Comparative Analysis of Multiple Criteria Decision Making (MCDM) Approach in Warehouse Location Selection of Agricultural Products in Thailand

Martusorn Khaengkhan[1], Chattrarat Hotrawisaya[2], Bhuk Kiranantawat[3], Mohd Rizaimy Shaharudin[*4]

[1-3]*College of Logistics and Supply Chain Management, Suan Sunandha Rajabhat University, Thailand*

[*4]*Faculty of Business & Management, Universiti Teknologi MARA, 08400 Merbok, Kedah, Malaysia*

[1] martusorn.kh@ssru.ac.th

[2]chattrarat.ho@ssru.ac.th

[3]bhuk.ki@ssru.ac.th

[*4]rizaimy@uitm.edu.my

Abstract **- The objective of this study was to select the suitable warehouse location, which is the focus for business organisations that buy, produce, and store the agricultural products of grass flowers, by using the Multiple Criteria Decision Making theory (MCDM). Three methods were used, which were the Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Seven main factors that influence the selection of an agricultural product warehouse were explored - the size of the area, land price, labour cost, utilities, the quantity of raw materials in the area, ease of access to the place, and distance from the source of the raw materials to the location. Five areas for the warehouse Chiang Rai province, Thailand were compared to ascertain the suitability of warehouse location by using these factors. The results show that Pa Sang Sub-district, Mae Chan District (E) was the most suitable for the agricultural product warehouse. This study can be further applied to decision making in agricultural businesses.**

Keywords **-** *Decision Making, Location Selection, SAW, TOPSIS, AHP*

1. Introduction

Currently, to operate a successful business, one of the most important business activities is product distribution. Product distribution is considered an important activity in the management of supply chains, which can help increase product value, and competitiveness in the market [1]. The warehouse maintains the balance between the demand from customers and the number of products available. The demand rate from customers is often unstable and there are also many other factors involved. In business operations, uncertain and unstable demand from customers will cause an imbalance from time to time. However, if products are stored at the right time, and in the right quantity and location, the demand from customers will be met continuously. Every business, whether in agricultural or industrial products, is considered important to the economy of every country. Warehousing is an important activity in business which can help the business to become successful.

Grass flowers are the main raw material for the production of grass brooms. Grass flowers only bloom once a year according to the season. The time in which grass flowers can be harvested is from November to March only, causing the price of the grass flowers to highly fluctuate. The price of grass flowers is low during the season due to the large amount of harvest. However, the price is higher after the end of the season. As manufacturers need grass flowers to produce brooms all year round, it causes suppliers to buy grass flowers as much as possible in order to have enough grass flowers to meet manufacturers' needs throughout the year. Therefore, suppliers need to find a suitable location for the establishment of a grass storage warehouse. In this research, the area in the Chiang Rai province, which is in the northern region of Thailand, was studied because it is a province that produces a lot of grass flowers. There are many suppliers of grass flowers who need a guideline for selecting a suitable location for the establishment of a grass storage warehouse which will help with logistics activity costs.

This study explored the selection of the location for businesses of grass flowers, which are used in the

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

production of grass booms. In this case, the importance of the selection of suitable locations for the businesses is emphasised. Choosing a good or suitable location is considered one of the factors that affect the success of the business. Grass brooms are essential for cleaning every home in Thailand and many countries around the world, such as Malaysia, the Philippines, and Indonesia. The service life of grass brooms is short. Thus, the demand of this market is constantly increasing. Production and sales of grass have increased continuously. Therefore, grass brooms have become a revenue-generating business for many communities in the north and north-east of Thailand. The production of grass brooms requires a lot of raw materials, which are grass flowers.

Therefore, in choosing a warehouse location, close attention must be paid to the proximity of the raw materials and the ease of access, size of the land, land price, labour costs, various transportation modes used to access the area, and distance from the raw materials to the area. Thus, various factors will affect the selection of the location of the business because the location is very important to the business activities of the organisation, such as transportation planning, investment, and income [2]. These are factors that can be used to select the appropriate location for the establishment of a warehouse to help reduce the cost of the logistics activities of the business.

2. Literature Review and Methods

2.1 Research Design

The factors that influence the selection of warehouse locations were explored based on the interviews with five suppliers in the industry and the review of the literature related to the location decision of a warehouse. Sixteen factors were identified which included land price, size of area, number of raw material suppliers, quantity of raw materials in the area, accessibility of the area, access to labour, distance from the source of the raw materials, number of competitors in the area, utilities, Feng Shui, environment, transportation modes, community views, future opportunities, sources of funds, and transportation routes. All factors have been considered by using the ratings from suppliers and five related parties in the Pairwise Comparison which was analysed by using the Analytic Hierarchy Process (AHP). From the analysis of sixteen factors, each factor was ranked and then, eliminated at 95%. The results unveiled only seven factors that had affected the selection of the location of the grass flower warehouse - size of the area (X1), land price (X2), labour cost (X3), utilities (X4), quantity of raw materials in the area (X5), ease of access to the area (X6), and distance from the source of the raw materials to the area (X7). These factors were used to determine the selection of five areas.

Based on the preliminary area screening with the Geographic Information System using specific criteria for determining the appropriate areas, fourteen suitable areas were found. Those areas were explored, with the purpose of studying the details of each area and the feasibility of using each area to establish a grass flower warehouse in Chiang Rai. After exploring the areas with the initial screening using the Geographic Information System (GIS), each area was evaluated to determine whether it was suitable according to the business owners' main criteria of the area price not exceeding 600,000 baht. The areas were evaluated by using the Conjunctive Method in which the Minimal Cutoff was defined. However, it was found that some areas did not match the business owners' criteria and they were eliminated. Five potential areas which fit the business owners' criteria were selected. Each area had the following details as shown in Figures 1, 2, 3, 4, and 5 and Table 1:

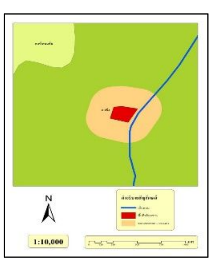

Figure 1. Area (A)

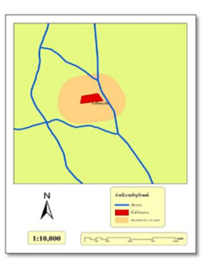

Figure 2. Area (B)

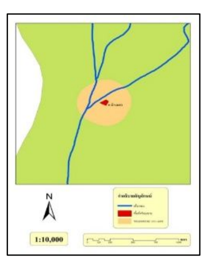

Figure 3. Area (C)

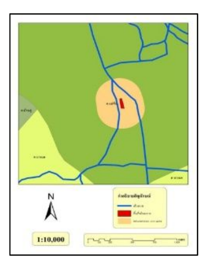

Figure 4. Area (D)

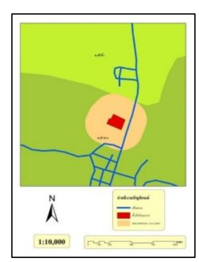

Figure 5. Area (E)

Table 1. Details of the Five Areas

Factors	Krung Sub-district, Chiang Khong District (A)	Sri Don Chai Sub-district, Chiang Khong District (B)	Ban Saew Sub-district, Chiang Saen District (C)	Mae Chan Sub-district, Mae Chan District (D)	Pa Sang Sub-district, Mae Chan District (E)
Size of the area (X1)	16000 m²	14400 m²	8000 m²	4800 m²	14400 m²
Land price (X2)	฿ 400,000 (per 1,600 m²)	฿ 600,000 (per 1,600 m²)	฿ 350,000 (per 1,600 m²)	฿ 500,000 (per 1,600 m²)	฿ 300,000 (per 1,600 m²)
Labour cost (X3)	3 (excellent)	3 (excellent)	1 (poor)	2 (good)	2 (good)
Utilities (X4)	3(excellent)	3 (excellent)	2 (excellent)	3 (excellent)	3 (excellent)
Quantity of raw materials in the area (X5)	300 tonnes/annum	200 tonnes/annum	50 tonnes/annum	500 tonnes/annum	500 tonnes/annum
Ease of access to the area (X6)	5 (excellent)	5 (excellent)	5 (excellent)	5(excellent)	5 (excellent)
Distance from the source of the raw materials to the area (X7)	1 (fair)	3 (excellent)	1 (good)	2(good)	2 (good)

Subsequently, the five areas were screened and analysed using GIS again to determine the most suitable area for establishing a grass flower warehouse. Multiple Criteria Decision Making (MCDM) consisting of three methods has been applied, namely, the SAW method, TOPSIS method, and AHP method. Next, an appropriate comparison was conducted to select the best warehouse location for the respective businesses that buy, produce, and store the agricultural products of grass flowers.

2.2 SAW Method

The SAW Method is a simple, hassle-free process. It is calculated from the product of the weight value. And the appropriateness of each rule; then, the sum of all the rules are multiplied together. The highest scoring option will be selected first. The steps of the SAW method are as follows:

Step 1. Change the range of the rules to a range of comparisons. The set of rules can be divided into 2 types, which are the positive criteria and negative criteria, each of which is based on one of the following equations:

$$\text{Positive criteria} \quad r_{ij} = \left(\frac{a_{ij}}{c_{ij}^{*}}\right), j \in B \qquad c_{ij}^{*} = \max c_{ij}, j \in B \tag{1}$$

$$\text{Negative criteria} \quad r_{ij} = \left(\frac{a_{ij}}{c_{ij}^{*}}\right), j \in B \qquad a_{ij}^{*} = \max a_{ij}, j \in C \tag{2}$$

Step 2. Find alternatives in each choice by considering the following equation:

$$v_i = \sum_{j=1}^{n} W_j r_{ij} \qquad i = 1,2\ldots,m \tag{3}$$

by r_{ij} Instead of the adjusted score of the choice

Step 3. When the matrix V is added and the weight value of each rule is added, include the scores from all the criteria in each choice by considering the following equation:

$$V_i = \sum_{j=1}^{n} v_i \qquad i = 1,2,\ldots,m \tag{4}$$

Step 4. The appropriate selection of the decision will be determined by the V_j value of each choice. The most appropriate option is the most valuable option, which is V_j, then arrange suitable options for the least appropriate option.

2.3 TOPSIS Method

TOPSIS is known as one of the most reliable methods in Multi Criteria Decision Making. This method works by hypothesising two artificial alternatives of ideal and negative ideal. The ideal alternative is an alternative that has the greatest element values, such as the maximum benefit and minimum cost. The study selected the options of the nearest to the ideal solution and most extreme from the negative ideal solution [3]. This method works when the information has a clear-cut boundary. However, when the information is vague, the Fuzzy Set Theory must be applied to convert the information for analysis. In relation to this, TOPSIS fully utilises the attributes of the information, creates a cardinal ranking of the alternatives, and the attribute preferences are not necessarily independent from each other [4].

The steps of the TOPSIS analysis are as follows:
Step 1. Construct a normalised decision matrix
Step 2. Construct the weights for the normalised decision matrix
Step 3. Determine the positive ideal and negative ideal solutions
Step 4. Calculate the separation measures for each alternative. The separation from the positive ideal alternative is:

$$S_i^* = \sqrt{\sum_j^m \left(v_{Aj} - v_j^*\right)^2} \qquad , j = 1, 2, 3,\ldots, n, \qquad (5)$$

Negative Ideal:

$$S_i^- = \sqrt{\sum_j^m \left(v_{Aj} - v_j^-\right)^2} \qquad , j = 1, 2, 3,\ldots, n, \qquad (6)$$

Step 5. Calculate the relative closeness to the ideal solution, Vi:

$$C_i = \frac{S_i^-}{\left(S_i^* + S_i^-\right)} \qquad , i = 1, 2, 3,\ldots, m \qquad (7)$$

Many principles of decision-making are often used to evaluate and select various options that contain different data. As the data are sometimes different or vague, a careful selection of the decision making method must be made so that a quality decision can be made which will lead to satisfactory results.

2.4 Method Analytic Hierarchy Process (AHP)

AHP is a multiple criteria decision-making method. It is a value approach to make subjective comparisons for each pairwise of attributes or

alternatives using a ratio scale and also works by converting unquantifiable factors to be quantifiable in order to provide a rationale answer [5]. AHP is performed by setting goals and problems in a hierarchical order using the priority of the criteria from the first criterion to the final criterion until the desired alternative is determined. It is one of the popular

criteria chosen to evaluate and analyse various patterns, such as by [6] who adapted the AHP technique to create the model of transportation problems and analyse the investment to choose the warehouse. In this study, AHP technique was adapted to develop a model of transportation problems and investment analysis to select the best warehouse location by comparing two locations in Bangkok, Thailand, which were subjected to the transportation legal regulations [6]. In another study by [7], they used the fuzzy AHP analysis with important criteria to find the best alternative for selecting a freight logistics hub under the proper criteria. These criteria could indicate the significances of the importance of the route in terms of being the new route linked between Khunming, Yunnan

Precinct, and Bangkok, Thailand. Other than the AHP technique, there were many criteria reported from other research works, which were major decisions. For example, [8] adapted the three multi criteria decision making approach in regards to the new centre of the air traffic of the European Union, assigned to administrate the air traffic transportation business.
There are 4 four main steps of AHP as follows:
Step 1. Divide the problem into a hierarchy of goal, criteria, sub-criteria, and alternatives.
Step 2. Enter the input data into the Pairwise Comparison Matrix to determine the weights for comparison of the various criteria. Given that,
A1, A2, A3,...A_n are the decision criteria,
The analysis is conducted in the form of the matrix n x n:

$$\begin{bmatrix} A_1 & A_2 & A_3 \\ 1 & A_2/A_1 & A_3/A_1 \\ A_1/A_2 & 1 & A_3/A_2 \\ A_1/A_3 & A_2/A_3 & 1 \end{bmatrix} \begin{matrix} \\ A_1 \\ A_2 \\ A_3 \end{matrix}$$

Step 3. Estimate the weights through the Geometric Mean.

Step 4. Set the weights with respect to the criteria or sub-criteria, and the ratings with respect to the alternatives.
The basis of the criteria for the location of the warehouse of grass in the Chiang Rai Province was the Conjunctive constrain method. The filtering factors were as below:

1. It must be less than 50 kilometers from the material source.
2. It must be located on the main transport routes.
3. It must have main roads linking to the area.

3. Results

3.1 SAW Method

In the data analysis, the first step was to smooth the data shown above. This would make the data considerably more convenient. From Table 2, the data was smoothed with Vector Normalisation. For the weight configuration for this study, the Ratio Weighting method was used, which was considered a heavy weight by considering the geometric mean of each factor. The weighted values were then calculated by multiplying the score by the smoothness multiplied by the weight of each factor as shown in Table 3.

Table 2. Smooth Adjustment Information and the Weight Value of the Factors

	Weight Value of Factors	**A**	**B**	**C**	**D**	**E**
X1	0.1789	0.4399	0.2932	0.5027	0.3519	0.5865
X2	0.1368	0.5880	0.5586	0.2940	0.2940	0.4116
X3	0.1263	0.3885	0.4856	0.1943	0.5828	0.4856
X4	0.0947	0.3714	0.3714	0.1857	0.3714	0.7428
X5	0.0632	0.5000	0.5000	0.3000	0.4000	0.5000
X6	0.0632	0.5774	0.5774	0.1925	0.3849	0.3849
X7	0.0632	0.2294	0.6882	0.2294	0.4588	0.4588

Table 3. Results by the SAW Method and Sequence

Alternative	**Score**	**Rank**
A	0.4610	3
B	0.4622	2
C	0.3232	5
D	0.4117	4
E	**0.4904**	**1**

Table 3 showed the SAW results. From the result, Alternative **(E)**, which was the area in the Pa Sang Sub-District, Mae Chan District, Chiang Rai Province, was considered to be the most suitable area for the selection of the grass collection areas by the SAW method.

grass flowers in the Chiang Rai Province, using the identified seven factors, such as size of the area (X1), land price (X2), labour cost (X3), utilities (X4), quantity of raw materials in the area (X5), ease of access to the area (X6), and distance from the source of the raw materials to the area (X7).

3.2 TOPSIS Method

The TOPSIS method was utilised to choose the suitable criteria. The appropriate criteria were set by considering the possible choices of the warehouses of

When TOPSIS adjusted the weight to a standard, it calculated the weight factor by multiplying the available information to make a smooth adjustment to the weighting normalisation and by identifying positive ways and negative ways by calculating v_j^* and v_j^- of the numerical consideration. The weight for this study used the Ratio Weighting, which was the weight of the value Geometric Mean of each factor in order to apply for the S^{*} S^{-} and C^{*}.

Table 4. Results of the Weighting Normalisation and Identifying the Positive and Negative Ways

Criteria	A	B	C	D	E	v_j^*	v_j^-
X1	0.0787	0.0525	0.0899	0.0630	0.1049	0.1049	0.0525
X2	0.0804	0.0764	0.0402	0.0402	0.0563	0.0804	0.0402
X3	0.0316	0.0316	0.0190	0.0253	0.0316	0.0316	0.0190
X4	0.0365	0.0365	0.0122	0.0243	0.0243	0.0365	0.0122
X5	0.0145	0.0435	0.0145	0.0290	0.0290	0.0435	0.0145
X6	0.0199	0.0199	0.0133	0.0199	0.0199	0.0199	0.0133
X7	0.0169	0.0169	0.0169	0.0084	0.0084	0.0169	0.0084

Table 5. Results of TOPSIS, showing S^*, S^-, and C^*, and the Ranking

Alternative	S^*	Rank	S^-	Rank	C^*	Rank
A	0.0580	2	0.0657	3	0.5312	2
B	0.0649	3	0.0695	2	0.5174	3
C	0.0939	5	0.0390	5	0.2936	5
D	0.0715	4	0.0590	4	0.4519	4
E	**0.0356**	**1**	**0.0886**	**1**	**0.7134**	**1**

From Tables 4 and 5, the results of TOPSIS indicated that E, in the Pa Sang Sub-district of the Mae Chan District, was the most suitable location for the warehouse, followed by A, Krung Sub-district, Chiang Khong District; B, Sri Don Chai Sub-district, Chiang Khong District; D, Mae Chan Sub-district, Mae Chan District; and C, Ban Saew Sub-district, Chiang Saen District.

3.3 AHP Method

The Analytic Hierarchy Process (AHP) was used to select the suitable factors. The appropriate criteria were set using the pre-determined seven criteria, such as size of the area (X1), land price (X2), labour cost (X3), utilities (X4), quantity of raw materials in the area (X5), ease of access to the area (X6) and distance from the source of the raw materials to the area (X7). Finally, the scores were summed by multiplying the weight of each criterion, as shown in Table 6.

Table 6. Results of the Total Sum of the Alternatives' Scores by the AHP Method

Alternative	Score	Rank
A	0.2331	2
B	0.2073	3
C	0.1260	5
D	0.1712	4
E	**0.2624**	**1**

From the AHP results, it showed that E**,** in the Pa Sang Sub-District, Mae Chan District of the Chiang Rai Province, was the most suitable location for the grass flower warehouse.

3.4 Summary of the Comparisons Amongst the Three Methods

Based on the multiple criteria decision-making (MCDM) approach, the findings of the rankings from the three methods, which had been averaged with the results of the sequence mean, are illustrated in Table 7; and the summary of the results sequence for each final score consistent with the determined sequence are shown in Table 8.

Table 7. Results from the MCDM Method and the Sequence Mean

Selections	SAW METHOD	TOPSIS METHOD	AHP METHOD	Sequence Mean
A	3	2	2	2.33
B	2	3	3	2.67
C	5	5	5	5
D	4	4	4	4
E	**1**	**1**	**1**	**1**

Table 8. Summary of the Results of Each Final Score

Sequence	SAW METHOD		TOPSIS METHOD		AHP METHOD	
	Selection	Score	Selection	Score	Selection	Score
1	**E**	**0.4904**	**E**	**0.7134**	**E**	**0.2624**
2	A	0.4622	B	0.5312	A	0.2331
3	B	0.4610	A	0.5174	B	0.2073
4	D	0.4117	D	0.4519	D	0.1712
5	C	0.3232	C	0.2936	C	0.1260

After all the data was analysed to find the most appropriate location by using the three decision making methods of SAW, TOPSIS, and AHP, it can be concluded that alternative E (Pa Sang Sub-district, Mae Chan District) is the most appropriate choice to establish a grass flower warehouse under the seven factors. This is because the size of the area and the price are acceptable to the suppliers. Also, the labour cost is lower than in the other areas with access to utilities and a large quantity of raw materials. Moreover, the area is easily accessible by trucks and not more than 50 km away from the source of the raw materials. From the comparison of the 3 methods, the second rank was A (Krung Sub-district, Chiang Khong District), followed by B (Sri Don Chai Sub-district, Chiang Khong District), D (Mae Chan Sub-district, Mae Chan District), and C (Ban Saew Sub-district, Chiang Saen District).

4. Conclusion

The purpose of this study was to select the warehouse location, which was the most suitable for businesses that buy or produce agricultural products to store the agricultural product of grass flowers, by using the multiple Criteria Decision Making theory (MCDM). MCDM was used to assist in the analysis and comparison of the results of the selection of the location of the agricultural product warehouse. Three methods were used, which were the Simple Additive Weighting (SAW), Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The results were compared from the three findings of the three decision making methods.

From the study, it was found that E, in the Pa Sang Sub-district, Mae Chan District, Chiang Rai Province, was selected to be the most suitable location for the grass flower warehouse. This was because the results from the three methods consistently indicated that this location was the best as compared to the rest. From the comparison of the three methods, it showed that A (Krung Sub-district, Chiang Khong District) was the second rank and B (Sri Don Chai Sub-district, Chiang Khong District) was the third rank. This was because these two areas fit the factor of land price which was higher than E but lower than the others. Moreover, the labour cost in these areas was lower than the rest and the access to utilities and a large quantity of raw materials were practically good.

This study employed one of many decision-making methods to find the most suitable location for a warehouse or a location for a business. There are other theories of decision making which can be utilised to compare and select different factors accurately, such as the ELECTRE method and the Fuzzy Set method used in the selection process. This study can be extended using the ELECTRE method and the Fuzzy Set method to assist in making an accurate selection of the agricultural product warehouse location, especially when the factors used in the selection process contain information that has no clear boundary and is incomplete. The two studies which used the ELECTRE method and the Fuzzy Set method were the, Application of Fuzzy AHP and ELECTRE to China Dry Port Location Selection [9] and A decision making method based on interval type-2 fuzzy sets: An approach for ambulance location preference [10].

From these two studies, it can be seen that the two theories were used because the factors selected contained information that was not clear-cut and had inexact values.

In addition, this study may be applied to future research on the selection of a location for different types of businesses or types of products, such as rice, corn, longan, cassava or industries that produce physical products. It can also be applied to the development and extension of other research work on decision making in agricultural businesses.

References

[1] Shaharudin, M.,R., Rashid, N. R., Wangbenmad, C., Hotrawaisaya, C. and Wararatchai, P., "A Content Analysis of Current Issue in Supply Chain Management", *International Journal of Supply Chain Management*, 2018 7(5) (2018) 199-212.

[2] Sudathip, T. and Sakda, H., *Business,* Empan Limited, Bangkok, 2004.

[3] Jahanshahloo, G. R., Lotfi, F. H. and Izadikhah, M., "Extension of the TOPSIS method for decision-making problems with fuzzy data", *Applied Mathematics and Computation*, 181(2) (2006) 1544-1551.

[4] Chou, Y. S., Chang, H. Y. and Shen, Y. C., "A fussy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes", *European Journal of Operational Research*, 189 (2008) 132-145.

[5] Vaidya, O. S. and Kumar, S., "Analytic hierarchy process: An overview of applications", *European Journal of Operational Research*, 169 (2006) 1-29.

[6] Kengpol, A., "Design of a decision support system to evaluate the investment in a new distribution centre", *International Journal of Production Economics*, 90(1) (2007) 59–70.

[7] Nimsrikul, P. and Sopadang, A., "Application of Multiple Criteria Decision Making for selecting the freight logistics hub in Thailand", in *Proceedings of the GTT Conference, Phetchaburi, Thailand,* 2008, 930- 941.

[8] Janic, M. M. and Reggiani, A., "An application of the Multiple Criteria Decision Making (MCDM) analysis to the selection of a new hub airport", *European Journal of Transport and Infrastructure Research*, 2(2) (2002) 113–141.

[9] KA, B., "Application of Fuzzy AHP and ELECTRE to China Dry Port location selection", *The Asian Journal of Shipping and Logistics*, 27(2) (2011) 331-354.

[10] Abdullah, L., Adawiyah, C. W. R. and Kamal, C. W., "A decision making method based on interval type-2 fuzzy sets: An approach for ambulance location preference", *Applied Computing and Informatics*, 14(1) (2018) 65–72.