SOLVING THE MEDICAL DEVICE SUPPLIER SELECTION PROBLEM USING INTEGRATED AHP-TOPSIS METHOD:A CASE OF SAMPLE HOSPITAL IN THAILAND

By
Miss Juan DING

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
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Solving the Medical Device Supplier Selection Problem Using Integrated AHP-TOPSIS Method:A Case of Sample Hospital in Thailand

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Title	Solving the Medical Device Supplier Selection Problem Using Integrated AHP-TOPSIS Method:A Case of Sample Hospital in Thailand
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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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CHAPTER 1

INTRODUCTION

1.1 Motivation

As one of the key industries developed by the Thai government, the medical industry has enormous development prospects. In recent years, the outbreak has accelerated the development of Thailand's domestic medical industry, which not only meets domestic needs but also greatly enhances Thailand's position as an important medical industry center in Association of Southeast Asian Nations (ASEAN).

With the steady development of Thailand's medical industry and various factors such as aging population, the medical device market has generated great demand. At the same time, the outbreak of the COVID-19 has made the medical device industry become one of the most prominent industries at present. During this pandemic, medical devices such as ventilator, oxygen concentrator, and vaccine refrigerators played a crucial role in improving patients' conditions (Asadi et al., 2022; Nayeri et al., 2022). Therefore, given the importance of the mentioned industry, investigating the supply chain management problem for this industry is necessary. In this regard, the supplier selection problem is known as one of the significant branches of the supply chain problems (Fallahpour et al., 2018).

It should be pointed out that the medical device market is a highly regulated and competitive field, and product compliance, quality, and some other factors are crucial. Similarly, choosing a suitable supplier of materials and equipment in the healthcare sector is essential because it directly affects the patient's health and the organization's effectiveness and quality of services. The process of supplier selection for medical devices is a multi-criteria decision making (MCDM) problem, which involves various criteria that need to be evaluated by experts (Ali & Kassam, 2022).

However, the decision-making process usually needs to consider multiple criteria at the same time, and requires multiple standard technologies to assist decision making. In the field of multi-criteria decision-making conditions, decision makers should follow the principle of rationality when choosing the most suitable alternative, that is, to assess

a limited set of interdependent or independent criteria (Chen, 2019; Chen, 2015). The supplier selection problem is diversified and contains the characteristics of multi-indicator standards, complexity, and non-structure. It is a multi-standard selection problem (Guo et al., 2017; Keshavarz Ghorabaee et al., 2017; Shi et al., 2018; Tong et al., 2019).

Decision-making tasks often ignore subjective and objective factors, such as the failure to consider data information, an incorrect expression of preferences, qualitative criteria, and other qualitative criteria (Chen et al., 2006; Zhang et al., 2009). Most methods are designed to solve the problem of supplier selection in non-complex situations (De Boer et al., 1998).

The problem of selection and ranking of a supplier of medical devices as well as a quality management system for medical devices is an important issue covered by ISO 13485 standard (Medical devices - Quality management systems Requirements for regulatory purposes - ISO 13485). Medical devices cover different types of devices (regular medical devices, sterile medical devices or active implantable medical devices and implantable medical devices). The issue of the purchase of medical devices has a number of dimensions: medical, human, economic, social and environmental. It is clear that the selection and ranking of suppliers is a complex management problem (Tadić et al., 2014).

According to Walczak et al. (1993), "supplier selection is a group effort lead by a physician from the orthopedic medical staff and supported by representatives from three administrative areas: the business manager of the operating room, the director of materials' management, and the administrator for the orthopedic service line." The criteria objectives are conflicting, thus selection of appropriate suppliers is far from a trivial task (Tadić et al., 2014). The problem becomes more complicated if we consider the practical assumption that the opposed criterion is different relative importance.

There are various mathematical techniques for MCDM problem such as analytic hierarchy process (AHP), data envelopment analysis (DEA), analytic network process (ANP), FAHP, ANP, Goal programming, Genetic algorithm (GA), etc. (Kirytopoulos et al., 2008). On the other hand, criteria evaluation is carried out by obtaining the importance of criteria through decision-makers or expert judgments. The criteria evaluated by the

experts' subjective decisions are subject to uncertainty and subjectivity. The main objective of this paper is to make it more grounded for selecting an appropriate supplier from the pool of suppliers through multi criteria decision making techniques such as AHP and TOPSIS.

So far, there have been some articles using AHP or TOPSIS to solve problems. ERDEBİLLİ et al. (2021) developed supplier ranking in the dental sector for orthodontic brackets supplier selection, which used an intuitionistic fuzzy set with the TOPSIS method. Khumpang and Arunyanart (2019) used the Rank Order Centroid method and Fuzzy TOPSIS method for medical equipment supplier selection for a hospital in Thailand (Ali & Kassam, 2022). AHP and Vikor integration offered by (Luthra et al., 2017) on the Green Supplier Selection problem in automobile company companies (Utama, 2021). Fuzzy TOPSIS was developed by Shen et al. (2013) to complete Green Supplier Selection in an automobile manufacturing company.

However, given the above, actual problems are often more complex than we imagine, some articles have combined AHP and TOPSIS to address related supplier selection issues. (Azimifard et al., 2018) proposed the Analytical Hierarchy Process (AHP) that is integrated by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for solving GSS based on the country in the steel industry. In addition, Freeman and Chen (2015) developed AHP-Entropy- TOPSIS on supplier selection at an electronic machinery manufacturer (Utama, 2021). A novel decision-making model of TOPSIS integrated entropy-AHP weights is proposed by Chen (2020) to select the appropriate supplier of building material. Manivel and Ranganathan (2019) analyzed the alternatives, criteria and sub criteria of the supplier selection process for hospital pharmacy by multi criteria decision making approach of Fuzzy Analytic Heuristic Process (FAHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) methods. (Pramanik et al., 2017) calculated a supplier selection index in which TOPSIS integrated with AHP and QFD played an important role. Ali and Kassam (2022) developed an integrated fuzzy (AHP-TOPSIS) model for supplier ranking in the dental sector.

So far, researcher has not found a combination of AHP and TOPSIS to solve the selection problem of medical device suppliers. This study aims to fully utilize the advantages of AHP and TOPSIS, as well as their combined use, to perfectly solve the problem of hospitals choosing medical devices suppliers, simplify the decision-making process, make it reasonable to follow, and further improve the medical level of hospitals.

1.2 Research Objective

1) To solve the medical devices supplier selection problem for the hospital.

2) To propose a practical template for selecting medical device suppliers that is basically feasible in the medical industry in Thailand.

1.3 Research Contributions

The main contributions of this thesis are:

1) Receive a practical template for selecting medical device suppliers.

2) Obtaining effective decision-making tools.

1.4 Research Scope and Limitations

This research examined only the application of TOPSIS integrated with AHP in the medical device supplier selection for the sample hospital in Thailand. The researcher classified the scope into 4 aspects as follows:

1) The respondent for the questionnaire is from a well-known company in the medical device industry in Thailand.

2) The scope of content is to focus on the medical device supplier selection for the sample hospital with ATOPSIS integrated with AHP.

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

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

1.5 Expected Results

1) To solve the medical devices supplier selection problem for the hospital.

2) To propose a practical template for selecting medical device suppliers that is basically feasible in the medical industry in Thailand.

1.6 Definition of Terms

A Practical Template: A practical template typically refers to a standardized format or structure that is designed to be easily understood and applied in various contexts. It serves as a guide or a starting point for creating or implementing something, such as a document, a process, or a project.

TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision-making method used to determine the best alternative among a set of options.

AHP: Analytic Hierarchy Process (AHP) is a technique for prioritizing and comparing multiple criteria in a hierarchical structure.

TOPSIS Integrated with AHP: When TOPSIS is integrated with AHP, the AHP method is used to determine the weights or importance of the criteria, and these weights are then used in the TOPSIS algorithm to calculate the final rankings of the alternatives. By integrating TOPSIS with AHP, the AHP method provides a systematic approach for determining the weights or importance of criteria, while the TOPSIS algorithm helps in ranking and selecting the most suitable alternative based on those weighted criteria. This combined approach can be useful in decision-making processes where there are multiple criteria and alternatives to consider.

CHAPTER 2

LITERATURE REVIEW

2.1 Analytic Hierarchy Process (AHP)

2.1.1 Motivation

There is a limited amount of academic research on the selection of medical devices suppliers at the moment. (Diaconu et al., 2017) stated that 40%-70% of the medical equipment in low- and middle-income countries is unfit for purpose or unused (Karadayi-Usta & Bozdag, 2020). Misuse of medical equipment can lead to increased costs and inadequate maintenance services. As a result, a reliable supplier can not only provide high-quality products, but also provide comprehensive after-sales service and technical support.

The analytic hierarchy process (AHP) is a systematic and hierarchical analysis method that combines qualitative and quantitative analysis. The essence of this method is the analysis decision of complex problems, utilizing less quantitative information to mathematize the thinking process of decision-making, thereby providing a simple decision-making method for multi-objective, multi-criteria, or unstructured decision-making problems. It is a model for making decisions on complex systems that are difficult to quantify.

2.1.2 The Basic Steps of AHP

AHP is a popular weighting method proposed bySaaty (1988) , based on pairwise comparisons between elements (Utama, 2021). The fundamental of AHP is the scoring method: determining indicators, scoring different schemes of indicators, and determining weights for indicators. Used to handle evaluations with unknown data.

AHP decomposes the problem into constituent factors and aggregates and combines them at different levels based on their ,correlation, influence, and membership relationships forming a multi-level analytical structure model. Thus, the problem ultimately boils down to the determination of the relative important weights of the lowest level)solutions, measures, etc. for decision-making(relative to the

highest level)overall goal(or the arrangement of the relative order of .advantages and disadvantagesThe basic steps are as follows:

Step 1: Consider the following questions.

1) What are the evaluation objectives?

2) What are the plans for achieving the goal?

3) What are the evaluation criteria or indicators for the plan?

Draw a hierarchical structure diagram of the decision objectives, decision criteria (considered factors), and decision objects.

1) At the highest level (target level): the purpose of the decision and the problem to be solved.

2) Intermediate layer (criterion layer or indicator layer): Factors to consider and criteria for decision-making.

3) Lowest layer (solution layer): Alternative solutions for decision-making.

Or draw the evaluation system (tree chart or table) as shown in Figure 1 (including multi-level indicators):

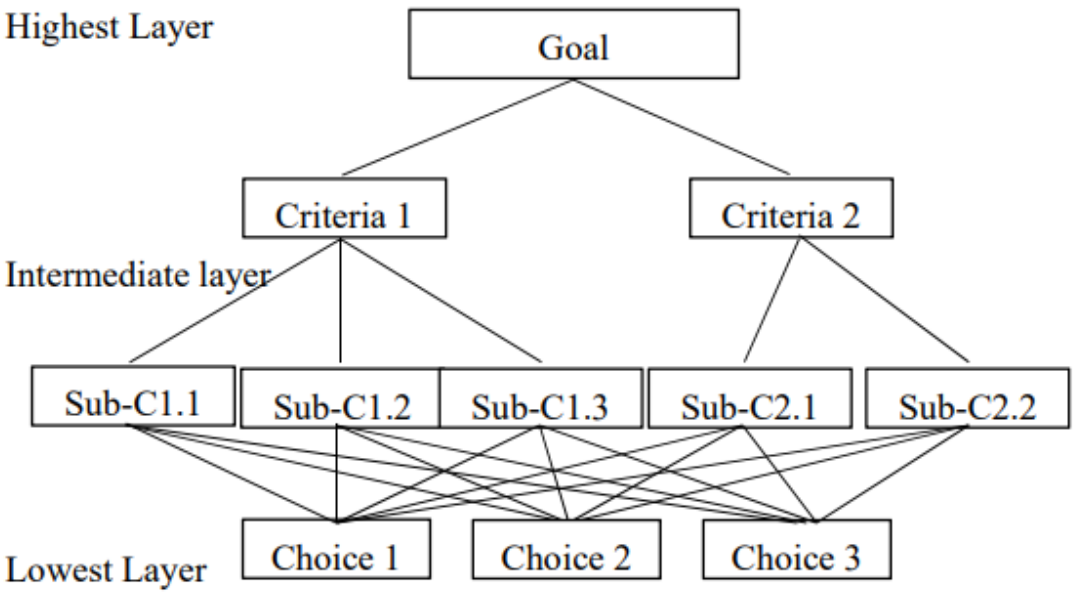

Figure 1. Structured AHP model

Step 2: Constructing a judgment matrix (Paired comparison matrix)

When determining weights, only qualitative results (such as percentages) are given, which are often not accepted by others. Therefore, the consistent matrix method is adopted, which is:

1) Compare not all factors together, but in pairs;

2) At this point, relative scales are used to minimize the difficulties caused by various factors in comparison and improve accuracy (Table 1).

Table 1. Fundamental scale of Thomas L. Saaty

Verbal Judgments	Intensity of Importance
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8

source: Saaty (1988)

Paired comparison matrix is a comparison that represents the relative importance of all factors in this layer against a certain factor (quasi side or target) in the previous layer. The element a_{ij} of the paired comparison matrix represents the comparison result of the factor i relative to the factor j, and this value is given using 1-9 scaling method from Saaty (1988).

Define and meet (2.1).

$$a_{ij} = \text{the importance of element i relative to element j}$$
$$= \frac{\text{the importance of i}}{\text{the importance of j}} = a_{ik} a_{kj} \quad (2.1)$$

Pairwise comparison matrices have been operated to compare each element of the hierarchy structure as shown in Eq. (2.2).

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \quad (2.2)$$

Step 3: Estimate the relative weights.

The relative weight (W) of elements in each pairwise comparison matrix is computed by the eigenvalue method. W of matrix (A) is obtained from Eq. (2.3).

$$AW = \lambda_{max} W \quad (2.3)$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nw_i} = \frac{1}{n} \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} a_{ij} w_j}{w_i} \quad (2.4)$$

Where λ_{max} = the biggest eigenvalue of matrix A

Step 4: Check consistency

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (2.5)$$

Necessary and sufficient conditions for uniform matrices

$$\begin{cases} a_{11} > 0 \\ a_{11} = a_{22} = \cdots a_{nn} = 1 \\ [a_{i1}, \cdots, a_{in}] = k_i [a_{11}, \cdots, a_{1n}] \end{cases}$$

In regard to:

Uniform matrix: then we naturally take the corresponding maximum eigenvalue n normalized eigenvectors of (w_1, w_2, ..., w_n), and $\sum_{i=1}^{n} w_i = 1$.

Where w_i = The weight value of the degree that the factor i in the lower level affects a certain factor in the upper level

Non uniform matrix: use the normalized feature vector corresponding to its maximum feature root as the weight vector W = (w_1, w_2, ..., w_n), then AW = λ_{max} W. The method of determining the weight vector in this way is called the feature root method.

Theorem:

1) The unique non-zero eigenvalues of n-order uniform matrices are n.

2) N order reciprocal matrix A ($a_{ij} > 0$, $a_{ij} = \frac{1}{a_{ij}}$, $a_{ii} = 1$) Maximum characteristic root $\lambda \geqq n$, when and only when $\lambda = n$, A is consistent matrix.

λ continuously depends on a_{ij}, the more input than n, the more severe the inconsistency of A. Using the feature vector corresponding to the maximum eigenvalue as the weight vector of the influence degree, the greater the degree of inconsistency, the greater the judgment error caused.

The consistency of the judgments from the decision makers is estimated through the Consistency Ratio (CR) of matrices. Consistency ratio is computed as shown in Eq. (2.6).

$$CI = \frac{(\lambda_{max} - n)}{(n - 1)} \tag{2.6}$$

Where CI = Consistency Index

n = Number of elements in the matrix

There is complete consistency when CI=0, satisfactory consistency when CI is close to 0, more severe the inconsistency when CI becomes more and more.

Next step:

$$CR = \frac{CI}{RI} \tag{2.7}$$

Where CR = Consistency Ratio

RI = Random Index computed for matrices that depends of n

Table 2. List of RI values

n	3	4	5	6	7	8	9	10	11	12	13
RI	0.58	0.89	1.12	1.24	1.33	1.40	1.45	1.49	1.51	1.54	1.56

source: Alonso and Lamata (2006)

If CR<0.1, it can be considered that the consistency of the judgment matrix is acceptable; however, if it is not, the research must redo the whole process.

Step 5: Results.

Make decisions and document the decision-making process, especially recording all the reasons for making the decision.

2.1.3 Applications of AHP

AHP is a systematic and hierarchical problem-solving method. Its basic idea is to decompose a complex problem into several levels and then establish criteria between different levels. By quantitatively analyzing the criteria at each level, the final weights are obtained and the degree of superiority and inferiority of each scheme is evaluated. This method is suitable for multi-objective, multi factor, and multi-level decision-making processes.

The suitable knowledge management tools were evaluated by decision-makers from a leading telecommunications company in Hong Kong with the help from Ngai and Chan (2005) through AHP method. The proposal management process of a company for decorating public gardens and park structures was analysed by Bertolini et al. (2006) with a hierarchical structure derived from AHP. Rad et al. (2011) sorted

university majors based on similarity and difference using the AHP algorithm. Vidal et al. (2011) combined AHP and Balanced Scorecard to evaluate the performance of a Brazilian telecommunications company by prioritizing multiple performance perspectives and indicators. An AHP-based evaluation procedure was used to help (Melón et al., 2008) to choose the best educational program for Valencia Polytechnic University and conduct educational science research to provide strict evaluation methods for management departments. Vidal et al. (2011) defined complexity scales and sub scales and utilized AHP theory to assist a startup in the entertainment industry (musical production) for making decisions in analyzing investment portfolios. With the application of AHP, the key performance indicators for Occupational safety and health management systems were selected by Podgórski (2015) based on a set of SMART (Specific, Measurable, Achievable, Relevant and Time-bound) standards.

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

2.2.1 Intention

The advantage of the AHP method in the decision-making process 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.

A well-known and commonly used multi-criteria decision making (MCDM) method called TOPSIS was proposed by Hwang et al. (1981), which is the technique for order preference by similarity to an ideal solution. 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. In addition, the

TOPSIS method can also consider the weights of different factors and objectively evaluate risks.

2.2.2 Operational Process of TOPSIS

Determining the ideal best and worst solutions according to the normalized raw data matrix is the basic idea of TOPSIS. Then, by calculating the distance between each evaluated solution and the best and worst solutions, the closeness between the solution and the best solution is obtained, which serves as the basis for evaluating the advantages and disadvantages of each evaluated object.

General steps of TOPSIS analysis method:

Step 1: There are m targets (limited targets) and n attributes, and the expert's evaluation value for the attribute j of target i is x_{ij}, the initial judgment matrix V is:

$$V = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{i1} & \dots & x_{ij} & \dots \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{2.8}$$

Step 2: Due to the different dimensions of each indicator, it is necessary to normalize the decision matrix:

$$V' = \begin{bmatrix} x'_{11} & x'_{12} & \dots & x'_{1n} \\ x'_{21} & x'_{22} & \dots & x'_{2n} \\ \dots & \dots & \dots & \dots \\ x'_{i1} & \dots & x'_{ij} & \dots \\ \dots & \dots & \dots & \dots \\ x'_{m1} & x'_{m2} & \dots & x'_{mn} \end{bmatrix} \tag{2.9}$$

Where

$$x'_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k-1}^{n} x^2_{ij}}} \qquad \text{i=1, 2} \cdots \text{m; j=1,2} \cdots \text{n.} \qquad (2.10)$$

Step 3: According to AHP method, obtain the information weight matrix B of expert groups on attributes, and form a weighted judgment matrix:

$$Z = V'B = \begin{bmatrix} x'_{11} & x'_{12} & \dots & x'_{1n} \\ x'_{21} & x'_{22} & \dots & x'_{2n} \\ \dots & \dots & \dots & \dots \\ x'_{i1} & \dots & x'_{ij} & \dots \\ \dots & \dots & \dots & \dots \\ x'_{m1} & x'_{m2} & \dots & x'_{mn} \end{bmatrix} \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1n} \\ w_{21} & w_{22} & \dots & w_{2n} \\ \dots & \dots & \dots & \dots \\ w_{i1} & \dots & w_{ij} & \dots \\ \dots & \dots & \dots & \dots \\ w_{m1} & w_{m2} & \dots & w_{mn} \end{bmatrix}$$

$$= \begin{bmatrix} f_{11} & f_{12} & \dots & f_{1n} \\ f_{21} & f_{22} & \dots & f_{2n} \\ \dots & \dots & \dots & \dots \\ f_{i1} & \dots & f_{ij} & \dots \\ \dots & \dots & \dots & \dots \\ f_{m1} & f_{m2} & \dots & f_{mn} \end{bmatrix} \qquad (2.11)$$

Step 4: Obtain the positive and negative ideal solutions of the evaluation objective based on the weighted judgment matrix:

Positive ideal solution:

$$f^*_j = \begin{cases} \max(f_{ij}),\ j \in J^* \\ \\ \min(f_{ij}),\ j \in J' \end{cases} \qquad j=1, 2, ..., n. \qquad (2.12)$$

Negative ideal solution:

$$f'_j = \begin{cases} \min(f_{ij}),\ j \in J^* \\ \\ \max(f_{ij}),\ j \in J' \end{cases} \qquad j=1, 2, ..., n. \qquad (2.13)$$

Where J^* represents benefit indicators, J' represents cost indicators.

Step 5: Calculate the Euclidean distance between each target value and the ideal value:

$$S^*_i = \sqrt{\sum_{j=1}^{m}(f_{ij} - f^*_j)^2} \qquad j=1, 2, ..., n. \qquad (2.14)$$

$$S'_i = \sqrt{\sum_{j=1}^{m}(f_{ij} - f'_j)^2} \qquad j=1, 2, ..., n. \qquad (2.15)$$

Step 6: Calculate the relative closeness of each target:

$$C^*_i = \frac{S'_i}{S^*_i + S'_i} \qquad i=1, 2, ..., m. \qquad (2.16)$$

Step 7: Sort the goals based on their relative closeness to form a decision-making basis.

2.2.3 Utilization of TOPSIS

TOPSIS method is a multi-attribute decision analysis method that can help us consider problems in multiple aspects, thus making more comprehensive and accurate decisions. In practical applications, the TOPSIS method is widely used in various fields.

A TOPSIS group decision aggregation model was proposed by Huang and Li (2012) which solved the problems of compromise oriented decision-making. Davoodi et al. (2011) used the TOPSIS method to determine the dual cap shape of the material model that can be used for small car bumper crossbeams. Lozano-Minguez et al. (2011) proposed a method for selecting the optimal solution for offshore wind power generation through systematic evaluation in different configurations using the widely used multi criteria decision-making method TOPSIS. A reliable and detailed robot database was generated and maintained by (Bhangale et al., 2004) with TOPSIS on the different relevant attributes of robots, which helped to simplify the problem of robot selection. Moghassem (2010) provided valuable assistance in selecting suitable drop tubes for 30Ne rotor yarn and adjusting them to improve the production efficiency of weft knitting machines through TOPSIS. Monjezi et al. (2012) applied TOPSIS to investigate the blasting operation of the Taiareh limestone mine and selected the most suitable blasting mode. Berger (2006) generated a future description of the agricultural system by cycling through each time step in the simulation to address various driving factors of change. The prioritization of wetland restoration in the Clarence River Basin (New South Wales, Australia) was evaluated and ordered with TOPSIS method applied from Liu et al. (2006). TOPSIS was used for decision to support in selecting the anti-flood water tank that should be filled to achieve the best response to flood accidents by Ölçer and Majumder (2006) in emergency situations. A method for evaluating, comparing, sequencing, and optimal selection of raw materials for anaerobic digestion was proposed by Rao and Rao and Baral (2011) according to TOPSIS, one of Multiple Attribute Decision Making approach. Sadeghzadeh and Salehi (2011) adopted TOPSIS to list the basic solutions for the development of fuel cell technology as automotive power systems, and attempted to find development solutions for fuel cell strategic technology through technology, economy, appropriate attention and investment areas.

2.3 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Integrated with Analytic hierarchy process (AHP)

2.3.1 Introduction

Just as AHP has drawbacks, the TOPSIS method also has some 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.

Overall, the AHP method and TOPSIS method each have their own advantages and disadvantages, and specific applications need to be selected based on different evaluation objects and needs. If the evaluation object has multiple hierarchical structures and needs to consider the influence relationships between different levels, then the AHP method is more suitable. If the evaluation object does not have multiple hierarchical structures and only needs to be simply sorted, then the TOPSIS method is more suitable.

Of course, using AHP or TOPSIS methods alone also has certain limitations. In order to make decisions more accurately, a combination of multiple methods can be used. This study first used the AHP method to establish a hierarchical structure, and then used the TOPSIS method to calculate the distance and proximity of each scheme, ultimately obtaining the optimal scheme.

2.3.2 Steps for Combining AHP and TOPSIS

Based on the previous text, this study proposes a research method that combines AHP and TOPSIS to establish models and solve problems to select medical devices supplier for the hospital in Thailand.

Application steps are given in Figure 2.

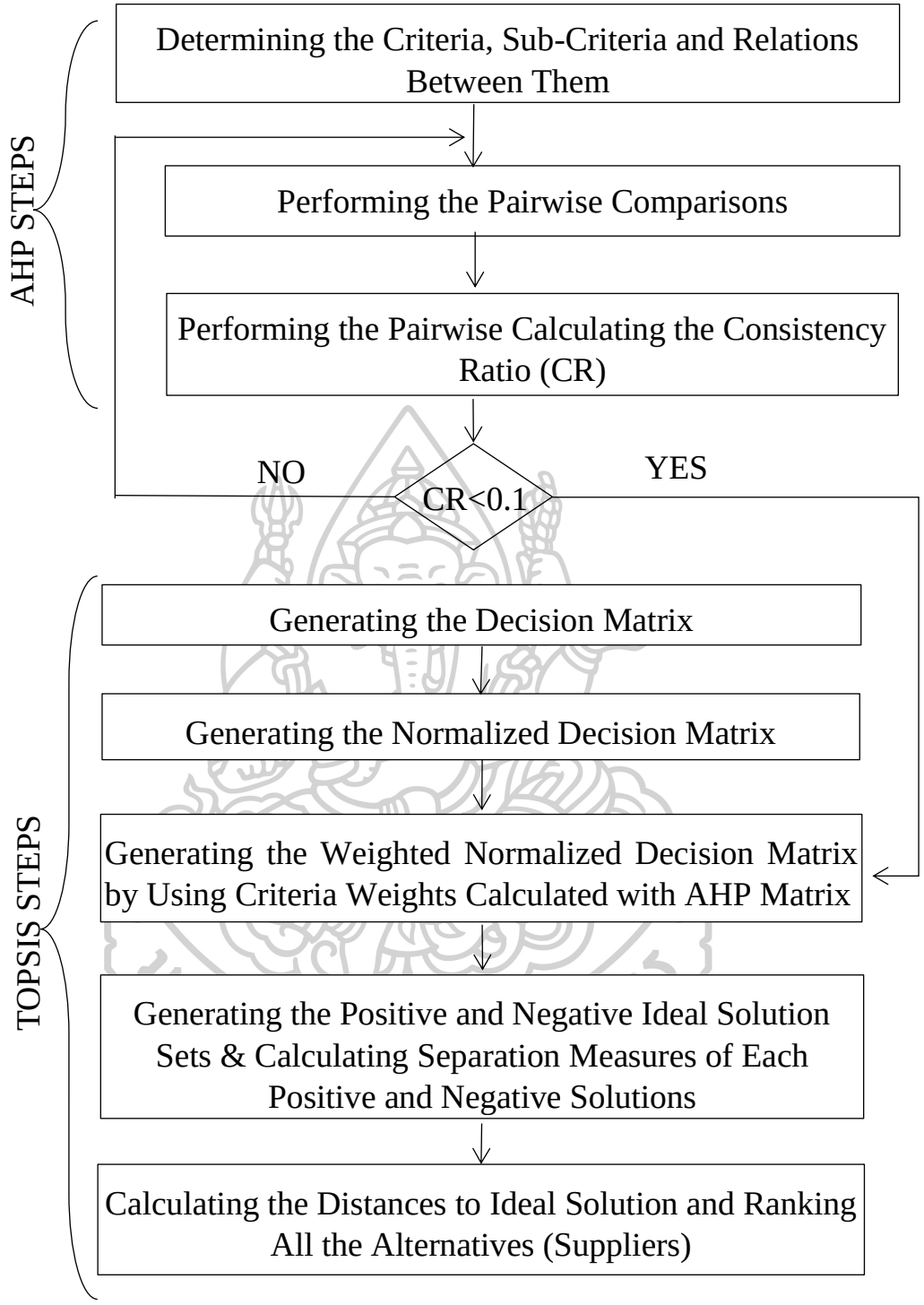

Figure 2. Application Steps
source: Saaty (1980); Hwang et al. (1981); Özcan et al. (2018)

2.3.3 Applications of AHP Integrated TOPSIS

The method combined AHP and TOPSIS for selecting supplier in natural gas cycle power plant was proposed by Özcan et al. (2018). There were 3 criteria (casting, machining and coating) which directly affect the material quality from the power plant specialists by considering 9 parameters (given in Figure 3) for supplier selection problem for gas turbine rotor blade parts in Natural Gas Combined Cycle Power Plant. According to these criteria, 6 potential suppliers were evaluated with the AHP-TOPSIS combination and the most suitable supplier was obtained (Özcan et al., 2018).

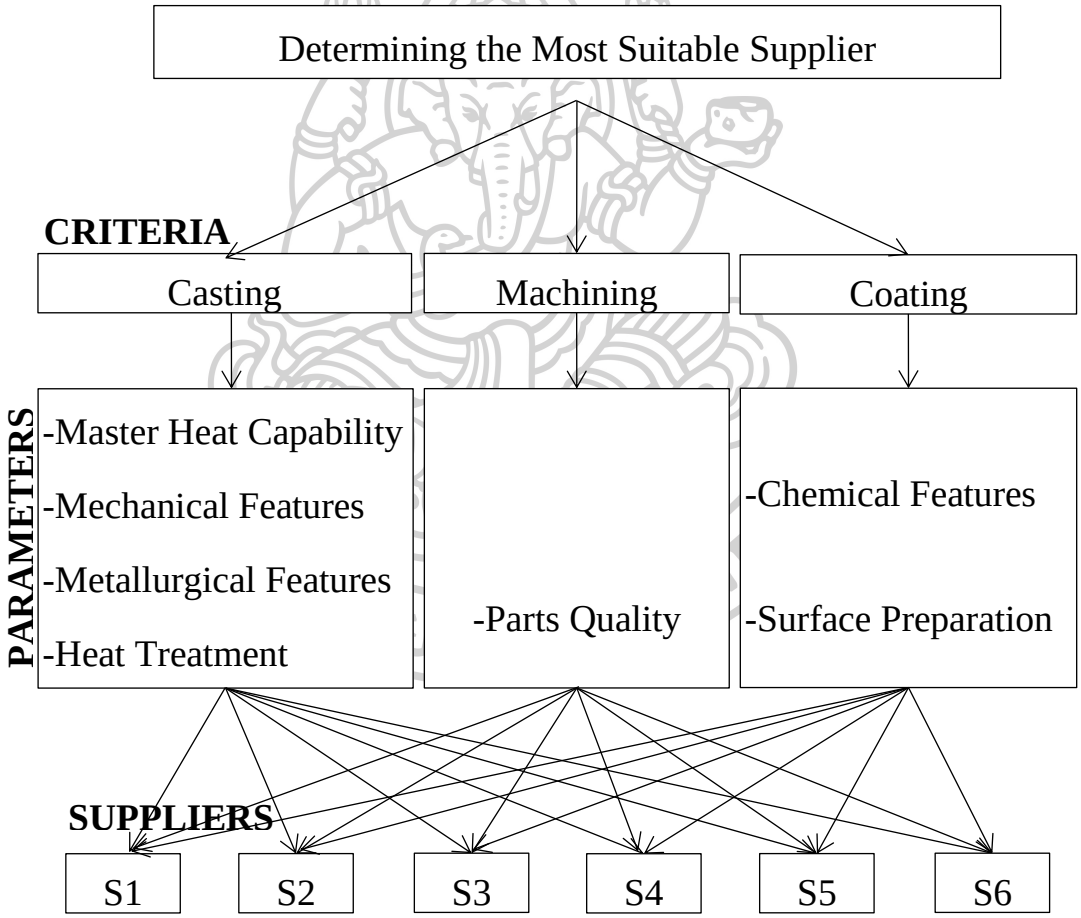

Figure 3. Hierarchical structure
source: Özcan et al. (2018)

Thy calculated criteria weights with AHP by following the steps given in Figure 2, the data is given in Table 3.

Table 3. Criteria weights

Criteria	w
Casting	0,778
Machining	0,111
Coating	0,111

source: Özcan et al. (2018)

The alternative supplier priorities gotten by TOPSIS methodology were started to be calculated after the criterion weights. The decision matrix was constructed by researchers, power plant and procurement specialists, which was shown in the Table 4.

Table 4. Decision matrix

Suppliers	C1	C2	C3
S1	10	2	10
S2	6	10	5
S3	9	4	5
S4	10	2	3
S5	6	2	3
S6	4	1	2

source: Özcan et al. (2018)

The matrix weighted by the criteria weights calculated with AHP and normalized by the normalized decision matrix was obtained as a result of the normalization of the decision matrix. Then ideal and negative ideal solution sets were prepared to calculate the distances to the ideal and negative ideal solutions, in other words, alternative supplier priorities

(Table 5) were obtained by calculating the separation measures from these sets (Özcan et al., 2018).

Table 5. Supplier priorities

Suppliers	Score	Ranking	Suppliers	Score	Ranking
S1	0,729	1	S4	0,664	2
S2	0,412	4	S5	0,131	5
S3	0,603	3	S6	0,034	6

source: Özcan et al. (2018)

Finally, suppliers of gas turbine rotor blade components were obtained through the joint AHP-TOPSIS method in their research.

Utama (2021) who made the selection for green supplier selection in Indonesia with the Integration of AHP and TOPSIS is another example. In addition, the optimal transfer station location in Istanbul of Turkey was selected by Önüt and Soner (2008) with a comparative analysis of AHP and TOPSIS technologies (Chen, 2020). It can be seen that Iran's mining industry was considered the best sustainable supplier for Iran's steel industry and LRAN was considered the best sustainable supplier for most suppliers in Iran's steel industry from the research about AHP-TOPSIS application published by Azimifard et al. (2018). Utama (2021) integrated AHP and TOPSIS methods to select suppliers for Indonesian offset printing companies based on eight standards, in which quality standard was proved to be the most important. According to the report using hybrid AHP-TOPSIS analysis from Sindhu et al. (2017), it was concluded that the most suitable location to install solar power generation in Indian was Sonepat, followed by Rohtak, Chandigarh, Gurgaon, and Hisar in Haryana. A scientific and rigorous decision support system was provided by Barrios et al. (2016) through the integration of AHP-TOPSIS, which was also used for strategic and complex decision-making. AHP and TOPSIS were integrated into a series of preference models for human exploration of Mars at the Johnson Space Center to achieve the goal of prioritizing manned space mission simulators, which was proposed by Tavana and Hatami-Marbini (2011). A new method for solving Internet of health thing security

assessment that has never been used before for system evaluation and decision-making was presented by Wang et al. (2020) using AHP-TOPSIS methods.

2.4 Conclusion

AHP and TOPSIS can be combined in supplier selection to comprehensively consider the weights and evaluations of different factors and attributes. The comprehensive use of AHP and TOPSIS methods can effectively combine subjective and objective evaluations, mixing the weights with evaluations of multiple factors and attributes, in order to select the most suitable supplier. However, this process requires to ensure the professional knowledge and credibility of decision-makers and evaluators when determining criteria and weights, as well as evaluating based on accurate and reliable data.

2.5 Problem Description

2.5.1 Introduction

The Thailand International Medical Equipment and Hospital Supplies Exhibition, hosted by Dusai, is one of the most professional and well-known medical exhibitions in Thailand. Every two years, it alternates with the MEDICAL FAIR ASIA in Singapore, showcasing the latest instruments, equipment, products, and services from the medical field worldwide. As one of the most influential medical device exhibitions in Southeast Asia, Medical Fair Thailand attracts approximately 900 exhibitors from over 40 countries and over 10000 visitors per session. The exhibition will gather industry elites from various fields such as hospitals, diagnostics, pharmaceuticals, healthcare, rehabilitation equipment and equipment, to jointly seek cooperation and development in the healthcare industry in Southeast Asia in the future. In addition, the exhibition provides information and communication opportunities for medical suppliers, industry professionals, government agencies, hospital managers, doctors, and other healthcare experts.

Medical devices play a crucial role in the modern medical field, which not only helps doctors provide better diagnosis and treatment, but also ensuring the safety and rehabilitation of patients. Thailand is one of

the main medical device markets in Southeast Asia. Thai medical devices have received great attention in the international medical market, with a wide variety of products covering various medical fields.

The rich variety and high quality of medical devices in Thailand have won recognition and trust from the international market, making important contributions to the development of the Thai medical industry. There are various categories of medical devices in Thailand, covering multiple fields such as treatment, diagnosis, laboratory, rehabilitation, healthcare, nursing, disinfection, and accessories. These devices play an important role in medical work, providing reliable support for the treatment and rehabilitation of patients. Therapeutic instruments are equipment and tools used for medical purposes, including various surgical instruments, syringes, infusion sets, cardiac pacemakers, etc. These devices play a crucial role in medical operations, helping doctors perform surgeries, treat patients, and monitor their condition. Diagnostic instruments are equipment and tools used for detecting and diagnosing diseases, including blood pressure meters, blood glucose meters, X-ray machines, ultrasound machines, etc. These devices can help doctors accurately diagnose patients and develop reasonable treatment plans. Laboratory instruments are equipment and tools used for scientific experiments, research, and analysis, including microscopes, centrifuges, pH meters, test tube racks, etc. These devices are widely used in medical research, drug development, and clinical experiments, providing reliable technical support for the development of the medical field. Rehabilitation equipment is a device and tool used for rehabilitation treatment, including physical therapy equipment, rehabilitation training equipment, orthotics, etc. These devices can help patients recover their function and mobility, and improve their quality of life. Health care equipment is equipment and tools used for personal health care, including electric toothbrushes, massagers, thermometers, etc. These devices can help people maintain health, prevent diseases, and improve their quality of life. Nursing equipment is equipment and tools used for nursing and caring for patients, including nursing beds, wheelchairs, nursing carts, etc. These devices can provide a convenient and comfortable nursing environment, promoting the recovery and stability of patients. Disinfection equipment is equipment and tools used for

disinfection and sterilization, including disinfection cabinets, sterilizers, disinfectants, etc. These devices can effectively kill bacteria and viruses, ensuring the cleanliness and safety of the medical environment. Medical device accessories are accessories and auxiliary equipment used for medical devices, including batteries, sensors, connecting cables, etc. These accessories can provide power, signal transmission, and connection functions to ensure the normal operation of medical devices.

It is not difficult to imagine that choosing medical device suppliers has become an important issue in their work for hospital staff faced with so many types of medical devices. In the same way, it is not a simple task to select suitable medical device suppliers or find reliable partners among numerous suppliers.

It’s clear that evaluation and selection of suppliers is an important issue in ISO 13485, so the suggested procedure is aiming to improve the quality of suppliers’ ranking and selection Tadić et al. (2014). This article selects a medical device supplier selection problem in a hospital in Thailand as a study case. Based on the AHP-TOPSIS model proposed earlier, it is hoped that the efficiency and effectiveness of related work can be improved by solving this case and providing reference for similar problems.

2.5.2 Determination of Relevant Criteria

This study aims to help a sample company in Thailand handle with the medical devices supplier selection problem using the theories of AHP and TOPSIS methods. Some authoritative journals have been selected and read by searching with keywords "supplier selection" and "medical devices".

The evaluation criteria for ranking medical equipment suppliers by Tadić et al. (2014) are: unit cost (monetary unit), delivery time (in hours), communication frequency, financial stability and strength (based on financial background), reliability and conformity of product requirements. Cao et al. (2022) re-evaluated the suppliers' performance of a medical device company based on standards (products/service quality, delivery, timeline, and flexibility). Alamroshan et al. (2022) combined two main indicators of green and agility, as well as material cost, environmental

performance evaluation, manufacturing flexibility, service level, and system reliability indicators to rank potential suppliers and select the best supplier. ForouzeshNejad (2023) studied supplier selection issues and helped supply chain managers become more familiar with the business environment by considering the leagile, sustainability, and Industry 4.0 (I4.0) indicators in the medical device industry. ARSLAN and YAĞCI (2019) prioritizes five medical device suppliers of a technology park member enterprise to provide the best benefits for the company's operations based on these criteria: price, quality, service (barter, repair, training), address (shipping time), reliability, flexibility, supplier country risk and reliability of logistics companies.

Potential key indicators extracted from the literature have been studied in selecting medical device suppliers after reading these journals.

Firstly, the reputation of the supplier is one of the important criteria for selection. A reputable supplier is usually rigorously audited and certified, capable of providing high-quality, standard compliant products. You can learn about the supplier's reputation by consulting their official website and other medical institutions, or referring to professional evaluations. In addition, the time and scale of cooperation with suppliers can also be considered, which are important indicators for evaluating supplier reputation.

Secondly, quality is one of the key factors in selecting suppliers. The quality of medical devices is directly related to the safety and treatment effectiveness of patients. We should place importance on their product quality control system and understand their production process and quality inspection process when selecting suppliers. Suppliers can be required to provide product quality certification and testing reports to ensure that their products meet relevant standards and regulatory requirements.

In addition, environmental performance evaluation cannot be ignored. It is crucial to improve their environmental protection and social responsibility performance as more and more attention is paid to environmental protection and social responsibility issues in the supply chain. For example, the supplier's environmental management, sustainable development strategy and the company's social responsibility performance should meet the requirements of laws and regulations.

The supplier's after-sales service is also one of the important considerations for selection. Problems are inevitable during the use of medical devices, and timely technical support and after-sales service provided by suppliers will greatly reduce the risks and losses of medical institutions. The after-sales service policies, service scope and response time can be learnt before the decision. You can communicate with other medical institutions to understand their cooperation experience with suppliers and evaluate their after-sales service quality.

The price is also one of the important considerations. It is necessary to comprehensively consider the balance between price and quality when selecting suppliers because the price of medical devices is usually high. You can compare with different suppliers to understand the market situation and competition, in order to obtain reasonable prices. Better cooperation conditions can be obtained after negotiating prices and payment methods with suppliers.

Finally, the stability of partners is also important. Medical device suppliers often have long-term cooperative relationships with medical institutions, which means the stability and reliability of suppliers are very significant. You can evaluate the stability of suppliers by checking their business history, financial status, and partnership relationships. The long-term cooperation agreements with suppliers could be considered to ensure the stability and reliability of the supply.

After discussion, the selection criteria for medical devices have been determined as follows: reputation, quality, environmental performance evaluation, after-sales service, price, stability. This article will combine the key criteria with the opinions from relevant experts and ultimately form the decisive criteria for selecting medical device suppliers for the hospital in Thailand.

Table 6. Criteria and Serial Number

Criteria Number	Criteria Name
C_1	Reputation
C_2	Quality
C_3	Environmental performance evaluation
C_4	After-sales Service
C_5	Price
C_6	Stability

2.5.3 Information About the Sample Company

The research subjects of this study are medical industry experts from National Healthcare Systems Company Limited (N Health), which is a proud member of the Bangkok Dusit Medical Services (BDMS)- a Bangkok-based multinational group of companies whose core businesses are in hospital and healthcare interests in the Asia Pacific region. N Health is ASENAN's leading provider of laboratory services with over 2,000 employees across the ASEAN economies. It also offers a wide range of high quality ancillary healthcare services. According to the company, there are a total of four alternative solutions.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter introduces the research design and methodology for supplier selection based on research objectives, combining AHP and TOPSIS.

3.1 Research Method

This research methodology is divided into 3 stages as follows:

The first stage of this study was to extensively review literature, articles, or books on AHP, TOPSIS, Thai medical devices, and supplier selection through Google Scholar website and other channels. In order to understand the relevant information of Thailand's medical industry and medical device industry, as well as how previous researchers applied AHP and TOPSIS to solve the problem of supplier selection.

The second stage is to propose a mixed model that combines the advantages of AHP and TOPSIS to solve the supplier selection problem, based on a sufficient understanding of how they are applied. According to relevant literature, this method has been applied to solve some multi criteria decision problems.

In the last stage, through data research from multiple relevant experts and a series of calculations based on the AHP-TOPSIS mixed model, the importance ranking of six key factors (price, payment, delivery time, service, setting up a budget and quality) that affect supplier selection was obtained, and the best solution was selected from four Thai medical device suppliers. Finally, the research results of this case study and the application forms of the AHP-TOPSIS hybrid model were summarized.

3.2 Research Tools

3.2.1 Questionnaire

This survey questionnaire is divided into two parts. Survey questionnaire-1 collects scoring data for pairwise comparison of six key factors (price, payment, delivery time, service, setting up a budget and quality) based on their importance level. Survey questionnaire-2 scores the importance level of four alternatives from six levels in sequence.

3.2.2 Expert Review Meeting

Expert review meetings are an important decision-making and review mechanism, whose significance and role have been widely applied in various industries. The meetings are considered an effective means of quality assurance and risk control in fields such as scientific research, technology, engineering, and medicine. Its main functions are as following:

1) Ensure the quality of work or projects.

2) Control risks and reduce losses.

3) Improve the scientificity and reliability of decision-making.

4) Promote the exchange and sharing of professional knowledge and experience.

In this study, multiple Thai healthcare industry professionals will be invited to participate in this review meeting, and the data collection work for the above survey questionnaire will be completed.

3.3 Data Selection

This article conducts a case study on the selection of medical device suppliers in a hospital in Thailand. Six criteria will be used to determine the optimal solution among four suppliers. Table 1 in Chapter 2 serves as the basis for judging the weights of the six criteria, while Table 7 serves as the scoring basis for the importance of the four suppliers at six different levels.

Table 7. 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	$8<x\leq10$

3.4 Conceptual Framework

3.4.1 Research Hypothesis

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

Hypothesis 2: The suppliers available for selection can directly represent different types of local medical device suppliers in Thailand.

3.4.2 Proposed Conceptual Framework

Six key criteria have been summarized shown in Table 6 based on a comprehensive review of a large number of relevant literature and the opinions of some medical industry professionals. The proposed conceptual framework is shown in Figure 4.

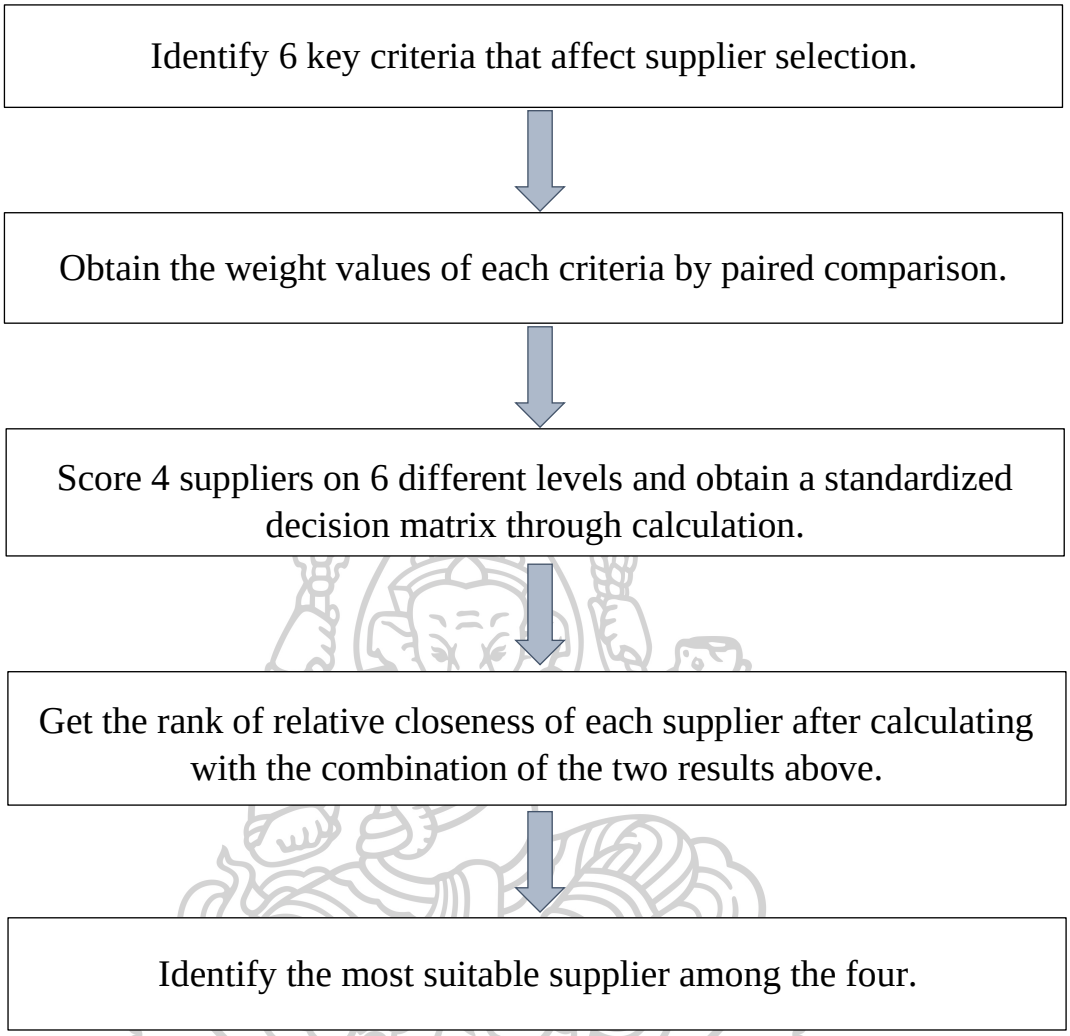

Figure 4. Conceptual Framework

3.5 Research Procedure

The research procedure for papers helps to establish a reasonable research framework and methods. By conducting research and comparing research methods, suitable research methods and data analysis methods can be selected. Meanwhile, through comprehensive analysis of relevant research, a logically complete and scientifically rigorous research framework can be established to ensure the comprehensiveness and accuracy of the research. Before starting this survey, the researcher has designed a complete research procedure, as shown in Figure 5.

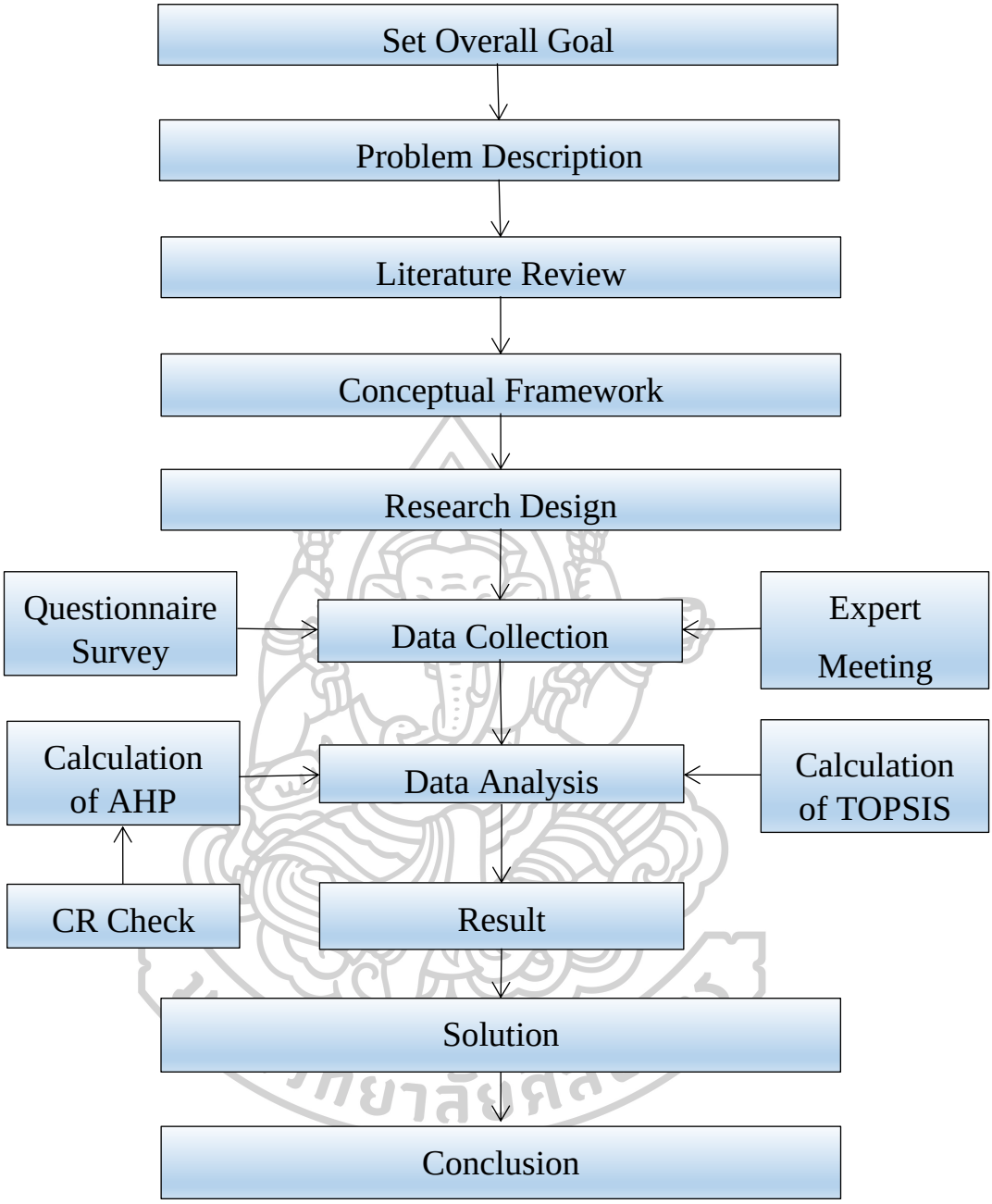

Figure 5. Research Procedure

CHAPTER 4
RESULTS AND ANALYSIS

The research sample company of this article is a national healthcare company in Thailand, and the objectives of this study are:

1) To solve the medical devices supplier selection problem for the hospital.

2) To propose a practical template for selecting medical device suppliers that is basically feasible in the medical industry in Thailand.

The AHP-TOPSIS model in Figure 6 will be applied in the data analysis process of six survey questionnaires.

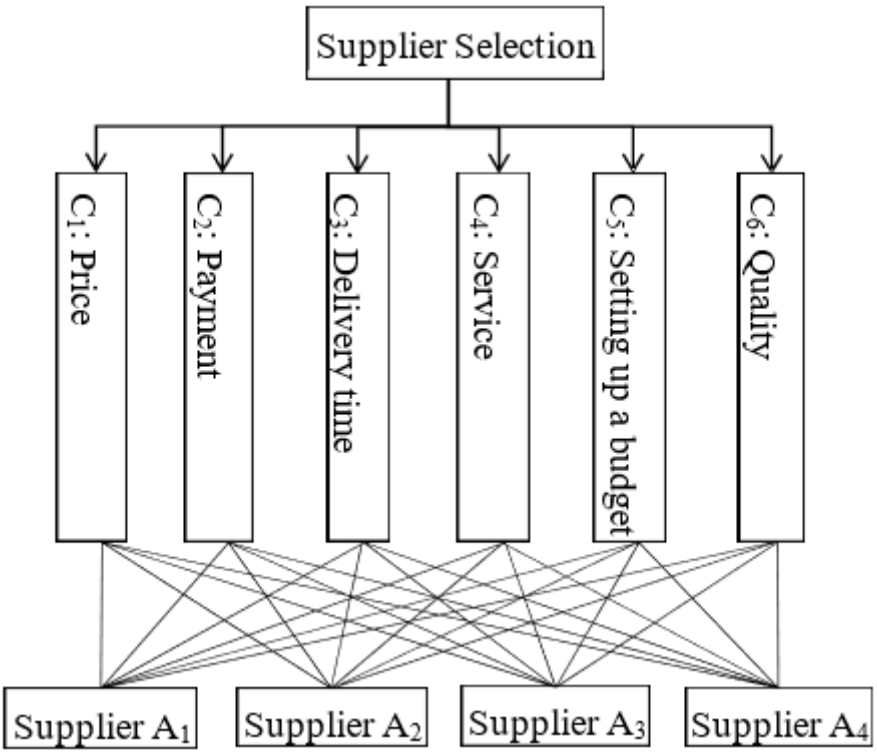

Figure 6. AHP-TOPSIS model

All four suppliers are companies that sell high priced medical equipment, such as radiation equipment, computed tomography, magnetic resonance imaging, and ventilators. The equipment sold by these four companies is standard certified.

The survey questionnaire is mainly divided into two parts. The first part is item objective congruence (IOC) test, the second part contains basic information of the interviewees in Section A, AHP assessment for criteria compared in Pair in Section B, and the assessment on different criteria for alternative A_1 to A_4 in Section C.

The research results are as follows.

4.1 The Results of IOC

Item Objective Congruence (IOC) method is a technique which enables content validity, otherwise a subjective process, to be quantified (Fouzul Kareema & Bt Zubairi, 2021; Rovinelli & Hambleton, 1976).

Item Objective Congruence is used to evaluate the development phase of a project, with the main purpose of providing a mathematical extension model applicable to multidimensional indicators for project development, providing evidence for obtaining information from measurement management and quality assessment, and developing a common testing theory program.

Researcher used IOC to test the reliability and validity of survey questionnaires, evaluate the validity of data and the rigor and appropriateness of procedures. The evaluation system of the survey questionnaire is reflected in the form of a scale, and the rationality of its preparation determines the usability and credibility of the evaluation results. IOC provides effective support for the reliability and validity evaluation of the survey questionnaire in this study.

The values of IOC and its meaning are shown in Table 8.

Table 8 . IOC value X and meaning

IOC Value	Meaning
$X \leq 5$	Unacceptable
$0.5 < X \leq 0.6$	Relatively Poor
$0.6 < X \leq 0.7$	Questionable
$0.7 < X \leq 0.8$	Acceptable
$0.8 < X \leq 0.9$	Positive
$0.9 < X \leq 1.0$	Available

IOC not only tests the consistency between questionnaire items and research objectives, but also constructs and detects invalid items that need to be modified or deleted, improving the quality of survey questionnaires. The use of IOC enables this study to be based on quantitative analysis and scientifically and effectively analyze the reliability and validity of the questionnaire, thereby promoting researcher to obtain more objective comprehensive evaluations from the questionnaire survey.

Table 9 shows the IOC results for all indicators of the questionnaire survey.

Table 9. 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	Price	+1	+1	+1	3	1.00	available
2	Payment	+1	+1	+1	3	1.00	available
3	Delivery Time	+1	+1	+1	3	1.00	available

Table 10. IOC for Section A, Section B and Section C (Continue)

Question		Comment score from expert			Total	IOC Value	Result
		1st	2nd	3rd			
4	Service	+1	+1	+1	3	1.00	available
5	Setting up a Budget	+1	+1	+1	3	1.00	available
6	Quality	+1	+1	+1	3	1.00	available
Section C: The Assessment on Different Criteria for Alternative A_1, A_2, A_3, A_4							
1	Price	+1	+1	+1	3	1.00	available
2	Payment	+1	+1	+1	3	1.00	available
3	Delivery Time	+1	+1	+1	3	1.00	available
4	Service	+1	+1	+1	3	1.00	available
5	Setting up a Budget	+1	+1	+1	3	1.00	available
6	Quality	+1	+1	+1	3	1.00	available

From Table 9, it can be seen that all indicators in this survey questionnaire are valid indicators and can be used as key indicators for this survey to obtain factual research results.

4.2 The Results of Section A

Section A of the questionnaire is about the basic information of the interviewees from the sample company in Thailand. The basic information of respondents is a very important part of survey research, which can help us understand their background information and better understand their views and attitudes.

Figures 7 to 12 show the relevant information of the respondents regarding gender, age, highest level of education, current job position, main duties and responsibilities, and length of service in the company.

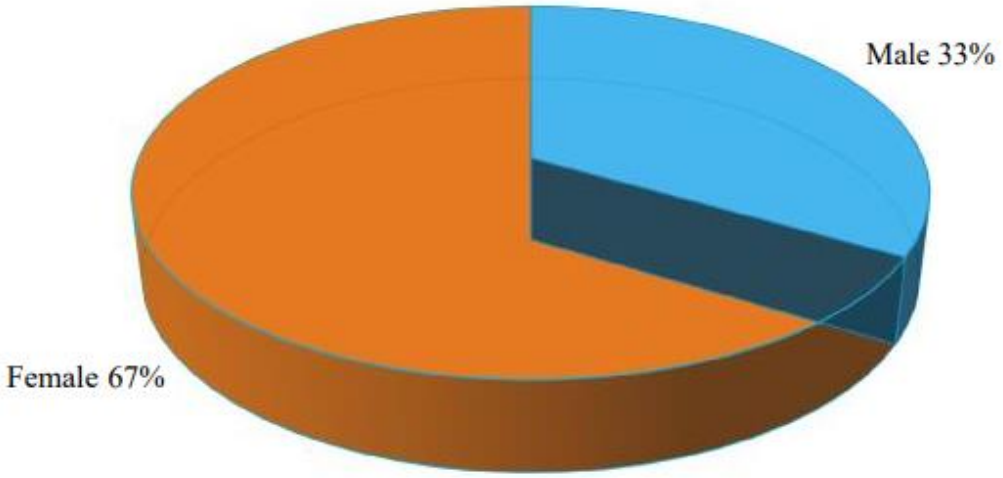

Figure 7. Gender

Figure 7 shows that among all respondents, males accounted for 33% and females accounted for 67%.

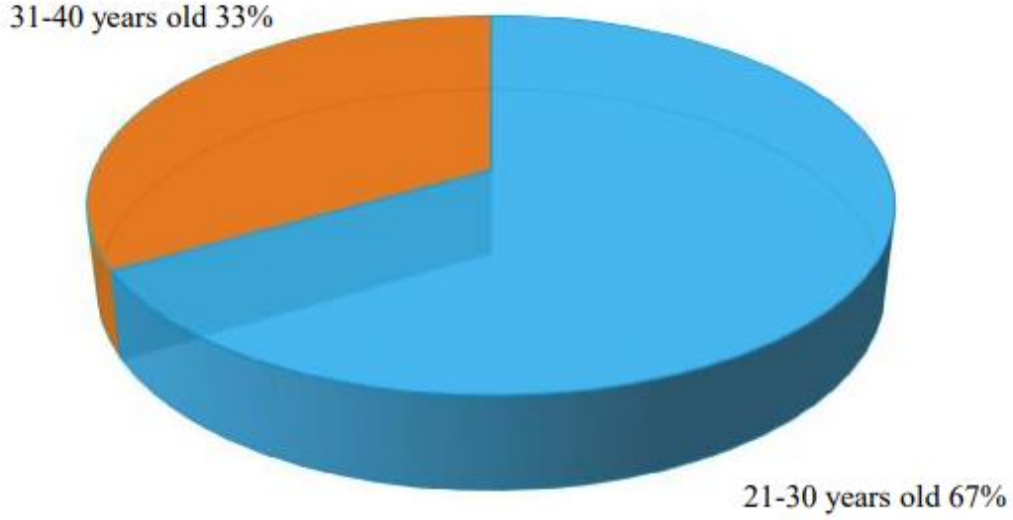

Figure 8. Age

From Figure 8, it can be seen that the age of the respondents is mainly

in two stages, with 67% of respondents aged between 21 and 30 and 33% aged between 31 and 40.

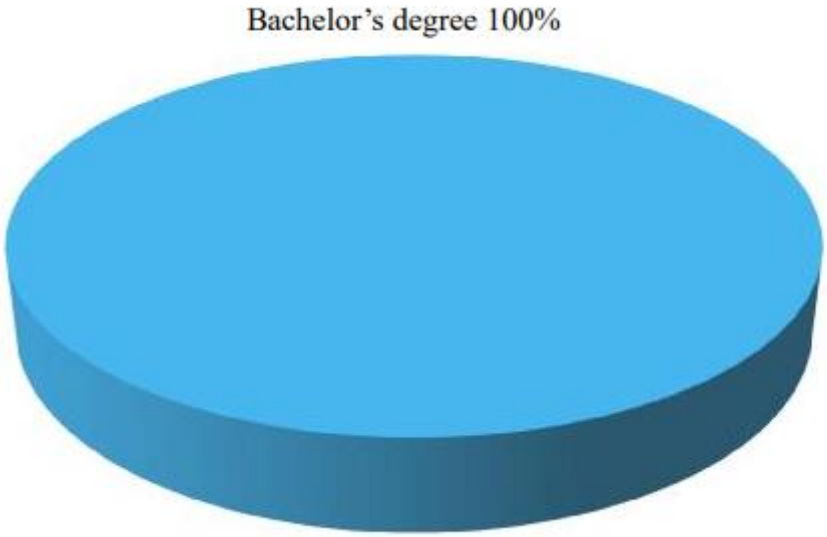

Figure 9. Highest Level of Education

Figure 9 shows that all respondents have a bachelor's degree.

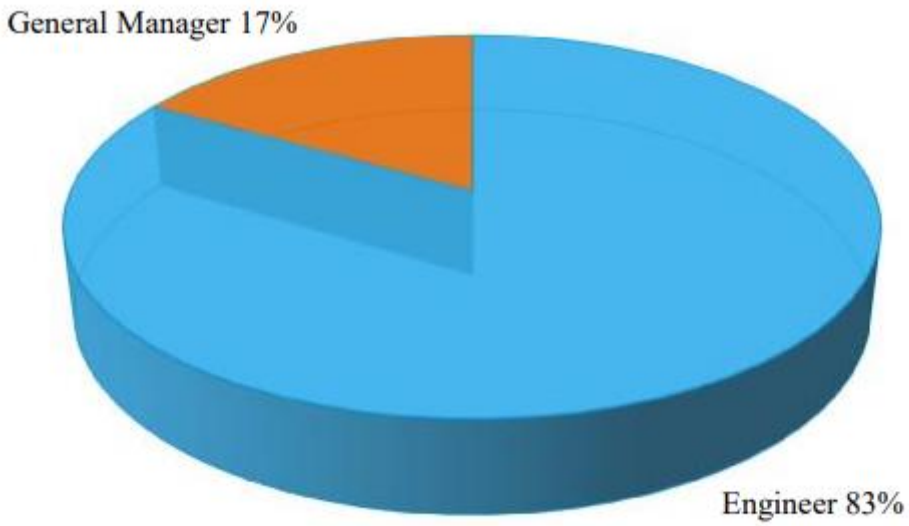

Figure 10. Current Job Position

From Figure 10, it can be seen that there are two types of positions

among the respondents, with engineer accounting for 83% and general manager accounting for 17%.

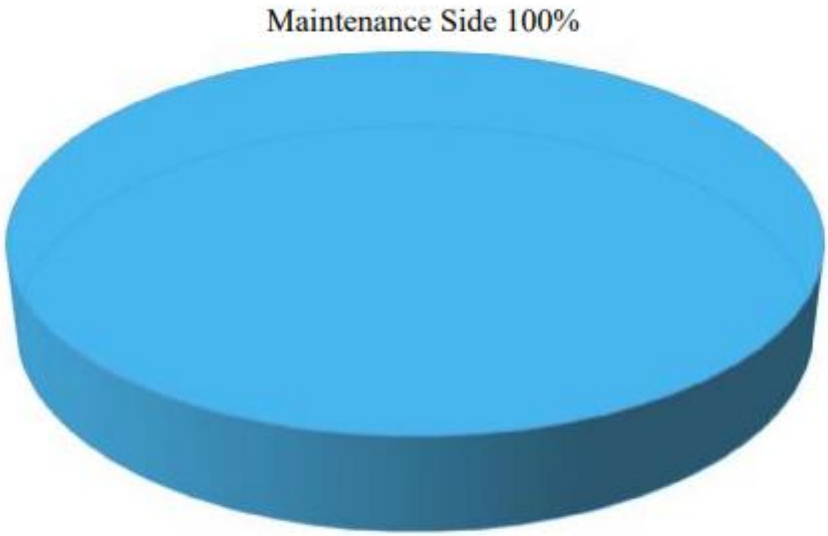

Figure 11. Main Duties and Responsibilities

Figure 11 shows that all respondents are responsible for equipment maintenance in their work.

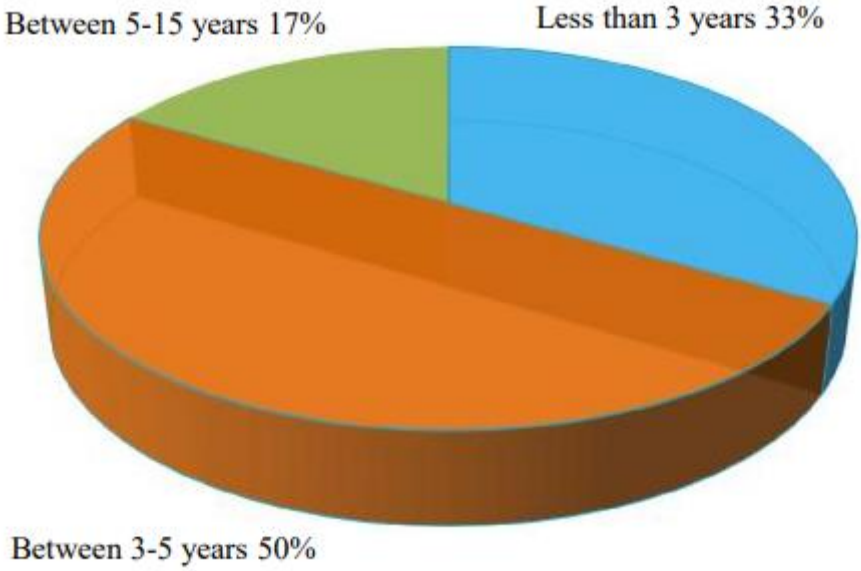

Figure 12. Working Time

From Figure 12 shows that the work experience of the respondents can be divided into three types. In terms of length of time, the proportion of those who have worked for less than three years is 33%, the proportion between 3 and 5 years is 50%, and the proportion of those who have worked for more than 5 years but less than 15 years is 17%.

From these data, it can be seen that the respondents selected for this survey are able to provide professional and objective evaluations and data, which helps to obtain objective and ideal results for this survey.

4.3 The Results of Section B

The initial data of AHP can be obtained from Section B of the survey questionnaire, as shown in Table 10.

Table 11. Initial Data from Section B

Comparison in Pair	Scores from Respondents						AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th		
C_1-C_2	7	1	3	1	-2	1	1.833	2
C_1-C_3	-5	-5	-3	-4	-5	-4	-4.333	-5
C_1-C_4	-9	-9	-8	-7	-9	-9	-8.500	-9
C_1-C_5	-7	1	1	1	-2	-3	-1.500	-2
C_1-C_6	-9	-6	-7	-6	-9	-7	-7.333	-8
C_2-C_3	1	-5	4	2	2	2	1.000	1
C_2-C_4	-9	-8	-8	-7	-9	-9	-8.333	-9

Table 12. Initial Data from Section B (Continue)

Comparison in Pair	Scores from Respondents						AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th		
C_2-C_5	-8	1	1	-2	-2	-2	-2.000	-2
C_2-C_6	-9	-8	-5	-8	-5	-9	-7.333	-8
C_3-C_4	-9	-8	-9	-9	-9	-8	-8.667	-9
C_3-C_5	-6	-7	1	6	7	3	0.667	1
C_3-C_6	-9	-9	-6	-8	-7	-9	-8.000	-8
C_4-C_5	8	8	5	8	7	4	6.667	7
C_4-C_6	1	1	2	1	2	1	1.333	2
C_5-C_6	-8	-7	-3	-6	-5	-7	-6.000	-6

Pairwise comparison between criteria can be formed from the data in the "ROUNDUP" column of Table 10 and Formula 2.1 in Chapter 2 , as shown in Table 11.

Table 13. Pairwise comparison between criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1.000	2.000	0.200	0.111	0.500	0.125
C_2	0.500	1.000	1.000	0.111	0.500	0.125
C_3	5.000	1.000	1.000	0.111	1.000	0.125
C_4	9.000	9.000	9.000	1.000	7.000	2.000
C_5	2.000	2.000	1.000	0.143	1.000	0.167
C_6	8.000	8.000	8.000	0.500	6.000	1.000

Normalization evaluation matrix, weight and consistency ratio can be calculated from Table 11 according to Formula 2.2 to 2.7 in Chapter 2, and the results are shown in Table 12.

Table 14. Normalization evaluation matrix, weight and consistency ratio

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	Weight(%)
C_1	0.039	0.087	0.010	0.056	0.031	0.035	4.314
C_2	0.020	0.043	0.050	0.056	0.031	0.035	3.923
C_3	0.196	0.043	0.050	0.056	0.063	0.035	7.385
C_4	0.353	0.391	0.446	0.506	0.438	0.565	44.967
C_5	0.078	0.087	0.050	0.072	0.063	0.047	06.612
C_6	0.314	0.348	0.396	0.253	0.375	0.282	32.799
CR=0.079							

According to Table 12, the calculated CR is less than 0.1, so it can be considered that the consistency of the judgment matrix is acceptable. At the same time, it also indicates that the judgment matrix formed by the paired comparison data of the six criteria in this survey is a valid matrix, and the calculated weight values are also valid weight values. These weight values can be used in the subsequent TOPSIS calculation process.

Figure 13 shows the main result of AHP calculation, which is the weight values of each criteria. It is obvious that element criteria 4 (after-sales service) has the highest weight value of 44.97%, followed by criteria 6 (stability) with a weight value of 32.80%.

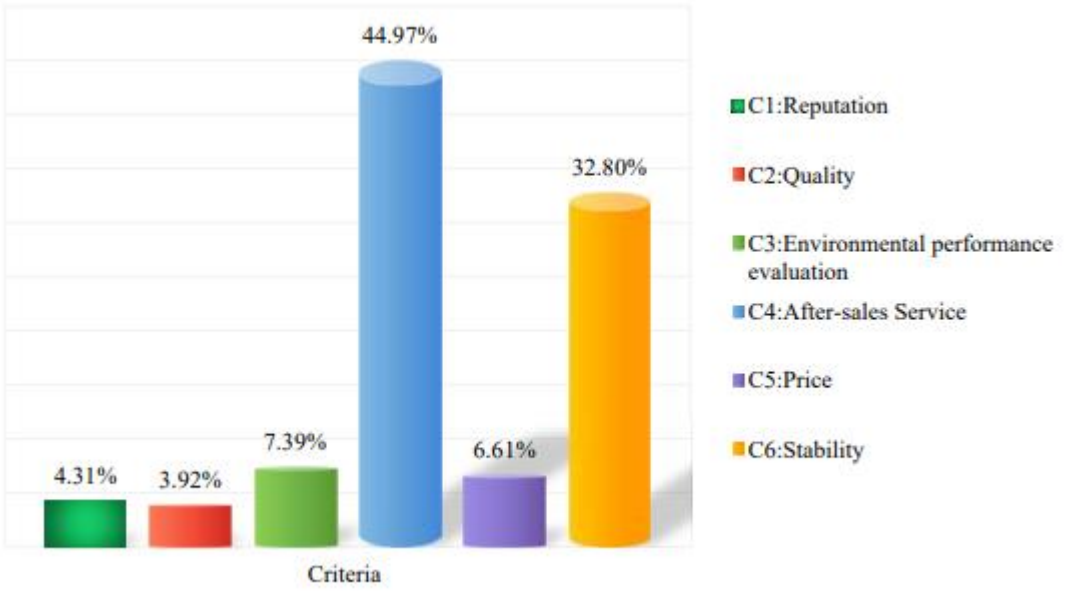

Figure 13. Weight of the Criteria

4.4 The Results of Section C

There are four alternative options in this study case, namely four medical device suppliers from Thailand, marked as A1 company, A2 company, A3 company, and A4 company in this article.

In section C of the survey questionnaire, four alternative options were rated based on the importance of six criteria, resulting in four sets of data. Table 13 synthesizes and preliminarily processes these four sets of data, as shown below.

Table 15. Initial Data from Section C

Comparison in Pair	Scores from Respondents						AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th		
A_1-C_1	6	5	5	6	6	5	5.500	6
A_1-C_2	5	6	5	6	5	5	5.333	6
A_1-C_3	5	5	5	5	6	5	5.167	6
A_1-C_4	6	6	6	6	6	6	6.000	6

Table 16. Initial Data from Section C (Continue)

Comparison in Pair	Scores from Respondents						AVG	ROUNDUP
	1st	2nd	3rd	4th	5th	6th		
A_1-C_5	6	6	5	5	6	5	5.500	6
A_1-C_6	7	7	7	7	6	7	6.833	7
A_2-C_1	7	7	6	7	7	7	6.833	7
A_2-C_2	4	5	5	5	5	5	4.833	5
A_2-C_3	4	5	6	5	4	6	5.000	5
A_2-C_4	7	7	7	7	6	7	6.833	7
A_2-C_5	6	6	6	6	6	6	6.000	6
A_2-C_6	7	7	7	7	7	7	7.000	7
A_3-C_1	5	5	5	5	7	6	5.500	6
A_3-C_2	4	4	4	5	5	4	4.333	5
A_3-C_3	4	4	5	5	5	5	4.667	5
A_3-C_4	5	6	5	5	5	6	5.333	6
A_3-C_5	5	5	5	5	5	5	5.000	5
A_3-C_6	6	6	6	6	6	6	6.000	6
A_4-C_1	6	6	5	5	6	6	5.667	6
A_4-C_2	4	4	4	4	4	5	4.167	5
A_4-C_3	4	5	5	4	5	4	4.500	5
A_4-C_4	6	6	5	5	6	5	5.500	6
A_4-C_5	5	6	6	5	5	5	5.333	6
A_4-C_6	6	6	6	6	5	6	5.833	6

According to Equation 2.10 in Chapter 2, normalization evaluation matrix of criteria and alternatives can be calculated by combining the data in Table 13, as shown in Table 14.

Table 17. Normalization evaluation matrix of Criteria - Alternatives

Supplier Alternative	Criteria					
	C_1	C_2	C_3	C_4	C_5	C_6
A_1	0.479	0.569	0.569	0.479	0.520	0.537
A_2	0.559	0.475	0.475	0.559	0.520	0.537
A_3	0.479	0.475	0.475	0.479	0.434	0.460
A_4	0.479	0.475	0.475	0.479	0.520	0.460

Based on the data in Table 14, the weighted normalization evaluation matrix, ideal solution and negative ideal solution in Table 15 can be calculated using equations 2.11 to 2.13 in Chapter 2.

Table 18. Weighted Normalization Evaluation Matrix, Ideal Solution and Negative Ideal Solution

Supplier Alternative	Criteria					
	C_1	C_2	C_3	C_4	C_5	C_6
A_1	0.021	0.022	0.042	0.215	0.034	0.176
A_2	0.024	0.019	0.035	0.251	0.034	0.176
A_3	0.021	0.019	0.035	0.215	0.029	0.151
A_4	0.021	0.019	0.035	0.215	0.034	0.151
f^*	0.021	0.022	0.035	0.251	0.029	0.176
f'	0.024	0.019	0.042	0.215	0.034	0.151

From equations 2.14 to 2.16, using the values of ideal solution and negative ideal solution in Table 15, the values of Euclidean distance and relative closeness in Table 16 can be obtained.

Table 19. Final Evaluation of the Location Alternatives

Supplier Alternative	Euclidean Distance (S^*)	Euclidean Distance (S')	Relative Closeness (C^*)
A_1	0.037	0.026	0.410
A_2	0.008	0.044	0.854
A_3	0.044	0.010	0.181
A_4	0.044	0.008	0.150

The final calculating result of TOPSIS is relative closeness (C^*). Sorting by the magnitude of their values, the results are shown in Figure 14.

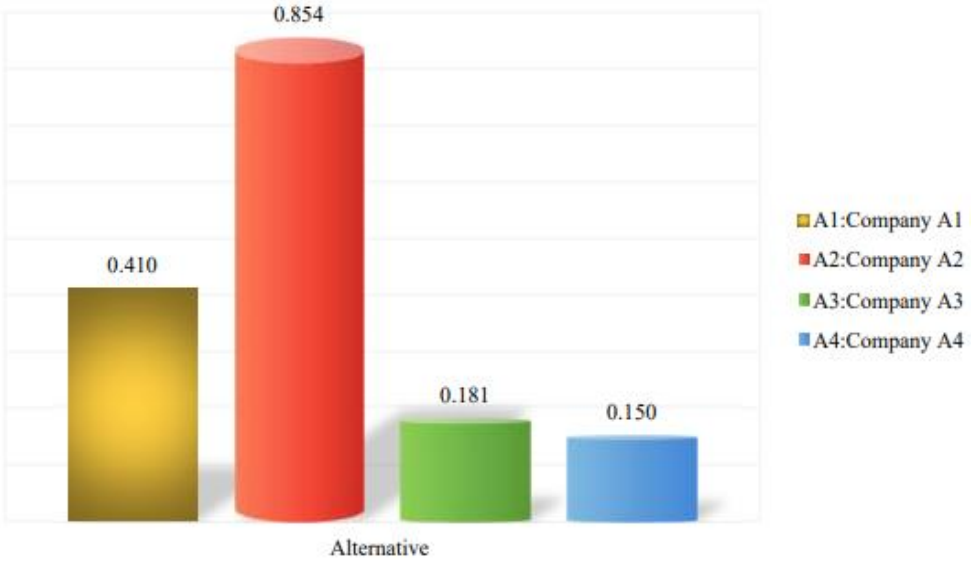

Figure 14. Relative Closeness (C)*

It is obvious that the relative closeness value of Company 02 is closest to 1, at 0.854, followed by Company 01, at 0.410. Therefore, Company 02 is the optimal option in this supplier selection case, followed by Company 01.

CHAPTER 5

CONCLUSION

5.1 Results of Research Objective 1

From the calculation section of AHP in the previous text, the results can be obtained: among the six key factors affecting the supplier selection, the most important one is criteria 4, which is known as after sales service, followed by criteria 6, which is called stability.

The importance of after-sales service (Criteria 4) is reflected in the following aspects.

1) After sales service is an effective measure to maintain customer satisfaction and loyalty. It is understood that if a customer's complaint is not taken seriously by the company, two-thirds of customers will turn to the company's competitors for purchasing behavior; If the complaint is ultimately resolved, approximately 70% of customers will continue to visit the company. If the complaint is properly and promptly resolved, the proportion of customers who continue to visit will increase to 95%.

2) After sales service is a good remedy for enterprises to get rid of price wars. In today's increasingly serious homogenization of products, after-sales service as a part of sales has become an important territory for many manufacturers and businesses to compete for consumers.

3) Good after-sales service is the best promotion before the next sale. Good after-sales service brings good reputation and more consumers. In marketing, whoever will have more consumers is the winner.

4) Good after-sales service is a symbol of the quality of famous brand products and enterprises. The so-called after-sales service refers to various behaviors and activities taken from the signing of the order to the termination of the product function, with the premise of maintaining customer interests. Good after-sales service is an important way to establish a corporate brand and promote its image, and it is also one of the competitiveness of enterprises.

5) Good after-sales service itself is also a profit point. In the short term, there is no profit in after-sales service. In the long run, if the amount of repairs reaches a certain level, it can be profitable.

6) Good after-sales service can provide decision-making data and supervise other systems.

Next, according to the weight values of each criterion calculated by AHP, it can be seen from the TOPSIS calculation results that the nearest to 1.0 among the relative closeness values of the four suppliers is from Company 02, which means that Company 02 is the most suitable medical device supplier selected for the sample company in this case.

The relationship between Company 02 and its after-sales service is crucial in ensuring customer satisfaction and the overall success of the business.

1) Customer support: The after-sales service provided by Company 02 plays a significant role in providing ongoing support to customers. This includes addressing any issues, providing technical assistance, and ensuring the proper functioning of the medical devices.

2) Product maintenance and repairs: The after-sales service from Company 02 involves handling product maintenance and repairs. This helps in prolonging the lifespan of the medical devices and ensures that they are always in optimal condition.

3) Product upgrades: The after-sales service from Company 02 may also involve providing upgrades or updates to the medical devices to enhance their performance or add new features. This helps in meeting the changing needs of customers and staying competitive in the market.

4) Training and Education: The after-sales service from Company 02 often includes providing training and education to customers on how to use the medical devices effectively and safely. This helps in ensuring that customers can make the most out of the products they have purchased.

5) Building Trust and Loyalty: The after-sales service from Company 02 can help in building trust and loyalty among customers. By promptly addressing any issues or concerns, the supplier can demonstrate its commitment to customer satisfaction and strengthen its relationships with customers.

5.2 Results of Research Objective 2

Based on the summary of the entire process of this case, it can be concluded that, AHP-TOPSIS (Analytic Hierarchy Process-Technique for Order of Preference by Similarity to Ideal Solution) is a decision-making method for supplier selection that combines AHP and TOPSIS technologies. By comparing and weighting the evaluation criteria of various medical device suppliers, and then calculating the distance and proximity between each medical device supplier and the ideal solution, the best supplier is selected.

In the AHP-TOPSIS supplier selection paper, researchers first listed criteria for supplier evaluation, such as reputation, quality, environmental performance evaluation, after sales service, price, and stability. Then, the weights of each criterion are determined through expert surveys and AHP. This can quantify the importance of different criteria and provide a basis for subsequent evaluations.

Next, the researchers create a matrix for evaluating medical device suppliers, which includes the ratings of each supplier on each criterion. Use standardized methods to process matrices to ensure comparability of ratings between different criteria.

Then, using the TOPSIS method, the researchers calculated the Euclidean distance between each supplier and the formal solution (with maximum score) and the negative solution (with minimum score). The smaller the distance, the closer it is to the formal solution, while the larger the distance, the closer it is to the negative solution.

Finally, the researchers ranked the suppliers based on their proximity and selected the best medical device supplier from high to low. The greater the proximity, the closer the medical device supplier is to the official solution and is considered the best choice.

Through the AHP-TOPSIS method, researchers are able to systematically evaluate and select suppliers, taking into account the weights and relative importance of multiple criteria, in order to achieve better decision results.

In summary, in the process of using the AHP-TOPSIS comprehensive model to solve the selection theory of medical device suppliers in Thailand, researchers determine criterion weights based on AHP and use

TOPSIS to calculate the proximity and distance of medical device suppliers, in order to select the best medical device supplier. This method combines qualitative and quantitative analysis, which can help decision-makers make more reasonable and accurate choices of medical device suppliers.

5.3 Summary

The application of AHP-TOPSIS method in the selection of medical device suppliers can help decision-makers evaluate the comprehensive strength of different suppliers more scientifically and systematically, reduce the influence of subjective factors, and improve the accuracy and reliability of decision-making.

Through the AHP-TOPSIS method, decision-makers can decompose the supplier selection problem into multiple criteria and use the Analytic Hierarchy Process to determine weights based on the importance of the criteria. In this way, decision-makers can conduct a comprehensive evaluation of suppliers based on considering multiple criteria, rather than being limited to comparing a single criterion. In the medical device industry, technical support and quality control from suppliers are usually important criteria, and these factors can be more comprehensively considered through the AHP-TOPSIS method.

Through the TOPSIS method, decision-makers can convert the comprehensive evaluation of suppliers into numerical indicators for supplier ranking and selection. The TOPSIS method compares suppliers with the most ideal and least ideal situations, and determines the quality of suppliers based on comprehensive scores. This allows decision-makers to have a simple and intuitive understanding of the differences among different suppliers and choose the supplier that best matches their own needs.

In the selection of medical device suppliers, the application of AHP-TOPSIS method can reduce cooperation risks and improve cooperation effectiveness. Decision makers can choose the supplier that best matches their own needs based on weights and comprehensive ratings, thereby reducing cooperation risks and improving the stability and reliability of the supply chain.

The application of AHP-TOPSIS method in the selection of medical device suppliers can improve the scientificity and accuracy of decision-making, comprehensively consider the needs of multiple criteria, reduce cooperation risks, and promote supply chain optimization and innovation. This will have a positive impact on procurement decisions and supply chain management in the medical device industry.

5.4 Implications

The application of AHP-TOPSIS method in the selection of medical device suppliers have the following impacts on the selection of suppliers in the medical device industry and other industries:

1) Improving the scientificity and accuracy of decision-making: The AHP-TOPSIS method decomposes the supplier selection problem into multiple criteria, determines the weights of each criterion through the Analytic Hierarchy Process, and then conducts comprehensive evaluation and ranking of suppliers through the TOPSIS method. This scientific decision-making method can reduce the influence of subjective factors and improve the scientificity and accuracy of decision-making.

2) Consider multiple requirements through multi criteria evaluation: The AHP-TOPSIS method can consider multiple criteria, such as reputation, quality, environmental performance evaluation, after sales service, price, and stability, so as to comprehensively evaluate the comprehensive strength of suppliers. In the medical device industry, technical support and quality control from suppliers are crucial, while in other industries, standards such as price and delivery time may be more emphasized. AHP-TOPSIS can flexibly adjust and configure these guidelines according to the needs of different industries.

3) Reducing risks and improving cooperation effectiveness: Through the AHP-TOPSIS method, decision-makers can comprehensively compare and evaluate different suppliers, taking into account the differences in various factors. This enables decision-makers to choose suppliers that best match their own needs, thereby reducing cooperation risks and improving cooperation effectiveness.

4) Promoting supply chain optimization and innovation: The AHP- TOPSIS method can help decision-makers analyze and evaluate the comprehensive strength of suppliers, and provide a basis for relative

weights. This enables decision-makers to have a clear understanding of the performance of each supplier on different criteria, providing reference for optimization and innovation in other aspects of the supply chain.

In general, the AHP-TOPSIS method can improve the scientificity and accuracy of decision-making in supplier selection in the medical device industry and other industries, comprehensively consider the needs of multiple criteria, reduce cooperation risks, and promote supply chain optimization and innovation.

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APPENDIX

APPENDICE

Questionnaire

ICO

Research Title

Solving the Medical Device Supplier Selection Problem using Integrated AHP-TOPSIS Method: A Case of Sample Hospital in Thailand

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Questionnaire on criteria affecting the medical device supplier selection. The objective of this assessment is to assess the opinions of experts on the criteria in each section. The content is consistent with the objectives of the research.

Research objectives:

1) To solve the medical devices supplier selection problem for the hospital.

2) To propose a practical template for selecting medical device suppliers that is basically feasible in the medical industry in Thailand.

Please tick √ in the Conformity value box in Table 10 according to Table 9.

Table 20. 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 are not sure whether 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 criteria:

1) Price: It is necessary to comprehensively consider the balance between price and quality when selecting suppliers because the price of medical devices is usually high.

2) Payment: Different payment methods can have an impact on the prices provided by suppliers

3) Delivery Time: If you are very sensitive to time and need to receive

the product quickly, you may need to choose a supplier for quick delivery, even if the price may be higher. If your time requirements are not very urgent, you can choose a supplier with a lower price, but it requires a longer delivery time.

4) Service: Problems are inevitable during the use of medical devices, and timely technical support and after-sales service provided by suppliers will greatly reduce the risks and losses of medical institutions.

5) Setting up a Budget: Depending on your budget constraints, you may need to screen suppliers and compare prices from different suppliers.

6) Quality: The quality of medical devices is directly related to the safety and treatment effectiveness of patients.

Table 21. 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	Price				
2	Payment				
3	Delivery Time				
4	Service				

Question		Opinion Level			Suggestions
		+1	0	-1	
5	Setting up a Budget				
6	Quality				
Section C: The Assessment on Different Criteria for Alternative A_1, A_2, A_3, A_4					
1	Price				
2	Payment				
3	Delivery Time				
4	Service				
5	Setting up a Budget				
6	Quality				

Suggestions:

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PPENDICE

Questionnaire

Criteria and Alternative

Research Title

Solving the Medical Device Supplier Selection Problem using Integrated AHP-TOPSIS Method: A Case of Sample Hospital in Thailand

Advisor

Dr. Thammawit Prasert

Engineering Program in Engineering Management

Department of Industrial Engineering and Management

Graduate School, Silpakorn University

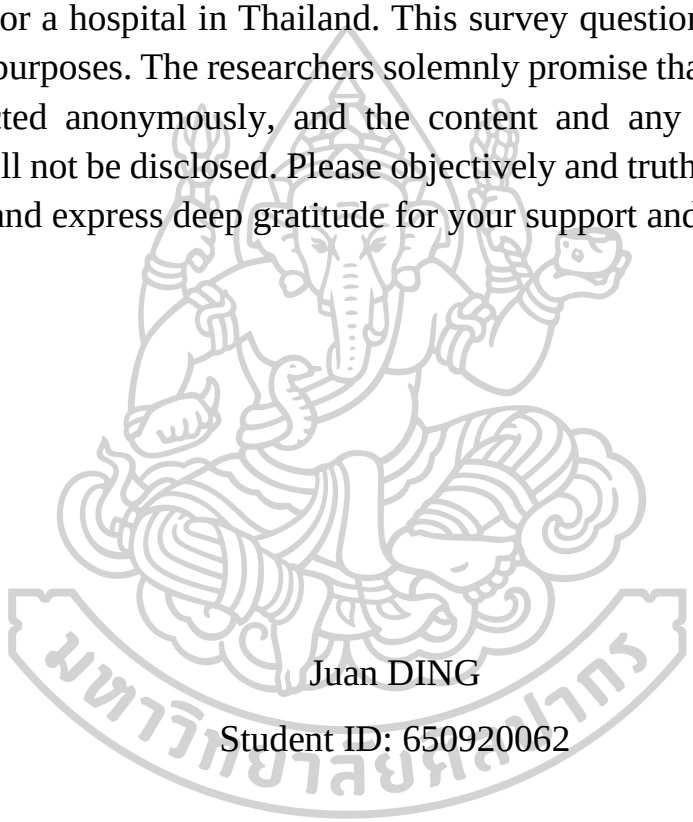
This questionnaire consists of three parts as follows:

Section A: General personal information questionnaire of respondents.

Section B: AHP assessment for criteria compared in pair.

Section C: TOPSIS assessment for alternatives in aspect of different criteria.

This survey aims to study the selection of medical equipment suppliers for a hospital in Thailand. This survey questionnaire is only for academic purposes. The researchers solemnly promise that this survey will be conducted anonymously, and the content and any information you provide will not be disclosed. Please objectively and truthfully reflect your thoughts, and express deep gratitude for your support and cooperation!



Juan DING

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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 criteria for the medical device supplier selection, CHOOSE and CIRCLE ONLY ONE NUMBER in Table 2 according to Table 11.

Table 22. Fundamental scale of Thomas L. Saaty

Verbal Judgments	Intensity of Importance
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8

List of criteria:

7) Price: It is necessary to comprehensively consider the balance between price and quality when selecting suppliers because the price of medical devices is usually high.

8) Payment: Different payment methods can have an impact on the prices provided by suppliers

9) Delivery Time: If you are very sensitive to time and need to receive the product quickly, you may need to choose a supplier for quick delivery, even if the price may be higher. If your time requirements are not very urgent, you can choose a supplier with a lower price, but it requires a longer delivery time.

10) Service: Problems are inevitable during the use of medical devices, and timely technical support and after-sales service provided by suppliers will greatly reduce the risks and losses of medical institutions.

11) Setting up a Budget: Depending on your budget constraints, you may need to screen suppliers and compare prices from different suppliers.

12) Quality: The quality of medical devices is directly related to the safety and treatment effectiveness of patients.

Table 23. AHP Assessment for Criteria Compared in Pair

Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Payment
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery Time
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Setting up a Budget
Price	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Payment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery Time
Payment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Payment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Setting up a Budget
Payment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Delivery Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service
Delivery Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Setting up a Budget
Delivery Time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Setting up a Budget
Service	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
Setting up a Budget	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality

Section C

TOPSIS assessment for alternatives in aspect of different criteria.

Please mark √ in the box of Table 3-6 for the level of opinion of each criterion for the medical device supplier selection.

Table 24. The Assessment on Different Criteria for Alternative A_1

Alternative A_1	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Price							
Payment							
Delivery Time							
Service							
Setting up a Budget							
Quality							

Table 25. The Assessment on Different Criteria for Alternative A_2

Alternative A_2	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Price							
Payment							
Delivery Time							
Service							
Setting up a Budget							
Quality							

Table 26. The Assessment on Different Criteria for Alternative A_3

Alternative A_3	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Price							
Payment							
Delivery Time							
Service							
Setting up a Budget							
Quality							

Table 27. The Assessment on Different Criteria for Alternative A_4							
Alternative A_4	Opinion Level						
	least	little	somewhat little side	moderate	somewhat very side	a lot	the most
Price							
Payment							
Delivery Time							
Service							
Setting up a Budget							
Quality							

VITA

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