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Prioritization of Sustainable Supply Chain Management Practices in an Automotive Elastomer Manufacturer in Thailand

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ABSTRACT

Nowadays the sustainable awareness trend is increasing. The consumers' attitude has changed, causing companies to pay more attention to management in a sustainable way. Effective sustainable supply chain management (SSCM) can increase social, economic, and environmental benefits. Important factors from literatures were gather and organized to be a framework for SSCM. The proposed framework incorporates the whole supply chain for both internal and external activities, which can be applied to a manufacturer. The case study factory, which is an automotive elastomer producer has planned to adopt SSCM, so it needs to know the main factors for its operations. Logarithmic fuzzy preference programming method (LFPP) was used to rank SSCM criteria. The results of ranking important criteria showed that external factors (government and competition) were the most significant criteria that the factory has determined. Government and competitors are significant drivers that initiate the company to implement SSCM. Regulations and standards were good guidelines to SSCM for the factory. Next, the Triple Bottom Line (TBL) criteria (social, economic, environment) were considered in the overall operations. Not only concerning about cost and profit, but also environmental effect and social responsibility are cooperated. Finally, internal factors (supplier, consumption, and company) were considered with low level of importance. The proposals of actions of the company were also shown as a guideline for a manufacturer.

1. Introduction

This paper is an extension of work of a similar concept presented initially in the ICIEA 2019 conference [1]. The previous work considered the criteria for green supply chain management (GSCM), while the current work extended the scope to sustainable supply chain management (SSCM). In this research, the main criteria for SSCM were collected and organized to be a new framework for an automotive elastomer factory [1–4].

The evolution of process flow management from raw materials to finished goods is known as supply chain management (SCM). SCM plays an important role in any organization's success. However, there are many operations in the supply chain, which cause environmental impact to the social communities. The concept of sustainability has gained increased popularity due to the increase in environmental problems. Organization's management strategies have to improve and adjust to the current world situation for survival and friendly environment by not destroying the environment and not harming social communities. The use of environmentally friendly raw materials in the most effective way is one of the interesting practices [5]. Moreover, the participation of communities by corporate social responsibility (CSR) activities or developing community projects, helps to ensure the longevity of the organization.

SSCM is effective management that considers economic, environmental, and social performances at the same time in the supply chain. The basic aim of GSCM is to eliminate all wastes within the industrial system and limit use of hazardous substances. The aims of SSCM concern not only profit but also environmental and social dimensions, called a Triple Bottom Line (TBL). Companies must consider environmental effects from

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processes in the supply chain such as purifying the toxic water or air emitted by the manufacturing process before releasing it to the environment to maintain good health in the community [6]. There are many pieces of research on case studies of SSCM. Some of them consider the specific operation in the supply chain such as supplier selection, reverse logistics, packing, etc [7–9]. However, the overall framework for SSCM for a supply chain needs to be clarified and important factors also need to be highlighted.

SSCM has various factors that affect the operations, which differ in each organization; also, the levels of action within each organization need to be considered differently too. Sari (2017) recommended considering inbound operations, production operations, outbound operations, and reverse logistics as primary criteria for the decision making in GSCM practices [10]. Uygun and Dede (2016) suggested a green design, green purchasing, green transformation, green logistics, and reverse logistics criteria. These activities are mainly concerned with environmental awareness [11]. Wu et al. (2020) and Mastrocinque et al. (2020) considered TBL as primary criteria throughout the SCM [12,13]**.** These criteria need to prioritize and formulate appropriate internal management strategies to achieve more benefit for the stakeholders in the most efficient way.

Multi-criteria decision making (MCDM) method is one of the most commonly used methods for ranking [14]. There are many methods of MCDM such as Analytical Hierarchy Process (AHP), Fuzzy Set Theory, Case-based Reasoning, Data Envelopment Analysis (DEA), Simple Multi-Attribute Rating Technique, Goal Programming, Simple Additive Weighting (SAW), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [15,16]. However, in evaluation criteria, the decision-maker may not be able to precisely decide the value for the decision, so the fuzzy set concept was proposed [17]. Then, many fuzzy methods for prioritization were presented [18]; these include the logarithmic least-squares method, geometric mean method, extent analysis method, lambda-max method, fuzzy preference programming method (FPP), linear goal programming method, and logarithmic fuzzy preference programming method (LFPP). Nevertheless, these methods still have some pitfalls to avoid [19–21]. The LFPP method has been chosen in this research to prioritize the criteria for three main reasons. The first reason is realistic computation; there is not an argument about this method from literature reviews. The second reason is that the data's consistency can be calculated, and can be re-evaluated over a short evaluation time. Finally, LFPP can maintain Saaty's AHP assessment rules in all aspects.

In this research, a case study of an automotive elastomer manufacturer was studied. Currently, the case study factory has already applied GSCM, but the management team desire to get a higher level of consideration about sustainability to survive in rapidly changing societies. The new goal of the factory is to implement SSCM in order to focus on social, economic, and environmental aspects. So, the main criteria that influence SSCM implementation should be investigated initially. A new framework of SSCM for the factory is presented. The organization's main objective is to achieve the lowest internal costs (the most profitable) and the least impact on the environment (using environmentally friendly raw materials and the most efficient use) to ensure that the product is green before releasing it to the market and consumers. Criteria were used to construct a new framework composed of SSCM factors for both internal and external factors, it can be used with any factory. All critical factors are integrated into the framework, which can satisfy the qualified policy of the factory. This research aims to prioritize the important criteria that affect the SSCM of the case study factory by use of LFPP, so that the factory can know which criteria should be emphasized and invested firstly. Then, the goals and direction can be clearly set. The proposals of actions of the factory also present in this research.

This research is organized as follows: Section 2 mentions the definition of SSCM and the detail about SSCM activities involved in the operations. Relevant literature was reviewed to determine the important criteria for SSCM of the case study. Section 3, calculation procedure by LFPP method is discussed. Section 4, the results from prioritization of the important criteria that affect the SSCM in this case study are deliberated. Conclusion, discussion, and future research are presented in section 5.

2. Sustainable Supply Chain Management

SSCM is an extension of GSCM, which mainly focuses on environmental, economic, and social dimensions [7]. These three dimensions are related to the Triple Bottom Line (TBL) principles [22], in which the perspectives are focused on the achievement and success of an organization in the economy, environment, and society as shown in Figure 1. They are the key to success of sustainable development, which needs to be balanced [13,22,23].

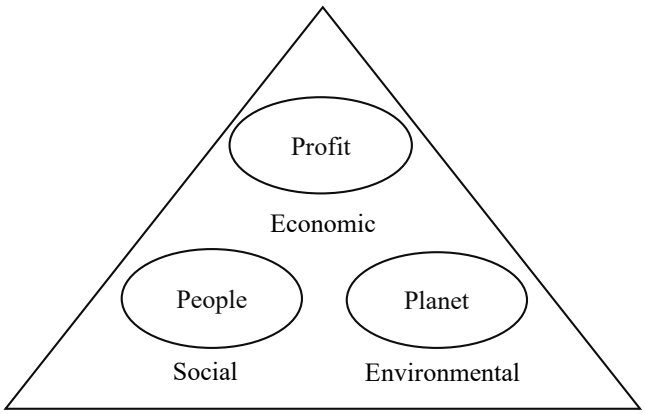

Figure 1: Triple bottom line for SSCM [24]

The objective of the organization previously only focused on profit, which cannot maintain sustainability. Many companies have turned to concern about people, societies, stakeholders, planet, and environmental responsibility. The TBL-based business aim is not only high profit, but also more consideration about the social and environmental problems. TBL shows profit at the top of the triangle. It is an economic dimension that almost all organizations desire.

The concept of people or humans in TBL is to emphasize fair business practices to the communities, employees, and societies by not causing harm to workers and people in the communities, but at the same time, the business has to make a profit for shareholders. Moreover, fair trade must be performed for the people dimension to balance with a social perspective.

Planet or natural dimension means a business should support sustainability and the diversity of the environment. The operations of the company must produce as little waste as possible from resources and must use recycling methods and reduce toxic gas and wastes to secure the environment and biodiversity, so the planet dimension is identical with an environmental perspective.

2.1. Sustainable activities

SSCM has comprehensive activities throughout the workflow processes. SSCM activities must care about social, economic, and environmental dimensions at the same time. These three perspectives incorporated with administrative activities start from planning strategies through to reverse logistics activities. They are described as follows:

- Sustainable strategy and planning: Strategic planning by top management is essential for organizations' initiative to improve and change [25]. If there is no strategic planning or goal setting, there is no direction that makes people understand the management intent [29, 30]. The implementation of SSCM defines the company's goal to sustainability, in which everyone should adhere to the three perspectives: social, economic, and the environment in all operations.
- Sustainable design: The design is not only for recyclable packaging or readily biodegradable products [8,28,29]; SSCM's sustainability design goes beyond that. Green design is a comprehensive design across SCM that is the best starting point for green purchasing, green production, green packaging, and green logistics. In recent years, biodegradable materials from renewable natural resources have received extensive government support.
- Sustainable purchasing: The purchasing managers need to be aware of sustainable raw materials that have to be compared among suppliers. There are many factors to be concerned about, which are cost, delivery, quality, environmentally friendly products, and value. Besides, the company also has the freedom to choose suppliers and avoid bribery from suppliers [7].
- Sustainable production: The production process design has many points to consider [8], such as a suitable location for machinery to reduce energy consumption or less fuel consumption and to get the best performance, type of source of energy, the amount of waste produced by the production [30].
- Sustainable packaging: The essential feature of product packaging is the ability to protect products from contamination damage, and deterioration. The packaging design may include special techniques to make good quality packaging, which is designed according to the 3R theory, which is recyclable (the product can be modified and reuse), reduce (reduce the use of raw materials in the production of packaging or the product itself), and reuse (the product or packaging can be reused). Also, packaging design should be easily disassembled for digestibility and create as low waste material percentage as possible [8,28,30]. Moreover, biodegradable packaging is also a favorite choice for manufacturers.
- Sustainable logistics: The green logistics design process has many points to consider, such as the design of the distribution route for the most efficient transportation, the minimization of the number of trips [31,32], the reduction of transport cost, the volume of the empty return transport called backhauling [33], the selection of transport vehicles to reduce CO_2 emissions that cause environmental impact [34], the selection of third-party logistics service providers [35], the warehouse design for convenient loading and unloading of products without congestion, and the reduction of waiting time and administrative costs [28]. If sustainable logistics can be applied, it can cover three perspectives, which are social perspectives such as management of traffic congestion, economic perspective by reducing the transportation cost and transportation fuel consumption, and environment perspective by reducing the number of transportation trips and distances to reduce the greenhouse gas emission.
- Sustainable consumption: Determine how to consume the raw materials in the right way to minimize the processes that bring environmental pollution. The instructions must be written in words that are easily understood. The company must analyze consumer trends, consumer characteristics [36], customer green preference [37,38], and consumer purchase behavior [39] of the new generation of people who are becoming increasingly influential in the global green and sustainable market [40].
- Sustainable reverse logistics: Due to the increasing environmental impact today, various industries need more control over the amount of waste from the production processes [9]. Controlling waste is a waste management process that needs to delve into great detail to achieve the most efficient reduction in pollution and use resources efficiently [28]. Therefore, setting up a waste center is needed to receive the used products to facilitate consumers and initiate reverse logistics to be more successful [40].

2.2. Sustainable criteria for implementation

Every activity consists of essential components; for example, green purchasing has a vital role in choosing which supplier is suitable to deliver material that satisfies the company's qualification standards. Therefore, a review of the critical criteria that directly affect SSCM activities must be compiled to cover all management practices. In the previous work, the guidelines for GSCM were proposed [1]. There are 6 criteria: government, competitor, social, supplier, customer, and company to prioritize the criteria that are important to GSCM. Further pieces of literature have proposed more criteria for SSCM. These criteria can be incorporated to construct the SSCM framework for defining an action plan as shown in Table 1.

Table 1: The main criteria for SSCM implementation.

Criteria	company	supplier	competition	consumption	govemment	social	economic	environment
[2]	✓	✓	✓	✓	✓	✓	✓	✓
[3]	✓	-	-	-	-	✓	✓	✓
[4]	✓	✓	✓	-	-	✓	✓	✓
[5]	✓	-	✓	✓	✓	✓	✓	✓
[8]	✓	-	-	-	✓	✓	✓	✓
[13]	✓	-	-	-	✓	✓	✓	✓
[26]	✓	-	✓	-	-	-	-	✓
[27]	✓	✓	-	✓	✓	-	✓	-
[29]	✓	✓	-	-	-	-	✓	✓
[41]	✓	✓	-	✓	-	-	-	-
[42]	✓	-	-	-	-	✓	✓	✓
[43]	✓	-	✓	✓	-	-	✓	-
[44]	✓	✓	-	✓	-	-	-	✓
[45]	✓	✓	-	✓	✓	-	-	✓
[46]	✓	-	-	-	-	-	-	✓
[47]	✓	-	-	-	✓	✓	✓	✓
[48]	✓	✓	✓	✓	-	-	-	✓
[49]	✓	-	-	-	-	✓	-	✓
[50]	✓	✓	-	-	-	✓	✓	✓
[51]	✓	✓	✓	-	✓	✓	✓	✓
[52]	✓	✓	-	-	-	-	✓	-
[53]	✓	✓	-	-	-	-	✓	✓
[54]	✓	-	-	✓	✓	-	✓	-

There are 8 main criteria related to SSCM; company, supplier, competition, consumption, government, social, economic, and environment.

2.3. The sustainable supply chain management framework

In the past, the SCM of an organization was not complicated and consisted of a few stakeholders. Most companies focused on developing economic efficiency, such as technical quality development, reducing cost, and improving delivery performance. However, today, business operations are more complicated, leading to a broader range of stakeholders [55]. Supply chain activities are transformed into a complicated network model [56]. The suppliers, manufacturers, distributors, and logistic providers must work together to enhance their competitiveness. Meanwhile, other stakeholders such as consumers, investors, employees, and society pressure the manufacturers to be concerned about social and environmental issues that affect them. Therefore, nowadays organizations have adopted a sustainable development approach to their SCM [6,33], which considers whole parts of the operation throughout the supply chain known as SSCM. SSCM helps the organization to reduce the risk rate and enhances the competitiveness of the business. Promoting good corporate governance throughout the life cycle of products and services can improve environmental performance, social performance, operations performance, and competitiveness of an organization [57].

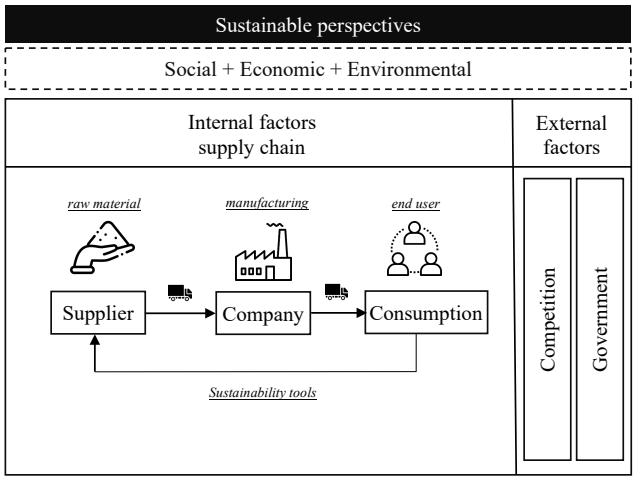

Figure 2: A framework of an SSCM for a manufacturer

A new framework of an SSCM is proposed in this research as shown in Figure 2. It consists of three parts. The first part is external factors, referring to surrounding factors that can indirectly affect the corporate supply chain, which are competition and government. The second part is internal factors, referring to the composition of the main parts of the supply chain, which start from supplier, to company, and end at consumption. Next, the TBL consists of environmental, social, and economic aspects. They are the basis for sustainability. Sustainability tools can be applied to the framework to support the implementation. Whitehead et al. (2020) proposed the tools, which consist of 3 groups; tools for action, tools for analysis and evaluation, and tools for communication [58]. It is also summarized tools and approaches for sustainability, which are cradle to cradle, GSCM, life cycle analysis (LCA), eco-design, reverse logistics, design for environment (DFE), Quality Function Deployment (QFD) for the environment, sustainable value analysis tool (SVAT), sustainability balanced scorecard (SBSC), corporate social responsibility (RSC) and sustainable value stream mapping (Sus-VSM) [59]. These sustainability tools can help an organization's supply chain to achieve successful SSCM. Criteria based on the framework are summarized in Figure 3. They can be described as follows.

Government is the criterion related to enacting laws to enforce and setting standards or regulations that industrial factories must follow. Government criterion is divided into two parts: enforcement of laws or policies and recommendations for

manufacturers from the government. Industries must follow the government laws; if any factory fails to follow the laws, there are penalties. Policies and recommendations from the government might be disregarded if the company is not willing to implement them. It depends on the individual organization's willingness or the opinions of executives within the organization. Many policies require action and enforcement that a business may select by itself or by the government. The role whereby a government can facilitate sustainability will depend on its authority which is different in each country. For example, a government with strong political leaders may generate models which benefit the local community and focus on supporting economic growth. In welfare-state models, the government provides services to firms and nonprofit organizations or takes on social-economic development [60]. Manufacturers determine their profit and level of energy efficiency. The government has sustainable goals that relate to saving energy, seeking profit, and increasing social welfare. Therefore, sustainability is a fundamental issue for both organizations and the government [61].

Competition in the market is one of the critical factors. Competition may be in the form of price, quality, variety of products, responsiveness, or environmental awareness, etc. In the case of SSCM implementation, social trends and substitute goods can affect consumers in making a decision. The organization should be concerned about the market trend to adapt to the competitive market. If the organization does not become active or is slow to adjust to consumption flow, it will lose market share. Competition in each type of market is different. Every organization needs fair competition as an ideal, but in the real situation, it may not be. Therefore, the rapid change of the organization is an advantage and benefit for the organization. The company's choices can affect the decisions of the firm's competitors. The firm invests in sustainability only if it can gain more revenue or reduce cost [62].

Economic sustainability has been defined as gaining more income and stability for society. In the current situation, an economy which does not disturb natural, social, and human societies is needed for sustainability [63]. If the current situation of the economy is getting worse, the investment in SSCM operations will be debated at management board level, and the SSCM operations may be delayed. On the other hand, if the economy is good, a high profit from operations or good cash flow may allow an organization to be able to start SSCM operation quickly. Moreover, the policy formulation from the government is an important factor. For example, if the government requires less tax on the green product, the product price will not be high, it will generate more incentives for consumption and produce more profit. The organization also wants to make more of the products that are best-sellers in the market. All the above result from the first criterion, which is government.

The social factor has direct and indirect effects on SSCM that start with employees on the production line. If the organization has sustainable production management, such as equipped with technology to optimize the use of resources as needed and get the most efficient outputs, minimize energy consumption and air polluting emissions [64], employees do not have the risk of direct exposure to volatile chemicals during production, production accidents will be reduced and the operators of manufacturing plant should have a good quality of life as well. Furthermore, supposing the organization has a policy to apply CSR, it will benefit the surrounding communities. The government is very important in supporting the policy by reducing tax for industrial factories that implement CSR [65, 66], which makes companies willing to undertake CSR projects.

The environment is related to various problems concerning pollutants from water [67], air, and other wastes from factories, which create increasing problems. Reduction of CO_2 emissions, energy consumption [71, 72] and wastes from the processes, products, packaging, and any substances that can increase the world's temperature, are critical issues. Different environmental regulations have started to emerge and be proposed to companies by governments. Companies must comply with environmental legislation existing in each country. Moreover, standards related to environmental consideration are one of the effective tools for the company to apply.

Selecting suppliers that market environmentally friendly raw materials without affecting the surrounding communities can help when implementing SSCM. However, this criterion is difficult to apply in order to make a significant impact on SSCM because organizations cannot enforce or control all suppliers, so choosing a supplier is yet another option in implementing SSCM within the organization. The selection of suppliers requires several factors to be considered [22, 70]. The key principles are the high quality of raw materials, reasonable prices, and on-time delivery.

Consumption can take place only if consumers are more aware of the environment and communities. The eco-label campaign is part of the approachability that can greatly appeal to consumers who are passionate about green consumption. Using its features is an important selling point. Currently, the consumer has a greater preference for healthy and environmentally friendly products [71]. Consumer perspective in sustainability is the driver for a company in the caring economy [72].

The company, including the management team, realize that the operation of SSCM requires a budget for investment [62]. Furthermore, employees within the organization have to adjust to the work with more responsibilities [73]. They must also cooperate to achieve the company strategic goal of SSCM. Moreover, organizations should provide support such as services, knowledge, information, training and facilities for them to achieve efficiency and effectiveness as soon as possible.

Criteria

Company
- Information
- Top management support and motivation
- Process /System operation
- Strategy and goal
- Incentives and rewards
- Reputation loss
- Business characteristics
- Organizational culture
- Innovation

Supplier
- Raw material use (material toxicity and chemicals)
- Trade groups
- Certification

Consumption
- Green image
- Green product
- Consumers' characteristics
- Reverse logistics
- Feedback

Competition
- Market segment
- Product pricing
- Competitive advantage
- Fair competition

Government
- Laws / Regulation / Standard
- Government support
- Disposal green policies
- Environmental policies of government
- Transparency
- Pressure

Social
- Communities
- Corporate social responsibility

Economic
- Cost and benefit
- Tax on green product
- Production cost

Environment
- CO_2 emission
- Risk management
- Pollution prevention
- Energy reduction
- Waste reduction

3. Logarithmic fuzzy preference programming method

Wang and Chin (2011) have proposed a logarithmic fuzzy preference programming method (LFPP) for finding the weight to prioritize the fuzzy number by comparing pairs of the dataset from the decision matrix [74]**.** The basis of this method was developed from the FPP method of Mikhailov (2004) by using nonlinear functions computation to find the weight with the following [75]:

$$ln\ \tilde{a}_{ij} \approx (ln\ l_{ij}, ln\ m_{ij}, ln\ u_{ij}),\ i, j = 1,..., n. \quad (1)$$

where $\tilde{a}_{ij}$ is an approximate triangular fuzzy number.

The membership function is shown below.

$$\mu_{ij}\left(ln\left(\frac{w_i}{w_j}\right)\right) = \begin{cases} \dfrac{ln\left(\frac{w_i}{w_j}\right) - ln\ l_{ij}}{ln\ m_{ij} - ln\ l_{ij}}, ln\left(\frac{w_i}{w_j}\right) \le ln\ m_{ij} \\ \dfrac{ln\ u_{ij} - ln\left(\frac{w_i}{w_j}\right)}{ln\ u_{ij} - ln\ m_{ij}}, ln\left(\frac{w_i}{w_j}\right) \ge ln\ m_{ij} \end{cases} \quad (2)$$

$\mu_{ij}\,(ln\ (w_i/w_j))$ is a membership of function $ln\ (w_i/w_j)$ belonging to the approximate triangular fuzzy judgment $ln\ \tilde{a}_{ij}$. A crisp priority vector to maximize the minimum membership degree $\lambda = \min\{\mu_{ij}(\ln(w_i/w_j)) \mid i = 1,\ldots, n-1; j = i+1,.., n\}$. The subsequent model can be constructed as

Maximize λ

$$\text{Subject to} \begin{cases} \mu_{ij}\left(\ln\left(\frac{w_i}{w_j}\right)\right) \ge \lambda, i = 1, \ldots, n-1; j = i+1, \ldots, n, \\ w_i \ge 0, i = 1, \ldots, n, \end{cases} \quad (3)$$

or as

Maximize 1 - λ

$$\text{Subject to} \begin{cases} \ln w_i - \ln w_j - \lambda \ln(m_{ij}/l_{ij}) \ge \ln l_{ij}, \\ -\ln w_i + \ln w_j - \lambda \ln(u_{ij}/m_{ij}) \ge -\ln u_{ij}, \\ i = 1, \ldots, n-1; j = i+1, \ldots, n, \\ w_i \ge 0, i = 1, .., n. \end{cases} \quad (4)$$

To avoid λ from taking a negative value, Wang and Chin (2011) proposed nonnegative deviation variables δ_{ij} and η_{ij} for $i = 1,\ldots,n-1$ and $j = i+1,\ldots, n$ such that they meet the following inequalities:

$\ln w_i - \ln w_j - \lambda\ln(m_{ij}/l_{ij}) + \delta_{ij} \geq \ln l_{ij}$, $i = 1,\ldots, n-1; j = i+1,\ldots, n$,

$-\ln w_i + \ln w_j - \lambda\ln(u_{ij}/m_{ij}) + \eta_{ij} \geq -\ln u_{ij}$, $i = 1,\ldots, n-1; j = i+1,\ldots, n$.

Then, the model to maximize the minimum membership degree becomes

MODEL: LFPP

$$Minimize J = (1-\lambda)^2 + M \cdot \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\left(\delta_{ij}^2 + \eta_{ij}^2\right)$$

$$Subject\ to \begin{cases} x_i - x_j - \lambda ln\left(m_{ij}/l_{ij}\right) + \delta_{ij} \geq lnl_{ij}, \\ i = 1,\ldots,n-1; j = i+1,\ldots,n, \\ -x_i + x_j - \lambda ln\left(u_{ij}/m_{ij}\right) + \eta_{ij} \geq -ln\, u_{ij}, \\ i = 1,\ldots,n-1; j = i+1,\ldots,n, \\ \lambda, x_i \geq 0, i = 1,\ldots,n, \\ \delta_{ij}, \eta_{ij} \geq 0, i = 1,\ldots,n-1; \\ j = i+1,\ldots,n, \end{cases} \quad (5)$$

Let $x_i = ln\, w_i$ for $i = 1,\ldots, n-1$,

M is a large constant value, x_i^* is an optimal solution, λ is a membership degree, δ_{ij}, η_{ij} are nonnegative deviation variables for $i = 1,\ldots, n$-1 and $j = i+1,\ldots, n$ and

$l_{ij} = 1/u_{ji}$, $m_{ij} = 1/m_{ji}$, $u_{ij} = 1/l_{ji}$ *and* $0 < l_{ij} \leq m_{ij} \leq u_{ij}$ for all $i,j = 1,\ldots,n; j \neq i$.

Normalize the value of x_i^* and sorting fuzzy pairwise comparison matrices by (6)

$$w_i^* = exp(x_i^*)/\ \Sigma^n{}_{j=1}\, exp(x_i^*),\ i = 1,\ldots, n. \quad (6)$$

where $exp(\ )$ is the function of exponential for which the calculation is $exp(x_i^*) = e^{x_i^*}$ for $i = 1,\ldots, n$.

w_i^* is the weight of each criterion from $i = 1,\ldots, n$.

The following equation is used to check the consistency of data.

$$l_{ij} \leq w_i/w_j \leq u_{ij},\ i = 1,\ldots, n-1, j = i+1,\ldots, n. \quad (7)$$

4. Prioritizing of SSCM criteria for the case study

The SCM process of an automotive elastomer manufacturer has a flow chart as shown in Figure 2. The supply chain flow process begins with the purchasing process, where sources of the best raw materials for the company such as a polymer, fillers, softeners, and other additives are procured. A supplier who has the lowest cost, which high-quality products and delivery on time was selected. After receiving raw materials, the production is done according to production planning. After the products are finished and pass the quality inspection, they are transferred to the packing process. Then, finished goods are delivered to customers. There are environmental concerns in all of the above activities, which need to be reviewed through three aspects: social, economic, and environmental. These processes are internal factors of the SCM. Additionally, the process would not be complete if it did not take the external factors into account. The external factors are competitors and the government. The competition between the companies is considered in terms of price, quality, strategies, and market share. Also, the company needs to follow the laws and regulations of the government. However, the government also provides support to the company to reach international standards. The three sustainable perspectives are integrated with both internal and external factors. The company can control all processes by setting the procedures for each aspect by using sustainability tools that can help an organization's supply chain to achieve successful SSCM.

The automotive elastomer manufacturer has decided to apply SSCM in the company, so the importance of each criterion needs to be clarified. Then, everyone in the company can move in the same direction emphasizing the critical criteria. Eight criteria in the previous section were considered and ranked. A fuzzy decision matrix was constructed and evaluated by five experts who are key men in the factory: the procurement supervisor, planning supervisor, quality control supervisor, production engineer, and research and development engineer who has worked in this company for more than 10 years. The decision matrix is shown in Table 2. Model in equation (5) for this fuzzy pairwise comparison matrix can be written as

$$Minimize\ J = (1-\lambda)^2 + M \cdot \sum_{i=1}^{7}\sum_{j=i+1}^{8}\left(\delta_{ij}^2 + \eta_{ij}^2\right)$$

$$Subject\ to \begin{cases} x_1 - x_2 - \lambda\ln\left(\frac{0.35}{0.26}\right) + \delta_{12} \geq \ln(0.26), \\ -x_1 + x_2 - \lambda\ln\left(\frac{0.57}{0.35}\right) + \eta_{12} \geq -\ln(0.57), \\ x_1 - x_3 - \lambda\ln\left(\frac{0.34}{0.24}\right) + \delta_{13} \geq \ln(0.24), \\ -x_1 + x_3 - \lambda\ln\left(\frac{0.46}{0.34}\right) + \eta_{13} \geq -\ln(0.46), \\ x_1 - x_4 - \lambda\ln\left(\frac{1.52}{0.80}\right) + \delta_{14} \geq \ln(0.80), \\ -x_1 + x_4 - \lambda\ln\left(\frac{2.41}{1.52}\right) + \eta_{14} \geq -\ln(2.41), \\ \vdots \\ x_7 - x_8 - \lambda\ln\left(\frac{2.09}{0.99}\right) + \delta_{78} \geq \ln(0.99), \\ -x_7 + x_8 - \lambda\ln\left(\frac{3.19}{2.09}\right) + \eta_{78} \geq -\ln(3.19), \\ \lambda, x_1, x_2, x_3, \ldots, x_8 \geq 0, \\ \delta_{12}, \delta_{13}, \delta_{14}, \ldots, \delta_{78} \geq 0, \\ \eta_{12}, \eta_{13}, \eta_{14}, \ldots, \eta_{78} \geq 0. \end{cases} \quad (8)$$

Taking a sufficiently large number for M, say M=1000, to solve this model with Lingo 17.0 as shown in Figure 4, the optimal solution can be obtained as

Table 2: Fuzzy comparison matrix of the aggregated weights of the criteria

Criteria		C_1 Company			C_2 Supplier			C_3 Competition			C_4 Consumption		
C_1	Company	1.00	1.00	1.00	0.26	0.35	0.57	0.24	0.34	0.46	0.80	1.52	2.41
C_2	Supplier	1.74	2.83	3.87	1.00	1.00	1.00	0.29	0.37	0.51	1.25	2.00	3.06
C_3	Competition	2.19	2.93	4.11	1.97	2.69	3.47	1.00	1.00	1.00	1.32	2.05	3.10
C_4	Consumption	0.42	0.66	1.25	0.33	0.50	0.80	0.32	0.49	0.76	1.00	1.00	1.00
C_5	Government	1.55	2.64	3.68	2.76	3.82	4.85	0.49	0.80	1.35	2.30	3.32	4.34
C_6	Social	1.64	2.09	3.13	1.07	1.52	2.22	0.40	0.64	0.94	1.00	1.52	2.46
C_7	Economic	1.43	2.00	5.00	1.05	1.28	2.78	0.45	0.81	1.00	1.01	1.56	2.56
C_8	Environment	1.59	2.94	3.33	1.27	1.61	2.50	0.45	0.66	0.99	1.28	1.79	4.35
Criteria		C_5 Government			C_6 Social			C_7 Economic			C_8 Environment		
C_1	Company	0.27	0.38	0.64	0.32	0.48	0.61	0.20	0.50	0.70	0.30	0.34	0.63
C_2	Supplier	0.21	0.26	0.36	0.45	0.66	0.93	0.36	0.78	0.95	0.40	0.62	0.79
C_3	Competition	0.74	1.25	2.05	1.06	1.55	2.49	1.00	1.23	2.21	1.01	1.51	2.22
C_4	Consumption	0.23	0.30	0.44	0.41	0.66	1.00	0.39	0.64	0.99	0.23	0.56	0.78
C_5	Government	1.00	1.00	1.00	1.52	2.27	3.37	1.49	2.07	3.07	1.09	1.98	2.98
C_6	Social	0.30	0.44	0.66	1.00	1.00	1.00	0.98	0.99	1.00	1.01	1.12	1.32
C_7	Economic	0.33	0.48	0.67	1.00	1.01	1.02	1.00	1.00	1.00	0.99	2.09	3.19
C_8	Environment	0.34	0.51	0.92	0.76	0.89	0.99	0.31	0.48	1.01	1.00	1.00	1.00

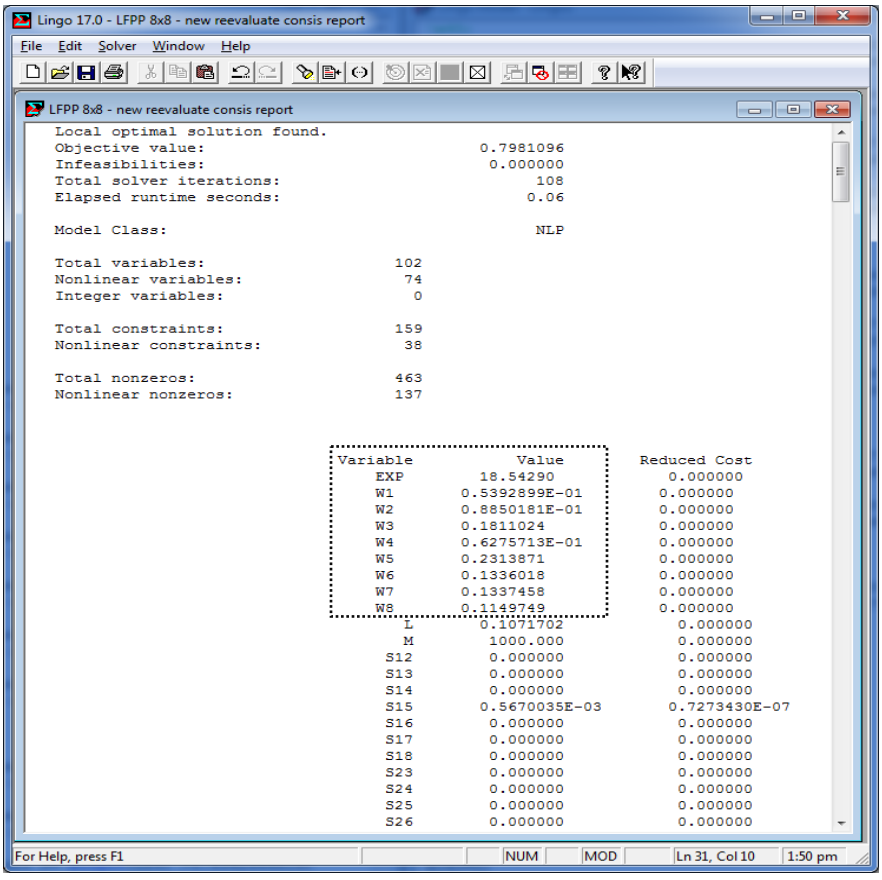

Figure 4: The result obtained from Lingo 17.0.

$$x_1^* = 0, x_2^* = 0.4656, x_3^* = 1.1459, \dots, x_8^* = 0.5329,$$
$$\delta_{12}^*, \delta_{13}^*, \delta_{14}^*, \dots, \delta_{78}^* = 0,$$
$$\eta_{12}^* = 0.0889, \eta_{13}^*, \eta_{14}^*, \dots, \eta_{78}^* = 0,$$

based on which, normalization of LFPP priorities as

$$w_1^* = \frac{EXP(x_1^*)}{\sum_{i=1}^{8} EXP(x_i^*)} = 0.0620,$$
$$w_2^* = \frac{EXP(x_2^*)}{\sum_{i=1}^{8} EXP(x_i^*)} = 0.0988,$$
$$w_3^* = \frac{EXP(x_3^*)}{\sum_{i=1}^{8} EXP(x_i^*)} = 0.1951,$$
$$\dots,$$
$$w_8^* = \frac{EXP(x_8^*)}{\sum_{i=1}^{8} EXP(x_i^*)} = 0.1057.$$

According to (7), the results of the consistent test found that there were four pairs outside the specified limits: a_{12}, a_{15}, a_{23}, and a_{25}, so the decision-makers needed to reevaluate the pairwise comparison judgment as shown in Table 3.

After reevaluating, weights were found and the importance could be sorted as shown in Table 4 and Figure 5. Lingo 17.0 with Intel (R) Core (TM) i5-3570 CPU @ 3.40GHz RAM 8.00 GB 64-bit was used to calculate weights of each criteria. The total calculation time for weights criteria was 0.06 seconds.

The prioritizing results clearly show that external factors, which are government and competition, are the main criteria for applying SSCM in the factory. Then, the economic, social, and environment criteria, which are TBL factors for sustainability, are considered. Their weights are similar which means that the emphasis of the factory on TBL is balanced. Finally, supplier, consumption, and company, which are internal factors have lower weightings.

Table 3: Reevaluate fuzzy comparison matrix

Criteria		C_1 Company			C_2 Supplier			C_3 Competition			C_4 Consumption		
C_1	Company	1.00	1.00	1.00	0.26	0.35	0.65	0.24	0.34	0.46	0.80	1.52	2.41
C_2	Supplier	1.54	2.83	3.87	1.00	1.00	1.00	0.29	0.37	0.52	1.25	2.00	3.06
C_3	Competition	2.19	2.93	4.11	1.92	2.69	3.47	1.00	1.00	1.00	1.32	2.05	3.10
C_4	Consumption	0.42	0.66	1.25	0.33	0.50	0.80	0.32	0.49	0.76	1.00	1.00	1.00
C_5	Government	1.55	2.64	4.55	2.50	3.82	4.85	0.49	0.80	1.35	2.30	3.32	4.34
C_6	Social	1.64	2.09	3.13	1.07	1.52	2.22	0.40	0.64	0.94	1.00	1.52	2.46
C_7	Economic	1.43	2.00	5.00	1.05	1.28	2.78	0.45	0.81	1.00	1.01	1.56	2.56
C_8	Environment	1.59	2.94	3.33	1.27	1.61	2.50	0.45	0.66	0.99	1.28	1.79	4.35
Criteria		C_5 Government			C_6 Social			C_7 Economic			C_8 Environment		
C_1	Company	0.22	0.38	0.64	0.32	0.48	0.61	0.20	0.50	0.70	0.30	0.34	0.63
C_2	Supplier	0.21	0.26	0.40	0.45	0.66	0.93	0.36	0.78	0.95	0.40	0.62	0.79
C_3	Competition	0.74	1.25	2.05	1.06	1.55	2.49	1.00	1.23	2.21	1.01	1.51	2.22
C_4	Consumption	0.23	0.30	0.44	0.41	0.66	1.00	0.39	0.64	0.99	0.23	0.56	0.78
C_5	Government	1.00	1.00	1.00	1.52	2.27	3.37	1.49	2.07	3.07	1.09	1.98	2.98
C_6	Social	0.30	0.44	0.66	1.00	1.00	1.00	0.98	0.99	1.00	1.01	1.12	1.32
C_7	Economic	0.33	0.48	0.67	1.00	1.01	1.02	1.00	1.00	1.00	0.99	2.09	3.19
C_8	Environment	0.34	0.51	0.92	0.76	0.89	0.99	0.31	0.48	1.01	1.00	1.00	1.00

Table 4: Comparison result for reevaluate

Criteria		Weight
C_5	Government	0.2314
C_3	Competition	0.1811
C_7	Economic	0.1337
C_6	Social	0.1336
C_8	Environment	0.1150
C_2	Supplier	0.0885
C_4	Consumption	0.0628
C_1	Company	0.0539

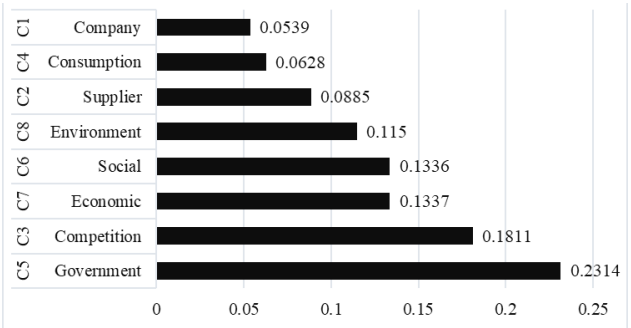

Figure 5: SSCM criteria weights

External pressures from the government and competitors' impact on SSCM for the automotive elastomer manufacturer in Thailand. There are some regulations and laws that control environmental problems that are caused by small particles and hazardous chemicals. The factory has followed the standards of the Ministry of Industry and certified ISO 14001:2015 for many years. The environmental issue is one of the company's strategies. It has an operation plan to protect the environment such as use fewer chemical substances, reduce wastes and pollution, etc. These two factors are very important in leading the factory to the implementation of SSCM.

In the competitive market with rapid change, the factory needs to adjust itself to satisfy the target market, which is the global market. Most of the management team in this factory are foreigners who mainly focus on the global trend. Sustainable awareness for the manufacturer is currently in practice.

The economic issue is important for all profit organizations to survive. However, it should be balanced with social and environment issues. Every project about sustainable management in the factory has to be evaluated by feasibility analysis before implementing it.

The company implemented GSCM before desiring to switch to SSCM, so environmental concerns have existed in almost all of the supply chain. It has been certified to ISO14001:2015 for many years and still keeps track to reduce environmental problems of the factory.

The factory has a policy to select high-quality suppliers. These selected suppliers can help the company to improve the firm's competitiveness across its supply chain. Reasonable price, high quality of raw materials, and fast response are the main factors of the selection. The existing suppliers rarely consider sustainability.

Most customers of the factory are foreign customers, who have less concern about the sustainability of the products. The company products are small parts for automotive manufacturers. Most of the automotive manufacturers are considering clean technology involving combustion in the engine, which is not related to the case study company's products.

The company has the least weight of importance for SSCM. It operates for maximizing profits but the regulations, standards, laws, and stakeholders have forced the company to be concerned not only with profit but also the environment and social issues.

5. Conclusions

This research proposes a framework for SSCM that combines the whole supply chain. It is applied to the case study factory, which is an automotive elastomer producer. Criteria are collected and factors (government and competition), TBL factors (environment, rearranged into the framework, which is suitable for a manufacturer. Three main groups of criteria, which are external social, and economic), and internal factors (supplier, company, and customer) are reviewed. These factors are prioritized by the LFPP method, which has advantages over other methods. Government and competition are the most important criteria for the case study factory that force it to implement SSCM. Laws, regulations, and standards are carefully determined and set for the company to achieve. They are set has the highest priority for the company to achieve. Market and competitors are studied and the operation plan related to these criteria is defined. Environment, social, and economic criteria are the next factors that the factory is concerned about. They are considered to be at the same level of importance, which is balanced according to the concept of SSCM. Profit is still the goal that the factory wants to achieve, but there is also an environmental concern and the certified environmental standard to be satisfied. Moreover, the factory has plans for corporate social responsibility activities with the communities in its action plan. Existing SCM involves suppliers, the company, and customers. They are considered as the less important criteria. The proposals of actions of the case study factory was shown as an example for the other factories.

For future research, the level of SSCM performance in each practice tool should be evaluated to know the efficient tools for the implementation of SSCM.

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