Multi Criteria Supplier Selection from Social Aspects in Thai Tyre Rubber Industry

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Abstract

One of the main issues for companies and organisations is choosing the most appropriate supplier regarding social issues. Besides traditional criteria, companies started to focus on social issues in supplier selection. The methods of group decision making are well established approaches to tackle this issue which could allow decision makers to determine socially selected suppliers' problems. Many existing researches, nonetheless, encompasses scant review of ambiguity which is involved in the process of selecting suppliers. Hence, this study aims to propose a method combines the strength of the Fuzzy sets to deal with an uncertainty or vagueness with AHP-TOPSIS approach to select suppliers by concerning social aspects. AHP method used to identify criteria weights and TOPSIS approach is utilized to sort and select the best appropriate supplier. According to the literature review and company requirements, the criteria in social perspectives was developed to eight criteria. This study uses the questionnaire to gather data from top five manager's judgements who had been chosen based on purposive and self-selection sampling in each department. A case study was carried out in Thailand in the Tyre rubber sector to validate result. The findings demonstrate that Job security *(34%)* is the most important criteria, following by Employees' health and safety *(16%)* and Training programs *(12%)* respectively. The study also presents that "Supplier D" is the most suitable supplier above other suppliers.

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Introduction

Over the previous two decades, the study of sustainability in supply chain management has increased. While the economic, environment, and social aspect are concentrated in the studies (Purvis et al., 2019), the social dimension were not much explored due to complexity of human behaviour in workplace (Carter & Easton, 2011). The environmental aspects of sustainability have been immensely researched in the supply chain and legislation have been created for green sustainability. According to the very complex human problems, very little has been achieved on social sustainability in the supply chain (Seuring & Muller, 2008). In recent years, the awareness of social sustainability has enhanced not only in private company, but also in public company (Badri et al., 2017). An ethically questionable behaviour of suppliers has a major influence on brand image and business (Ehrgott et al., 2011). For instance, in South Africa, Mmereki et al. (2019) argued that waste tyres production led to health problems in communities. Another issue was in automotive industry, Mansouri (2016) analysed the impacts leading to unethical action in emission tests.

In Thailand industry, sustainability has been widely implemented in multiple sectors, including the tyre rubber manufacturers. A necessary raw material for producing car tyres is rubber. Demand from Thailand's automotive industry has steadily increased (Chanchaichujit et al., 2016). Several manufacturers, who demand tyre rubber for their manufacturing, are increasingly engaging in sustainable supplier selection. Typically, the firm carefully assesses relevant sustainable criteria when choosing a supplier of tyre rubber. Nonetheless, focusing only on economic and environmental aspects probably won’t be certainly in the final selection because, now, raising awareness about social issues are vital to clients. Bonfanti and Bordignon (2017) described various aspects from a big international company which forced labours from Thai suppliers in terms of human rights, human trafficking, safety, health and hygiene in fisheries industry. In Thai apparel sector, some companies recruited illegal women immigrant workers from neighbourhood areas because they accepted lower wages (Kusakabe & Pearson, 2013). Most of these circumstances underline the weakness of the upstream elements of supply chain affecting suppliers. Suppliers, nevertheless, play a key role in achieving competition among companies (Krause et al., 2007). The decision of the favour suppliers is therefore an essential part of such policy. Although many researchers have examined methods for vendor selection based on parameters such as cost, reliability, lead time, and environment, the application of social concerns is less investigated (Kim et al., 2016). Several studies examined the selection and assessment of suppliers. The studies solely focused on conventional business and economic factors (Ishizaka & Labib, 2011). A few studies concentrated exclusively on the selection and assessment of suppliers' social sustainability. Decision in supplier's selection is a multiple criteria decision making (MCDM) problem which is influenced by several adversarial factors. In Various single multi criteria decision making models, they have been introduced and applied to support the process of selecting a supplier, for example, AHP, ANP, ELECTRE, PROMETHEE, TOPSIS and so on. Moreover, in expressing judgments, the terms of multiple criteria and constraints of decision makers are expressed in vague terms.

Therefore, in this paper, a combined AHP and TOPSIS model with fuzzy sets is introduced for select the proper supplier using the social perspectives criteria in a case study of Thai tyre rubber industry. AHP is designed to solve multiple criteria in complex hierarchy problem. TOPSIS is to evaluate the outstanding alternative among different decision alternatives. Fuzzy sets can handle vague or uncertainty data that are related with decision maker's opinion.

Objectives

1. To identify the significant criteria weights in social criteria.
2. To evaluate the most desired supplier from social aspects.
3. To propose a combined Fuzzy MCDM model.

Literature Review

In this section, the literature review comprises two parts that include the review of criteria in social decision making and an existing application of decision making in supplier selection.

1. Criteria of social multi criteria decision making

Over the years, studies have addressed a number of important criteria in supplier selection. The common criteria were mainly focused on price, quality and delivery (Tracey &

Leng Tan, 2001). For instance, the literature review of Ho et al. (2010) claims that price, service management and R&D affecting green supplier selection. Banaeian et al. (2018) noted that the cost, availability and quality are the three most common factors in the choice of supplier. Karpak et al. (2001) determined the importance criteria on supplier selection consisting of cost, quality and delivery reliability. Also, from the study of Park and Karishan (2001), they used mostly traditional criteria to evaluate supplier. However, Humphreys et al. (2003) stated that studies of supplier selection that consider social perspectives are limited. In recent years, social issues are the crucial importance in the process of procuring raw materials in sustainable supply chain (Govindan et al., 2015). By giving less attention about social dimensions in supplier selection, current studies have identified different social issues in the supply network. Nonetheless, the social requirements will be highly subjective and differ from country to country. The literature reviews and surveys conducted by experts describe the various social requirements for Thailand. The criteria are summarized in Table 1.

Table 1 Criteria in social decision making

Criteria	Brief definition	Author(s)
Employees' health and safety (Cr1)	This criterion concerns enforcement of high standards in terms of health and the climate at work.	Azadnia et al. (2015) , Baynal and Sari (2016)
Training programs (Cr2)	This attribute supports the community in your local area by providing through employment and educational initiatives.	Huq et al. (2016),
Labour rights (Cr3)	This attribute concerns about under age labor and human trafficking.	Zhou and Xu (2018), Govindan et al. (2015)
Employee welfare (Cr4)	This criterion relates to facilities, services and amenities to retain employees.	Cowper-smith and de Grosbois, (2011)
Brand image (Cr5)	This factor relates to firm's reputation in social perspectives to customers.	Govindan et al. (2015), Cowper-smith and de Grosbois, (2011)

Table 1 Criteria in social decision making *(continued)*

Criteria	Brief definition	Author(s)
Disclosure of information (Cr6)	This criterion relates to open access their information on social concerns during process of manufacturing to public.	Luthra et al. (2017)
Equal employment (Cr7)	This factor concerns gender traits while providing job opportunities.	Bai and Sarkis (2010), Theobald and Arkani, (2007)
Job security (Cr8)	This criterion relates to the recruiting employees based on their experience from recruitment to permanent staff.	Klassen and Vereecke. (2012), Thornton et al. (2013)

Source : Author

2. Existing multi criteria decision making techniques in supplier selection

Several studies have glanced at the problem of supplier selection in a multi-criteria manner with an increasing number of decision-making techniques. Kannan et al. (2014) developed the green suppliers with the combined assistance of fuzzy TOPSIS in green practices. Jia et al. (2015) presented TOPSIS method in supplier selection problems in textile fashions considering sustainability aspects. In India, Mani et al. (2016) applied AHP method to choose suppliers in automotive sector. Giannakis et al. (2020) implemented multi criteria decision making model called ANP to identify and rank sustainability metrics in various manufacturing sectors. Srinual et al. (2019) presented how fuzzy AHP can select supplier based on environmental criteria. Lin et al. (2017) adopted Fuzzy Weight Average model to evaluate in green supplier selection. Amir et al. (2010) implemented fuzzy sets with VIKOR method in supplier selection for automobile part manufacturing. In carbon management awareness problem, Hsu et al. (2013) utilized a method is called DEMATEL to select supplier. From earlier studies, it found that a hybrid approach to coping with MCDM issues with fuzzy logic has been used for limited studies, since most of those MCDM decision support tools are ostensibly logical by decision makers (Bai et al., 2016). However, changes in the preferences and judgements of rational and irrational decision-makers cause more uncertainty. In fact, it could become a fallacy to apply objective principles to explain decision making decisions correctly. To handle this problem, fuzzy logic applications are helpful for handling complex verbal phrases. Therefore, the proposed methodology in this study, a social multi criteria decision making method with FAHP and FTOPSIS are applied to supplier selection using decision maker's opinions. Such integrated methods improve the methodology's comprehension and consistency.

Materials and methods

A case study of Tyre rubber sector in Thailand is adopted in this study which especially immature with respect to social aspects development. The study was conducted through a questionnaire with managers' opinions. Each section outlines the data collection and the description of the suggested method used to facilitate each selection. A combined MCDM model implementation for fuzzy AHP– fuzzy TOPSIS method is summarised in Figure 1.

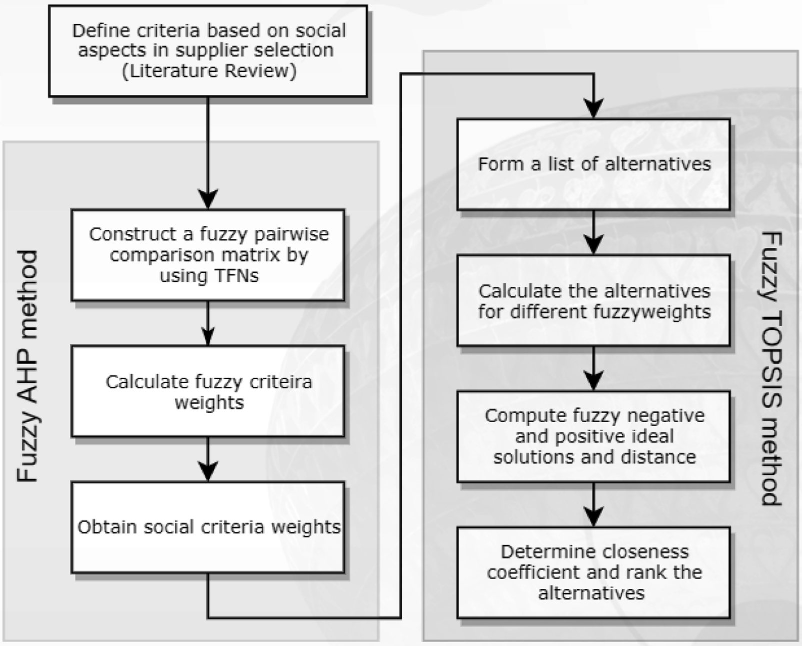

Figure 1 Flow chart of the proposed MCDM method

Source : Author

1. Data collection

As presented in Table 2, the group decision makers were selected based on an integration approaches of self-selection and subjective sampling. These decision makers (DMs) select and evaluate a suitable criteria and supplier based on position and experience in workplace.

Table 2 Detail of decision makers in this case study

Decision maker (DM)	Position	Experience (years)
DM 1	Materials Manager	5
DM 2	Materials Manager	3
DM 3	Line Manager	4
DM 4	Logistics Manager	4
DM 5	R & D Manager	4

Source : Author

2. The Proposed a combined fuzzy MCDM method

Owing to panel of experts' judgement are vague and ambiguous, fuzzy logic are applied to compensate. FAHP-FTOPSIS is a hybrid decision making approach of AHP and TOPSIS. The method utilizes fuzzy sets theory to overcome ambiguity issues (Büyüközkan & Çifçi, 2012).

2.1 Fuzzy AHP model

To figure out a complicated and an unstructured issue, AHP is one of the MCDM approaches by establishing a hierarchical structure in both numerical and qualitative data (Saaty, 1994). While AHP method aims to acquire the expertise, the traditional AHP method is always inadequate represent uncertainty in human cognition. Fuzzy AHP has therefore been used to determine anomalies of decision makers. The procedure can be explained as follows:

Step1. Define proper linguistic terms as TFNs for identify criteria weights

According to fuzzy set theory, TFNs (Triangular Fuzzy Numbers) is represented to the importance of each criterion in pairwise comparison matrix from linguistic terms in Table 3.

Table 3 Linguistic terms and TFNs in pairwise comparison matrix

Fuzzy Linguistic Terms	Fuzzy number	Triangular Fuzzy Numbers (TFNs) – *(l,m,u)*
Absolutely importance	$\tilde{9}$	(8, 9, 9)
Strongly importance	$\tilde{7}$	(6, 7, 8)
Fairy importance	$\tilde{5}$	(4, 5, 6)
Weakly importance	$\tilde{3}$	(2, 3, 4)
Equally importance	$\tilde{1}$	(1, 1, 1)

Source : Büyüközkan, G., & Çifçi, G. (2012)

Step2. Construct the fuzzy comparison matrices by TFNs

The results of pairwise comparisons are collected in the matrix $\widetilde{A}$ is constructed as given below:

$$\widetilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & \tilde{a}_{nn} \end{bmatrix} \quad (1)$$

, where $\tilde{a}$ is = (l_{ij}, m_{ij}, u_{ij}) each criterion score in a fuzzy comparison matrix

Step3. Calculate the geometric mean of fuzzy values

$$\tilde{u}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \ldots \otimes \tilde{a}_{in})^{1/n} \quad (2)$$

Step4. Compute the fuzzy weight of each criteria.

$$\widetilde{w}_i = \tilde{u}_1 \otimes (\tilde{u}_1 \oplus \tilde{u}_2 \ldots \oplus \tilde{u}_n)^{-1} \quad (3)$$

Step5. Normalized weight criterion

2.2 Fuzzy TOPSIS model

In this section, the FTOPSIS model which was extended by Chen (2000) for ranking the alternatives or the suppliers. The linguistic assessment of the group decision makers on suppliers for each attribute applying fuzzy logic. The procedure can be described below.

Step1. Decide linguistic value as TFNs for decision makers to evaluate the alternatives

The linguistic scale used for solutions rating relate with each criterion is given in Table 4.

Table 4 Linguistics scale for each alternative (Jiang et al., 2008)

Linguistic variable	Triangular Fuzzy Numbers (TFNs) – *(a,b,c)*
Very Good (VG)	(7, 9, 10)
Good (G)	(5, 7, 9)
Medium (M)	(3, 5, 7)
Poor (P)	(1, 3, 5)
Very Poor (VP)	(0, 1, 3)

Source : Jiang, Y.-P., Fan, Z.-P., & Ma, J. (2008)

Step2. Determine the aggregated fuzzy rating of the alternatives under each criterion

$$\tilde{w}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \quad (4)$$

, where a_{ij}= min$\{a_{ijk}\}$, b_{ij}= 1/K$\sum_{k=1}^{K} b_k$, c_{ij}= max$\{c_{ijk}\}$, k = no. of decision makers (1, 2, ..., K)

Step3. Construct the fuzzy decision matrix

Step4. Normalize fuzzy decision matrix

$$\tilde{R} = [\tilde{r}_{ij}]_{m*n} \text{ ; i=1, 2..., m, j=1, 2..., n}$$

$$\tilde{r}_{ij} = \left({a_{ij}}/{c_j^+}, {b_{ij}}/{c_j^+}, {c_{ij}}/{c_j^+} \right) \text{ where } c_j^+ \text{ represent max } c_{ij} \quad (5)$$

Step5. Find weighted normalized decision matrix

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_{ij} \quad (6)$$

Step6. Compute the fuzzy ideal solution in positive (FPIS) and negative (FNIS)

$$\text{FPIS } (A^+) = (\tilde{v}^+{}_1, \tilde{v}^+{}_2, \ldots, \tilde{v}^+{}_n) \quad (7)$$

$$\text{FNIS } (A\text{-}) = (\tilde{v}^-{}_1, \tilde{v}^-{}_2, \ldots, \tilde{v}^-{}_n) \quad (8)$$

, where $\tilde{v}^+{}_j$ = max $\{\tilde{v}_{ij}\}$ and $\tilde{v}^-{}_j$ = min $\{\tilde{v}_{ij}\}$, i = 1, 2 ..., m, j = 1, 2 ..., n

Step7. Determine the distance from FPIS and FNIS of each alternative

$$DS_i{}^+ = \sum_{j=1}^{n} d_v (\tilde{v}_{ij}, \tilde{v}^+{}_j) \quad (9)$$

$$DS_i{}^- = \sum_{j=1}^{n} d_v (\tilde{v}_{ij}, \tilde{v}^-{}_j) \quad (10)$$

Step8. Evaluate alternatives by measuring the closeness coefficient CC_i

$$CC_i = {DS_i{}^-}/{(DS_i{}^+ - DS_i{}^-)} \quad (11)$$

The alternatives with the highest CC_i is selected and rank in descending order.

Results

The major manufacturer of automobile parts in eastern part of Thailand, mainly produces car tyre rubber encountered the pressure to protect the social and ethical issues coming from consumers, suppliers and the governments. To engage in the business and gain the leverage over competitors in the market, company strictly emphasizes supplier selection based on social perspectives. Decision makers which consists of five experts use eight criteria to select four suppliers (A, B, C, D) for the implementation of FAHP and FTOPSIS. The detail of the production unit for car tyres and the details of suppliers are not released due to proprietary policy. Figure 2 depicts the hierarchy structure of the supplier selection.

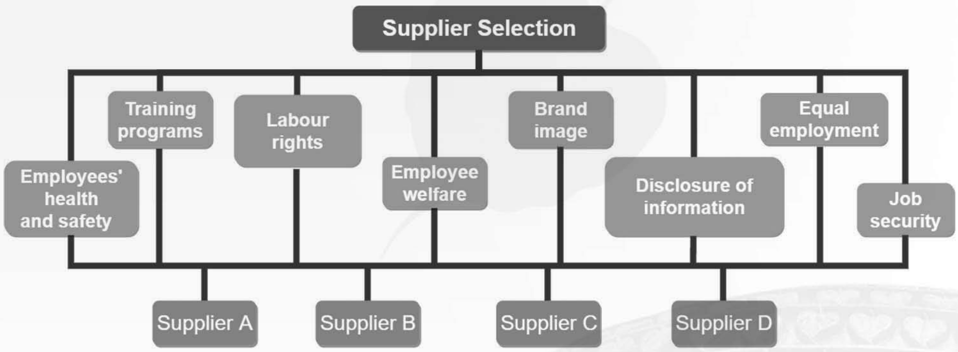

Figure 2 A hierarchy structure of supplier selection

Source : Author

1. Calculating the weights for social criteria

By applying a fuzzy analytical hierarchy (FAHP), the weights of the chosen eight attributes are calculated. The comparison criteria weight matrix which is determined by five respondent managers can be seen in Table 5.

Table 5 Criteria matrix in fuzzy terms

Criteria	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8
Cr1	$\tilde{1}$	$1/\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{9}$	$1/\tilde{3}$	$\tilde{5}$	$1/\tilde{3}$
Cr2	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$1/\tilde{7}$	$1/\tilde{3}$	$\tilde{7}$	$1/\tilde{3}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Cr8	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	$\tilde{5}$	$\tilde{7}$	$\tilde{1}$

Source : Author

The data in the Table 5 are analysed by using R programming which can be presented in Figure 3 and the fuzzy weight of each attribute are determined in Figure 4.

```

#Install library
library(knitr)
library(testthat)
library(FuzzyAHP)

#Set directory path
setwd("C:/Users/Dell/Desktop")

#Define a filename
matrixFile =  "social.csv"
#Import a file
SocialMatrix = read.csv(matrixFile, sep = ";",
                stringsAsFactors = FALSE, header = TRUE, row.names = 1, strip.white = TRUE)
#Create a matrix
SocialMatrix_weight = as.matrix(SocialMatrix)
#Set a matrix dimension 8*8 (8 criteria)
SocialMatrix = matrix(SocialMatrix_weight, nrow = 8, ncol = 8, byrow = TRUE)
#Identify fuzzy numbers to compare each criterion in a matrix
SocialMatrix = pairwiseComparisonMatrix(SocialMatrix)
#Fill TFNs values in a criteria weight Matrix
fuzzySocialMatrix= fuzzyPairwiseComparisonMatrix(SocialMatrix)
#Show TFNs values in a citeria weight Matrix
print(fuzzySocialMatrix)
#Compute criteria weights
result = calculateWeights(fuzzySocialMatrix)
#Display a result
print(result)
```

Figure 3 Fuzzy AHP in R programming

Source : Author

```
> print(fuzzySocialMatrix)
              C_1           C_2           C_3           C_4           C_5           C_6           C_7
C_1       (1;1;1) (1/4;1/3;1/2)       (4;5;6)       (4;5;6)       (8;9;9) (1/4;1/3;1/2)       (4;5;6)
C_2       (2;3;4)       (1;1;1)       (2;3;4)       (4;5;6) (1/8;1/7;1/6) (1/4;1/3;1/2)       (6;7;8)
C_3 (1/6;1/5;1/4) (1/4;1/3;1/2)       (1;1;1) (1/6;1/5;1/4) (1/9;1/9;1/8)       (4;5;6)       (6;7;8)
C_4 (1/6;1/5;1/4) (1/6;1/5;1/4)       (4;5;6)       (1;1;1)       (8;9;9) (1/6;1/5;1/4) (1/4;1/3;1/2)
C_5 (1/9;1/9;1/8)       (6;7;8)       (8;9;9) (1/9;1/9;1/8)       (1;1;1) (1/6;1/5;1/4)       (6;7;8)
C_6       (2;3;4)       (2;3;4) (1/6;1/5;1/4)       (4;5;6)       (4;5;6)       (1;1;1) (1/4;1/3;1/2)
C_7 (1/6;1/5;1/4) (1/8;1/7;1/6) (1/8;1/7;1/6)       (2;3;4) (1/8;1/7;1/6)       (2;3;4)       (1;1;1)
C_8       (2;3;4)       (2;3;4)       (4;5;6)       (4;5;6)       (2;3;4)       (4;5;6)       (6;7;8)
              C_8
C_1 (1/4;1/3;1/2)
C_2 (1/4;1/3;1/2)
C_3 (1/6;1/5;1/4)
C_4 (1/6;1/5;1/4)
C_5 (1/4;1/3;1/2)
C_6 (1/6;1/5;1/4)
C_7 (1/8;1/7;1/6)
C_8       (1;1;1)
> #Compute criteria weights
> result = calculateWeights(fuzzySocialMatrix)
> #Display a result
> print(result)
   [,1]
w1 "(0.1251;0.16;0.205)"
w2 "(0.0928;0.1227;0.1597)"
w3 "(0.0464;0.0567;0.0713)"
w4 "(0.0508;0.063;0.0786)"
w5 "(0.0759;0.0884;0.1049)"
w6 "(0.0874;0.1151;0.1479)"
w7 "(0.0318;0.0408;0.0512)"
w8 "(0.2815;0.3533;0.412)"
```

Figure 4 Fuzzy weight criteria result in R programming

Source : Author

Then, the weights obtained from fuzzy matrix was computed a normalized weight criterion. Table 6 shows the summary of social criteria weight.

Table 6 Summary of weight criteria

Criteria	Weight (W)			Averaged weight criterion	Normalized weight criterion	Percentage (%)	Ranking
Cr1	0.1251	0.16	0.205	0.1634	0.1622	16.22	2
Cr2	0.0928	0.1227	0.1597	0.1251	0.1241	12.41	3
Cr3	0.0464	0.0567	0.0713	0.0581	0.0577	5.77	7
Cr4	0.0508	0.063	0.0786	0.0641	0.0637	6.37	6
Cr5	0.0759	0.0884	0.1049	0.0897	0.0891	8.91	5
Cr6	0.0874	0.1151	0.1479	0.1168	0.1159	11.59	4
Cr7	0.0318	0.0408	0.0512	0.0413	0.0410	4.10	8
Cr8	0.2815	0.3533	0.412	0.3489	0.3464	34.64	1

Source : Author

It can be seen from the result of Table 6, Job security (Cr8-34%) is the most significant criterion following by Employees' health and safety (Cr1-16%) and Training programs (Cr2-12%) respectively, while Equal employment (Cr7) is the least importance among eight criteria.

2. Ranking of final suppliers' selection

After applying the FAHP method to determine social attribute weights, the FTOPSIS method is used for the analysis to select and rank the supplier. Five decision makers decide the linguistic rating to four suppliers in each criterion by using linguistics variables from Table 3. The linguistics rating results obtained by the decision makers' responses. The sample rating from first respondent was displayed in Table 7.

Table 7 Linguistics results from 1st decision maker

Alternative	Criteria							
	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8
Supplier A	M	M	P	P	M	G	P	P
Supplier B	G	G	VG	G	M	P	VG	M
Supplier C	P	VP	P	VP	VP	M	P	P
Supplier D	VG	G	G	VG	G	G	VG	G

Source : Author

The next step is to convert the linguistics rating from all decision makers into TFNs as seen in Table 8.

Table 8 TFNs values from five decision makers

Criteria	Alternative			
	Supplier A	Supplier B	Supplier C	Supplier D
Cr1	(4.6,6.6,8.4)	(2.2,4.2,6.2)	(3.8,5.8,7.8)	(1.2,1.6,3.4)
Cr2	(2.6,4.6,6.6)	(4.6,6.6,8.4)	(1.2,3,5)	(4.4,6.2,7.8)
Cr3	(4.2,6.2,8.2)	(3.4,5.4,7.4)	(1.6,3.4,5.4)	(6.2,8.2,9.6)
Cr4	(2.6,4.6,6.6)	(3.4,5.4,7.4)	(1.2,2.6,4.6)	(1.4,3.4,5.4)
Cr5	(2.2,4.2,6.2)	(1.4,3.4,5.4)	(1.2,1.6,3.4)	(5.16,7.08,8.6)
Cr6	(2.2,4.2,6.2)	(1.2,3,5)	(2.6,3.2,4.8)	(4.4,6.2,7.8)
Cr7	(0.6,2.2,4.2)	(2.2,4.2,6.2)	(2,2.4,4)	(3.6,5.4,7.2)
Cr8	(2.2,4.2,6.2)	(1.2,3,5)	(2.6,3.2,4.8)	(4.4,6.2,7.8)

Source : Author

Then, using package Fuzzy MCDM in R programming to implement Fuzzy TOPSIS Method as shown in Figure 5 and Figure 6.

FuzzyTOPSIS.R

```
#Install packages
install.packages("gtools", repos="https://cran.rstudio.com/")
install.packages("RankAggreg", repos="https://cran.rstudio.com/")
install.packages("FuzzyMCDM", repos="https://cran.rstudio.com/")
install.packages("readxl")
#Install library for calculating Fuzzy TOPSIS
library(gtools)
library(RankAggreg)
library(FuzzyMCDM)
library(readxl)
#Set directory path
setwd("C:/Users/Dell/Desktop/social criteria")
#Import TFNs values from decision makers' respondents
TFN_values <- read_excel("data_supplier.xlsx", sheet= 1,col_names = TRUE)
#Convert Excel file to a matrix structure
TFN_values_matrix<-as.matrix(TFN_values)
#Display TFN_values
print(TFN_values)
#Fill criteria weight from fuzzy AHP method)
Social_criteria_weight <- c(0.125,0.160,0.205,0.093,0.123,0.159,0.046,0.056,0.071,
                            0.051,0.063,0.078,0.076,0.088,0.105,0.087,0.115,0.148,
                            0.031,0.041,0.051,0.281,0.353,0.412)
#Define criteria is benefit(max) or cost(min)
Benefit_criteria <- c('max','max','max','max','max','max','max','max')
#Implement Fuzzy TOPSIS model from FUZZYMCDM package
FuzzyTOPSISVector(TFN_values_matrix,Social_criteria_weight,Benefit_criteria)
```

Figure 5 Fuzzy TOPSIS in R programming

Source : Author

The final step was to identify the alternatives based on closeness coefficient to the ideal solution. The result from R programming was given in Table 9.

```
> print(TFN_values)
# A tibble: 4 x 24
  Cr1...1 Cr1...2 Cr1...3 Cr2...4 Cr2...5 Cr2...6 Cr3...7 Cr3...8 Cr3...9 Cr4...10 Cr4...11 Cr4...12 Cr5...13 Cr5...14 Cr5...15 Cr6...16 Cr6...1
7 Cr6...18
    <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl
>    <dbl>
1     4.6     6.6     8.4     2.6     4.6     6.6     4.2     6.2     8.2      2.6      4.6      6.6      2.2      4.2      6.2      2.2      4.
2     6.2
2     2.2     4.2     6.2     4.6     6.6     8.4     3.4     5.4     7.4      3.4      5.4      7.4      1.4      3.4      5.4      1.2      3
     5
3     3.8     5.8     7.8     1.2     3       5       1.6     3.4     5.4      1.2      2.6      4.6      1.2      1.6      3.4      2.6      3.
2     4.8
4     1.2     1.6     3.4     4.4     6.2     7.8     6.2     8.2     9.6      1.4      3.4      5.4      5.16     7.08     8.6      4.4      6.
2     7.8
# … with 6 more variables: Cr7...19 <dbl>, Cr7...20 <dbl>, Cr7...21 <dbl>, Cr8...22 <dbl>, Cr8...23 <dbl>, Cr8...24 <dbl>
> #Fill criteria weight from fuzzy AHP method)
> Social_criteria_weight <- c(0.125,0.160,0.205,0.093,0.123,0.159,0.046,0.056,0.071,
+                             0.051,0.063,0.078,0.076,0.088,0.105,0.087,0.115,0.148,
+                             0.031,0.041,0.051,0.281,0.353,0.412)
> #Define criteria is benefit(max) or cost(min)
> Benefit_criteria <- c('max','max','max','max','max','max','max','max')
> #Implement Fuzzy TOPSIS model from FUZZYMCDM package
> FuzzyTOPSISVector(TFN_values_matrix,Social_criteria_weight,Benefit_criteria)
  Alternatives       R.1       R.2      R.3     Def_R Ranking
1            1 0.1222688 0.5194047 2.028307 0.7046991       2
2            2 0.0725217 0.3123795 1.219758 0.4236329       4
3            3 0.1021896 0.3142289 1.399470 0.4597626       3
4            4 0.2014678 0.6512285 2.215552 0.8369889       1
>
```

Figure 6 Closeness coefficient and ranking result in R programming

Source : Author

Table 9 The result of CC_i and alternatives ranking

Alternative	CC_i	Ranking
Supplier A	0.704	2
Supplier B	0.423	4
Supplier C	0.459	3
Supplier D	0.837	1

Source: Author

For this study, the result demonstrated that "Supplier D" has the highest closeness coefficient in overall which mean that Supplier D was the most appropriate supplier with social concern criteria in Thai tyre rubber firm, trailed by Supplier A, Supplier C and B.

Discussion

The amount of supplier selection in literature reviews has increased exponentially in the last few years. Nonetheless, in Thailand, there is limited research existing on tyre rubber industry. For this case study, the result depicts that Job security (0.34), Employees' health and safety (0.16) and Training programs (0.12) are the first three importance criteria based on social concerns which support by the claims of Bai et al. (2019) and Guarnieri and Trojan (2019) to select a proper supplier. This is also supported by previous findings that labour rights and equal employment in social aspects are less significant criteria (Thornton et al., 2013). In addition, the results of selected supplier indicate that the top of the rankings with the highest closeness coefficient was Supplier D (0.837) followed by Suppliers A (0.704), C (0.459), and B (0.423) respectively. Although from this outcome Supplier D is regarded as the best supplier, Employees' health and safety and Employee welfare with lowest scores on social aspects for Supplier D which corresponds to Baskaran et al. (2011) and Goebel et al. (2012).

Conclusion

To help build perspectives in social effective supplier selection, selection of suppliers is where MCDM tools are useful. The study provides a hybrid model combining FAHP and FTOPSIS methods to support decision makers for deciding the most suitable supplier. This study has considered eight social criteria comprising of Employees' health and safety (Cr1), Training programs (Cr2), Labour rights (Cr3), Employee welfare (Cr4), Brand image (Cr5), Disclosure of information (Cr6), Equal employment (Cr7) and Job security (Cr8). The weighted criteria are determined by FAHP method. The descending order of eight criteria is summarized as Cr8>Cr1>Cr2>Cr6>Cr5>Cr4>Cr3>Cr7. After defining the weights, these weights and the scores of alternatives in suppliers are analysed by FTOPSIS method. In accordance with the results of the four suppliers ' closeness coefficients, it is concluded that Supplier D is the main supplier and Supplier B is the lowest supplier.

However, there are several limitations to the study. Firstly, all the relevant supplier selection criteria cannot be considered due to environmental and other conditional restrictions. Therefore, only key attributes that affect socially responsible supplier selection have been frequently referred to in this study. Secondly, experts in their selection processes have different views which, due to ambiguous or two-sided judgements, may lead to different findings depending on the industry. This study is also confined to a specific industry field in the Tyre rubber sector. The survey was conducted with top-level executives from the rubber sector. In the future, the decision-making process in next study should overcomes the shortcomings of the subjective views from expertise. Further study could also be tailored to the preference of suppliers in other industries.

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