HANDLING THE FACILITY LOCATION ISSUES OF MEDICAL DEVICE REPAIR CENTER WITH A HYBRID AHP-TOPSIS APPROACH: A CASE ON THE FACILITY LOCATION SELECTION IN THE WESTERN THAILAND

By
Miss Daidi XIE

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
Silpakorn University
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Facing the long-term market demand caused by Thailand's aging population and the outbreak of the COVID-19, while setting up hospitals and medical institutions to maintain people's demand for medical treatment, the utilization rate of various medical devices has also increased sharply, inevitably resulting in an urgent problem, namely, the maintenance of medical devices. The goal of this study is to combine two decision-making mathematical models, AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), to solve the site selection problem for a medical device maintenance center in western Thailand. This case comprehensively considers and analyzes ten key factors that affect the site selection with four candidate locations. After conducting interviews and research with seven senior experts from the medical device maintenance industry, and combining AHP and TOPSIS calculations, two main data analysis results were obtained. The weight values of the ten key factors obtained from the AHP operation indicate the three most important influencing factors, first customer quantity, second opportunities for the future, then making a profit. Based on another set of values of relative closeness calculated by TOPSIS, it can be concluded that position Prachuap Khiri Khan is the optimal solution for the case. The AHP-TOPSIS model proposed in this article fully utilizes the advantages of both algorithms and simplifies the calculation process to a certain extent. This model can be applied to address similar issues in medical industries, and can even be utilized in a wider range of multi criteria decision-making issues.

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Daidi XIE

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

1.1 Motivation

It is reported that a large area of Thailand has entered an aging society since 2022. The number of people aged 60 and above has increased in the population structure of Thailand, accounting for more than 20% of the total population of Thailand. The demand for certain medical devices and equipment (such as x-ray machine, MRI, Ventilator, masks, latex gloves et al.) is increasing at a fast rapid because of the demographic changes and the COVID-19 pandemic. The situation will continue for a long time in deep degrees with the fact that the spread of the virus is still not effectively controlled in many countries, leading the increasing number of infections. It is reasonable to believe that the battle against the virus will become a kind of daily behavior gradually.

Taken together, these factors provide an opportunity to develop the industry of medical devices and equipment. Thailand governments put great importance on the development due to the population of medical industry among foreign patients. As one of the results, building health centers is becoming part of the goals set by the government. It is reported that Thailand will focus on solving the problems of restricting the development of the medical industry and complete the overall upgrading task of Thailand's medical value industry chain quickly. The action plan will be divided into three steps. Firstly, the production and investment of medical devices and equipment will be promoted. Secondly, more market channels will be expanded and public hospitals will be encouraged to use more domestic medical equipment. Thirdly, medical research and development will be supported strongly.

There are more than 1,000 public hospitals and about 400 private hospitals in Thailand at present. Most of the medical institutions are concentrated in Bangkok and other central parts of Thailand. 60% of Thai medical equipment import orders come from public hospitals and 40% from private hospitals or nursing homes. Healthcare investment in

Thailand is increasing rapidly in response to the growing demand. The number of hospitals is significantly progressive at the same time.

Medical equipment dealing with patients’ care includes ranging from small and simple devices to complex and big devices. This ranking can be found in different types of hospitals and primary care settings (Hamdi et al., 2012). According to the studies conducted in Iran, about one-third of the costs of setting up and equipping the hospital is allocated for purchasing medical equipment (Karimi et al., 2017). Usually, much more money is spent on maintaining equipment over than on its procurement (Jamshidi et al., 2014). Therefore, medical devices and equipment repair helps to reduce costs, improve hospital service levels and protect or promote the normal operation of equipment performance. One of the effective ways to solve this problem is to increase the number of medical devices and equipment repair center. As a result, the facility location problems of the new medical devices and equipment repair center cannot be ignored.

The location problem is one of the classic problems in operations research. Site selection is one of the most important long-term decisions. The service methods, service quality, service efficiency, service costs, et al. are directly affected by the quality of site selection, which affects the profits, market competitiveness and even determines the fate of enterprises in further degree. Facility location means to select a suitable location where companies can keep their inventories, sustain their economic benefits and perform their logistics, production, and procurement functions. A wrong location selection can cause the growing costs in production and logistics, as well as difficulties in finding or reaching key resources such as raw material, human resources, other resources used for processes, governments support and infrastructure. The correctness of a specific location for proposing facility operations depends largely on what location factors are selected and calculated, as well as their possible effect on corporate objectives and processes (Rahman et al., 2018).

Location selection is one of the most delicate decisions because of the expensive and long-term effects from its nature. It is harder than any other strategic decisions to return back once it is selected. The decision involves location seeking, relocation or expansion. The identification, analysis and evaluation of alternatives are encompassed in the decision process, which also includes selection among them. The decision making process gets more complicated with every new criterion since there are many criteria to evaluate for a location (Yaşlıoğlu & Önder, 2016). In the case of facility location selection for the new medical devices and equipment repair center, the factors chosen include: skill of the worker, proximity to customers, community attitude, communication network, transportation, land, water, availability of raw materials, infrastructural facilities; government policy, climate condition, political conditions, construction, human resources, and other facilities (Rahman et al., 2018). There have been many debates and try outs to figure out the best practice to choose the right decision making process and tool with along (Yaşlıoğlu & Önder, 2016). Facility location has a well-developed theoretical background (Baumol & Wolfe, 1958). Generally, research in this area has been focused on optimizing methodology of facility location selection (Brown & Gibson, 1972; Erlenkotter, 1975; Rosenthal et al., 1978). The general procedure for making location decisions consists of the following steps: First is to decide the criteria that will be used to evaluate location alternatives. Second is to identify criteria that are important. Third is to develop location alternatives. Fourth is to evaluate the alternatives and make a selection (Stevenson, 1996).

Given that, criteria for possible evaluation were extracted from the literature and discussed with certain professionals (Yaşlıoğlu & Önder, 2016). In the optimal decision-making process, many different techniques have been proposed to overcome the difficulty from many criteria that must be considered and evaluated simultaneously. These technologies have also been applied in practice over time. Some of these techniques include mathematical techniques, intuitive techniques, financial techniques, simulations and some contemporary techniques based on hierarchy such as Analytical Hierarchical Processing (AHP), the Technique of Order Preference by a Similarity to Ideal Solution

(TOPSIS), Fuzzy Logic and Fuzzy TOPSIS, Fuzzy AHP, Analytical Network Processing (ANP) (Eleren, 2010; MacCarthy & Atthirawong, 2003; Yaşlıoğlu & Önder, 2016).

In this study, the main focus is on using Analytical Hierarchical Processing (AHP) and the Technique of Order Preference by a Similarity to Ideal Solution (TOPSIS) to address site the selection issue for a medical devices and equipment repair center in Thailand. The MCDM model Analytic Hierarchy Process (AHP) introduced by Saaty (1989) is one of the powerful techniques to obtain the factors' and sub-factors' weights. The model is widely used in numerous fields of engineering, economics and operations management. The weights of factors and sub-factors are calculated by the pair-wise comparison matrix (Ghorui et al., 2020). The Technique of Order Preference by a Similarity to Ideal Solution (TOPSIS) developed by Hwang et al. (1981) is a logistic approach to select the best alternatives in real life problems when there are several conflicting qualitative and quantitative criteria need to be evaluated. The idea of this technique is that the best alternative is closest to the positive ideal solution (PIS) and farthest from the negative ideal solution (NIS). Decision making problems with uncertainty nowadays play an important role (Abdel-Basset et al., 2018; Garg, 2016; Kumar & Garg, 2018; Sarkar, 2012; Sarkar et al., 2011; Selvachandran et al., 2018).

A brief summary of some applications of AHP are presented: AHP technique at school site selection (Uslu et al., 2017), hospital facility location selection problem (Aydın et al., 2009; Datta, 2012; İnce et al., 2017; Vafaei & Oztaysi, 2014; Vahidnia et al., 2009; Wu et al., 2007), facility layout (Aiello et al., 2006). Since TOPSIS technique is one of the most commonly applied techniques to determine facility locations. Some advantages of this method can be summarized as: the understandable and logical conception, the reason of human choices, simple computation, high efficiency and permission to assess the best and worst option's relative performance (Pınar & Antmen, 2019).

In this study, the Analytic Hierarchy Process and TOPSIS methods will be used to rank facility location issues of a medical devices and equipment maintenance center in Thailand. First the weights of the standards will be calculated using Analytic Hierarchy Process. Because AHP is a very successful tool for converting qualitative judgments into quantitative judgments. Then, the standards' weights (the output of AHP) will be used as the input of TOPSIS to rank facility locations. Thus, the best solution to this problem can be obtained.

1.2 Research Objective

1) To solve the location selection issue for a medical devices and equipment repair center in the west of Thailand.

2) To propose a usable template for addressing medical devices and equipment location selection issues.

1.3 Research Scope and Limitations

This research examined only the application of hybrid model of AHP and TOPSIS in the location selection for a medical devices and equipment maintenance center in the west of Thailand. The researcher classified the scope into 4 aspects as follows:

1) The scope of the participants is among the workers or experts in the industry of medical devices and equipment in the west of Thailand.

2) The scope of content is to focus on site selection for the maintenance center throughout the method from hybrid model of AHP and TOPSIS.

3) Area boundaries: The researcher defined the area in this study as the west of Thailand.

4) Scope of time: Data collection will be finished during November of 2023.

1.4 Expected Results

1) To acquire the ideal site for the medical devices and equipment maintenance center in the west of Thailand.

2) To obtain the template for addressing location selection issues.

1.5 Research Contributions

The main contributions of this thesis are:

1) Receive a usable template for addressing medical devices and equipment location selection issues.

2) To extend the service life of medical devices and equipment, improve the use efficiency, and play a positive role in combating the COVID-19.

1.6 Definition of Terms

MCDM/MCDA: Multiple-criteria decision-making multiple-criteria decision analysis is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making (both in daily life and in settings such as business, government and medicine).

AHP: The Analytic Hierarchy Process is a method for organizing and analyzing complex decisions, using math and psychology. It was developed by Thomas L. Saaty in the 1970s and has been refined since then (Saaty, 1972).

TOPSIS: The Technique for Order of Preference by Similarity to Ideal Solution is a multi-criteria decision analysis method, which was originally developed by Hwang et al. (1981) with further developments by Yoon in 1987, and Hwang, Lai and Liu in 1993.

PIS/NIS: TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution (PIS) and the longest geometric distance from the negative ideal solution (NIS).

CHAPTER 2
LITERATURE REVIEW

2.1 Analytic Hierarchy Process

2.1.1 Intention

For the location selection of medical device maintenance centers in Thailand which involves complex social, economic, and ecological issues, if it is based on experience and subjective judgment, it lacks the necessary scientificity and may result in significant errors. Analytic Hierarchy Process (AHP) is a new systematic analysis method that combines qualitative and quantitative analysis. It expresses and processes human subjective judgments in quantitative form.

The root of AHP can be dated back to the work of Saaty in 1972. It is a widely used tool in the problem of multi-criteria decision making (MCDM) (Saaty, 1972, 1994; Yu et al., 2021). The reasons for choosing to use AHP are:

1) AHP is flexible and can be used as an independent tool or in combination with other tools to solve decision-making problems;

2) AHP has a small sample size, high consistency, and is easy to use;

3) AHP is widely used.

2.1.2 Analytic Hierarchy Process (AHP)

AHP is a decision-making method that decomposes elements related to decision-making into levels such as goals, criteria, and plans, and conducts qualitative and quantitative analysis on this basis. Using Analytic Hierarchy Process modeling to solve practical problems can be :done in the following five steps

Step 1: .Define the problem and determine the goal

Step 2Analyze the relationship between various factors in the : system and establish a hierarchical structure of the system.

Firstly, organize and hierarchy the system problems to construct a hierarchical analysis structural model. In the model, complex problems are decomposed, and the decomposed components are called elements. These elements are then divided into several groups according to their attributes, forming different levels. Elements at the same level serve as guidelines to govern certain elements at the next level, while at the same time being governed by elements at the upper level. The hierarchy can be divided into three categories:

1) The top level: There is only one element in this level, which is the predetermined goal or ideal result of the problem, hence it is also called the goal level.

2) The intermediate level: This level includes the criteria that need to be considered in the intermediate links involved in achieving the goals. This layer can be composed of several levels, thus there are criteria and sub criteria, and this layer is also called the criteria layer.

3) The lowest level: This level includes various measures, decision-making options, etc. that can be chosen to achieve goals, and is .therefore also known as the measure or solution layer

The hierarchical structure formed by the dominant relationship between upper level elements and lower level elements is called hierarchical hierarchy. Of course, the upper level element can dominate all the lower level elements, but it can also only dominate some of them. The number of levels in a hierarchical hierarchy is related to the complexity of the problem and the level of detail that needs to be analyzed, and it is not limited. Each element in each level should generally not exceed 9 elements, as having too many dominant elements can make it difficult for couples to compare and judge. The quality of the hierarchical structure is extremely important for solving problems, Of course, the quality of establishing a hierarchical structure is closely related to the decision-maker's comprehensive and profound .understanding of the problem

Step3: Compare the importance of each element at the same level with respect to a certain criterion in the previous level, and construct a judgment matrix for pairwise comparison.

In a hierarchical structure, set the upper level element C as the criterion, and the next level element dominated by it is the relative importance of u_1, u_2, ..., u_n to criterion C is the weight. This can usually be divided into two situations:

1) If the importance of u_1, u_2, ..., u_n to C can be quantified (such as currency, weight, etc.), and its weight can be directly determined.

2) If the problem is complex, the importance of u_1, u_2, ..., u_n to C cannot be directly quantified and can only be qualitatively determined, therefore, the weight is determined using a pairwise comparison method. The method is: for criterion C, which of the elements u_i and u_j is more important, and what is the degree of importance? Usually, the importance degree is assigned based on a scale of 1-9. The meaning of the scale of 1-9 is listed in the table below.

Table 1. The Meaning of Scale

Scale	Meaning
1	Compared to two elements, they are equally important
3	Compared to the two elements, the former is slightly more important than the latter
5	Compared to the two elements, the former is significantly more important than the latter
7	Compared to the two elements, the former is more strongly important than the latter
9	Compared to the two elements, the former is more strongly important than the latter
2,4,6,8	Intermediate value of adjacent judgments mentioned
Count Backwards	If the importance ratio of element i to j is a_i, then the importance ratio of element j to element i is $a_{ji} = \frac{1}{a_{ij}}$

For criterion C, the comparison of the relative importance between n elements yields a pairwise comparison judgment matrix $A = (\mathrm{a}_{ij})_{n \times n}$,

which is

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{2.1}$$

Where a_j is the proportional scale of the importance of elements u_i and u_j relative to C. The judgment matrix A has the following properties:

$$a_{ij} > 0 \ , \ a_{ji} = \frac{1}{a_{ij}} \ , \ a_{ii} = 1 \tag{2.2}$$

The properties of a judgment matrix indicate that a judgment matrix with n elements only needs to provide n (n-1) / 2 elements of the upper (or lower) triangle, that is, only n (n-1) / 2 comparative judgments need to be made.

If all elements of matrix A satisfy $a_i \times a_{jk} = a_{ik}$, then A is called a consistency matrix.

Not all judgment matrices meet the consistency condition, and there is no need for such a requirement. It is only possible to meet the consistency condition in special circumstances.

Step4: Calculate the relative weight of the compared elements to the criterion using the judgment matrix and verify the consistency of the matrix.

(1) Calculation of relative weights of elements under a single criterion:

Given A is the judgment matrix of n elements u_1, u_2, ..., u_n for criterion C, find the relative weights w_1, w_2, ..., w_n of u_1, u_2, ..., u_n for criterion C, written in vector form, is $W = (w_1, w_2, ..., w_n)^T$.

Weight calculation method:

1) Summation method: Normalize the arithmetic mean of n row vectors in the judgment matrix A, and approximate it as a weight vector, i.e.

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n}a_{kj}} \qquad i=1, 2, ..., n. \tag{2.3}$$

The calculation steps are as follows:

Firstly, normalize the elements of matrix A by row.

Secondly, add the normalized rows.

Thirdly, divide the added vectors by n to obtain the weight vector

Similarly, the column sum normalization method is used for calculation, namely,

$$w_i = \frac{\sum_{j=1}^{n}a_{ij}}{n\sum_{k=1}^{n}\sum_{j=1}^{n}a_{kj}} \qquad i=1, 2, ..., n. \tag{2.4}$$

2) Rooting method, also known as geometric averaging method, involves geometrically averaging the row vectors of matrix A and normalizing them to obtain the weight vector. The formula is

$$w_i = \frac{\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n}a_{kj}\right)^{\frac{1}{n}}} \qquad i=1, 2, ..., n. \tag{2.5}$$

The calculation steps are as follows:

Firstly, multiplying the elements of matrix A by columns yields a new vector.

Secondly, open each component of the new vector to the nth power.

Thirdly, normalize the obtained vector to become the weight vector.

3) The method of finding characteristic roots.

The Eigenroot Problem of Judgment Matrix A:

$$AW = \lambda_{\max}W \tag{2.6}$$

Where λ_{max} (found from equation 2.9) is the maximum eigenvalue of matrix A, W is the corresponding feature vector, and the obtained W can be used as a weight vector after normalization.

(2) Consistency Testing of Judgment Matrices:

When calculating the weight vector under a single criterion, consistency testing must also be performed. In the construction of judging short matrices, it is not required that judgments have transitivity and consistency, that is, they do not strictly hold $a_i \times a_{jk} = a_{ik}$, which is determined by the complexity of objective things and the diversity of human understanding. But it is necessary to require that the judgment matrix satisfy general consistency. If there is a judgment that A is extremely important than B, B is extremely important than C, and C is also extremely important than A, it is clearly against common sense, and a chaotic judgment matrix that cannot withstand scrutiny may lead to decision-making errors. Moreover, the reliability of the various methods for calculating ranking weight vectors (i.e. relative weight vectors) mentioned above is questionable when the judgment matrix deviates too much from consistency. Therefore, it is necessary to test the consistency of the judgment matrix. The specific steps are as follows:

1) Calculate consistency indicator CI.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{2.7}$$

2) Find the corresponding average random consistency indicator RI.

The following table provides the average random consistency indicators obtained from 1000 calculations of the 1-14 order reciprocal matrix.

Table 2. Average Random Consistency Index RI

Matrix order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41

Matrix order	9	10	11	12	13	14
RI	1.46	1.49	1.52	1.56	1.58	1.59

3) Calculate consistency ratio CR.

$$CR = \frac{CI}{RI} \tag{2.8}$$

When CR < 0.1, it is considered that the consistency of the judgment matrix is acceptable; When CR ≧ 0.1, appropriate corrections should be made to the judgment matrix.

In order to discuss consistency, it is necessary to calculate the maximum eigenvalue λ_{max} of the matrix. In addition to the commonly used eigenvalue method, the following formula can also be used:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nw_i} = \frac{1}{n} \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} a_{ij} w_j}{w_i} \tag{2.9}$$

4) Calculate the total ranking weight of each layer element on the target layer. The above obtained is the weight vector of a set of elements to a certain element in the previous layer. The final goal is to obtain the ranking weights of each element, especially those in the lowest layer, for the target, which is called the total ranking weight, in order to select a solution. The overall ranking weight is important for synthesizing the weights under a single criterion from top to bottom, and conducting a layer by layer overall judgment consistency test.

$$W^{(K-1)} = (w_1^{(k-1)}, w_2^{(k-1)}, \Lambda\ , w_{k-1}^{(k-1)})^T \tag{2.10}$$

$$P_j^{(k)} = (p_{1j}^{(k)}, p_{2j}^{(k)}, \Lambda\ , p_{n_k j}^{(k)})^T \tag{2.11}$$

$$P^{(k)} = (p_1^{(k)}, p_2^{(k)}, \Lambda\ , p_{n_{k-1}}^{(k)})^T \tag{2.12}$$

Let $W^{(K-1)}$ represents the sorting weight vector of n_{k-1} elements on the (k-1)-th layer relative to the total target, and use $P_j^{(k)}$ to represent the sorting weight vector of n_k elements on the k-th layer relative to the j-th element on the (k-1)-th layer as the criterion. The weight of elements which aren't controlled by element j is taken as zero. The matrix $P^{(k)}$ is a $n_k \times n_{k-1}$ order matrix which represents the sorting of elements on the k-th layer towards each element on the (k-1)-th layer. Therefore, the total sorting W of elements on the k-th layer towards the target is:

$$W^{(K)} = (w_1^{(k)}, w_2^{(k)}, \Lambda\ , w_{n_k}^{(k)})^T = P^{(k)} W^{(k-1)} \quad (2.13)$$

Or

$$w_i^{(k)} = \sum_{j=1}^{n_{k-1}} p_{ij}^{(k)} w_j^{(k-1)} \quad \text{i=1,2,...,n} \quad (2.14)$$

And the general formula is

$$W^{(K)} = P^{(k)} P^{(k-1)} \Lambda\ W^{(2)} \quad (2.15)$$

where (W^2) is the total sorting vector of the elements on the second layer, and it is also the sorting vector under a single criterion.

To conduct consistency testing layer by layer from top to bottom, if the consistency index $CI_j^{(k)}$, average random consistency index $RI_j^{(k)}$, and consistency ratio $CR_j^{(k)}$ (where j=1, 2, ..., n_{k-1}) based on element j on layer (k-1) have been obtained, then the comprehensive index $CI_{(k)}$ of layer k is:

$$CI^{(K)} = (CI_1^{(K)}, \Lambda\ , CI_{n_{k-1}}^{(K)}) W^{(K-1)} \quad (2.16)$$

$$RI^{(K)} = (RI_1^{(K)}, \Lambda\ , RI_{n_{k-1}}^{(K)}) W^{(K-1)} \quad (2.17)$$

where $CR^{(K)} < 0.1$, it is considered that all judgments of the hierarchical hierarchy at the level of layer k have overall satisfactory consistency.

Step5: Calculate the composite weights of each layer element on the system objectives and sort them.

2.1.3 Applications of AHP

Since the method was proposed, it has been applied in many areas such as environmental science, management science, manufacturing engineering, energy evaluation and selection, etc. (Ananda & Herath, 2009; Badri, 1999; Chan & Kumar, 2007; Chatzimouratidis & Pilavachi, 2008; Kahraman et al., 2004; Kahraman et al., 2009; Ramanathan, 2001; Wei et al., 2005; Yu et al., 2021).

Chai et al. (2013) used the AHP method to specify a value representing the preference of a given alternative solution for each additional solution. These values can be used to classify and select alternative solutions based on a hierarchical structure. Gupta et al. (2010) illustrated and assessed the role the AHP played in simulation software evaluation and selection. Jadhav and Sonar (2011) pointed out that AHP is the widely used existing software evaluation techniques. According to Tam and Tummala (2001), AHP is also applied to improve the group decision making in selecting a vendor that satisfies customer specifications. Also, it is found that the decision process is systematic and that using the proposed AHP model can reduce the time taken to select a vendor. Mendes Jr et al. (2016) presented a theoretical framework to assist companies to assess their current stage of maturity for a demand-driven supply chain and to develop strategies to progress towards higher maturity levels. Guimarães et al. (2018) developed a new method to help an industry select the right discrete-event simulation software, which helped improve the productivity of a given process.

2.2 Technique for Order of Preference by Similarity to Ideal Solution

2.2.1 Motivation

The Technique for Order Preference by Similarity to ideal Solution (TOPSIS) developed by Hwang et al. (1981) is a technique to evaluate the performance of alternatives through the similarity with the ideal solution (Krohling & Pacheco, 2015). The central idea of this method is to first determine the positive and negative ideal values of various indicators. The so-called positive ideal solution is the best value (scheme) of an idea, and its various attribute values reach the best value among the candidate schemes, while the negative ideal solution is the worst value (scheme) of another idea. Then, the weighted Euclidean distance between each scheme and the ideal and negative ideal values is calculated, and the degree of closeness between each scheme and the optimal scheme is obtained, as a criterion for evaluating the quality of a plan.

TOPSIS method is one of the comprehensive evaluation methods for multi-objective decision-making with limited options. After processing the original data with the same trend and normalization, it eliminates the influence of different indicator dimensions and fully utilizes the information of the original data. Therefore, it can fully reflect the differences between different options and objectively reflect the actual situation. It has the advantages of authenticity, intuition, and reliability. Moreover, it has no special requirements for sample data, so its application is becoming increasingly widespread.

2.2.2 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

Let the set of alternative solutions for an attribute decision problem be X:

$$X = \{x_1, x_2, \Lambda\ , x_m\} \tag{2.18}$$

Y_t represents n attribute values of scheme x_i :

$$Y_t = \{y_{t1}, y_{t2}, \Lambda\ , y_{tn}\} \tag{2.19}$$

When the objective function is f_j :

$$y_{ij} = f_j(x_i) \quad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.20}$$

The ideal solution x^* is a virtual optimal solution that does not exist in the solution set X, where each attribute value is the best value of that attribute in the decision matrix. The negative ideal solution x^0 is the virtual worst-case scenario, where each attribute value is the worst-case value of that attribute in the decision matrix. In n-dimensional space, compare the distances between alternative solutions x_i in solution set X with ideal solution x^* and negative ideal solution x^0. The solution that is both close to the ideal solution and far from the negative ideal solution is the best solution in solution set X. And based on this, the priority order of each alternative solution in solution set X can be determined.

According to the concept of solving multi-attribute decision-making problems with ideal solutions, as long as appropriate distance measures are defined in the attribute space, alternative solutions and ideal solutions can be calculated. The TOPSIS method uses Euclidean distance. As for using both ideal and negative ideal solutions, it is because sometimes when using only ideal solutions, there may be situations where two alternative solutions have the same distance from the ideal solution. In order to distinguish the advantages and disadvantages of these two solutions, negative ideal solutions are introduced and the distance between these two solutions and the negative ideal solution is calculated. The solution with the same distance from the ideal solution is the best.

To find the relative closeness of x_i to the ideal solution:

$$C_i^* = \frac{d_i^0}{d_i^0 + d_i^*} \quad \text{i=1, 2, ..., m.} \tag{2.21}$$

$$0 \le C_i^* \le 1 \quad \text{i=1, 2, ..., m.} \tag{2.22}$$

If x_i is an ideal solution, then $C_i^* = 1$; If x_i is a negative ideal solution, then $C_i^* = 0$; The closer C_i^* is to 1, the ranking of the plan moves forward.

The algorithm steps of TOPSIS method:

Step1: Use the method of vector normalization to obtain the canonical decision matrix.

The original decision matrix is denoted as Y the transformed decision matrix is denoted as Z:

$$Y = (y_{ij}) \quad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.23}$$

$$Z = (z_{ij}) \quad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.24}$$

Then: $$z_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{m} y_{ij}^2}} \qquad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.25}$$

Step2: Construct a weighted norm matrix X:

$$X = (x_{ij}) \qquad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.26}$$

Solution set w is given by the creator:

$$w = (w_1, w_2, \Lambda\ , w_n)^T \tag{2.27}$$

Then: $$x_{ij} = w_j z_{ij} \qquad \text{i=1, 2, ..., m; j=1, 2, ..., n.} \tag{2.28}$$

Step3: Determine the ideal solution x^* and negative ideal solution x^0.

the ideal solution $$x_j^* = \begin{cases} \max\limits_i x_{ij} & \text{j is a benefit type attribute} \\ \min\limits_i x_{ij} & \text{j is a cost type attribute} \end{cases} \qquad \text{j=1, 2, ..., n.} \tag{2.29}$$

the negative Ideal solution $$x_j^0 = \begin{cases} \min\limits_i x_{ij} & \text{j is a benefit type attribute} \\ \max\limits_i x_{ij} & \text{j is a cost type attribute} \end{cases} \qquad \text{j=1, 2, ..., n.} \tag{2.30}$$

Step4: Calculate the distance from each solution to the ideal solution and negative ideal solution.

The distance from alternative x_i to the ideal solution is:

$$d_i^* = \sqrt{\sum_{j=1}^{n} (x_{ij} - x_j^*)^2} \qquad \text{i=1, 2, ..., m.} \tag{2.31}$$

The distance from alternative x_i to the negative ideal solution is:

$$d_i^0 = \sqrt{\sum_{j=1}^{n}(x_{ij} - x_j^0)^2} \qquad \text{i=1, 2, ..., m.} \qquad (2.32)$$

Step5: Calculate the queuing index values for each scheme.

$$C_i^* = \frac{d_i^0}{d_i^0 + d_i^*} \qquad \text{i=1, 2, ..., m.} \qquad (2.31)$$

$$0 \le C_i^* \le 1 \qquad \text{i=1, 2, ..., m.} \qquad (2.32)$$

Step6: Determine the order of advantages and disadvantages based on the descending order of C_i^* values.

2.2.3 Utilization of TOPSIS

It can be seen that TOPSIS method is a very practical multi-attribute decision analysis method, which can help us consider problems in multiple aspects and make more comprehensive and accurate decisions. In practical applications, we can flexibly apply the TOPSIS method according to specific situations, providing strong support for enterprise management, marketing, investment decision-making, and other fields.

Hu et al. (2023) used TOPSIS method to optimize the anti-aging performance of high content polymer modified asphalt. Gómez-López et al. (2009) successfully selected the optimal disinfection process before sewage treatment using the TOPSIS method under multiple stakeholder criteria. Montanari (2004) also proposed a methodology, based on the TOPSIS method, to estimate the environmental efficiency of 15 thermal energy power plants (Gómez-López et al., 2009). Lai et al. (1994) solved the Bow River Valley water quality management problem using the second-order compromise operation of the max-min operator based on TOPSIS method. The TOPSIS method can help Deng et al. (2000) identify the correlation between financial ratios and evaluation results, and reflect the performance differences of enterprises in various financial ratios, thereby helping them evaluate and rank the relative performance of competing companies.

2.3 Enhancing the strengths of AHP and TOPSIS

2.3.1 Introduction

The advantage of AHP method is that it can maximize the consideration of expert opinions and quantify the opinions of each expert into weights. In addition, the AHP method can also consider the mutual influence relationships between different levels, thereby more accurately assessing risks. However, the AHP method also has some drawbacks. Firstly, the AHP method requires experts to have a certain understanding and experience of the problem, and the quality of evaluation depends on the individual abilities and levels of the experts. Secondly, the AHP method quantifies the information provided by experts, and the subjectivity and uncertainty of expert opinions inevitably affect the evaluation results.

The advantage of TOPSIS method is that it is easy to understand and does not require too much subjective judgment from experts. It can directly standardize and calculate the evaluation matrix. The TOPSIS method can also consider the weights of different factors and objectively evaluate risks. Similarly, this method also has drawbacks. Firstly, when standardizing and calculating the evaluation matrix, it is necessary to assign weights to each factor. However, assigning weights is a highly subjective process. Secondly, the TOPSIS method can only find the optimal solution and cannot consider the situation of sub optimal solutions, which may lead to incomplete evaluation results.

This article aims to solve the problem of site selection for medical device maintenance centers in Thailand. Based on the previous text, it is not difficult to understand that the AHP method can objectively give the weights of various factors, while the TOPSIS method can comprehensively consider various factors provided by relevant experts. If these two methods are combined, the accuracy of such multi criteria evaluation systems can be greatly improved.

2.3.2 Applications of AHP - TOPSIS Hybrid

The AHP-TOPSIS method is a multi-criteria decision analysis method that can help decision-makers comprehensively compare and rank multiple evaluation indicators and alternative solutions to assist decision-making. Throughout the literature, the AHP-TOPSIS method can be applied to various decision-making problems, such as location selection, supplier selection, investment decision-making, etc.

TOPSIS-AHP simulation model was illustrated to solve a simplified supplier selection problem in SCM by Wu (2007). When considering the different attributes that affect the selection decision of non-traditional machining processes, Chakladar and Chakraborty (2008) proposed a method based on a combination of AHP and TOPSIS to select the most suitable non-traditional machining process for a specific combination of work piece materials and shape features. In order to improve the performance of electronic supply chain management in the Indian automotive industry located in the Delhi region, Tyagi et al. (2014) developed a hierarchical based model using AHP and TOPSIS. Singh and Kumar (2013) attempted to apply the AHP-TOPSIS hybrid method to measure the likelihood of success in using advanced manufacturing technologies in the manufacturing industry in northern India. AHP and TOPSIS approaches were applied to solve the problem of selecting a solid waste transfer site in Istanbul, Turkey by Önüt and Soner (2008). Kusumawardani and Agintiara (2015) studied the application of the AHP-TOPSIS hybrid method in the manager selection process of a well-known telecommunications company in Indonesia. Bathrinath et al. (2021) proposed the most influential risk identification and prevention measures using the AHP and TOPSISI methods, mitigating the risks and key choices that affect the industrial performance of a leading textile industry in southern Tamil Nadu, India. Also, there was a specific case studied by Yaşlıoğlu and Önder (2016) to solve facility location problem for a plastic goods manufacturing company in Turkey based on the AHP-TOPSIS method.

2.4 Conclusion for AHP and TOPSIS

It can be seen that by combining AHP and TOPSIS methods, comprehensive comparison and ranking can be provided when facing multiple evaluation indicators and alternative solutions. This method has good practicality and applicability. Based on APH-TOPSIS, decision-makers can make decisions more scientifically and objectively, improving the accuracy and reliability of their decisions.

2.5 Analysis of the Site Selection Problem for the Sample Company

2.5.1 Description of Influencing Factors

It is necessary to find suitable location for enterprises to grow rapidly and vigorously. A correct location selection is equivalent to finding a lucky spot, which will accelerate the development of the company. On the contrary, a failed site selection may lead to slow development or even death of the enterprise. Therefore, we need to carefully discuss what are the most important factors that enterprises should consider when selecting a location.

Şahin et al. (2019) considered the correlation of complex factors, such as regional competition, transportation conditions, and regional popularity, and ranked candidate factors to assist in successfully selecting a new gas station in New York City. Şahin et al. (2019) studied a decision-making support model for the location of a new hospital in Muğla, Turkey based on six criteria (demand, accessibility, competitors, government, related industry and environmental conditions). Eleven criteria were selected by Tripathi et al. (2021) for the analysis of the location and sensitivity of the proposed hospital site in Prayagraj City, India to determine the impact of the hospital's location and level on the planning and development of the national health infrastructure, which included population density, proximity to slum area, land cost, accessibility (proximity to road and railway), distance to other hospital, possibility of extension, slope, air pollution, green area, and unhealthy industry. Based on four decision criteria (radius, distance, time, density), Rohman and Sari (2020) choose the best location for medical facilities with consideration from actual situations. Alosta et al. (2021) clearly represented the road network to optimize the optimal location of emergency medical service centers in Libya according to the decision criteria composed of response time, demand, coverage area and ambulance workload. Boyacı and Şişman (2022) provided a site selection method for two pandemic hospitals in Samsun, Turkey, with the criteria consisted of population density, distance to transportation network, distance to existing hospitals, distance to fire stations, land value, Slope, and distance to industrial areas.

After studying relevant literature, this article has identified the following standards as the basis for solving the problem in this case, shown in Table 3.1.

Near the Customer: When selecting a location, it is necessary to consider the geographical distribution of customers in order to conveniently provide services and products. Siting close to major customer groups can reduce logistics and transportation costs and provide faster services.

Near the Warehouse and Spares: It's essential to establish a relationship between storage facilities and the supply chain. Choosing a location close to suppliers and logistics centers will help shorten logistics time and reduce inventory costs.

Fast and Convenience of Service: It should be considered whether it is easy to obtain the necessary human and service resources, such as professional talents and delivery services.

Investment and Profit: Site selection decisions also need to consider construction and operating costs, as well as expected profit levels. The cost includes rent, water and electricity expenses, personnel salaries, decoration expenses, equipment and material purchase expenses, and so on. Lower costs and potential high profits will increase the attractiveness of site selection.

Customer Quantity: A crucial to maximize potential sales opportunities is the number of potential customers and market size. It is worth noting that population density or foot traffic may not necessarily represent the number of customers. Precise analysis needs to be conducted based on industry characteristics.

Opportunities for the Future: It is also important to consider future development trends and opportunities, such as the potential for development in emerging markets or industries. The evaluation of the development trend of store locations is actually to analyze urban planning.

The location selection needs to analyze the planning of urban construction, including both short-term and long-term planning. Operators must consider the long term and make the best location selection based on understanding the planning of transportation, streets, municipal facilities, greenery, public facilities, residential and other construction or renovation projects in the area.

Safety: Safety factors including the risks of natural disasters such as earthquakes, fires, floods, and social safety factors such as crime rates should be taken into account.

Transportation and return routes: Another important consideration is transportation convenience, including the proximity of roads, railways, ports, and airports, as well as the convenience of return logistics. The location selection must investigate the traffic situation, taking into account the distance from the station, road conditions, the nature of the station, and traffic linkage. The convenience of transportation, as well as the number and distance of parking lots, are also one of the influencing factors for passenger sources.

Table 3. Factors' Name and Serial Number

Serial Number	Factor Name
F_1	Near the Customer
F_2	Near the Warehouse and Spares
F_3	Fast and Convenience of Service
F_4	Investment
F_5	Make A Profit
F_6	Customer Quantity
F_7	Opportunities for the Future
F_8	Safety
F_9	Transportation for Return A Product to the Company
F_{10}	Transportation Lines

Taking into account the above factors, enterprises can choose the location plan that best meets their business needs and strategic goals. Specific site selection decisions require detailed market research and feasibility analysis.

2.5.2 Determination of Candidate Locations

Thailand has northern mountainous areas, with Central Thailand located in Southeast Asia, adjacent to Laos and Cambodia to the east, the Gulf of Thailand and the Andaman Sea to the south, Myanmar to the northwest, and Vietnam to the northeast. The national area is approximately 513120 square kilometers. Thailand is narrow from north to south, with a triangular shape, mainly composed of mountains, plains, plateaus, and rivers. The mountainous areas of Thailand are mainly distributed in the north and west, including large and small mountain ranges and hills. The highest peak is the Dawao Mountain located in the north, with an elevation of 2565 meters. Thailand is rich in natural resources, including rice, fruits, rubber, tobacco, wood, tungsten, iron ore, tin, manganese, copper, zinc, oil, natural gas, limestone, quartz, etc.

This survey will interview some experts in the medical device industry from the IDS Medical Systems (Thailand) Company (idsMED Group). This is a leading medical supply chain solutions company in Southeast Asia. It has an extensive distribution network with access to over 10,000 healthcare institutions and represents over 200 global medical brands in equipment and medical consumables. These include GE Healthcare, Philips, Maquet, Trumpf, Hill-Rom, Hamilton, Biosensors, Biotronik Smiths Medical, Teleflex, Ansell and others. idsMED has a workforce of 1,600 employees including 600 highly experienced field medical and sales specialists and over 200 professional bio-medical engineers providing installation and maintenance services.

According to the information disclosed by the company, considering the concentration of customers and the optimization strategy of overall service costs, the main target scope of this site selection is the western Thailand. Researcher has conducted data on six major provinces in western Thailand. The location of the provinces and hospitals in western Thailand on the map is shown in the following Figure 1 and Figure 2.

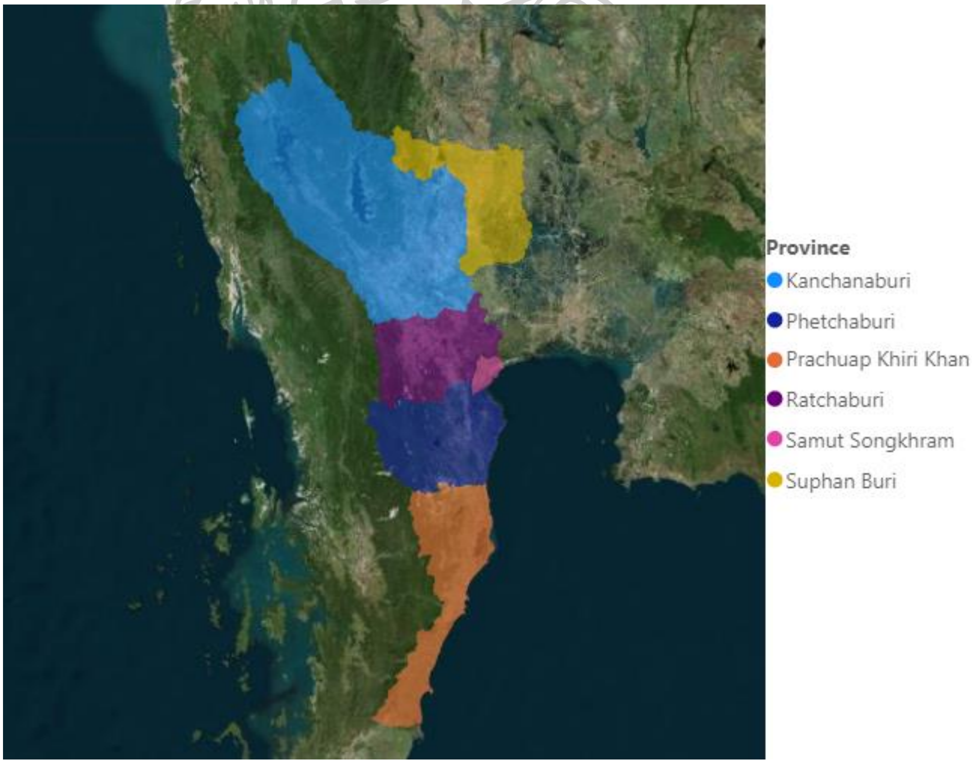

Figure 1. The Provinces in Western Thailand

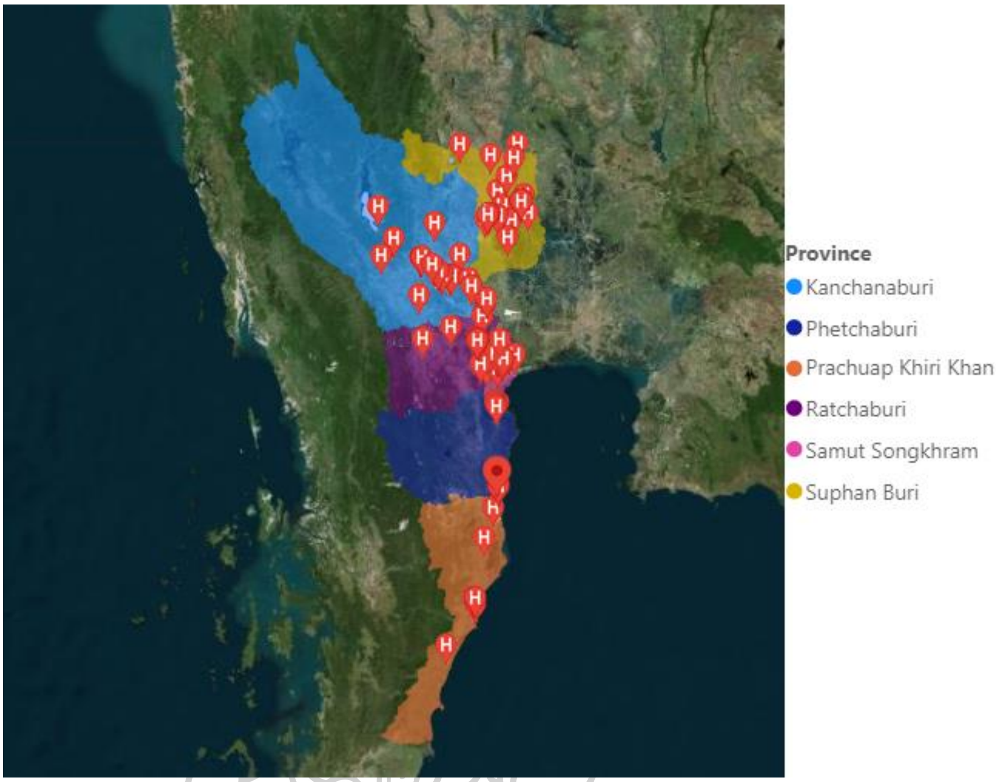

Figure 2. The Hospitals in Western Thailand

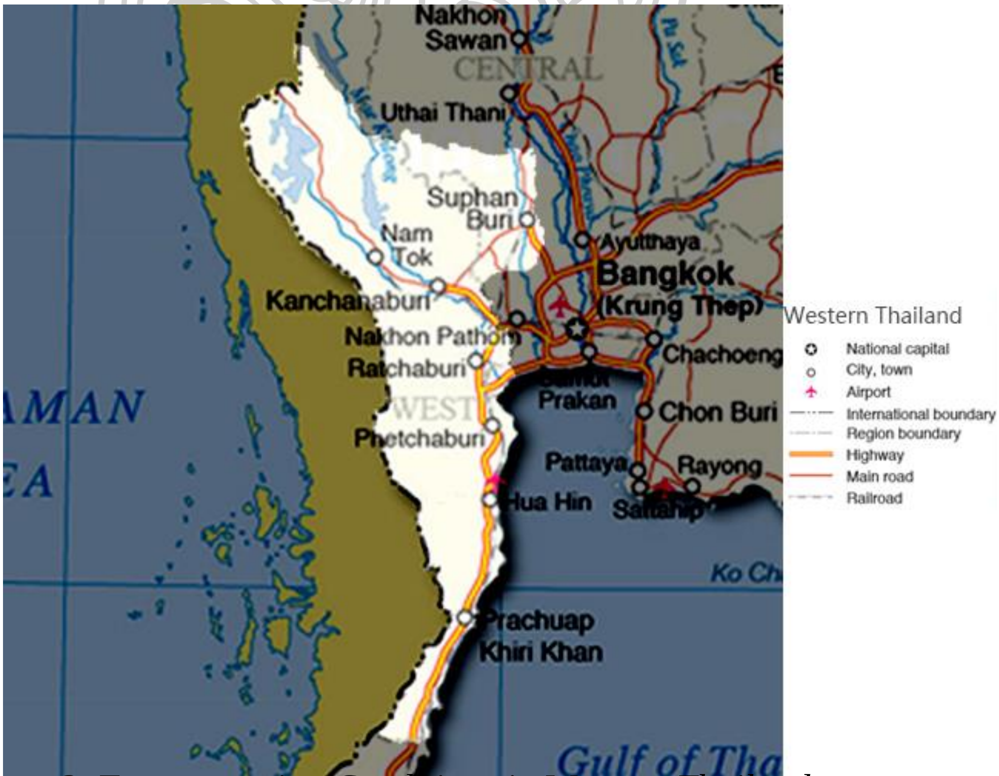

Figure 3. Transportation Conditions in Western Thailand

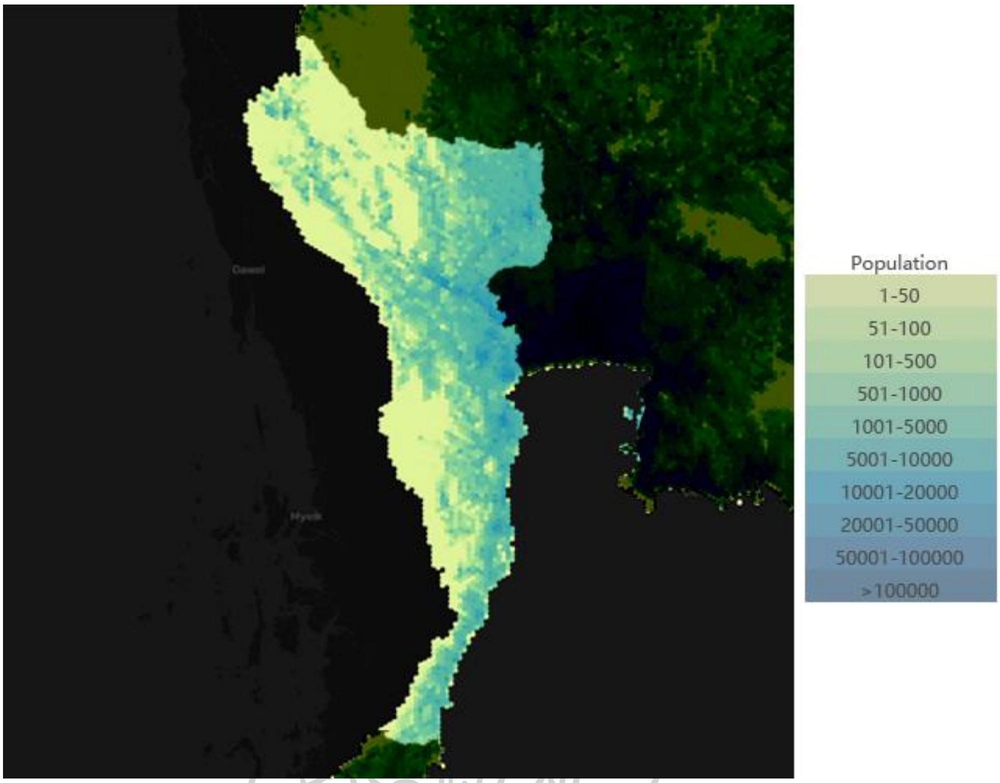

Figure 4. Population Density in Western Thailand

The transportation conditions and population density in western Thailand is shown in Figure 3 and Figure 4.

Based on the opinions of relevant experts, this study selected four candidate locations as the research subjects. The candidate locations to be selected are shown in Table 4.

Table 4. Candidate Locations and Serial Number

Serial Number	Candidate Locations
P_1	Kanchanaburi
P_2	Prachuap Khiri Khan
P_3	Phetchaburi
P_4	Ratchaburi

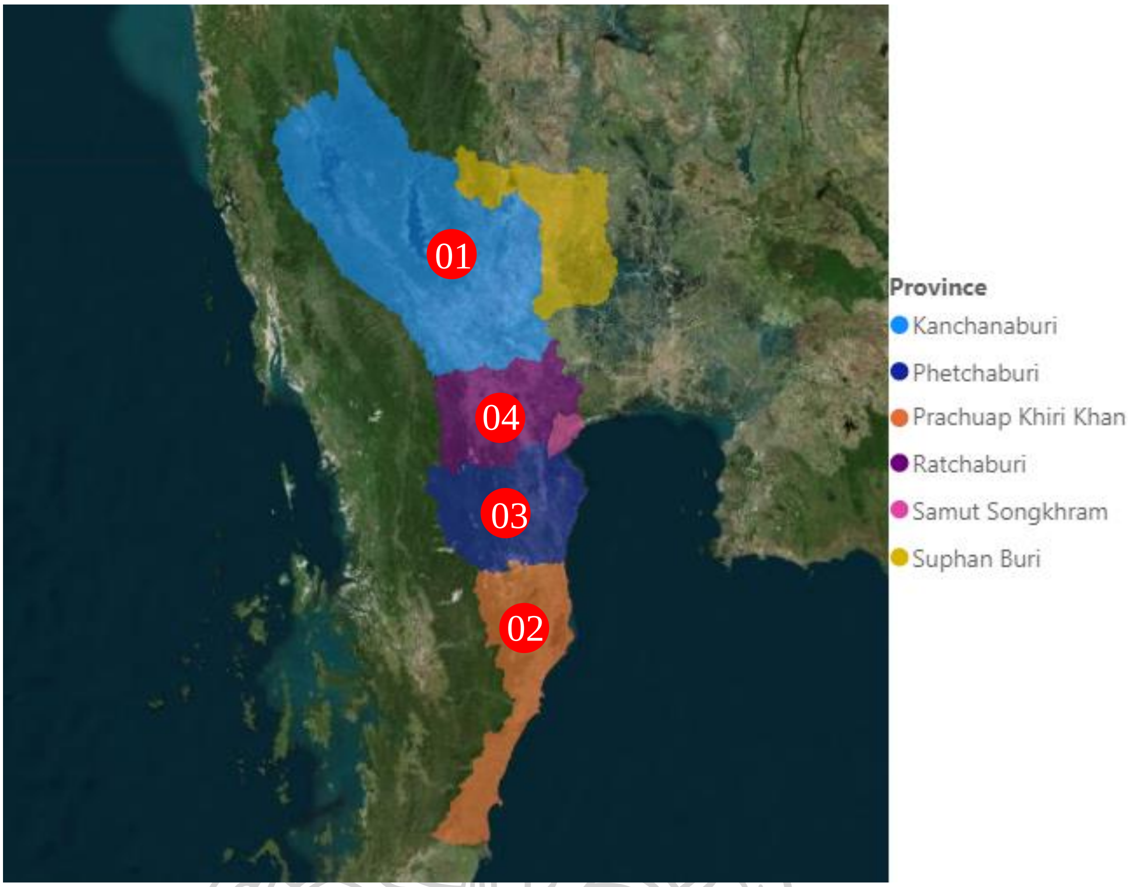

Figure 5. Candidate Locations in Map

Figure 5 shows the positioning of four candidate locations on the map as following picture.

CHAPTER 3

RESEARCH METHODOLOGY

Based on the literature review, this chapter aims to address the issue of site selection for medical device maintenance centers in the western Thailand and proposes a theoretically supported research methodology for the comprehensive application of AHP-TOPSIS.

3.1 Research Method

This research method is divided into the following three stages:

The first period is literature review. Search and read a large amount of relevant literature using keywords (AHP, TOPSIS, site selection) on the Google Scholar website, and use Thai websites and other local resources to understand information about the western region of Thailand, such as natural feature, transportation, population density, and the distribution of medical institutions such as hospitals.

Next is the research stage. Propose a feasible AHP-TOPSIS model to address the issue of selecting a location for a medical device maintenance center in the Western Thailand. Design a survey program, including questionnaire design and organization of the entire survey activity. Then conduct data analysis after obtaining data.

In the final period, the importance ranking of the 10 key factors affecting site selection is first obtained by analyzing the survey data. Then continue analyzing the data to find the best option from the four candidate addresses. Finally, the analysis of this case confirms the significant role of the mixed use of AHP and TOPSIS in solving multi criteria decision-making processes.

3.2 Research Hypothesis

Hypothesis 1: The key factors in the site selection process directly affect the selection results.

Hypothesis 2: The four candidate locations in the Western Thailand proposed by relevant experts are all practical and feasible options.

3.3 Conceptual Framework

After thoroughly reviewing the relevant literature on AHP, TOPSIS, and site selection, the advantages and disadvantages of AHP and TOPSIS were summarized, and a model that can be used to solve the site selection problem in this study was proposed, as shown in Figure 6.

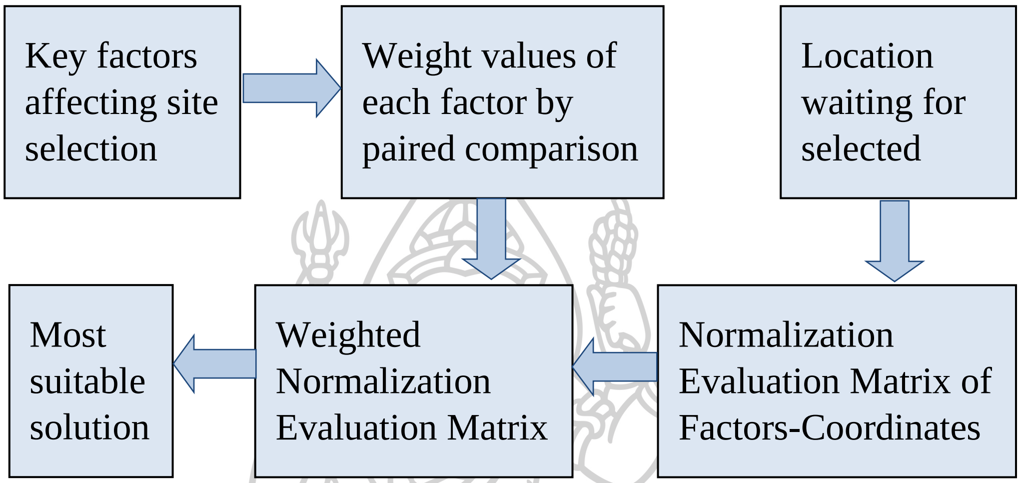

Figure 6. Conceptual Framework

3.4 Research Tools

3.4.1 Google Scholar Website

Google Scholar is a free online search engine designed to help users search for academic articles. It indexes the text format and subjects in published articles, and provides search functionality for academic literature including journal papers, degree theses, books, preprints, abstracts, and technical reports. Whether it's natural sciences, humanities, or social sciences, Google Scholar encompasses content from various disciplinary fields.

3.4.2 Expert Review Meeting

An expert review meeting is a meeting composed of a group of experts in a professional field, aimed at reviewing, reviewing, supervising, and guiding a certain work or project. The members of expert review meetings usually have high academic, technical, or industry experience and are able to conduct comprehensive analysis and evaluation of the projects or work being reviewed. This study will invite some experts from the Thai medical device industry to participate in this conference.

3.4.3 Questionnaire

Questionnaire survey is a research method that explores the current situation of facts, with the greatest purpose of collecting and accumulating basic information on various scientific and educational attributes of a target population. It can be divided into two categories: descriptive research and analytical research. The survey questionnaire mainly serves the following purposes:

1) Translate research objectives into specific questions.

2) Standardize the scope of questions and answers, so that each participant faces the same problem environment.

3) Obtain cooperation from respondents through wording, question flow, and image.

4) Can serve as a permanent record of research.

3.5 Collection of Information

This article conducts a case study on the site selection of medical device maintenance centers in the Western Thailand. Researcher will use ten criteria to determine the optimal choice between the four candidate sites. Table 1 (as shown in Chapter 2) is the basis for determining the weights of the ten factors (Table 3), while Table 5 is the scoring system for the importance of the four candidate addresses in 10 aspects.

Table 5. The Scoring System

Degree Level	Score Judgment (x)
Worse	$0<x\leq3$
Bad	$3<x\leq5$
Ordinary	$5<x\leq6$
Good	$6<x\leq8$
Better	$8<x\leq10$

3.6 Data Analysis

AHP and TOPSIS methods can help decision-makers determine the optimal site selection by comprehensively evaluating the weights and indicators of different factors.

3.6.1 The Calculation of AHP Method

AHP is a multi-criteria decision-making method that compares different factors in a hierarchical manner to obtain the weights between each factor. The specific steps include:

1) Determine decision objectives and criteria.

2) Establish a hierarchical structure.

3) Establish a judgment matrix.

4) Calculate weight.

5) Consistency check.

3.6.2 The Calculation of TOPSIS Method

The TOPSIS method is a distance based ranking method that determines the optimal site selection by calculating the distance between each site selection scheme and the ideal solution and negative ideal solution. The specific steps include:

1) Determine evaluation indicators.

2) Build a decision matrix.

3) Normalization.

4) Building a weight matrix.

5) Determine ideal solution and negative ideal solution.

6) Calculate the distance between each site selection scheme and the ideal and negative ideal solutions.

7) Determine the optimal location.

It should be noted that both AHP and TOPSIS methods require decision-makers to determine weights and evaluation indicators based on actual situations, and set judgment criteria. At the same time, selecting appropriate evaluation indicators and criteria is very important, which needs to be balanced and determined based on specific decision-making problems and backgrounds.

3.7 Research Procedure

The importance of research procedures in academic papers lies in helping researchers obtain reliable information, evaluate information quality, analyze the complexity of problems, and establish research frameworks and methods. These steps can ensure the accuracy, credibility, and repeatability of the paper, making it a research result with practical application and academic value. Research procedure of this paper is shown in Figure 7.

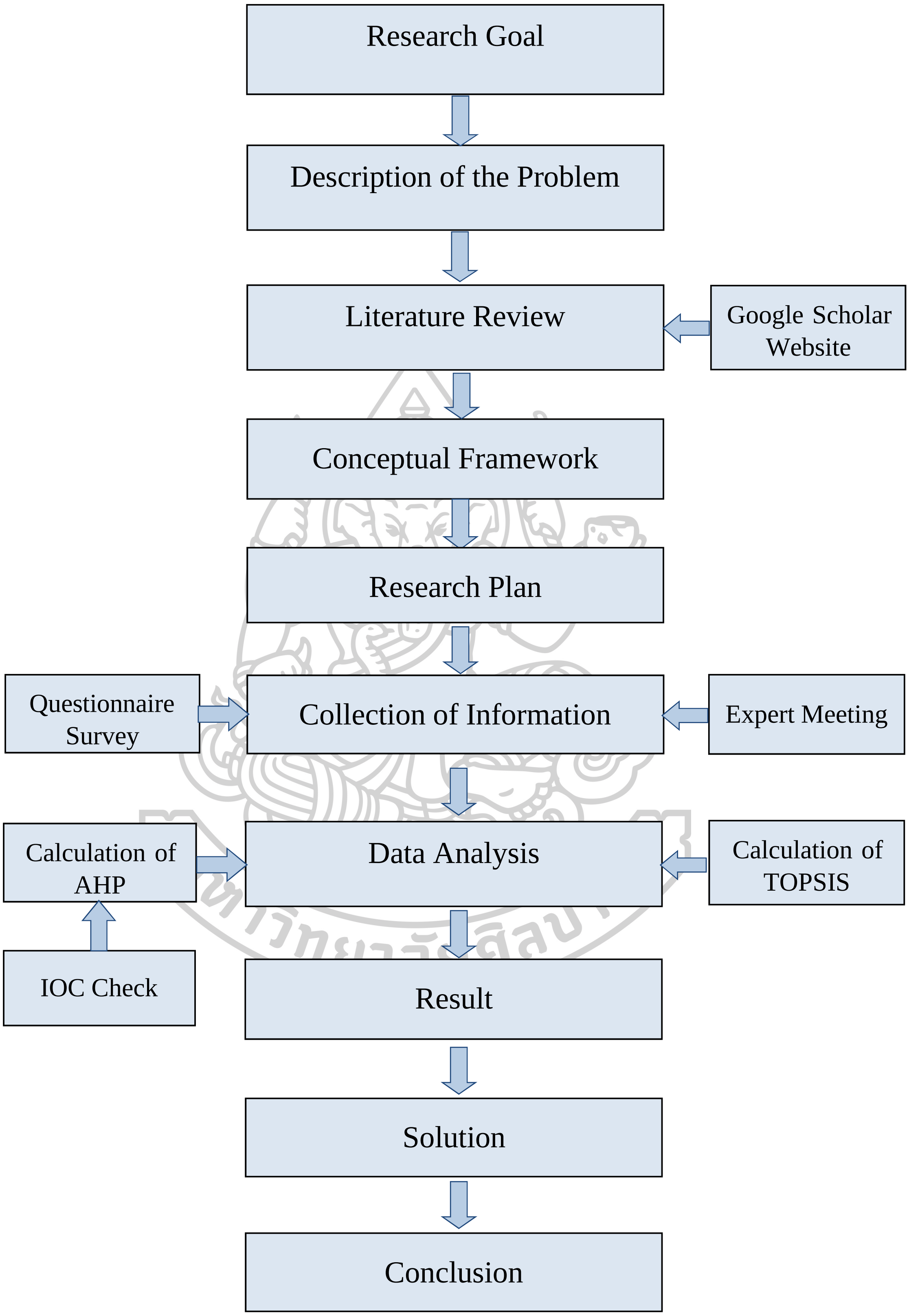

Figure 7. Research Procedure

CHAPTER 4

RESULTS AND ANALYSIS

The research purpose of this case is as follows:

1) To solve the location selection issue for a medical devices and equipment repair center in the west of Thailand.
2) To propose a usable template for addressing medical devices and equipment location selection issues.

The survey questionnaire is divided into two main parts, one is Item Objective Congruence (IOC) testing, and the other one includes basic information of the interviewees as Section A, AHP assessment for factors compared in Pair as Section B, and the assessment on separate four coordinates in aspect of different factors as Section C. The case company for this study is a multinational corporation group located in Bangkok, Thailand.

The research results can be found in the following content.

4.1 The Results of IOC

This study used Item Objective Congruence (IOC) testing to determine the validity of each indicator in the survey questionnaire.

Before conducting interviews with each interviewee, the researcher recruited a panel of three experts to evaluate the effectiveness of each indicator in the survey questionnaire. Experts rate each project based on whether the testing project measures the level of specific goals listed by the testing developer. Based on a scoring range of -1 to +1, giving them a rating of 1 (clearly measuring), -1 (clearly not measuring), or 0 (degree to which it measures the content area is unclear). The item with the highest score of 1 in the questionnaire was identified as an excellent item agreed upon by all experts, Items with scores between 0.5 and 1 will be retained, while items with scores between -1 and 0.5 will be revised, and items with a minimum score of -1 will be deleted. In this way, optimize the content of the survey questionnaire to ensure that the responses collected through instruments are reliable and consistent with the objectives.

The IOC value for each indicator is obtained by dividing the sum of scores for each expert by the number of experts as shown in table 6. From this table, it can be seen that the IOC value of each indicator in the survey questionnaire is equal to 1.00, which means that each indicator is a valid indicator and can be applied as a key factor in this case study.

Table 6 IOC for Section A, Section B and Section C

Question		Comment score from expert			Total	IOC Value	Result
		1st	2nd	3rd			
Section A: General personal information questionnaire of respondents							
1	Gender	+1	+1	+1	3	1.00	available
2	Age	+1	+1	+1	3	1.00	available
3	Highest Level of education	+1	+1	+1	3	1.00	available
4	Current job position	+1	+1	+1	3	1.00	available
5	Main duties and responsibilities	+1	+1	+1	3	1.00	available
6	Your length of service is related to the position.	+1	+1	+1	3	1.00	available
Section B: AHP Assessment for Criteria Compared in Pair							
1	Near the Customer	+1	+1	+1	3	1.00	available
2	Near the Warehouse and Spares	+1	+1	+1	3	1.00	available
3	Fast and Convenience of Service	+1	+1	+1	3	1.00	available
4	Investment	+1	+1	+1	3	1.00	available

Question		Comment score from expert			Total	IOC Value	Result
		1st	2nd	3rd			
5	Make a Profit	+1	+1	+1	3	1.00	available
6	Customer Quantity	+1	+1	+1	3	1.00	available
7	Opportunities for the Future	+1	+1	+1	3	1.00	available
8	Safety	+1	+1	+1	3	1.00	available
9	Transportation for Return a Product to the Company	+1	+1	+1	3	1.00	available
10	Transportation Lines	+1	+1	+1	3	1.00	available
Section C: The Assessment on Different Factor for Candidate Location $P_{1,}$ $P_{2,}$ $P_{3,}$ P_4							
1	Near the Customer	+1	+1	+1	3	1.00	available
2	Near the Warehouse and Spares	+1	+1	+1	3	1.00	available
3	Fast and Convenience of Service	+1	+1	+1	3	1.00	available
4	Investment	+1	+1	+1	3	1.00	available
5	Make a Profit	+1	+1	+1	3	1.00	available
6	Customer Quantity	+1	+1	+1	3	1.00	available
7	Opportunities for the Future	+1	+1	+1	3	1.00	available
8	Safety	+1	+1	+1	3	1.00	available

Question		Comment score from expert			Total	IOC Value	Result
		1st	2nd	3rd			
9	Transportation for Return a Product to the Company	+1	+1	+1	3	1.00	available
10	Transportation Lines	+1	+1	+1	3	1.00	available

4.2 The Results of Section A

The basic information of the respondents in the survey questionnaire refers to collecting data on their individual characteristics, such as age, gender, occupation, education level, etc. Its function and significance are as follows:

1) The basic information of the respondents can help researchers effectively analyze and interpret the survey results.
2) The basic information of the interviewees can assist researchers in classification and comparative analysis.
3) The basic information of the respondents can also assist researchers in sample selection and representative evaluation.

Understanding the basic information of survey respondents plays an important role and significance for researchers in enhancing the accuracy and reliability of survey research. As shown in Figure 8 to 13.

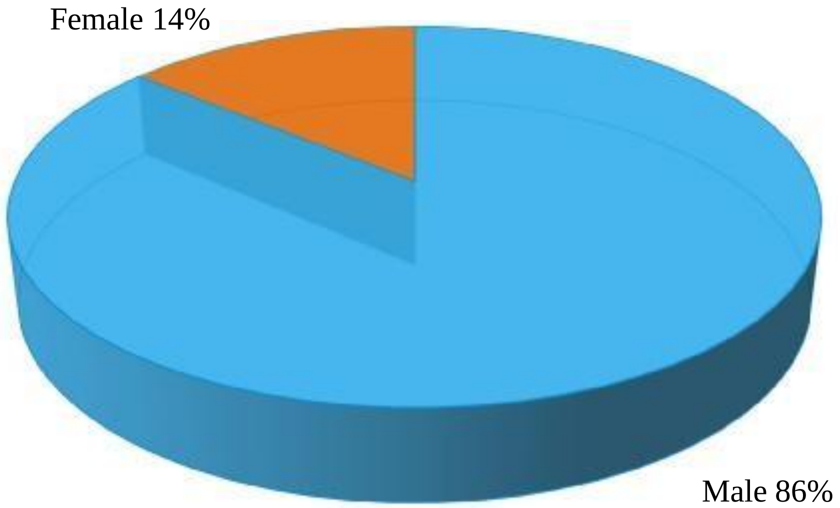

Figure 8. Gender

Figure 8 shows that 14% of the respondents are female and 86% are male.

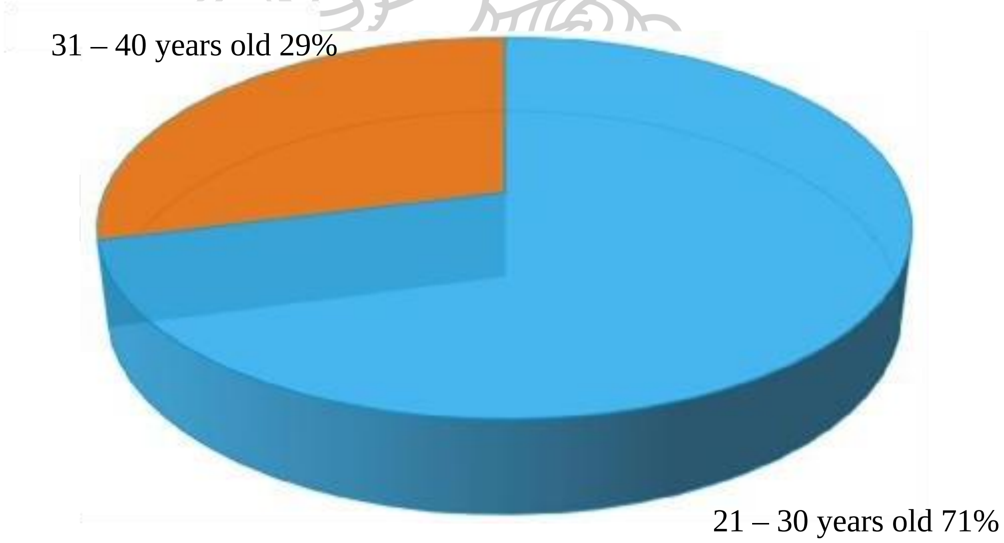

Figure 9. Age

From Figure 9, it can be seen that the age groups of the respondents are divided into two categories: one is between 21 and 30 years old, accounting for 71%; the other is between 31 and 40 years old, accounting for 29%.

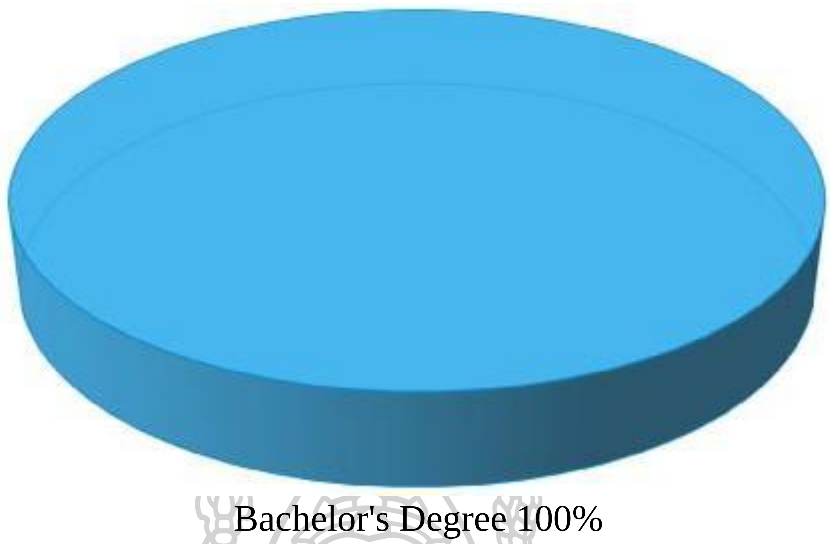

Figure 10. Highest Level of Education

From Figure 10, it can be seen that the highest education level of all respondents is Bachelor's Degree.

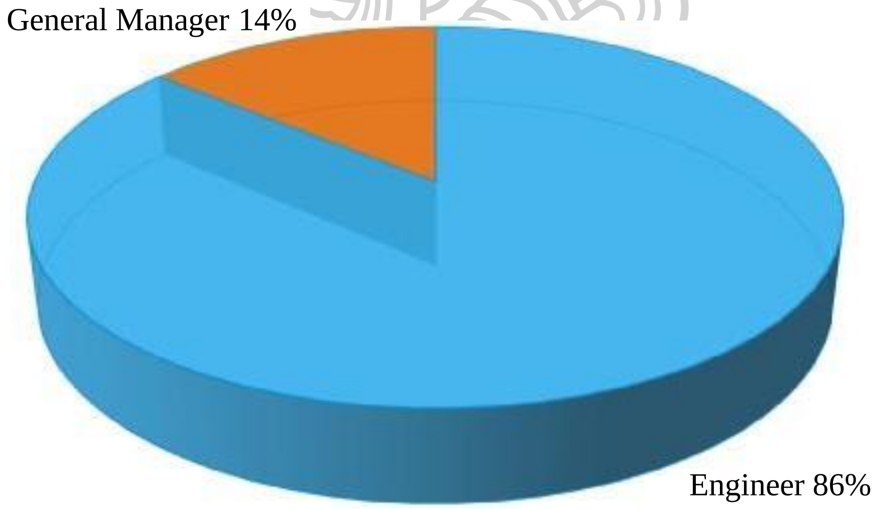

Figure 11. Current Job Position

Picture 11 shows that the current job positions of the interviewees are divided into two categories, with 86% being engineers and the other 14% being general managers.

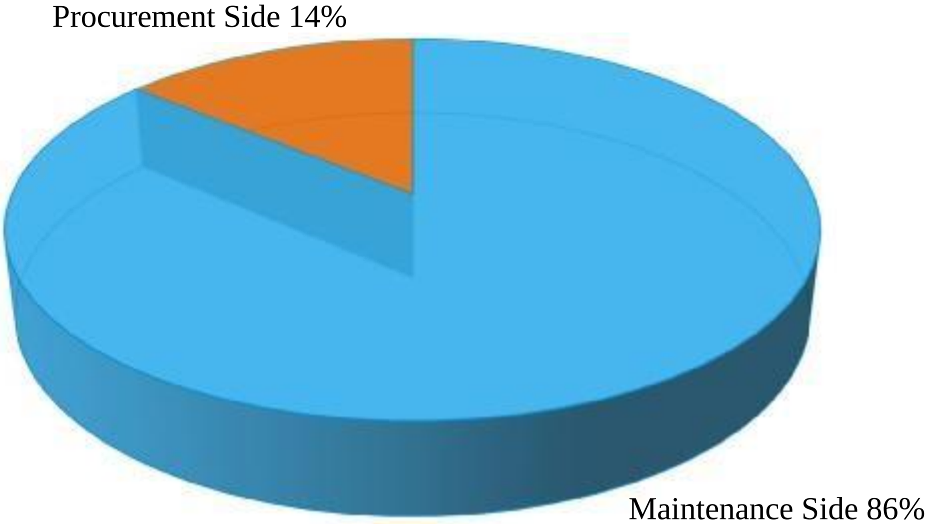

Figure 12. Main Duties and Responsibilities

There are two types of main duties and responsibilities in Figure 12, one is Maintenance side, accounting for 86%, and the other is Procurement, accounting for 14%.

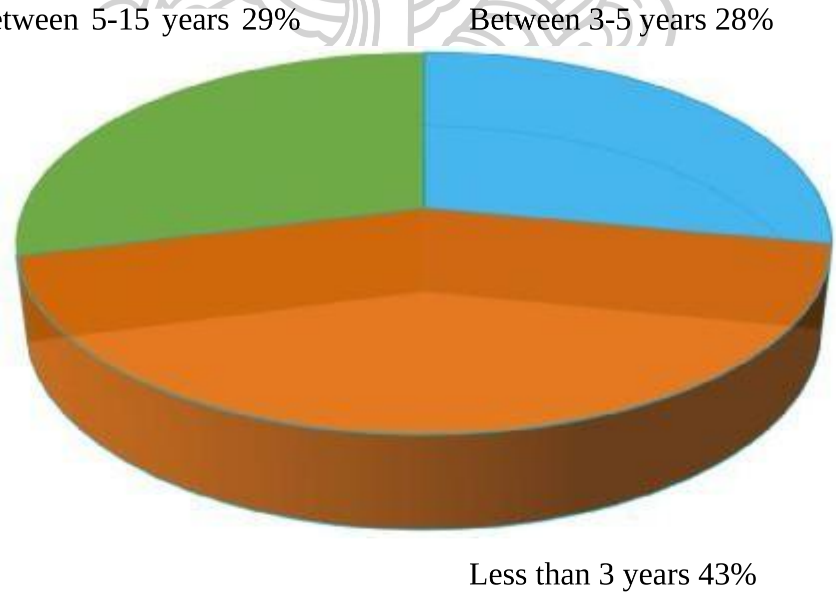

Figure 13. Working Time

Finally, regarding work experience, as shown in Figure 13, the respondents have three types of work experience. Firstly, those with less than 3 years account for 43%, followed by those between 3 and 5 years accounting for 28%, and then 5 to 15 years accounting for 29%.

The basic information of these interviewees shows that their interviews are meaningful, and the data obtained can be used for data analysis in this study, which helps researchers obtain authentic and effective research results.

4.3 The Results of Section B

The data collected in Part A of the survey questionnaire is the result of pairwise comparison of 10 factors for AHP calculation. There are a total of 7 respondents, and the initial data and preliminary processing results of Part A are shown in Table 7.

Table 7. Initial Data from Section B

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
F_1-F_2	6	5	9	-5	-4	-4	-2	0.7143	1
F_1-F_3	-7	-7	-8	-8	-9	-3	-5	-6.7143	-7
F_1-F_4	-5	6	1	2	-2	1	3	0.8571	1
F_1-F_5	1	-6	-6	-5	-5	-2	-3	-3.7143	-4
F_1-F_6	-9	-8	1	-9	-8	-7	-9	-7.0000	-7
F_1-F_7	-8	-8	-4	-9	-7	-7	-9	-7.4286	-8
F_1-F_8	1	-6	-6	-2	-3	-4	-4	-3.4286	-4
F_1-F_9	1	-5	7	-3	-2	-3	-4	-1.2857	-2
F_1-F_{10}	5	5	1	2	2	1	2	2.5714	3
F_2-F_3	4	-6	-3	-5	-6	-6	-5	-3.8571	-4

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
F_2-F_4	1	6	1	-6	-8	-6	-7	-2.7143	-3
F_2-F_5	5	5	-5	-5	-4	-4	-6	-2.0000	-2
F_2-F_6	-9	-7	-5	-5	-8	-9	-8	-7.2857	-8
F_2-F_7	-8	-7	1	-9	-8	-6	-6	-6.1429	-7
F_2-F_8	1	-6	-7	-4	-2	-3	-5	-3.7143	-4
F_2-F_9	1	-6	1	-6	-2	-2	-4	-2.5714	-3
F_2-F_{10}	-4	5	4	2	1	3	2	1.8571	2
F_3-F_4	-3	6	1	2	3	3	4	2.2857	3
F_3-F_5	-5	-4	-6	1	-3	-3	-3	-3.2857	-4
F_3-F_6	-5	-5	1	-6	-5	-5	-4	-4.1429	-5
F_3-F_7	-5	-4	3	-2	-6	-5	-5	-3.4286	-4
F_3-F_8	1	-5	-7	3	2	2	3	-0.1429	-1
F_3-F_9	1	-5	3	2	-2	-2	-3	-0.8571	-1
F_3-F_{10}	1	4	1	2	2	4	4	2.5714	3
F_4-F_5	-5	-6	-5	-3	-7	-6	-6	-5.4286	-6
F_4-F_6	-6	-6	-5	-4	-7	-7	-6	-5.8571	-6
F_4-F_7	-6	-7	1	-5	-8	-6	-7	-5.4286	-6
F_4-F_8	1	-5	-7	-2	-3	-3	-4	-3.2857	-4
F_4-F_9	1	-4	1	-4	-2	-2	-2	-1.7143	-2
F_4-F_{10}	1	4	3	2	2	4	4	2.8571	3
F_5-F_6	5	-6	5	1	-4	-3	-2	-0.5714	-1

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
F_5-F_7	1	-6	1	-2	-6	-3	-4	-2.7143	-3
F_5-F_8	1	-5	-7	6	6	8	8	2.4286	3
F_5-F_9	3	5	1	3	-2	2	-2	1.4286	2
F_5-F_{10}	3	5	1	4	5	6	3	3.8571	4
F_6-F_7	-5	6	2	1	3	3	3	1.8571	2
F_6-F_8	1	5	-7	3	3	5	4	2.0000	2
F_6-F_9	5	5	1	4	4	6	6	4.4286	5
F_6-F_{10}	5	5	1	6	4	4	6	4.4286	5
F_7-F_8	1	6	-7	3	4	5	5	2.4286	3
F_7-F_9	4	6	1	4	4	7	7	4.7143	5
F_7-F_{10}	4	7	1	7	4	7	6	5.1429	6
F_8-F_9	1	-5	5	1	1	-5	-6	-1.1429	-2
F_8-F_{10}	1	5	3	2	4	4	4	3.2857	4
F_9-F_{10}	1	6	1	4	7	3	3	3.5714	4

From the data in Table 7, pairwise comparison matrix between factors can be formed as shown in Table 8.

Table 8. Pairwise Comparison Between Factor

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1.000	1.000	0.143	1.000	0.250	0.143	0.125	0.250	0.500	3.000
F2	1.000	1.000	0.250	0.333	0.500	0.125	0.143	0.250	0.333	2.000
F3	7.000	4.000	1.000	3.000	0.250	0.200	0.250	1.000	1.000	3.000
F4	1.000	3.000	0.333	1.000	0.167	0.167	0.167	0.250	0.500	3.000
F5	4.000	2.000	4.000	6.000	1.000	1.000	0.333	3.000	2.000	4.000
F6	7.000	8.000	5.000	6.000	1.000	1.000	2.000	2.000	5.000	5.000
F7	8.000	7.000	4.000	6.000	3.000	0.500	1.000	3.000	5.000	6.000
F8	4.000	4.000	1.000	4.000	0.333	0.500	0.333	1.000	0.500	4.000
F9	2.000	3.000	1.000	2.000	0.500	0.200	0.200	2.000	1.000	4.000
F10	0.333	0.500	0.333	0.333	0.250	0.200	0.167	0.250	0.250	1.000

Using the data from Table 8 and combining formulas 2.1 to 2.17, normalization evaluation matrix, weight and consistency ratio can be calculated, as shown in Table 9. From Table 9, the calculate consistency ratio (CR) value is 0.0759, which is less than 0.1. Therefore, it can once again prove that the initial data obtained in Section A is valid and can be used in conjunction with the TOPSIS method to solve the site selection problem for the newly established medical device and equipment maintenance center of the sample company in this case study.

Table 9. Normalization evaluation matrix, weight and consistency ratio

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	0.028	0.030	0.008	0.034	0.034	0.035	0.026	0.019	0.031	0.086
F2	0.028	0.030	0.015	0.011	0.069	0.031	0.030	0.019	0.021	0.057
F3	0.198	0.119	0.059	0.101	0.034	0.050	0.053	0.077	0.062	0.086
F4	0.028	0.090	0.020	0.034	0.023	0.041	0.035	0.019	0.031	0.086
F5	0.113	0.060	0.234	0.202	0.138	0.248	0.071	0.231	0.124	0.114

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F6	0.198	0.239	0.293	0.202	0.138	0.248	0.424	0.154	0.311	0.143
F7	0.226	0.209	0.234	0.202	0.414	0.124	0.212	0.231	0.311	0.171
F8	0.113	0.119	0.059	0.135	0.046	0.124	0.071	0.077	0.031	0.114
F9	0.057	0.090	0.059	0.067	0.069	0.050	0.042	0.154	0.062	0.114
F10	0.009	0.015	0.020	0.011	0.034	0.050	0.035	0.019	0.016	0.029
Weight (%)	3.327	3.114	8.391	4.068	15.355	23.496	23.349	8.889	7.634	2.379
CR	0.0759									

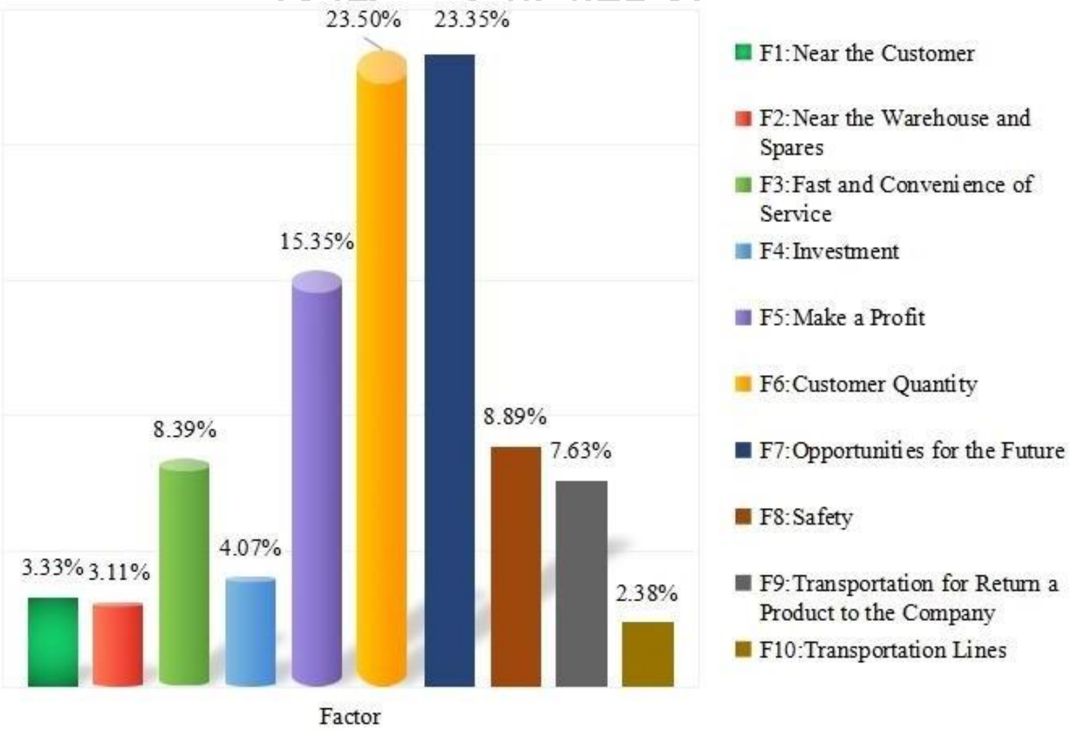

Figure 14. Weight of the Factor

Figure 14 shows the weight values of 10 key factors that affect the site selection. It can be easily concluded from the image that stability (F6) has the highest weight value at 23.50%, followed by opportunities for the future (F7), accounting for 23.35%, followed by Price (F5), accounting for 15.35%.

4.4 The Results of Section C

Section C of the survey questionnaire collected scores for four candidate positions based on 10 key factors. Similarly, there were a total of 7 respondents, and the researcher conducted preliminary processing on the initial data from 7 survey questionnaires to obtain the average and roundup values corresponding to the 7 data, as shown in Table 10.

Table 10. Initial Data from Section C

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
P_1-F_1	5	4	5	5	5	5	5	4.8571	5
P_1-F_2	4	3	5	6	4	6	5	4.7143	5
P_1-F_3	6	5	7	7	7	7	6	6.4286	7
P_1-F_4	6	4	5	4	5	6	5	5.0000	5
P_1-F_5	6	5	4	4	4	4	4	4.4286	5
P_1-F_6	5	5	5	5	5	5	5	5.0000	5
P_1-F_7	5	6	5	5	5	5	5	5.1429	6
P_1-F_8	5	4	6	6	6	6	6	5.5714	6
P_1-F_9	5	5	6	6	5	6	5	5.4286	6
P_1-F_{10}	4	3	5	4	5	6	5	4.5714	5
P_2-F_1	4	4	7	6	7	7	7	6.0000	6
P_2-F_2	5	3	6	6	5	7	6	5.4286	6
P_2-F_3	6	4	7	7	7	7	6	6.2857	7
P_2-F_4	6	4	4	4	4	5	4	4.4286	5

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
P_2-F_5	6	5	6	6	6	6	6	5.8571	6
P_2-F_6	5	5	7	6	7	7	7	6.2857	7
P_2-F_7	5	6	5	5	5	5	5	5.1429	6
P_2-F_8	5	4	6	6	5	6	6	5.4286	6
P_2-F_9	5	4	6	6	6	6	5	5.4286	6
P_2-F_{10}	4	3	6	5	6	7	6	5.2857	6
P_3-F_1	4	3	7	7	7	7	7	6.0000	6
P_3-F_2	5	4	6	6	5	7	6	5.5714	6
P_3-F_3	6	5	6	5	6	6	5	5.5714	6
P_3-F_4	6	4	5	5	5	6	5	5.1429	6
P_3-F_5	6	4	6	6	6	6	6	5.7143	6
P_3-F_6	5	5	6	6	6	6	6	5.7143	6
P_3-F_7	5	5	5	5	5	5	5	5.0000	5
P_3-F_8	5	4	6	5	5	6	6	5.2857	6
P_3-F_9	5	4	7	6	7	7	6	6.0000	6
P_3-F_{10}	4	4	7	7	7	7	7	6.1429	7
P_4-F_1	4	5	7	6	7	7	7	6.1429	7
P_4-F_2	5	5	7	7	6	7	7	6.2857	7
P_4-F_3	6	6	6	6	6	6	5	5.8571	6
P_4-F_4	6	4	5	5	5	6	5	5.1429	6
P_4-F_5	6	5	6	6	6	6	6	5.8571	6

Comparison in Pair	Scores from Respondents							AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th	7th		
P_4-F_6	5	5	6	5	6	6	6	5.5714	6
P_4-F_7	5	5	6	6	6	6	6	5.7143	6
P_4-F_8	5	4	6	6	5	6	6	5.4286	6
P_4-F_9	4	4	7	7	7	7	6	6.0000	6
P_4-F_{10}	4	4	6	6	6	7	6	5.5714	6

Based on the data in Table 10 and formula 2.25 in Chapter 2, normalization evaluation matrix of factors-coordinates can be calculated, as shown in Table 11.

Table 11. Normalization Evaluation Matrix of Factors-Coordinates

Candidate Position		P_1	P_2	P_3	P_4
Factor	F_1	0.4138	0.4966	0.4966	0.5793
	F_2	0.4138	0.4966	0.4966	0.5793
	F_3	0.5369	0.5369	0.4602	0.4602
	F_4	0.4527	0.4527	0.5432	0.5432
	F_5	0.4336	0.5203	0.5203	0.5203
	F_6	0.4138	0.5793	0.4966	0.4966
	F_7	0.5203	0.5203	0.4336	0.5203
	F_8	0.5000	0.5000	0.5000	0.5000
	F_9	0.5000	0.5000	0.5000	0.5000
	F_{10}	0.4138	0.4966	0.5793	0.4966

Subsequently, according to formulas 2.27 to 2.30 in Chapter 2, weighted normalization evaluation matrix, ideal solution and negative ideal solution were calculated as shown in Table 12.

Table 12. *Weighted Normalization Evaluation Matrix, ideal solution and negative ideal solution*

Candidate Position		P_1	P_2	P_3	P_4	x* j	x0j
Factor	F_1	0.0138	0.0165	0.0165	0.0193	0.0193	0.0138
	F_2	0.0129	0.0155	0.0155	0.0180	0.0180	0.0129
	F_3	0.0451	0.0451	0.0386	0.0386	0.0451	0.0386
	F_4	0.0184	0.0184	0.0221	0.0221	0.0184	0.0221
	F_5	0.0666	0.0799	0.0799	0.0799	0.0799	0.0666
	F_6	0.0972	0.1361	0.1167	0.1167	0.1361	0.0972
	F_7	0.1215	0.1215	0.1012	0.1215	0.1215	0.1012
	F_8	0.0444	0.0444	0.0444	0.0444	0.0444	0.0444
	F_9	0.0382	0.0382	0.0382	0.0382	0.0382	0.0382
	F10	0.0098	0.0118	0.0138	0.0118	0.0138	0.0098

Finally, from formulas 2.31 to 2.32 in Chapter 2, the distance from alternative to the ideal solution (d^*_j), the distance from alternative to the negative ideal solution (d^0_i), and the queuing index values for each scheme (C^*_j) were calculated, as shown in Table 13.

Table 13. Final evaluation of the location alternatives

Candidate Location	P_1	P_2	P_3	P_4
d^*_i	0.0420	0.0043	0.0293	0.0209
d^0_i	0.0216	0.0466	0.0242	0.0320
C^*_i	0.3397	0.9163	0.4523	0.6052
Rank	4	1	3	2

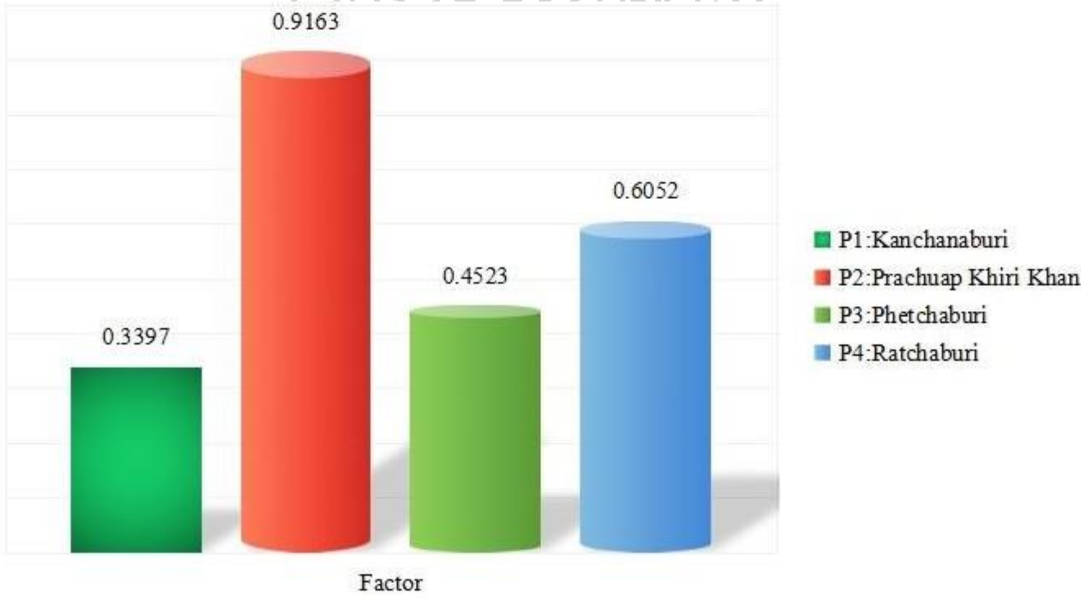

Figure 15. *Relative Closeness (C*)*

Image 15 shows the queuing index values for each scheme (C^*_i) of four candidate positions, and it can be seen at a glance that among these four candidate positions, the queuing index value of Prachuap Khiri Khan (P2) is closest to 1.0, which is the most ideal solution for this case study.

CHAPTER 5

CONCLUSION

5.1 Results of Research Objective 1

From the results of Section B, it can be seen that in this case, there are a total of ten factors that need to be considered for the site selection of the sample company for the newly built device and equipment maintenance center, namely near the customer (F_1), near the warehouse and spares (F_2), fast and convenience of service (F_3), investment (F_4), make a profit (F_5), customer quantity (F_6), opportunities for the future (F_7), safety (F_8), transportation for return a product to the company (F_9), and transportation lines (F_{10}).

From Figure "Weight of the Factor", it can be seen that among the calculated weight values of the 10 factors, the highest value is customer quantity (F_6), followed by opportunities for the future (F_7), and then make a profit (F_5).

Firstly, customer quantity plays multiple important roles in the selection of medical equipment maintenance centers.

1) Potential sales opportunities: The number of customers is one of the most important considerations for businesses when choosing a location. Choosing regions or locations with higher customer numbers can provide merchants with more sales opportunities. Regions with high population density and mobility typically mean a larger potential customer base, which can increase the sales and profit levels of businesses.

2) Target market coverage: Merchants need to choose regions or locations that can cover their target market. The number of customers is closely related to the matching degree of the merchant's target market. Merchants need to consider the positioning of their products or services and the characteristics of their target customers in order to choose regions with suitable customer numbers, which can better meet the needs of the target market, increase sales and profits.

3) Competition and market share: The number of customers is also related to the competition situation and market share of businesses in the location they choose. Choosing regions with relatively more customers but less competition can create better competitive advantages for businesses, increase market shares and profit levels.

4) Consumption ability: The number of customers should not only consider the quantity, but also their consumption ability. Merchants hope to choose regions with high consumer power customer groups, which can increase the transaction value and profit contribution of customers.

5) Development potential: The number of customers is also related to the development potential of the location. Choosing regions with growth potential can provide businesses with more development opportunities and achieve higher sales and profit growth in the future.

Therefore, in the selection of business locations, the number of customers is an extremely important factor to consider. Merchants need to weigh potential sales opportunities, target market coverage, competition and market share, consumption ability, and development potential to choose regions with suitable customer numbers, in order to maximize sales and profit potential.

Secondly, future opportunities play a crucial role in the selection of medical device maintenance centers. The following are several important roles of future opportunities in site selection decisions:

1) Market potential: Merchants should consider the future market potential when selecting locations. This includes factors such as population growth, improved consumption capacity, and changes in market demand. By choosing regions with potential, businesses can gain more customers and sales opportunities in the future, with greater development potential.

2) Economic development: Businesses usually pay attention to the future economic development expectations of the region. Choosing a region with rapid economic growth can provide businesses with more business opportunities and profits. The expansion of the market, improvement of the business environment, and opportunities for investment and innovation can all provide businesses with more opportunities in the future.

3) Technological innovation: Future opportunities also involve the prospects of technological innovation and development. Choosing a region with a favorable R&D and innovation environment allows businesses to benefit from technological progress and continuously enhance their competitiveness.

4) Industry trends: Businesses need to consider future industry trends and development directions. By choosing a location in a growing and

promising industry, businesses can quickly adapt to changes in market demand, seize future opportunities, and gain a competitive advantage.

In summary, businesses need to carefully consider future opportunities during the site selection process. Choosing an area with market potential, good economic development expectations, a favorable innovation environment, and industry trends can enable businesses to gain more business opportunities and the possibility of success in the future.

Thirdly, in the selection of medical device maintenance centers, profits play several important roles:

1) Sales opportunities: Merchants hope to choose regions or locations with potential sales opportunities. This includes factors such as sufficient customer traffic, stable market demand, and consumer purchasing power. Choosing regions with higher sales opportunities can increase the sales revenue of businesses, thereby improving profit levels.

2) Competitive advantage: Site selection is also crucial for businesses to have a competitive advantage. Merchants hope to choose regions or locations that can provide them with a competitive advantage. For example, commercial clusters or areas with special resources can bring more partners, supply chain convenience, and opportunities for cooperation and innovation to businesses, thereby improving profit levels.

3) Sustainable development: Businesses should also consider their potential for long-term sustainable development and profit growth when selecting locations. Choosing regions with good development prospects, market potential, and innovation environment can help businesses achieve stable profit growth and continue to gain competitive advantages in fiercely competitive markets.

Therefore, profit is an important consideration factor in site selection. Merchants need to weigh factors such as cost, sales opportunities, competitive advantage, and sustainable development in order to choose the most profitable location. This can provide merchants with better profits and long-term profitability. Taking these factors into consideration, the relative closeness values for the four candidate positions shown in Figure 15 were calculated. Among them, the relative closeness value for Prachup Khiri Khan was the highest and closest to 1.0. Therefore, in this case, the best solution for helping the sample company to solve the site selection of the newly established medical device maintenance center is Prachuap Khiri Khan.

The advantages of Prachuap Khiri Khan Province in Thailand as a location for medical equipment maintenance center include the following:

1) Geographical location: Prachuap Khiri Khan Province is located in central Thailand, close to Bangkok. This geographical location provides the region with a convenient transportation and logistics network, facilitating the transportation and distribution of medical equipment.

2) Medical facilities and professional talents: The Prachuap Khiri Khan Province has multiple hospitals and medical institutions, indicating that the region has corresponding medical facilities and professional talents. This provides a reliable resource for the equipment maintenance center to obtain professional technical support and cooperation opportunities.

3) Supporting services and supply chain: In Prachuap Khiri Khan Province, there are already many supporting services and supply chains related to the medical industry, such as logistics companies and accessory suppliers. The existence of these supporting services can provide fast and efficient support, making it convenient for equipment maintenance centers.

4) Talent cultivation and educational institutions: Prachuap Khiri Khan Province has multiple higher education institutions and technical colleges, providing a foundation for cultivating and training medical equipment maintenance technicians. This provides reliable human resources for the equipment maintenance center to support its provision of professional maintenance services.

5) Low cost and preferential policies: Compared to other regions, the labor and production costs in Prachup Khiri Khan Province are relatively low. In addition, the Thai government has provided a series of preferential policies and tax reductions to encourage the development of the healthcare industry. These low-cost and preferential policies provide a more competitive operating environment for equipment maintenance centers.

In summary, the advantages of Prachuap Khiri Khan Province as a location for medical equipment maintenance centers lie in its convenient geographical location, availability of medical facilities and professional talents, complete supporting services and supply chain, rich talent training institutions, relatively low costs, and support from preferential policies. These advantages make Prachuap Khiri Khan Province an attractive location for site selection.

5.2 Results of Research Objective 2

The AHP-TOPSIS model is a commonly used method for multi criteria decision analysis, which can be used for decision-making on the location of medical device maintenance centers. The following is an available template for using the AHP-TOPSIS model as the site selection for medical device maintenance centers:

1) Determine evaluation indicators, such as near the customer, near the warehouse and spares, fast and convenience of service, investment, make a profit, customer quantity, opportunities for the future, safety, transportation for return a product to the company, and transportation lines.

2) Determine the weight of each evaluation indicator: Use Analytic Hierarchy Process (AHP) to compare the importance of different indicators to determine their weights. By constructing a judgment matrix, calculate the weight of each indicator.

3) Data standardization: Standardize the original evaluation data for comparison and comprehensive analysis between different indicators.

4) Build a decision matrix: Fill the standardized data into the decision matrix, where the rows represent candidate locations and the list displays evaluation indicators.

5) Calculate weighted normalization value: Based on the weight of each evaluation indicator, calculate the weighted normalization value of each candidate site selection, that is, multiply the standardized value of each indicator by its corresponding weight, and sum the products.

6) Determine positive and negative ideal solutions: For each evaluation indicator, determine the positive and negative ideal solutions based on the weighted normalized values of the candidate site selection.

The maximum value of each indicator is taken for the solution of the positive ideal, and the minimum value of each indicator is taken for the solution of the negative ideal.

7) Calculate the distance between each candidate site and the positive and negative ideal solutions: Calculate the distance between each candidate site and the positive and negative ideal solutions.

8) Calculate the comprehensive evaluation index for each candidate site: Calculate the comprehensive evaluation index based on the distance from each candidate site to the positive and negative ideal solutions. The

larger the comprehensive evaluation index, the better the candidate site selection.

9) Select the best location: Based on the comprehensive evaluation index, select the candidate location with the highest comprehensive evaluation index as the best location for the maintenance center.

The above is a simple template for using the AHP-TOPSIS model as a location for maintenance centers. According to the actual situation, appropriate adjustments and optimizations can be made based on specific evaluation indicators and weights. It should be noted that the AHP-TOPSIS model is just a method, and the specific evaluation indicators and weights need to be determined based on the actual situation and the judgment of decision-makers.

5.3 Summary

The application of the AHP-TOPSIS model in the selection of medical device maintenance centers can provide decision-makers with a scientific and objective decision-making basis.

1) Comprehensive evaluation: The AHP-TOPSIS model combines Analytic Hierarchy Process (AHP) and TOPSIS (Technical Consistency Sorting Method) to determine the weights of different evaluation indicators and rank candidate sites. It can comprehensively consider the influence of multiple factors to obtain a comprehensive evaluation result.

2) Selection of evaluation indicators: In the selection of medical device maintenance centers, the selection of evaluation indicators is crucial. Factors such as feasibility, human resources, cost, and market potential can be considered. Through the AHP method, these evaluation indicators can be compared and their weights can be determined to ensure that the importance of each indicator is reasonably reflected in the decision-making process.

3) Comprehensive evaluation and optimal site selection: By calculating the comprehensive evaluation index of each candidate site selection, the advantages and disadvantages of each site selection scheme can be compared. The larger the comprehensive evaluation index, the better the site selection plan. According to the comprehensive evaluation index, decision-makers can choose the candidate site with the highest comprehensive evaluation index as the optimal site.

4) Flexibility and Optimization: The AHP-TOPSIS model has a certain degree of flexibility and can be adjusted and optimized according to actual situations. Decision makers can adjust the weight of evaluation

indicators based on specific needs, or add/remove evaluation indicators to more accurately reflect the actual situation of site selection decisions.

In summary, the application of the AHP-TOPSIS model in the selection of medical device maintenance centers can help decision-makers make scientific and objective site selection decisions. By reasonably selecting evaluation indicators, determining weights, standardizing data, calculating positive and negative ideal solutions, and comprehensive evaluation indices, decision-makers can better understand the advantages and disadvantages of each candidate site and make the best site selection decision.

5.4 Implications

The application of the AHP-TOPSIS model in the selection of medical device maintenance centers is not only applicable to the medical industry, but can also be applied to the selection decisions of other industries. The following is the impact of the AHP-TOPSIS model on site selection in the healthcare industry and other industries.

Firstly, in the healthcare industry:

1) Medical facility location selection: In the medical industry, the AHP-TOPSIS model can be used to select the location of medical facilities such as hospitals, clinics, and medical centers. Evaluation indicators can include factors such as population size, medical service demand, and medical insurance policy support.

2) Site selection for medical device production base: For medical device production enterprises, selecting a suitable production base is also crucial. In addition to human resources and cost considerations, factors such as supply chain support, tax policies, and market potential can also be included.

Secondly, in the retail industry:

1) Shopping mall location selection: In the retail industry, choosing a shopping mall location is crucial for commercial operations. Factors to consider include population density, consumption capacity, transportation convenience, and competition.

2) Convenience store location selection: Convenience store location selection decisions need to consider factors such as the number of surrounding residents, supporting facilities, competition, and accessibility.

Furthermore, in the manufacturing industry:

1) Factory Site Selection: When considering new factory locations, manufacturing enterprises need to comprehensively consider factors such as infrastructure, logistics support, human resources, and policy environment. The use of the AHP-TOPSIS model can help enterprises make more scientific site selection decisions.

2) Logistics center location: The location of a logistics center is crucial for the efficient operation of the supply chain. Evaluation indicators can include factors such as transportation convenience, logistics network coverage, labor costs, and tax policies.

Overall, the application of the AHP-TOPSIS model in site selection in the medical and other industries can help decision-makers objectively evaluate the advantages and disadvantages of candidate sites, taking into account the influence of multiple factors. By reasonably selecting evaluation indicators, determining weights, standardizing data, and calculating comprehensive evaluation indices, decision-makers can more accurately grasp the core factors of site selection decisions, thereby making the best site selection decision.

APPENDIX

APPENDICE

Questionnaire

IOC

Research Title

Handling the Facility Location Issues of Medical Device Repair Center with a Hybrid AHP-TOPSIS Approach: A Case on the Facility Location Selection in the Western Thailand

Advisor

Dr. Thammawit Prasert

Engineering Program in Engineering Management

Department of Industrial Engineering and Management

Graduate School, Silpakorn University

Questionnaire on factors affecting the facility location selection in the western Thailand. The objective of this assessment is to assess the opinions of experts on the factors. The content is consistent with the objectives of the research.

Research objectives:

To solve the location selection issue for a medical devices and equipment repair center in the west of Thailand.

Please tick √ in the Conformity value box in Table 8 according to Table 7.

Table 14. The Consistency Value and Meaning

The Consistency Value	Meaning
+1	You are sure that the assessment items are consistent with the research objectives.
0	You aren't sure if the assessment items are consistent with the research objectives or not.
-1	You are sure that the assessment items are not consistent with the research objectives.

List of factors:

1) Near the Customer: When selecting a location, it is necessary to consider the geographical distribution of customers in order to conveniently provide services and products. Siting close to major customer groups can reduce logistics and transportation costs and provide faster services.

2) Near the Warehouse and Spares: It's essential to establish a relationship between storage facilities and the supply chain. Choosing a location close to suppliers and logistics centers will help shorten logistics time and reduce inventory costs.

3) Fast and Convenience of Service: It should be considered whether it is easy to obtain the necessary human and service resources, such as professional talents and delivery services.

4) Investment: Site selection decisions also need to consider construction and operating costs. The cost includes rent, water and electricity expenses, personnel salaries, decoration expenses, equipment and material purchase expenses, and so on.

5) Profit: The expected profit levels are also need to be considered.

6) Customer Quantity: A crucial to maximize potential sales opportunities is the number of potential customers and market size.

7) Opportunities for the Future: The location selection needs to analyze the planning of urban construction, including both short-term and long-term planning.

8) Safety: Safety factors including the risks of natural disasters such as earthquakes, fires, floods, and social safety factors such as crime rates should be taken into account.

9) Transportation for Return a Product to the Company: Return Routes need to be considered.

10) Transportation Lines: Including the proximity of roads, railways, ports, and airports, as well as the convenience of return logistics. The location selection must investigate the traffic situation, taking into account the distance from the station, road conditions, the nature of the station, and traffic linkage. The convenience of transportation, as well as the number and distance of parking lots, are also one of the influencing factors for passenger sources.

Table 15. IOC for Section A, Section B and Section C

Question		Opinion Level			Suggestions
		+1	0	-1	
Section A: General personal information questionnaire of respondents					
1	Gender				
2	Age				
3	Highest Level of education				
4	Current job position				
5	Main duties and responsibilities				
6	Your length of service is related to the position.				
Section B: AHP Assessment for Criteria Compared in Pair					
1	Near the Customer				
2	Near the Warehouse and Spares				
3	Fast and Convenience of Service				
4	Investment				
5	Make a Profit				
6	Customer Quantity				
7	Opportunities for the Future				
8	Safety				
9	Transportation for Return a Product to the Company				
10	Transportation Lines				

Question		Opinion Level			Suggestions
		+1	0	-1	
Section C: The Assessment on Different Factor for Candidate Location $P_{1,}$ $P_{2,}$ $P_{3,}$ P_4					
1	Near the Customer				
2	Near the Warehouse and Spares				
3	Fast and Convenience of Service				
4	Investment				
5	Make a Profit				
6	Customer Quantity				
7	Opportunities for the Future				
8	Safety				
9	Transportation for Return a Product to the Company				
10	Transportation Lines				

Suggestions:

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APPENDICE

Questionnaire

Factors and Candidates

Research Title

**Handling the Facility Location Issues of Medical Device Repair Center with a Hybrid AHP-TOPSIS Approach:
A Case on the Facility Location Selection in the Western Thailand**

Advisor

Dr. Thammawit Prasert

Engineering Program in Engineering Management

Department of Industrial Engineering and Management

Graduate School, Silpakorn University

This questionnaire is divided into 3 parts, consisting of:

Section A: General personal information questionnaire of respondents.

Section B: AHP assessment for factors compared in pair.

Section C: TOPSIS assessment for candidate locations in aspects of ten factors.

Thank you very much for taking time out of your busy schedule to fill out this survey questionnaire. It is a purely academic survey questionnaire aimed at understanding the key factors affecting the location of medical device and requirement maintenance centers in western Thailand and addressing the issue of location selection for medical device maintenance centers in western Thailand based on the importance of these factors. This questionnaire is answered anonymously. The answers you provide will not be disclosed to any individuals or companies other than yourself. Your answers will only be used for academic research analysis. Please respond based on your professional knowledge and practical experience.

Thank you for your cooperation. Wishing you success in your work and all the best!

Daidi XIE

Student ID: 660920020

Student Program in Engineering Management

Department of Industrial Engineering and Management

Graduate School, Silpakorn University

Section A

General personal information questionnaire of respondents.

Please mark √ in the box according to your information.

1. Gender

☐ Male ☐ Female

2. Age

☐ 21-30 ☐ 31-40

☐ 41-50 ☐ 51-60

☐ 61-70 ☐ Other

3. Highest Level of education

☐ Below bachelor's degree ☐ Bachelor's degree

☐ Master's degree ☐ Doctoral degree

☐ Other

4. Current job position

☐ Chairman of the Board of Directors

☐ Managing Director

☐ General Manager

☐ Engineers

☐ Other

5. Main duties and responsibilities

☐ Organizational Management ☐ Procurement side

☐ Research and development ☐ Maintenance side

☐ Other

6. Your length of service is related to the position.

☐ Less than 3 years ☐ Between 3-5 years

☐ Between 11-15 years ☐ Between 16-20 years

☐ Other

Section B

For the statement below, please compare the relative SEVERITY with respect to: objective which is prioritization of factors for the facility location selection in the western Thailand, CHOOSE and CIRCLE ONLY ONE NUMBER in Table 10-12 according to Table 9.

Table 16. The Meaning of Scale

Scale	Meaning
1	Compared to two elements, they are equally important
3	Compared to the two elements, the former is slightly more important than the latter
5	Compared to the two elements, the former is significantly more important than the latter
7	Compared to the two elements, the former is more strongly important than the latter
9	Compared to the two elements, the former is more strongly important than the latter
2,4,6,8	Intermediate value of adjacent judgments mentioned above
Count Backwards	If the importance ratio of element i to j is a_i, then the importance ratio of element j to element i is $a_{ji} = \frac{1}{a_{ij}}$

Table 17. AHP Assessment for Criteria Compared in Pair

Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Near the Warehouse and Spares
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fast and Convenience of Service
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Investment
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Make a Profit
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Quantity
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Near the Customer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Fast and Convenience of Service
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Investment
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Make a Profit
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Quantity
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety

Table 18. AHP Assessment for Criteria Compared in Pair (cont.)

Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Near the Warehouse and Spares	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Investment
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Make a Profit
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Quantity
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Fast and Convenience of Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Make a Profit
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Quantity
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Investment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines

Table 19. AHP Assessment for Criteria Compared in Pair (cont.)

Make a Profit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Quantity
Make a Profit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Make a Profit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Make a Profit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Make a Profit	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Customer Quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Opportunities for the Future
Customer Quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Customer Quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Customer Quantity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Opportunities for the Future	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety
Opportunities for the Future	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A Product to the Company
Opportunities for the Future	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Safety	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation for Return A
Safety	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines
Transportation for Return A Product to the Company	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transportation Lines

Section C

TOPSIS assessment for candidate locations in aspects of ten factors.

Please mark **√** in the box of Table 13-16 for the level of opinion of each factor for the facility location selection in the western Thailand.

Table 20. The Assessment on Different Factor for Candidate Location P_1

Candidate Location P_1	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Near the Customer							
Near the Warehouse and Spares							
Fast and Convenience of Service							
Investment							
Make a Profit							
Customer Quantity							
Opportunities for the Future							
Safety							
Transportation for Return A Product to the Company							
Transportation Lines							

Table 21. The Assessment on Different Factor for Candidate Location P_2

Candidate Location P_2	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Near the Customer							
Near the Warehouse and Spares							
Fast and Convenience of Service							
Investment							
Make a Profit							
Customer Quantity							
Opportunities for the Future							
Safety							
Transportation for Return A Product to the Company							
Transportation Lines							

Table 22. The Assessment on Different Factor for Candidate Location P_3

Candidate Location P_3	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Near the Customer							
Near the Warehouse and Spares							
Fast and Convenience of Service							
Investment							
Make a Profit							
Customer Quantity							
Opportunities for the Future							
Safety							
Transportation for Return A Product to the Company							
Transportation Lines							

Table 23. The Assessment on Different Factor for Candidate Location P_4

Candidate Location P_4	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Near the Customer							
Near the Warehouse and Spares							
Fast and Convenience of Service							
Investment							
Make a Profit							
Customer Quantity							
Opportunities for the Future							
Safety							
Transportation for Return A Product to the Company							
Transportation Lines							

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