**		**12**
C 27							1	2	3	3	2	1						**C2 10**		**12**
C 28							3	3	3	2	1							**C2 9**		**12**
C 28								3	3	3	2	1						**C2 10**		**12**
C 29							3	3	3	2	1							**C2 10**		**12**

Table 4.8. Initial Comparison Matrices

Integrated Fuzzy Comparison Matrix

	C11			C12			C13			C14			C15			C16			C17			C18			C19			C110		
C11	1	1	1	1.0491	1.5280	2.0891	0.7598	1.0344	1.4282	0.5830	0.8130	1.2009	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.8822	1.2723	1.7567	0.5274	0.7418	1.0699	0.8822	1.2723	1.7567
C12	0.4787	0.6544	0.9532	1	1	1	0.8822	1.2723	1.7567	0.8327	1.2301	1.7151	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.8822	1.2723	1.7567	0.3539	0.4435	0.6238	0.5274	0.7418	1.0699
C13	0.7002	0.9668	1.3161	0.5692	0.7859	1.1335	1	1	1	1.2181	1.7741	2.3450	0.8822	1.2723	1.7567	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.5274	0.7418	1.0699	2.2134	3.1240	3.9748	1.4282	2.0891	2.7832
C14	0.8327	1.2301	1.7151	0.5830	0.8130	1.2009	0.4264	0.5637	0.8210	1	1	1	1.4282	2.0891	2.7832	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	0.3539	0.4435	0.6238	0.8822	1.2723	1.7567	0.8822	1.2723	1.7567
C15	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.3593	0.4787	0.7002	1	1	1	1.0491	1.5280	2.0891	1.0491	1.5280	2.0891	3.1240	4.2112	5.2560	3.1240	4.2112	5.2560	1.4282	2.0891	2.7832
C16	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	1	1	1	1.0491	1.5280	2.0891	0.3539	0.4435	0.6238	0.3539	0.4435	0.6238	0.8822	1.2723	1.7567
C17	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	0.4787	0.6544	0.9532	1	1	1	1.4282	2.0891	2.7832	0.3539	0.4435	0.6238	0.5587	0.7673	1.0959
C18	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	1.6031	2.2549	2.8258	0.1903	0.2375	0.3201	1.6031	2.2549	2.8258	0.3593	0.4787	0.7002	1	1	1	0.8822	1.2723	1.7567	0.5274	0.7418	1.0699
C19	0.9347	1.3480	1.8961	1.6031	2.2549	2.8258	0.2516	0.3201	0.4518	0.5692	0.7859	1.1335	0.1903	0.2375	0.3201	1.6031	2.2549	2.8258	1.6031	2.2549	2.8258	0.5692	0.7859	1.1335	1	1	1	0.8822	1.2723	1.7567
C110	0.5692	0.7859	1.1335	0.9347	1.3480	1.8961	0.3593	0.4787	0.7002	0.5692	0.7859	1.1335	0.3593	0.4787	0.7002	0.5692	0.7859	1.1335	0.9125	1.3032	1.7897	0.9347	1.3480	1.8961	0.5692	0.7859	1.1335	1	1	1

Table 4.9. Integrated Fuzzy Comparison Matrix

	Fuzzy Sum of Each Row			Fuzzy Synthetic Extent			Degree of Possibility of Mi > Mj										Degree of Possibility (Mi)	Normalization weights of criteria	Ranking
C21	8.6642	11.9902	16.2367	0.0561	0.1035	0.1909		1.000	0.834	1.000	0.698	1.000	1.000	1.000	0.967	1.000	0.698	0.1088	4
C22	7.9374	10.9429	14.8106	0.0514	0.0945	0.1742	0.929		0.759	0.945	0.620	1.000	1.000	0.686	0.894	1.000	0.620	0.0967	7
C23	10.6368	14.8101	19.5575	0.0689	0.1278	0.2300	1.000	1.000		1.000	0.868	1.000	1.000	1.000	1.000	1.000	0.868	0.1353	2
C24	8.4868	11.7400	15.8358	0.0550	0.1013	0.1862	0.984	1.000	0.816		0.678	1.000	1.000	1.000	0.950	1.000	0.678	0.1058	5
C25	12.8414	17.4040	22.5743	0.0831	0.1502	0.2655	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	0.1560	1
C26	6.0324	7.9595	10.8594	0.0391	0.0687	0.1277	0.673	0.748	0.499	0.690	0.353		0.974	0.479	0.634	0.895	0.353	0.0551	10
C27	6.2128	8.2266	11.2219	0.0402	0.0710	0.1320	0.700	0.775	0.526	0.717	0.381	1.000		0.500	0.662	0.921	0.381	0.0595	9
C28	8.2384	11.1600	14.6617	0.0533	0.0963	0.1724	0.942	1.000	0.767	0.959	0.624	1.000	1.000		0.906	1.000	0.624	0.0973	6
C29	9.2063	12.5145	16.1692	0.0596	0.1080	0.1901	1.000	1.000	0.860	1.000	0.717	1.000	1.000	1.000		1.000	0.717	0.1119	3
C210	6.7774	9.1004	12.5165	0.0439	0.0786	0.1472	0.785	0.858	0.614	0.802	0.472	1.000	1.000	0.841	0.748		0.472	0.0736	8
Sum	**85.0340**	**115.8484**	**154.4436**													**Sum**	**6.411**	**1.0000**	

Consistency Ratio (CRm)	**0.0902**	**Compare with <u>0.1</u>, They should be less than <u>0.1</u>**
Consistency Ratio (CRg)	**0.3253**	

Table 4.10. Results of Fuzzy Weighting Value of Environmental

4.2.4 Weighting Results for Sub-Criteria of Social (C3)

$W_{sub-C3} = (0.2153, 0.2078, 0.2203, 0.2169, 0.1397)^T$

				Initial Comparison Matrices																
	Left Criteria Is Greater									Right Criteria Is Greater										Total Number of Experts
	Perfect	Absolute	Very good	Fairly good	Good	Preferable	Not bad	Weak advantage	Equal	Weak advantage	Not bad	Preferable	Good	Fairly good	Very good	Absolute	Perfect			
C 31							4	3	3	2								C 32		12
C 31							2	2	4	3	1							C 33		12
C 31							1	2	3	4	2							C 34		12
C 31							3	3	3	2	1							C 35		12
C 32							3	3	3	2	1							C 33		12
C 32							2	4	3	2	1							C 34		12
C 32							3	3	3	2	1							C 35		12
C 33							5	3	3	1								C 34		12
C 33							3	3	3	2	1							C 35		12
C 34						3	3	3	2	1								C 35		12

Table 4.11. Initial Comparison Matrices

							Integrated Fuzzy Comparison Matrix								
	C31			C32			C33			C34			C35		
C31	1	1	1	1.0491	1.5280	2.0891	0.7598	1.0344	1.4282	0.5830	0.8130	1.2009	0.8822	1.2723	1.7567
C32	0.4787	0.6544	0.9532	1	1	1	0.8822	1.2723	1.7567	0.8327	1.2301	1.7151	0.8822	1.2723	1.7567
C33	0.7002	0.9668	1.3161	0.5692	0.7859	1.1335	1	1	1	1.2181	1.7741	2.3450	0.8822	1.2723	1.7567
C34	0.8327	1.2301	1.7151	0.5830	0.8130	1.2009	0.4264	0.5637	0.8210	1	1	1	1.4282	2.0891	2.7832
C35	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.5692	0.7859	1.1335	0.3593	0.4787	0.7002	1	1	1

Table 4.12. Integrated Fuzzy Comparison Matrix

	Fuzzy Sum of Each Row			Fuzzy Synthetic Extent			Degree of Possibility of Mi > Mj					Degree of Possibility (Mi)	normalization	Ranking
C31	4.2742	5.6477	7.4750	0.1227	0.2139	0.3727		1.000	0.977	0.993	1.000	0.977	0.2153	3
C32	4.0757	5.4292	7.1818	0.1170	0.2056	0.3581	0.966		0.943	0.959	1.000	0.943	0.2078	4
C33	4.3697	5.7991	7.5513	0.1255	0.2196	0.3765	1.000	1.000		1.000	1.000	1.000	0.2203	1
C34	4.2703	5.6958	7.5202	0.1226	0.2157	0.3749	1.000	1.000	0.985		1.000	0.985	0.2169	2
C35	3.0670	3.8365	5.1008	0.0881	0.1453	0.2543	0.657	0.695	0.634	0.652		0.634	0.1397	5
Sum	**20.0570**	**26.4084**	**34.8291**									**4.539**	**1.0000**	
												Sum		

Consistency Ratio (CRm)	**0.0388**	**Compare with <u>0.1</u>, They should be less than <u>0.1</u>**
Consistency Ratio (CRg)	**0.0976**	

Table 4.13. Results of Fuzzy Weighting Value of Social

Criteria	W_Concept	Sub-criteria	W_Local	Rank_Local	W_Global	Rank_ Global
Economic (C1)	0.390	Staff training (C11)	0.098	5	0.0384	12
		Delivery (C12)	0.100	4	0.0391	10
		Service level (C13)	0.115	2	0.0448	8
		Quality (C14)	0.101	3	0.0393	9
		Cost (C15)	0.123	1	0.0478	6
		Technology (C16)	0.063	11	0.0247	24
		Flexibility (C17)	0.065	10	0.0252	23
		Financial capability(C18)	0.095	6	0.0372	15
		Culture (C19)	0.093	7	0.0363	17
		Innovativeness (C110)	0.079	8	0.0309	20
		Relationship (C111)	0.067	9	0.0262	21
Environmental (C2)	0.343	Green products (C21)	0.109	4	0.0373	13
		Green image (C22)	0.097	7	0.0332	19
		Eco-design(C23)	0.135	2	0.0464	7
		Management commitment(C24)	0.106	5	0.0363	16
		Green technology(C25)	0.156	1	0.0535	5
		Pollution control(C26)	0.055	10	0.0189	26
		Recycle(C27)	0.060	9	0.0204	25
		Re-manufacturing(C28)	0.097	6	0.0334	18
		Environmental management system (C29)	0.112	3	0.0384	11
		Resource consumption(C210)	0.074	8	0.0253	22
Social (C3)	0.267	Human resource management (C31)	0.215	3	0.0575	3
		Corporate social responsibility (C32)	0.208	4	0.0555	4
		Health and safety (C33)	0.220	1	0.0588	1
		Human right issues (C34)	0.217	2	0.0579	2
		Relationship with stakeholders (C35)	0.140	5	0.0373	14

Table 4.14. Weighting and Ranking Results of FAHP

This research shown criteria of three group include Economic, Environmental and Social. **Table 4.14** demonstrate main criteria, sub-criteria and their final ranks based on their weights. According to this table, the following results are obtained: The Economic (C1) achieves the highest rank with the final weight of 0.390, followed by weights of Environmental (C2) and Social (C3) which are 0.343 and 0.267, respectively; weight of Cost (C15) is the highest at 0.123 and the lowest is Technology (C16) at 0.16 in Economic criteria; weight of Green technology (C25) and weight of pollution control (C26) hold opposite ranking which one has the highest weight and the other one has the lowest at 0.156 and 0.055, respectively in Environmental criteria; in Social criteria (C3), weight of Health and safety (C33) won the first priority at 0.220 and weight of Relationship with stakeholders (C35) is the lowest at 0.140. However, results of another research of (A and Maryam Darvishi, 2020) also using AHP model showed that weight of Economic benefits is at 0.089 which won the fifth out of seven main criteria and lower than our weight result of Economic criteria. Their best criterion is Environmental management initiatives at 0.383.

Besides showing local weight of sub-criteria, **Table 4.14** illustrates global weights of them. As a result, our final ranks include both local and global. In the Economic dimension, local weight of Service level (C13) is 0.115, Quality (C14) is 0.101 and local weight of Delivery (C12) is 0.100 which are high in local leads to their high ranking in global weight which are 0.0448, 0.0393 and 0.0391, respectively. Eco-design (C23), Environmental management system (C29), and Green products (C21) are the top three in the environmental dimension. Their local weights are 0.135, 0.112 and 0.109 which is correspond to the rank of 2,3, and 4. However, only Eco-design criteria is on top seven in global rank with the weight of 0.0464. Besides, Human right issues (C34) and Human resource management (C29) ranked 2 and 3 after Health and safety (C33) in the Social criteria. Both local weights and global weights of three sub-criteria are high and they ranked at top three in global rank which are 0.0588, 0.0579, and 0.0575, respectively.

Following results of (A and Maryam Darvishi, 2020), weights of Green recycling facilities and Green manufacturing capabilities are relatively low at 0.009 and medium at 0.022. Weight of Re-manufacturing (C28) is low also at 0.0334 in global weight and ranked 18 in the global rank. Darvishi showed that weight of Trained human resources is 0.002 and weight of Designing energy efficient products is 0.009. These weights are lower than weight of Staff training (C11) and weight of Eco-design (C23) which are 0.0384 and 0.464 ranked 12 and 7, respectively. Following results of one paper researching Agricultural Industry, weights of Training famers and Using recycled water are 0.16 and 0.134 which correspond to the rank of 1 and 4 (Banihabib et al, 2016). According to (G. Shubham Guptaa, 2019), weights of Environmental management system is the highest in all criteria at 0.169 as the same weight of Environmental management system (C29) which is relatively high at 0.112 and ranked 11. In this study, weights of Pollution control (C26) and Green image (C22) ranked of 26 and 19 with their weight is at 0.0189 and 0.0332, respectively. Global rank of their Eco-design (C23) is medium at 0.464 and ranked 7. In contrast, (G. Shubham Guptaa, 2019) shows weights of Pollution control, Quality and Green image are ranked as top four in all criteria are 0.155, 0.137, and 0.117, respectively. From results of (Bali, Kose and Gumus, 2013), their Green product criteria ranked in the middle as the same as our study with weight of Green products (C21) is 0.0373 and it ranked 13. Our rankings of two Sub-criteria are Environmental management system (C29) and Resource consumption (C210) in Environmental (C2) are completely opposite, weight of C29 is relatively high at 0.0384 and weight of C210 is restively low at 0.0253. In contrast, Environmental management system and Resource consumption are required at high level.

4.3. Fuzzy TOPSIS for Ranking

After the determination of the green supplier criteria, each of managers is asked to conduct a pairwise comparison with regard to the different criteria using the fuzzy linguistic assessment variables (see **Table 4.15** for these variables).

Fuzzy number	Linguistic	Triangular fuzzy scale $M = (l, m, u)$
1	Equal	(1,1,1)
2	Weak advantage	(1,2,3)
3	Not bad	(2,3,4)
4	Preferable	(3,4,5)
5	Good	(4,5,6)
6	Fairly good	(5,6,7)
7	Very good	(6,7,8)
8	Absolute	(7,8,9)
9	Perfect	(8,9,10)

Table 4.15. Linguistic Variables for The Ratings

A linguistic rating set of S was used to express the opinions of the managers, where S = (E, WA, NB, PR, G, FG, VG, A, PE).

Step 2: **Table 4.16** gives the integrated suitability ratings of four green suppliers (*A*1, *A*2, *A*3, *A*4 and A5) using Eq. (14).

	W1			W2			W3			W4			W5			W6			W7			W8			W9			W10		
	0.051	0.096	0.177	0.052	0.098	0.180	0.060	0.113	0.209	0.052	0.098	0.181	0.067	0.123	0.219	0.039	0.070	0.130	0.039	0.071	0.132	0.051	0.093	0.170	0.050	0.092	0.164	0.043	0.078	0.148
	c1			**c2**			**c3**			**c4**			**c5**			**c6**			**c7**			**c8**			**c9**			**c10**		
A1	6.167	8.417	10.250	1.000	2.667	4.917	1.167	2.667	5.000	2.833	5.000	7.417	6.167	8.417	10.250	1.167	2.667	5.000	3.083	5.417	7.833	1.000	2.667	4.917	2.833	5.000	7.417	5.250	7.750	10.000
A2	1.583	3.417	5.750	4.500	6.917	9.250	6.750	9.083	10.833	6.250	8.667	10.583	1.583	3.417	5.750	6.750	9.083	10.833	1.250	2.833	5.167	4.500	6.917	9.250	1.000	2.667	4.917	1.500	3.417	5.750
A3	3.083	5.417	7.833	3.667	6.083	8.333	3.250	5.583	8.000	3.333	5.750	8.083	3.333	5.750	8.083	3.250	5.583	8.000	5.750	8.250	10.250	4.500	6.917	9.250	4.500	6.917	9.250	3.167	5.417	7.833
A4	1.250	2.833	5.167	7.917	10.167	11.667	7.083	9.417	11.167	8.083	10.250	11.667	8.083	10.250	11.667	8.083	10.250	11.667	2.833	5.000	7.417	8.083	10.250	11.667	8.083	10.250	11.667	7.750	10.000	11.583
A5	5.750	8.250	10.250	2.833	5.083	7.583	1.500	3.333	5.917	1.167	2.917	5.250	1.167	2.917	5.250	1.167	2.917	5.250	6.250	8.667	10.583	1.167	2.917	5.250	1.167	2.917	5.250	1.667	3.167	5.417
	W11			**W12**			**W13**			**W14**			**W15**			**W16**			**W17**			**W18**			**W19**			**W20**		
	0.038	0.069	0.132	0.056	0.103	0.191	0.051	0.094	0.174	0.069	0.128	0.230	0.055	0.101	0.186	0.083	0.150	0.265	0.039	0.069	0.128	0.040	0.071	0.132	0.053	0.096	0.172	0.060	0.108	0.190
	c11			**C21**			**C22**			**C23**			**C24**			**C25**			**C26**			**C27**			**C28**			**C29**		
A1	0.833	2.333	4.583	1.000	2.417	4.583	5.250	7.750	10.000	3.417	5.750	8.167	2.833	5.000	7.417	6.167	8.417	10.250	2.833	5.000	7.417	0.833	2.333	4.583	3.083	5.417	7.833	1.000	2.667	4.917
A2	6.917	9.250	11.000	0.750	2.000	4.000	1.500	3.417	5.750	1.083	2.417	4.500	6.250	8.667	10.583	1.583	3.417	5.750	1.000	2.667	4.917	6.917	9.250	11.000	1.250	2.833	5.167	4.500	6.917	9.250
A3	2.500	4.667	7.083	2.833	5.083	7.583	3.167	5.417	7.833	1.833	3.750	6.083	6.750	9.083	10.833	1.000	2.667	4.917	4.500	6.917	9.250	2.500	4.667	7.083	5.750	8.250	10.250	3.667	6.083	8.333

A4	0.500	1.667	3.750	4.917	7.417	9.750	7.750	10.000	11.583	7.083	9.417	11.167	3.250	5.583	8.000	4.500	6.917	9.250	8.083	10.250	11.667	0.500	1.667	3.750	2.833	5.000	7.417	7.917	10.167	11.667
A5	6.417	8.750	10.583	1.000	2.667	4.917	1.667	3.167	5.417	2.833	5.000	7.417	7.083	9.417	11.167	3.667	6.083	8.333	1.167	2.917	5.250	6.417	8.750	10.583	6.250	8.667	10.583	2.833	5.083	7.583
	W21			**W22**			**W23**			**W24**			**W25**			**W26**			**W21**			**W22**			**W23**			**W24**		
	0.044	0.079	0.147	0.123	0.214	0.373	0.117	0.206	0.358	0.125	0.220	0.376	0.123	0.216	0.375	0.088	0.145	0.254	0.044	0.079	0.147	0.123	0.214	0.373	0.117	0.206	0.358	0.125	0.220	0.376
	c210			**C31**			**C32**			**C33**			**C34**			**C35**														
A1	1.167	2.667	5.000	7.083	9.417	11.167	0.833	2.333	4.583	2.500	4.667	7.083	1.167	2.667	5.000	3.250	5.583	8.000												
A2	6.750	9.083	10.833	1.500	3.333	5.917	6.917	9.250	11.000	0.500	1.667	3.750	6.750	9.083	10.833	7.083	9.417	11.167												
A3	3.250	5.583	8.000	3.250	5.583	8.000	2.500	4.667	7.083	6.417	8.750	10.583	3.250	5.583	8.000	1.500	3.333	5.917												
A4	7.083	9.417	11.167	7.083	9.417	11.167	0.500	1.667	3.750	6.917	9.250	11.000	7.083	9.417	11.167	6.917	9.250	11.000												
A5	1.500	3.333	5.917	1.500	3.333	5.917	6.417	8.750	10.583	0.833	2.333	4.583	1.500	3.333	5.917	0.833	2.333	4.583												

Table 4.16. Integrated matrix

Step 3 : Normalized performance of suppliers versus criteria. For simplicity and practicality, all of the fuzzy numbers in this thesis are defined in the closed interval [0, 1]. Consequently, the normalization procedure is no longer needed.

	W1									W2									W3									W4		
	0.051	0.096	0.177	0.052	0.098	0.180	0.060	0.113	0.209	0.052	0.098	0.181	0.067	0.123	0.219	0.039	0.070	0.130	0.039	0.071	0.132	0.051	0.093	0.170	0.050	0.092	0.164	0.043	0.078	0.148
	C1			**C2**			**C3**			C4			**C5**			**C6**			C7			**C8**			**C9**			C10		
A1	0.122	0.149	0.203	0.203	0.375	1.000	0.104	0.239	0.448	0.243	0.429	0.636	0.114	0.139	0.189	0.100	0.229	0.429	0.291	0.512	0.740	0.086	0.229	0.421	0.243	0.429	0.636	0.453	0.669	0.863
A2	0.217	0.366	0.789	0.108	0.145	0.222	0.604	0.813	0.970	0.536	0.743	0.907	0.203	0.341	0.737	0.579	0.779	0.929	0.118	0.268	0.488	0.386	0.593	0.793	0.086	0.229	0.421	0.129	0.295	0.496
A3	0.160	0.231	0.405	0.120	0.164	0.273	0.291	0.500	0.716	0.286	0.493	0.693	0.144	0.203	0.350	0.279	0.479	0.686	0.543	0.780	0.969	0.386	0.593	0.793	0.386	0.593	0.793	0.273	0.468	0.676
A4	0.242	0.441	1.000	0.086	0.098	0.126	0.634	0.843	1.000	0.693	0.879	1.000	0.100	0.114	0.144	0.693	0.879	1.000	0.268	0.472	0.701	0.693	0.879	1.000	0.693	0.879	1.000	0.669	0.863	1.000
A5	0.122	0.152	0.217	0.132	0.197	0.353	0.134	0.299	0.530	0.100	0.250	0.450	0.222	0.400	1.000	0.100	0.250	0.450	0.591	0.819	1.000	0.100	0.250	0.450	0.100	0.250	0.450	0.144	0.273	0.468
	W11			W12			W13			W14			W15			W16			W17			W18			W19			W20		
	0.038	0.069	0.132	0.056	0.103	0.191	0.051	0.094	0.174	0.069	0.128	0.230	0.055	0.101	0.186	0.083	0.150	0.265	0.039	0.069	0.128	0.040	0.071	0.132	0.053	0.096	0.172	0.060	0.108	0.190
	C110			C11			C21			C22			C23			C24			C25			C26			C27			c28		
A1	0.076	0.212	0.417	0.103	0.248	0.470	0.453	0.669	0.863	0.306	0.515	0.731	0.254	0.448	0.664	0.602	0.821	1.000	0.135	0.200	0.353	0.076	0.212	0.417	0.291	0.512	0.740	0.086	0.229	0.421

A2	0.629	0.841	1.000	0.077	0.205	0.410	0.129	0.295	0.496	0.097	0.216	0.403	0.560	0.776	0.948	0.154	0.333	0.561	0.203	0.375	1.000	0.629	0.841	1.000	0.118	0.268	0.488	0.386	0.593	0.793
A3	0.227	0.424	0.644	0.291	0.521	0.778	0.273	0.468	0.676	0.164	0.336	0.545	0.604	0.813	0.970	0.098	0.260	0.480	0.108	0.145	0.222	0.227	0.424	0.644	0.543	0.780	0.969	0.314	0.521	0.714
A4	0.045	0.152	0.341	0.504	0.761	1.000	0.669	0.863	1.000	0.634	0.843	1.000	0.291	0.500	0.716	0.439	0.675	0.902	0.086	0.098	0.124	0.045	0.152	0.341	0.268	0.472	0.701	0.679	0.871	1.000
A5	0.583	0.795	0.962	0.103	0.274	0.504	0.144	0.273	0.468	0.254	0.448	0.664	0.634	0.843	1.000	0.358	0.593	0.813	0.190	0.343	0.857	0.583	0.795	0.962	0.591	0.819	1.000	0.243	0.436	0.650
	W21			W22			W23			W24			W25			W26			W21			W22			W23			W24		
	0.044	0.079	0.147	0.123	0.214	0.373	0.117	0.206	0.358	0.125	0.220	0.376	0.123	0.216	0.375	0.088	0.145	0.254	0.044	0.079	0.147	0.123	0.214	0.373	0.117	0.206	0.358	0.125	0.220	0.376
	c29			c210			C31			C32			C33			C34			C35											
A1	0.104	0.239	0.448	0.634	0.843	1.000	0.076	0.212	0.417	0.227	0.424	0.644	0.104	0.239	0.448	0.291	0.500	0.716	0.104	0.239	0.448									
A2	0.604	0.813	0.970	0.134	0.299	0.530	0.629	0.841	1.000	0.045	0.152	0.341	0.604	0.813	0.970	0.634	0.843	1.000	0.604	0.813	0.970									
A3	0.291	0.500	0.716	0.291	0.500	0.716	0.227	0.424	0.644	0.583	0.795	0.962	0.291	0.500	0.716	0.134	0.299	0.530	0.291	0.500	0.716									
A4	0.634	0.843	1.000	0.634	0.843	1.000	0.045	0.152	0.341	0.629	0.841	1.000	0.634	0.843	1.000	0.619	0.828	0.985	0.634	0.843	1.000									
A5	0.134	0.299	0.530	0.134	0.299	0.530	0.583	0.795	0.962	0.076	0.212	0.417	0.134	0.299	0.530	0.075	0.209	0.410	0.134	0.299	0.530									

Table 4.17. Normalized matrix

Step 3: Calculate normalized weighted rating. Using Eq. (17), the normalized weighted ratings Gi can be obtained as shown in **Table 4.18.**

	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10		
A1	0.006	0.014	0.036	0.011	0.037	0.180	0.006	0.027	0.094	0.013	0.042	0.115	0.008	0.017	0.041	0.004	0.016	0.056	0.011	0.036	0.098	0.004	0.021	0.072	0.012	0.039	0.104	0.019	0.052	0.128
A2	0.011	0.035	0.140	0.006	0.014	0.040	0.036	0.092	0.203	0.028	0.073	0.164	0.014	0.042	0.161	0.022	0.054	0.121	0.005	0.019	0.065	0.020	0.055	0.135	0.004	0.021	0.069	0.006	0.023	0.074
A3	0.008	0.022	0.072	0.006	0.016	0.049	0.017	0.057	0.150	0.015	0.048	0.125	0.010	0.025	0.076	0.011	0.033	0.089	0.021	0.055	0.128	0.020	0.055	0.135	0.019	0.054	0.130	0.012	0.037	0.100
A4	0.012	0.042	0.177	0.004	0.010	0.023	0.038	0.095	0.209	0.036	0.086	0.181	0.007	0.014	0.032	0.027	0.061	0.130	0.010	0.033	0.093	0.035	0.082	0.170	0.035	0.081	0.164	0.029	0.068	0.148
A5	0.006	0.014	0.039	0.007	0.019	0.063	0.008	0.034	0.111	0.005	0.024	0.081	0.015	0.049	0.219	0.004	0.017	0.059	0.023	0.058	0.132	0.005	0.023	0.076	0.005	0.023	0.074	0.006	0.021	0.069
	C11			C21			C22			C23			C24			C25			C26			C27			C28			C29		
A1	0.003	0.015	0.055	0.006	0.026	0.090	0.023	0.063	0.150	0.021	0.066	0.168	0.014	0.045	0.124	0.050	0.123	0.265	0.005	0.014	0.045	0.003	0.015	0.055	0.016	0.049	0.128	0.005	0.025	0.080
A2	0.024	0.058	0.132	0.004	0.021	0.078	0.007	0.028	0.086	0.007	0.028	0.093	0.031	0.079	0.177	0.013	0.050	0.149	0.008	0.026	0.128	0.025	0.060	0.132	0.006	0.026	0.084	0.023	0.064	0.151
A3	0.009	0.029	0.085	0.016	0.054	0.149	0.014	0.044	0.118	0.011	0.043	0.125	0.033	0.082	0.181	0.008	0.039	0.127	0.004	0.010	0.028	0.009	0.030	0.085	0.029	0.075	0.167	0.019	0.056	0.136
A4	0.002	0.011	0.045	0.028	0.079	0.191	0.034	0.082	0.174	0.044	0.108	0.230	0.016	0.051	0.133	0.037	0.101	0.240	0.003	0.007	0.016	0.002	0.011	0.045	0.014	0.046	0.121	0.040	0.094	0.190
A5	0.022	0.055	0.127	0.006	0.028	0.096	0.007	0.026	0.081	0.017	0.057	0.153	0.035	0.085	0.186	0.030	0.089	0.216	0.007	0.024	0.109	0.023	0.056	0.127	0.032	0.079	0.172	0.014	0.047	0.124

	C210			C31			C32			C33			C34			C35														
A1	0.005	0.019	0.066	0.078	0.180	0.373	0.009	0.044	0.149	0.029	0.093	0.242	0.013	0.052	0.168	0.026	0.073	0.182												
A2	0.027	0.064	0.143	0.016	0.064	0.197	0.074	0.173	0.358	0.006	0.033	0.128	0.074	0.175	0.364	0.056	0.123	0.254												
A3	0.013	0.039	0.105	0.036	0.107	0.267	0.027	0.087	0.231	0.073	0.175	0.362	0.036	0.108	0.269	0.012	0.043	0.135												
A4	0.028	0.066	0.147	0.078	0.180	0.373	0.005	0.031	0.122	0.079	0.185	0.376	0.078	0.182	0.375	0.055	0.120	0.251												
A5	0.006	0.023	0.078	0.016	0.064	0.197	0.068	0.164	0.345	0.010	0.047	0.157	0.016	0.064	0.199	0.007	0.030	0.104												

Table 4.18. Weighted normalized matrix

Step 4 and 5: Calculate $A+$, $A-$, Di+, and Di−. As shown in **Table 4.19 and 4.20**, the distance of each green supplier from $A+$ and $A-$ can be calculated by Eq. (20), (21).

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26
A1	0.981	0.927	0.958	0.944	0.978	0.975	0.952	0.968	0.949	0.935	0.976	0.960	0.923	0.917	0.940	0.858	0.979	0.976	0.937	0.964	0.971	0.799	0.935	0.883	0.925	0.909
A2	0.940	0.980	0.892	0.914	0.930	0.935	0.971	0.931	0.969	0.966	0.930	0.966	0.960	0.958	0.907	0.931	0.948	0.929	0.962	0.922	0.924	0.911	0.807	0.946	0.805	0.860
A3	0.966	0.976	0.927	0.938	0.963	0.956	0.933	0.931	0.933	0.951	0.960	0.929	0.942	0.941	0.903	0.943	0.986	0.959	0.911	0.931	0.948	0.869	0.889	0.806	0.868	0.938
A4	0.925	0.988	0.889	0.901	0.983	0.928	0.955	0.906	0.908	0.920	0.981	0.903	0.905	0.876	0.935	0.878	0.991	0.981	0.941	0.894	0.921	0.799	0.948	0.796	0.798	0.862
A5	0.980	0.970	0.950	0.964	0.910	0.974	0.930	0.966	0.966	0.968	0.933	0.957	0.962	0.926	0.900	0.892	0.954	0.932	0.908	0.939	0.965	0.911	0.816	0.931	0.910	0.954

S1+	24.4196
S2+	24.0922
S3+	24.2005
S4+	23.7138
S5+	24.3683

Table 4.19. D+

	C1	C2	C3	C4	C5	C6	C7	C8	C9		C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26
A1	0.023	0.106	0.056	0.071	0.026	0.034	0.061	0.043	0.065		0.081	0.033	0.054	0.095	0.105	0.027	0.171	0.027	0.033	0.079	0.049	0.040	0.243	0.090	0.151	0.102	0.114
A2	0.084	0.025	0.130	0.105	0.096	0.078	0.039	0.085	0.042		0.045	0.084	0.047	0.053	0.056	0.049	0.091	0.075	0.085	0.051	0.095	0.092	0.120	0.233	0.077	0.237	0.166
A3	0.044	0.030	0.093	0.078	0.047	0.055	0.082	0.085	0.082		0.062	0.052	0.092	0.073	0.077	0.051	0.077	0.018	0.052	0.107	0.086	0.065	0.167	0.143	0.236	0.168	0.082
A4	0.106	0.014	0.134	0.117	0.020	0.085	0.057	0.111	0.108		0.095	0.027	0.120	0.113	0.149	0.031	0.152	0.010	0.027	0.075	0.125	0.095	0.243	0.073	0.246	0.245	0.164
A5	0.024	0.038	0.067	0.049	0.130	0.035	0.084	0.046	0.045		0.042	0.081	0.058	0.050	0.095	0.053	0.136	0.065	0.081	0.111	0.077	0.047	0.120	0.224	0.095	0.121	0.063

S1-	1.9787	
S2-	2.3390	
S3-	2.2040	
S4-	2.7405	
S5-	2.0369	

Table 4.20. D-

Step 6: Obtain the closeness coefficient. The closeness coefficients of green suppliers can be calculated by Eq. (22), as shown in **Table 4.21**. Therefore, the ranking order of the five green suppliers is *A*4 > *A*2 > *A*3 > *A*5 > A1. Consequently, the best green supplier is *A*4.

Rank of Alternatives			
A1	0.0750	**0.0750**	**5**
A2	0.0885	**0.0885**	**2**
A3	0.0835	**0.0835**	**3**
A4	0.1036	**0.1036**	**1**
A5	0.0771	**0.0771**	**4**

Table 4.21. Closeness coefficient of alternatives

As can be seen in **Table 4.21**, the rank of green suppliers based on the weights of their evaluation criteria are determined. Thus, this table can not only show the best green supplier, but also help to analyze the suppliers that fail to meet the specifications of the case business. **Table 4.21** demonstrate supplier A4 is the best choice, supplier A2, A3, A5 are respectively and the last is supplier 5. In general, supplier A4 is the most suitable when compare with sub-criteria are proposed.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

5.1. Conclusions

Green-oriented cooperation in every aspects of the supply chain has become a leading component as global awareness of environmental sustainability grows. Since environmental sustainability and sustainable growth are becoming increasingly important in different industries, a successful green supply selection strategy will help a business reduce environmental risks while still increasing its competitiveness. For supplier selection, a variety of individual and integrated approaches have been suggested. Many sets of criteria have since been developed to optimize this procedure. While there are many studies that consider the supplier selection, there are just a limited number that examine at environmental issues. The lack of awareness issue in the dispersed parameters assessing green-oriented supplier selection was supported by a study of the literature. As a result, the presented thesis includes a productive attempt to perform a systematic and reliable bibliometric study for green-oriented supplier selection.

This thesis suggests a novel approach for managers to select suppliers in a heterogeneous knowledge context based on the MCDM model. The evaluation values of candidate suppliers were defined in this model as economic, social and environmental with each category of information representing a different criterion. Then, to rank the candidate suppliers, the classic Fuzzy AHP and Fuzzy TOPSIS process was generalized and paired with the optimizing consensus approach. An empirical example from the automotive industry was presented, along with a comparative study with the extent methods, to show the utility of our proposed green supplier selection model. The results indicate that the proposed model's underlying concept is appropriate to managers and decision-makers, and that it is more suited to represent decision features and more in line with expert expectations in the real-world sustainable supplier selection process.

Various assessment criteria were selected from the literature and after consulting with industry experts. By combining the expert's inputs, aggregated pair-wise comparison matrices were developed, from which weights were calculated using Chang's extended form of Fuzzy AHP procedure. Cost, green technology, health and safety were the assessment criteria that earned the highest weight priority in this study, and were later used as inputs for the Fuzzy TOPSIS in order to pick the possible supplier. **Table 4.21** summarizes the empirical results from the case study using the proposed green supplier selection models. The priority values of the five suppliers considered, as well as their respective rankings, are presented in these results. With a priority value of 0.1036, Supplier

A4 was rated as the top supplier. A2, A3, A5, and A1 are the next suppliers, in that order. Despite the fact that A4 was chosen as the best supplier among the candidates and is recommended for contracting by the automaker, the supplier received low ratings on some evaluation criteria. The consistency test was also performed for the purpose to check the consistency of the expert's inputs. Organizations will use the results of the supplier assessment to boost the efficiency of their suppliers.

For future research, these MCDM models can also handle the complex and unpredictable environment of future studies by incorporating novel factors causing change. To assess the general relevance of the findings, this study may be extended to real supply chain cases in sectors such as electronics, textiles, dairy, and oil & gas. Different decision-making techniques, such as VIKOR, PROMETHEE, and GRA, may be used in future studies. The suggested model has a flaw in that subsystems aligned with the criteria are not taken into account when minimizing complexity. While many efforts have been made to select green suppliers, keeping the environment in mind remains a challenge. In addition, future studies will be needed to determine how to assign orders to the model's prospective green suppliers.

5.2. Managerial implications

For both researchers and practitioners in the field of GSCM, this thesis has some administrative and theoretical implications. The automobile manufacturer may involve complex post-selection discussions with the chosen supplier to see how certain lower-rated performance requirements can be improved using the other suppliers as a benchmark. In addition, the obtained results can be used as a guideline for the organization's supply chain, meaning that no irrelevant suppliers are permitted to join the supply chain. This would result in significant resource and expense savings, as well as a reduction in environmental impacts.

From a theoretical standpoint, the green supplier selection model built in this research provides the following benefits. First, heterogeneous knowledge is used to handle the evaluation values on various criteria for different features. This is more appropriate for complicated green supplier selection functions, and it also helps decision-makers to express their assessments about the information types that they prefer. Second, to assess the weight of each decision-maker, a maximizing consensus approach based on an optimization model is proposed. It will deal with situations where expert weight knowledge is only partially understood a priori. Third, to rate and select the most desired green provider, an expanded

MCDM approach is used. The suggested green supplier selection methods do not necessitate extensive computations but still provides a fair and reliable solution result. All of the criteria listed will assist organizations in coping with a range of problems and strengthening their attempts to produce environmentally sustainable products. Furthermore, the creation of GSS assessment standards using industry expert responses and literature is a major benefit of this proposed work. Managers will be able to test the observation stability using the applied data set.

This research also has practical implications for practitioners. Firstly, it provides some possible advantages by assisting managers in properly allocating green marketing behavior. A strategic green marketing dimension appears to be an important component of a green marketing campaign because it shows top management's long-term engagement and involvement in environmental strategies. That is, strategic initiatives such as low-carbon energy investment and R&D-related projects may be considered future priorities in a green marketing-oriented organization's business strategy. Second, while the thorough review of green criteria by inspections are crucial to verify that new suppliers comply, continuous audits are essential to foster GSCM success and collaborative efforts with legacy suppliers. The role of empowering SC partners in the achievement and success of GSCM should be understood by focal firms. Third, our findings suggest that Corporate social responsibility (CSR) could be essential, but the latter demands a distinct strategy due to the marketing-related tasks involved. In fact, this means that while a CSR policy is essential, it is not enough to plan and execute a green marketing strategy. This implies that tactical activities (such as the use of recycled products and green pricing policies) provide managers with the ability to a) improve their firm's green brand profile in the short-medium term and b) adjust their green marketing policy in response to external and internal environmental changes.

5.3. Limitations of this thesis

This study used FAHP and FTOPSIS methods to evaluate and select any green supplier which is the most suitable based on main criteria and sub-criteria. In those models, the evaluation based on results of weighting and ranking of different criteria. From previous research of experts, sub-criteria are presented as an important determinant when a business select green suppliers. However, there are some limits to this research which should be discussed in future studies.

Firstly, exact weights are used in this thesis to represent the relative importance and ranking of criteria. However, weight elicitation may be complicated in some cases, and imprecise data, such as weight intervals, fuzzy weights, or ordinal data, may be involved in the GSS challenge. In future research, it is proposed that criteria weights be evaluated using heterogeneous data. Second, in our proposed model, the assessment criteria are assumed to be independent. We failed to consider the scope for interactions and relationships between the sub-criteria. This research indicated that there are three main criteria but the assessment of each criteria and its sub-criteria is desultory. The subjective reason is AHP method suggests there must not be an excessive amount of 11 criteria. Future studies should take these considerations into account in order to create a more competitive green supplier range. The future research should be pursued in the hopes of applying the proposed methodology to other production and management decision-making issues, such as product design selection, position selection, office layouts, material replacement selection, versatile manufacturing processes, etc. As a result, future study projects would be able to figure out how to integrate the relationships between criteria into the green supplier selection decision process.

Furthermore, only one instance of the problem is used to demonstrate the developed green supplier selection model. Future studies may include a numerical experiment with a large number of cases to confirm the applicability and efficacy of the proposed green supplier selection method. Third, the psychological behaviors of the decision maker, which are essential considerations, were taken into account in the proposed process. However, authors of this thesis could not arrange meeting with more than 12 the high-level executives of automotive manufacturing companies. To be specific, not as expecting in the beginning process of conducting interview, authors could only have the chance to interview with 2 experts in the industry, and the others are development engineers, purchasing department, and team leaders which is not directly involved in the GSS process.

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APPENDIX

Fuzzy number	Linguistic	Triangular fuzzy scale $M = (l, m, u)$
1	Equal	(1,1,1)
2	Weak advantage	(1,2,3)
3	Not bad	(2,3,4)
4	Preferable	(3,4,5)
5	Good	(4,5,6)
6	Fairly good	(5,6,7)
7	Very good	(6,7,8)
8	Absolute	(7,8,9)
9	Perfect	(8,9,10)

With respect to the overall three group

Q1: How important is Economic (C1) when it is compared with Environmental (C2)?

Q2: How important is Economic (C1) when it is compared with Social (C3)?

Q3: How important is Environmental (C2) when it is compared with Social (C3)?

With respect to the main attribute "Economic"

Q4: How important is Cost (C11) when it is compared with Delivery (C12)?

Q5: How important is Cost (C11) when it is compared with Service level (C13)?

Q6: How important is Cost (C11) when it is compared with Quality (C14)?

Q7: How important is Cost (C11) when it is compared with Staff training (C15)?

Q8: How important is Cost (C11) when it is compared with Technology (C16)?

Q9: How important is Cost (C11) when it is compared with Flexibility (C17)?

Q10: How important is Cost (C11) when it is compared with Financial capability (C18)?

Q11: How important is Cost (C11) when it is compared with Culture (C19)?

Q12: How important is Cost (C11) when it is compared with Innovativeness (C110)?

Q13: How important is Cost (C11) when it is compared with Relationship (C111)?

Q14: How important is Delivery (C12) when it is compared with Service level (C13)?

Q15: How important is Delivery (C12) when it is compared with Quality (C14)?

Q16: How important is Delivery (C12) when it is compared with Staff training (C15)?

Q17: How important is Delivery (C12) when it is compared with Technology (C16)?

Q18: How important is Delivery (C12) when it is compared with Flexibility (C17)?

Q19: How important is Delivery (C12) when it is compared with Financial capability (C18)?

Q20: How important is Delivery (C12) when it is compared with Cultural (C19)?

Q21: How important is Delivery (C12) when it is compared with Innovativeness (C110)?

Q22: How important is Delivery (C12) when it is compared with Relationship (C111)?

Q23: How important is Service level (C13) when it is compared with Quality (C14)?

Q24: How important is Service level (C13) when it is compared with Staff training (C15)?

Q25: How important is Service level (C13) when it is compared with Technology (C16)?

Q26: How important is Service level (C13) when it is compared with Flexibility (C17)?

Q27: How important is Service level (C13) when it is compared with Financial capability (C18)?

Q28: How important is Service level (C13) when it is compared with Cultural (C19)?

Q29: How important is Service level (C13) when it is compared with Innovativeness (C110)?

Q30: How important is Service level (C13) when it is compared with Relationship (C111)?

Q31: How important is Quality (C14) when it is compared with Staff training (C15)?

Q32: How important is Quality (C14) when it is compared with Technology (C16)?

Q33: How important is Quality (C14) when it is compared with Flexibility (C17)?

Q34: How important is Quality (C14) when it is compared with Financial capability (C18)?

Q35: How important is Quality (C14) when it is compared with Cultural (C19)?

Q36: How important is Quality (C14) when it is compared with Innovativeness (C110)?

Q37: How important is Quality (C14) when it is compared with Relationship (C111)?

Q38: How important is Staff training (C15) when it is compared with Technology (C16)?

Q39: How important is Staff training (C15) when it is compared with Flexibility (C17)?

Q40: How important is Staff training (C15) when it is compared with Financial capability (C18)?

Q41: How important is Staff training (C15) when it is compared with Cultural (C19)?

Q42: How important is Staff training (C15) when it is compared with Innovativeness (C110)?

Q43: How important is Staff training (C15) when it is compared with Relationship (C111)?

Q44: How important is Technology (C16) when it is compared with Flexibility (C17)?

Q45: How important is Technology (C16) when it is compared with Financial capability (C18)?

Q46: How important is Technology (C16) when it is compared with Cultural (C19)?

Q47: How important is Technology (C16) when it is compared with Innovativeness (C110)?

Q48: How important is Technology (C16) when it is compared with Relationship (C111)?

Q49: How important is Flexibility (C17) when it is compared with Financial capability (C18)?

Q50: How important is Flexibility (C17) when it is compared with Cultural (C19)?

Q51: How important is Flexibility (C17) when it is compared with Innovativeness (C110)?

Q52: How important is Flexibility (C17) when it is compared with Relationship (C111)?

Q53: How important is Financial capability (C18) when it is compared with Cultural (C19)?

Q54: How important is Financial capability (C18) when it is compared with Innovativeness (C110)?

Q55: How important is Financial capability (C18) when it is compared with Relationship (C111)?

Q56: How important is Cultural (C19) when it is compared with Innovativeness (C110)?

Q57: How important is Cultural (C19) when it is compared with Relationship (C111)?

Q58: How important is Innovativeness (C110) when it is compared with Relationship (C111)?

With respect to the main attribute "Environmental"

Q59: How important is Green products (C21) when it is compared with Green image (C22)?

Q60: How important is Green products (C21) when it is compared with Eco – design (C23)?

Q61: How important is Green products (C21) when it is compared with Management commitment (C24)?

Q62: How important is Green products (C21) when it is compared with Green technology (C25)?

Q63: How important is Green products (C21) when it is compared with Recycle (C27)?

Q64: How important is Green products (C21) when it is compared with Re-manufacturing (C28)?

Q65: How important is Green products (C21) when it is compared with Environmental management system (C29)?

Q66: How important is Green products (C21) when it is compared with Resource Consumption (C210)?

Q67: How important is Green image (C22) when it is compared with Eco-design (C23)?

Q68: How important is Green image (C22) when it is compared with Management commitment (C24)?

Q69: How important is Green image (C22) when it is compared with Green Technology (C25)?

Q70: How important is Green image (C22) when it is compared with Pollution control (C26)?

Q71: How important is Green image (C22) when it is compared with Recycle (C27)?

Q72: How important is Green image (C22) when it is compared with Re-manufacturing (C28)?

Q73: How important is Green image (C22) when it is compared with Environmental management system (C29)?

Q74: How important is Green image (C22) when it is compared with Resource consumption (C210)?

Q75: How important is Eco - design (C23) when it is compared with Management commitment (C24)?

Q76: How important is Eco - design (C23) when it is compared with Green technology (C25)?

Q77: How important is Eco - design (C23) when it is compared with Recycle (C26)?

Q78: How important is Eco - design (C23) when it is compared with Re-manufacturing (C28)?

Q79: How important is Eco - design (C23) when it is compared with Environmental management system (C29)?

Q80: How important is Eco - design (C23) when it is compared with Resource consumption (C210)?

Q81: How important is Management commitment (C24) when it is compared with Green Technology (C25)?

Q82: How important is Management commitment (C24) when it is compared with Green Technology (C25)?

Q83: How important is Management commitment (C24) when it is compared with Pollution control (C26)?

Q84: How important is Management commitment (C24) when it is compared with Recycle (C27)?

Q85: How important is Management commitment (C24) when it is compared with Re-manufacturing (C28)?

Q86: How important is Management commitment (C24) when it is compared with Environmental management system (C29)?

Q87: How important is Management commitment (C24) when it is compared with Resource consumption (C210)?

Q88: How important is Green Technology (C25) when it is compared with Pollution control (C26)?

Q89: How important is Green Technology (C25) when it is compared with Recycle (C27)?

Q90: How important is Green Technology (C25) when it is compared with Re-manufacturing (C28)?

Q91: How important is Green Technology (C25) when it is compared with Environmental management system (C29)?

Q92: How important is Green Technology (C25) when it is compared with Resource consumption (C210)?

Q93: How important is Pollution control (C26) when it is compared with Recycle (C27)?

Q94: How important is Pollution control (C26) when it is compared with Re-manufacturing (C28)?

Q95: How important is Pollution control (C26) when it is compared with Environmental management system (C29)?

Q96: How important is Pollution control (C26) when it is compared with Resource consumption (C210)?

Q97: How important is Recycle (C27) when it is compared with Re-manufacturing (C28)?

Q98: How important is Recycle (C27) when it is compared with Environmental management system (C29)?

Q99: How important is Recycle (C27) when it is compared with Resource consumption (C210)?

Q100: How important is Re-manufacturing (C28) when it is compared with Environmental management system (C29)?

Q101: How important is Re-manufacturing (C28) when it is compared with Resource consumption (C210)?

Q102: How important is Environmental management system (C29) when it is compared with Resource consumption (C210)?

With respect to the main attribute "Social"

Q103: How important is Human resource management (C31) when it is compared with Corporate social responsibility (C32)?

Q104: How important is Human resource management (C31) when it is compared with Health and safety (C33)?

Q105: How important is Human resource management (C31) when it is compared with Human right issues (C34)?

Q106: How important is Human resource management (C31) when it is compared with Relationship with stakeholders (C35)?

Q107: How important is Corporate social responsibility (C32) when it is compared with Health and safety (C33)?

Q108: How important is Corporate social responsibility (C32) when it is compared with Human right issues (C34)?

Q109: How important is Corporate social responsibility (C32) when it is compared with Relationship with stakeholders (C35)?

Q110: How important is Health and safety (C33) when it is compared with Human right issues (C34)?

Q111: How important is Health and safety (C33) when it is compared with Relationship with stakeholders (C35)?

Q112: How important is Human right issues (C34) when it is compared with Relationship with stakeholders (C35)?