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นางสาววศินี อู่ไพบูรณ์

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A development of vendor selection process for commercial banking industry in Thail and by Fuzzy Analytical Hierarchy Process (FAHP)

Miss Vasinee Upaiboon

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Industrial Engineering
Department of Industrial Engineering
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Thesis Title	A development of vendor selection process for commercial banking industry in Thailand by Fuzzy Analytical Hierarchy Process (FAHP)
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วศินี อู่ไพบูรณ์ : การพัฒนากระบวนการคัดเลือกผู้ขาย สำหรับธุรกิจธนาคารพาณิชย์ในประเทศไทย โดยกระบวนการวิเคราะห์เชิงลำดับชั้นแบบฟัซซี่ (A development of vendor selection process for commercial banking industry in Thailand by Fuzzy Analytical Hierarchy Process (FAHP)) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร. สีรง ปรีชานนท์, 85 หน้า.

ในอุตสาหกรรมธนาคารพาณิชย์มีการแข่งขันสูงขึ้นเนื่องจากสภาพเศรษฐกิจที่เปลี่ยนแปลงไปและการเปลี่ยนแปลงเทคโนโลยี ธนาคารพาณิชย์จึงต้องปรับตัวเพื่อให้สามารถเพิ่มกำไรและส่วนแบ่งตลาดได้ เช่น การให้ความสนใจไปที่ธุรกิจหลักของธนาคารและจ้างบุคคลภายนอกมาทำงานส่วนอื่นๆ เป็นต้น อย่างไรก็ตามในการพิจารณาเลือกผู้ผลิตไม่ควรใช้ราคาเพียงอย่างเดียว แต่ควรพิจาณาจากปัจจัยอื่นๆด้วย เช่น คุณภาพ, ระยะเวลาการผลิต, การรับประกัน เป็นต้น งานในฝ่ายจัดซื้อมีความหลากหลายมากในแต่ละบริษัท ในการจัดซื้อแต่ละประเภทจะต้องคำนึงถึงปัจจัยและความสำคัญที่แตกต่างกัน รวมถึงความลำเอียงต่างๆ จึงทำให้งานมีความซับซ้อนมากขึ้น ดังนั้นเครื่องมือที่มาช่วยให้สามารถลดความซับซ้อน ความลำเอียงลง เพื่อให้สามารถเลือกผู้ผลิตที่เหมาะสมกับแต่ละงานที่สุด

จากการสัมภาษณ์ ในปัจจุบันธนาคารพาณิชย์ใช้ Price Performance Ratio (PPR) ในการประเมินเลือกผู้ขาย ซึ่งวิธีนี้จะให้ความสำคัญกับราคาเป็นหลัก จึงเกิดปัญหาสำหรับบางงานที่ผู้ขายที่เลือกมาไม่มีความสามาถเพียงพอในการทำงานให้บรรลุตามเป้าหมายและคุณภาพ ในงานวิจัยฉบับนี้ได้ศึกษาระบบการคัดเลือกผู้รับจ้างสำหรับงานที่เกี่ยวกับการก่อสร้างและดูแลระบบคอมพิวเตอร์ของธนาคารพาณิชย์ในกรุงเทพ ประเทศไทย ซึ่งควรคำนึงถึงปัจจัยที่เป็นตัวเลขและด้านคุณภาพ เช่น ราคา, คุณภาพ, วิธีการทำงาน, จำนวนบุคลากร, และความเสี่ยง เป็นต้น งานวิจัยจึงได้เสนอวิธีกระบวนการวิเคราะห์เชิงลำดับชั้นแบบฟัซซี่ในการคัดเลือกผู้ผลิต ซึ่งจะช่วยลดความซับซ้อนในการประเมินเลือกได้โดยการใช้แผนภูมิลำดับขั้นเข้ามาช่วย เปรียบเทียบแต่ละทางเลือก รวมทั้งช่วยเช็คดัชนีความสอดคล้องกันอีกด้วย หลังจากนั้นการคำนวณจะถูกนำมาใช้เพื่อคำนวณถ่วงน้ำหนัก ซึ่งผลที่ได้จากวิธี FAHP ซึ่งช่วยให้ทางธนาคารสามารถเลือกผู้ให้บริการได้ตรงตามความต้องการมากขึ้นในด้านคุณภาพ แม้จะไม่ได้เสนอราคาต่ำสุด ซึ่งหากใช้วิธีปัจจุบัน PPR ทางธนาคารจะได้ผู้ให้บริการที่เสนอราคาต่ำสุดเท่านั้น ซึ่งแสดงให้เห็นว่าวิธี FAHP นำปัจจัยอื่นๆมาคำนวณและสะท้อนออกมาในการประเมินได้มีคุณภาพมากขึ้น

ภาควิชา วิศวกรรมอุตสาหการ ลายมือชื่อนิสิต .....

สาขาวิชา วิศวกรรมอุตสาหการ ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ปีการศึกษา 2559

5871307521 : MAJOR INDUSTRIAL ENGINEERING
KEYWORDS: FUZZY AHP / FUZZY ANALYTIC HIERARCHY PROCESS (FUZZY-AHP) / FUZZY LOGIC / VENDOR SELECTION

VASINEE UPAIBOON: A development of vendor selection process for commercial banking industry in Thailand by Fuzzy Analytical Hierarchy Process (FAHP). ADVISOR: ASST. PROF. SEERONK PRICHANONT, Ph.D., 85 pp.

The ever-changing economic conditions and new disruptive technologies dramatically increase competitiveness among commercial banks. In order to improve their profit, the banks have to continuously improve their efficiency, i.e. focus on developing core business and delegate other business activities to outsourcing vendors. However, price should not be the only criterion for selecting vendors. Other factors such as quality, production lead time, warranty etc. should also be considered. Besides, some factors can be in qualitative forms, which makes the purchasing task even more difficult. The appropriate tools are therefore needed to simplify the task and mitigate the human bias effect in order to get the best supplier selection decsions for each project.

A large Thai commercial bank was chosen as the case study in this research. The case study bank has a purchasing department who oversees that purchasing activities for the three main areas: Systems and Maintenance, Building, and Information Technology. Price Performance Ratio (PPR), defined by vendor's offered price divided by performance, is used by the bank's procurement department as the main criterion to select a vendor. With PPR as the criterion, vendors with lowest offered price usually win the contract, even though this often lead to less-than-impressive results. In this research, we proposed the application of Fuzzy Analytical Hierarchy Process (Fuzzy AHP) to select vendors based on variety of attributes. Both in quantitative and qualitative forms such as price, quality, operating difficulty, and warranty conditions can be considered. An easy-to-use, yet effective software implementing the Fuzzy AHP was developed and tested on three real cases. The results showed that the program's result might be different from PPR one as the program criteria has been adjusted to reduce importance of the cost criteria and increase on other related criterion.

Department:	Industrial Engineering	Student's Signature	.....
Field of Study:	Industrial Engineering	Advisor's Signature	.....
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CONTENTS

Page

Page

Table of Figure

Pages

Table of Table

Pages

1. Introduction

In Thailand, all commercial banks are regulated by Bank of Thailand. The regulations allow commercial banks to operate basic transactions such as deposit, credit financing, foreign currency exchange and trading financial instrument. Moreover, other services that are allowed by Bank of Thailand include insurance agents, bank loan, received payment, transfer money and introduce financial products for risk management. Interest and exchange rate derivatives are examples of the area in which banks encounter. Not until recently, Bank of Thailand has changed commercial bank's regulations to favor development of financial market and also increase its efficiency and ability to compete in the market (Thailand).

Currently, Thai commercial banks are allowed to operate in 5 types of businesses as follows:

1. Insurance-related business
2. Securities-related business
3. Derivatives-related business
4. E-banking-business
5. Financial and other services business

There are 14 commercial banks in Thailand which are

1. Bangkok Bank
2. Krung Thai Bank
3. Bank of Ayudhya
4. Kasikornbank
5. Kiatnakin Bank
6. TMB Bank
7. Tisco Bank
8. Siam Commercial Bank
9. Thanachart Bank Public Company Limited
10. CIMB Thai Bank
11. Siam City Bank Public Company Limited
12. United Overseas Bank
13. Standard Chartered Bank
14. ICBC Bank

Banking service operations are complicated, fast-paced and risk-prone in nature. "This industry is very competitive" Khun Kittiya Tothanakasem said. She also added "especially, not only Bank of Thailand allows foreign banking to compete in

Thailand, but also customer behaviors change according to technologies". Based on the statistical data, 70% of customers' purpose is to deposit or withdraw cash. In the past, those transactions are only available at branches or automated teller machine (ATM). However, with the advance of technologies, transactions are more and more carried out via online transactions. In addition to using digital service to transfer money, using it to pay the electricity, water, telephone bills, top up their phone are also available. Not only personal use of banking has changed, but also usage in corporates well. Among medium to large sized company, they have moved from paying salaries in cash to transferring money directly to employees' bank accounts.

Undoubtedly, Thailand is moving to cashless society. The cashless society refers to people in the society purchased products or services by credit card, electronic money or electronic fund transferal rather than cash or check. The electronic money is a new market that many companies and startup are interested in, as shown in Figure 1: Competitor in electronic money.

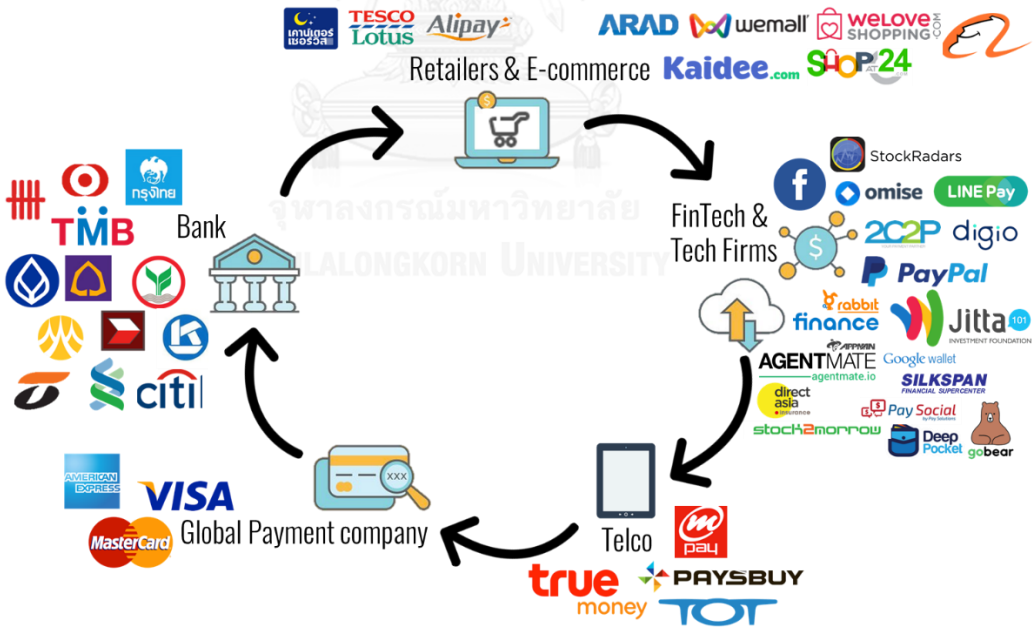

Figure 1: Competitor in electronic money

As a result, customer's behaviors under 30 years old are changing dramatically; they are less likely to interact with physical bank branches. While customers, who are 30 years old and above, prefer the old method which is doing transactions at the physical bank branches. The latter customer group has more purchasing power; thus,

each commercial bank cannot reduce number of branches yet. In the other words, they still have to keep physical branches while increasing IT channels to respond accordingly to the change in young generation's behavior. To satisfy their customer, commercial banks need to take fast and effective actions.

According to Figure 2: Difference between Baby Boomer and Millennial , as Thailand is moving from baby boomer generation to millennial generation, young generations have changed their behavior to react quickly to technologies.

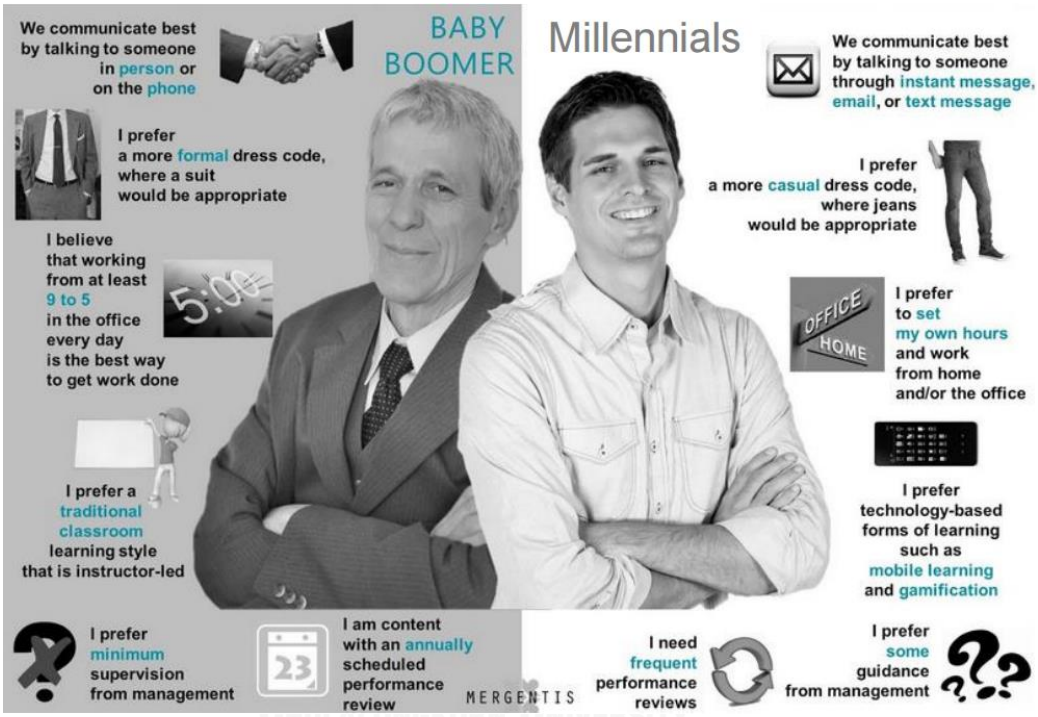

Figure 2: Difference between Baby Boomer and Millennial

Kasikornthai Research Center published that Thailand is currently transforming from analog economy to digital economy. Digital economy plays an important role of economy booming, for example, global hyper growth in trading, communication and services compared between 2005 and 2013. Digital economy has positive impact on trading business, more than double for communication business and over 10% for services.

According to US Consensus Bureau research, in 2025, number of millennial generation will be more than half of world population and more than 75% of world work force. The millennial generation consists of generation Y and generation X, which are people who were born after 1980 (DeNavas-Walt, Proctor et al. 2010).

Thailand also exhibits similar trend. Global Web Index & wearesocialsg research indicated that social and mobile Commerce in Thailand are becoming more popular. Thailand's e-Commerce ranks at 22nd of the world ranking. For mobile commerce, Thailand is at 5th, and Thailand's social media usage is at 11st of world ranking (wearesocialsg 2015). The difference between e-Commerce, m-Commerce and Social Media are shown in Figure 3: Difference between eCommerce, mCommerce and Social media.

Figure 3: Difference between eCommerce, mCommerce and Social media

To adapt faster to market's change and technology change, commercial bank industry have to increase efficiency and performance while reducing cost. According to the education departments of the US government's report, in most company material supplies and equipment purchasing accounted for approximately 40% to 60% of revenue (Kasilingam 1998). Therefore, it is important to select the right vendors. The supplier is also one of the competitive forces in the Competitive Forces Model (Porter 1980). Each company should develop the best practice for supplier management.

"Do what you do best and outsource the rest!" said Tom Peters, Management guru (Nicole 2011). In the beginning, businesses used outsourced companies mainly for cost reduction. Nowadays, the principle of using outsource

company have changed. The company not only outsourcing to reduce the costs, but also gain greater benefits and opportunities as follows;

a) Cost reduction.

   Since the starting of supplier management, company's cost reduction is one of the most important reasons why company should manage their supplier. Outsourcing fee is cheaper compare to starting new department, hiring new staffs and acquiring knowledge in the new field as an outsourced company has already acquired expertise in its field and also the economy of scale.

b) Manage and control process reduction.

   Especially in SME, they can reduce not only manage and control process that has to be done if they use inhouse, but also problem sloving process that occur from lack of expertise and staffs' errors. Moreover, after company follow up and evaluate results or products from suppliers, if they find out that the results are not satisfied the standard, they can easily terminate and change to better suppliers.

c) Traning cost reduction

   Since each suppiler has their own focus and profession in their field, their staffs are more likely to be trained properly compare to inhouse training. For inhouse training, a company need to develop knowledge, create practice, elvaluate and adjust. Those process takes time and cost. By using outsourced company, company will be able to cut out those compliated process and cost that might have occured.

d) Increase performance and efficiancy

   By using the right outsourced company, their professinalism and efficiency from the supplier also improve the company peroformance itself as indirect effects.

Reserchers have studied about how to select the right vendor for a company over a decade. For example, Damian said that majority of the comapny spend approximately 50% of their revenue on buying goods and services from suppliers, it indicated how important for a compamy to choose the right suppliers (Beil 2010). In

Best value Damian summarized supplier selection process in 6 steps as follows:
Identifying potential suppliers

1) Information requests to suppliers
    2.1) Request for Information
    2.2) Request for Proposal
    2.3) Request for Quotation
2) Contract terms
    3.1) Payment terms
3) Negotiation process
4) Supplier evaluation and contract award
5) Supplier selection research

However, outsourcing also has some threats. For instance, Joseph Chamie mentioned about changing in outsourcing trend over the past 10 years (Magnus 2012). Many American global companies that account for hiring 50% of American work forces has been reduced about 3 million positions while increased hired ratio in other countries. In other 11 European countries also encounter the same trend. These trend continue to go on as each company seek to reduce their cost by moving production based to low-income countries especially in Asia.

From the HfS researcher in USA researched about business service outsourcing in banking and financial service in 2013 (Koontz 2013). Analyze process-specific outsourcing trends that will drive growth in Banding and Financial services. These specific areas that HfS Research predicts will receive the most attention over next 12 to 18 months.

- Mortgage market will be an area of intense outsourcing with mortgage volume but hedging about future volume variability.
- Credit card business is the hottest area for outsourcing. Both services outsourcing such as local outsourcing service would give customers satisfaction and outsourcing for credit card production would make banking quickly response to customers.

- Commercial lending, the outsourcing in this field will provide more experience and customer's perception for higher success rate.
- Mobile banking is the primary tool financial institutions use to interact with different customer groups. The outsourcing in this field are platforms, service and support for new platforms.
- Payments is the new market for commercial banking as mention earlier but this method substantial technology and labor.
- Risk and compliance. In this service most, financial services companies have seen these operations double in size but still not effective. Outsource to consult is considered.

The conclusion of direct and indirect effected in Table 1: Direct and Indirect effect of cashless society;

Table 1: Direct and Indirect effect of cashless society

	Direct Effect	**Indirect Effect**
Opportunity	- opportunity to lean and adapt by using new technologies to create new business model. - Using technologies to increase efficiency and allow easier market expansion. - Transaction costs and cash management cost will be decreased as users using digital channel to do the transactions.	- Customers or startup with innovation will have exponential growth, therefore, they have potential to offer products or services to the bank including partner opportunities.
Threat	- Decreased in transaction fee revenue due to incentive policy from government to help convert user to digital channel - Hugh investment in new system	- Customer business might not be able to change accordingly

	- Risk of losing market to competitors especially middle class customers, which are first targeted customer of FinTech. - Reputation risking from technologies risk. For example, Failure to protect information from hackers, rapidly spread of true and fake news.	

In order to service in competitive market, commercial bank has to prepare for the change. One method that the bank selects is to reduce unnecessary activities and use outsourcing to serve customer better, one of which is back office or in-house activity. For example, since credit card or credit line approval process used to take 15 days, the bank has to decrease approval process down to 7 days. Improving the process can be done by moving all the resources to work on important activities and outsource other activities. For instance, raw data are input by using evaluation process and pay per performance to control the outsource company. Another example is moving cash to ATM activity, which is a very risky activity from robbery so it is one of the main activities that bank will be outsourcing to professional company.

From the examples above, selecting the right outsource company is very important; therefore, achievements in the procurement department is one of the key success factors in organization. Almost all purchasing decisions – based on quality, delivery and handling, marginal benefit, and price fluctuations - are decided by this department.

The outsourcing in banking can range from office equipment, premium products, services such as cash transferring, security guards, maids etc. and construction related work such as renovating branches, or building new one.

To operate organization effectively, the appropriate vendor plays a big role in enabling smooth operation with an organization. Facing the dilemma of cost and reliability of supplier, company faces the consideration of the quality of the result

delivered by the supplier. Simply put, cheap supplier might have unreliable and poor management and vice versa. Purchasing department therefore bear a heavy responsibility in making the right decisions on supplier selection of each and every outsourcing contract.

According to the historical data of the case-study company, the use of outsourcing company has doubled in 2015 14% or 6.4 billion baht of its revenue. Moreover, the trend is going up in the future as shown in Figure 4: Percentage of spending in outsourcing.

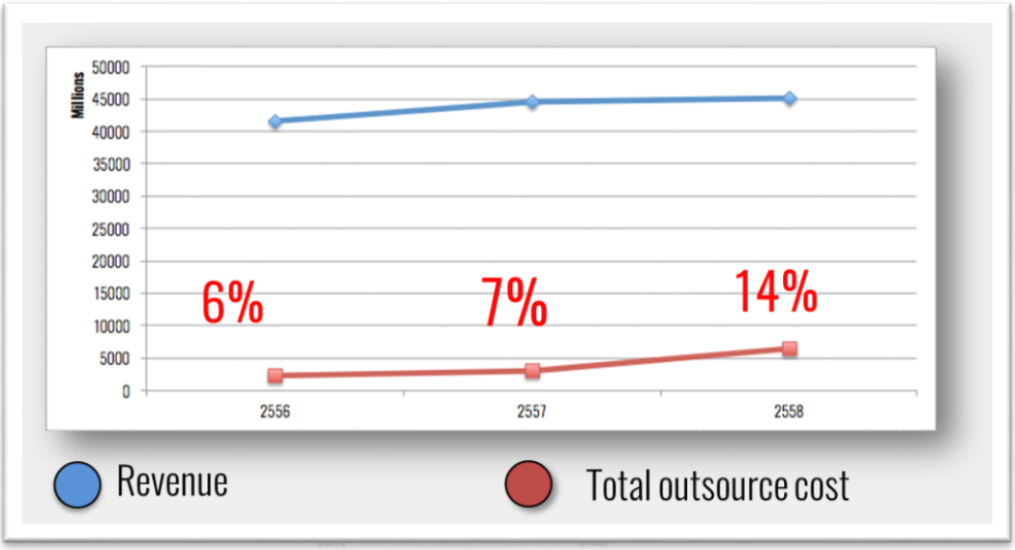

Figure 4: Percentage of spending in outsourcing

2. Procurement Process Background

2.1) Introduction to the procurement process

Referring to Oxford Business Group, they reported that Thailand's economic is heading toward slowdown stage. Hence, Thailand's top companies have to adapt themselves from conventional management, which focuses on people-oriented, and give priority to lifelong employment, to goal-oriented which focuses on objective, and goals aligning with company's vision, and mission. In order compete in today's market, companies have changed from in-house production to outsourcing activities from core competency. For instance, assembling automotive company use various

outsource companies in several areas including designing automotive, part production, and advertising and marketing services. (Group 2014) Furthermore, Thailand's construction material business, SCG group, hires outsource firm in several areas - SCG Precast uses outsource factory to produce high difficult precast concrete elements to control project's budget, schedule, and quality. According to Department of Business Development (Development), number of service providing companies as outsource increases significantly nowadays with wider range of expertise, price, quality, and capability of those firms. Hence, one of the biggest challenges of outsource firm selection is how to match their requirements with appropriate capability of outsource firms or vendors.

The case study company, registered in commercial banking business industry, aims to adapt itself to survive in present competitive market by implementing outsource strategy effectively. Mostly the responsibility for implementation falls to procurement department, which responses to purchase, or hire outsource firm to finish requested products, or services properly. There are 5 parties that relate to each purchase:

- User is any internal department who requests for products and services.
- Buyer is member or team in procurement department who process a project from start to finish.
- Support team is a team in procurement department who support every projects and make the project run smoothly. For example, coordinating with law team, paper work etc.
- Vendor is an outsource company who come for bidding a project.
- Finance team responses to complete the payment term after vendor selection finished.

The teams within procurement department are categorized into 2 sections, Non-IT and IT team. For this research, the author has chosen to study non-IT teams. There are 4 main teams among non-IT teams: Building team, Outsource team, General team and Support team as shown in Figure 5: Procurement Department Organization Chart. Each individual team has different responsibilities.

- Building team is responsible for construction and renovation project.
- Outsource team is responsible for service contract i.e. security guard, data entry.
- General team is responsible for other activities such as purchased debit card, credit card, premium product for customer etc.

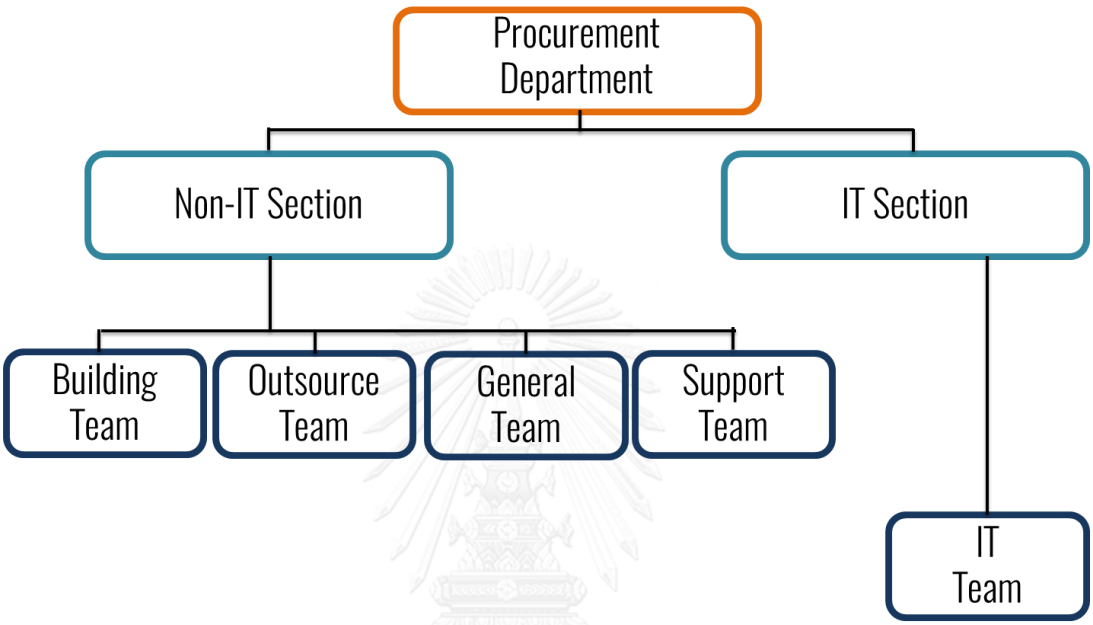

Figure 5: Procurement Department Organization Chart

2.2) Procurement Process

The current procurement process stems from user sending initial requirements indicating the services or products to procurement department. For cases' budget that is above 1 million, procurement department will coordinate with user to develop term of reference for the project. For the next step, user creates User Purchase Request or UPR and requests to procurement department. Finally, procurement department will assign UPR to appropriate team to handle the project.

After receiving UPR, the project team, then, follow the standard processes that are classified in 4 processes by amount of budget which are;

- Case 1: If the budget is under 100,000 baht, responsible team in procurement department sent out inquiry. Then, the team negotiates price and term with vendor. If all are agreed then they issue PA. All process as shown in Figure 6: Under 100,000 baht-budget procurement processes

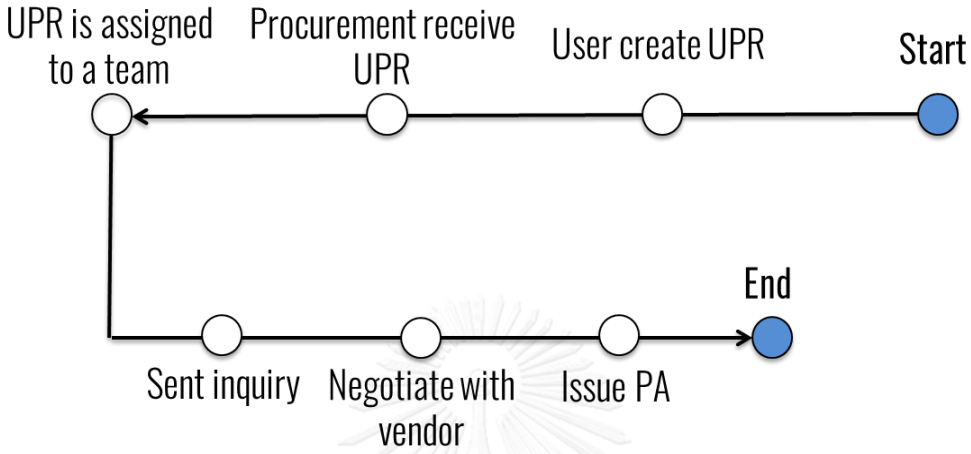

Figure 6: Under 100,000 baht-budget procurement processes

- Case 2: If the budget is between 100,000 – 1,000,000 baht, responsible team in procurement department sent out inquiries to at least 3 vendors. Then, the team negotiates with vendors then selects the best vendor and issue PA, PO. All process as shown in Figure 7: Budget between 100k – 1m procurement processes

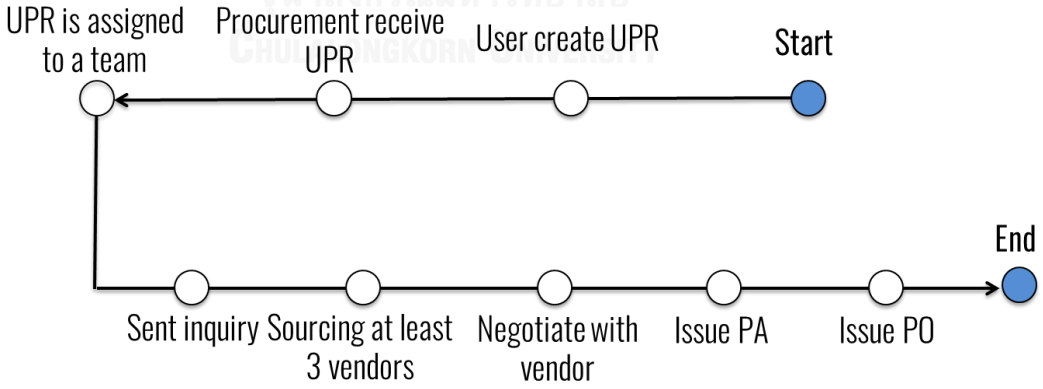

Figure 7: Budget between 100k – 1m procurement processes

- Case 3: If the budget is between 1,000,000 – 5,000,000 baht, the purchase request need to be approved by procurement committee. After that, the request will be proceed to procurement team to sourcing at least 3 vendors to bid in the bidding. The team negotiates with vendor. Then, the team prepares and presents PPR to the committee to approve. Procurement team issues PA, PO to vendor. All process as shown in Figure 8: Budget between 1m – 5m procurement processes.

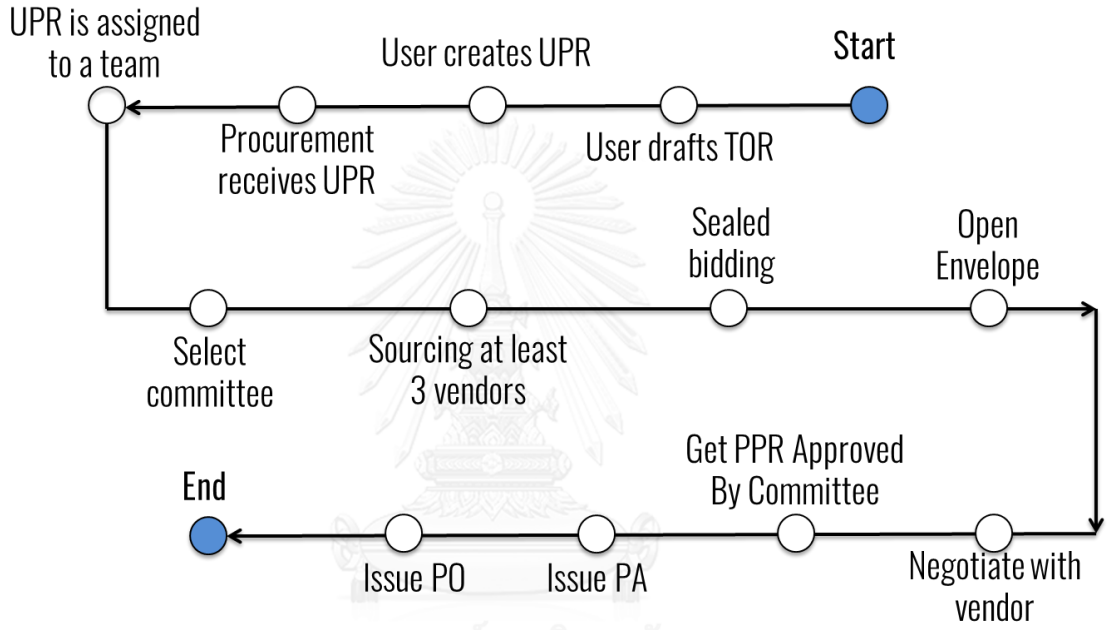

Figure 8: Budget between 1m – 5m procurement processes

- Case 4: If the budget is above 5,000,000 baht, firstly, the request will be assigned to committee to approve. Then procurement team will publish the requirement for any interested vendors to submit their bidding. After all vendors submitted, the offer will be considered and start negotiation process. The team prepares and presents PPR to the committee to approve. Procurement team issues PA, PO to vendor. All process as shown in Figure 9: Budget above 5m procurement processes.

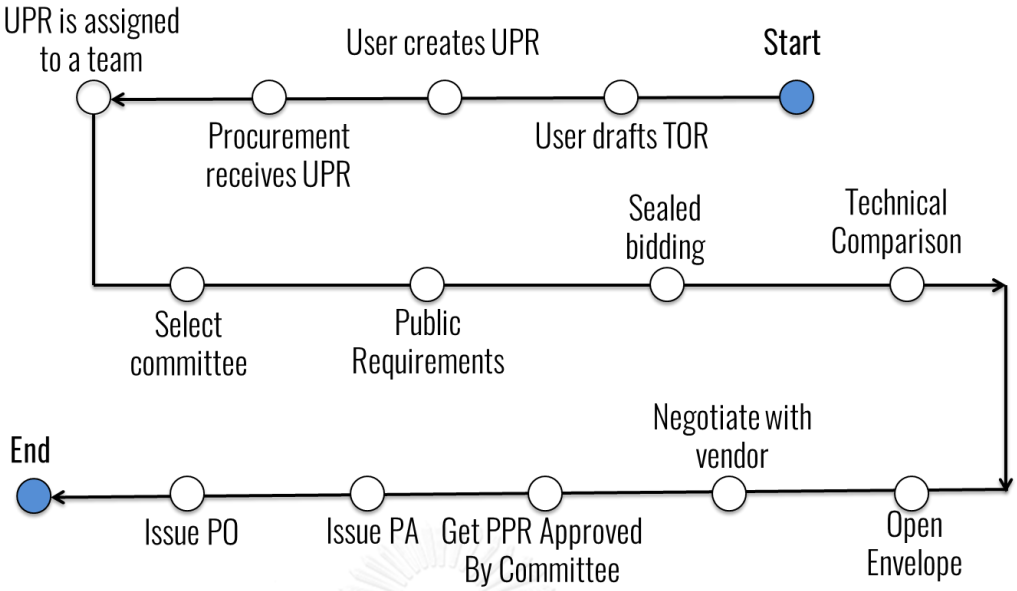

Figure 9: Budget above 5m procurement processes

From the case study company's data, the average UPR is 168 cases per month while average PA and PO are 174 cases per month and 198 cases per month respectively. The differences occur because one UPR sometimes generate up to 4 PA or PO. The PA number for case 1 and 2 together are 424 PA, which is 69% of total PA while for case 3 and 4, the number of PA 100 and 93 PA, which accounted for 16% and 15% respectively. Since case 1 and 2 together consist of 32,655,471.69 baht while case 3 alone 62,739,585.9 baht and case 4 247,519,825.9 baht. Case3 and case 4 combined accounted for 90% of total purchased value. As shown in Figure 10: Summary cases budget. Therefore, this report will focus on case 3 and case 4 because the total budget account for 90% of total amount which is 310,259,412 baht.

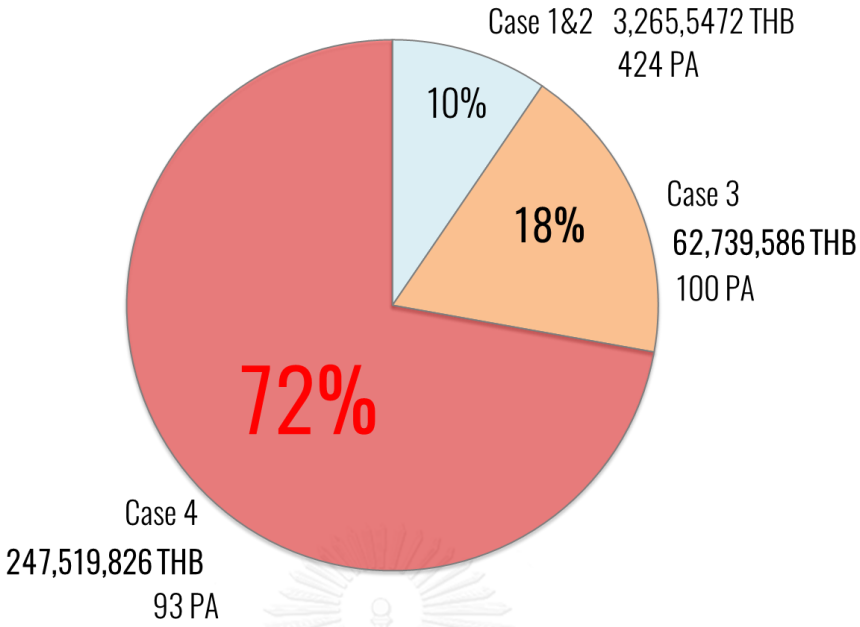

Figure 10: Summary cases budget.

Under the current vendor selection process, the bank tend to put more emphasis on price than other important attributes. This can lead to ineffective vendor selection decisions, since both good products and services can be represented by multiple attributes such as quality, terms of payments, warranty, and so on, rather than price alone. Moreover, sometimes selected vendors performed poorly or below satisfactory level. The inefficient situation occurred in bidding process of over 1 million baht budget request is described in Figure 11: Bidding Workflow.

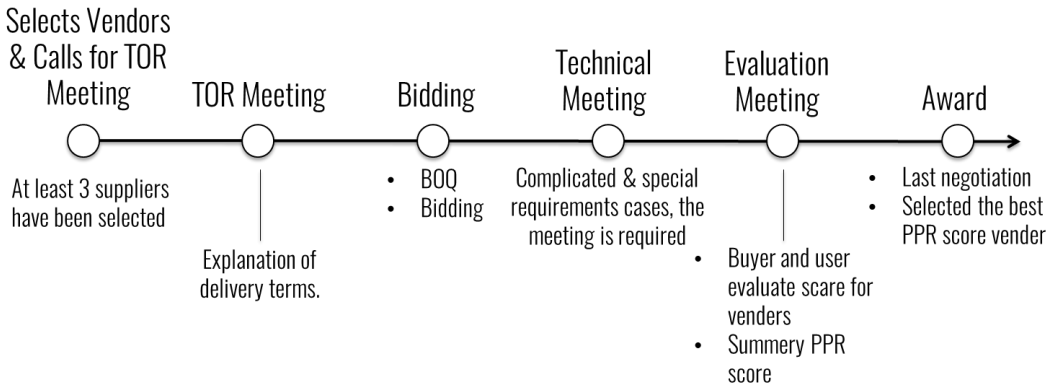

Figure 11: Bidding Workflow

2.3) Issues

The hidden problem that we gathered from the interview is that there are fail purchasing cases, which can be categorized in the below standard finished work, vendor terminations, and rejections. There is no proper data collection on those cases. The next best data available is the number of unapproved selected vendors, which is the case that the selected vendor from the selection process were not approved in the final stage and the company has to reselect new vendor. In 2015, there are 7,383 purchasing cases. In those cases, there are about 0.04% of total cases that turn into unapproved selected vendors. This type of error should be eliminated from the selection process. However, in order to have better picture of problems and improved selection results, the author recommends the company to collect "Number of Vendor Terminated" and "Vendor Performance Score" to create "The Value of Money Score."

The issues regarding poor management and vendor selection criteria for practical are described as following;

Problem 1: Price Performance Ratio score formula

Price Performance Ratio (PPR) is determined by total cost divided by the evaluation of performance score. The procurement officer will determine and weight other related criteria and sub-criteria other than the total cost offered. Then, they evaluate the criteria and calculate the performance score. However, the total cost has more impact in the formula than all other criteria. The higher value of the project, the more effect it has on the evaluation. The value of the total cost will be the a dividend, which is count as 100% while all other criteria combined will be a divisor and also count as 100%. Therefore, the price criteria is outweighed the other criteria. For example, company A offers total cost of 1 million baht and has performance score of 50, whereas company B offers 1.5 million baht and has performance of 80.

The PPR score will be 20,000 and 18,750 respectively. The result is clear that Company A will be chosen, with lower PPR but poorer performance.
In some case, the quality of vendor, which determined by many criteria such as quality of works/goods, completed on schedule etc., should be considered as first priority over total cost. However, with this method the quality of vendor has less importance than total cost. Another example, for the renovation of management office project, the procurement officer should give more weight to the quality of vendor. Otherwise, the bank could end up with less than expected work quality, delayed finished date, or other problems. However, using PPR criteria, vendors who have high score in quality factor won't be able to win the vendor that gives the lowest total cost.

Problem 2: Imperfect Match between Requested Procurement and Procured Product/Service

With current evaluation criterion, procurement department may not totally comprehend the preferences of the buyer. Moreover, Relying only on PPR might not be an appropriate practice for vendor selection. By using PPR, the bank tends to focus only on price attribute, which is an important attribute but not the only important ones. They might select underperformed vendor such as delay on schedule performance, poor quality of work or material etc. This results in imperfect match between the requested procurement and the procured product/service.

Problem 3: Unrecognized of avoiding lowest PPR vendor for conflict tasks.

With inexperienced and busy procurement officers, they might select the same vendor, which offers the lowest PPR score, for two conflicting tasks. For example, the data entry task is divided into 2 steps that are entry data activity and verify data activity. If vendor A is selected for entry data activity, they should not be selected for verify data activity even if they have the lowest PPR score. If the vendor has been selected for both tasks, there will be conflict of interest. Then, it might end up data

was never verified. The problem about PPR scoring is that it is not considered other criteria such as conflicting of interest. The procurement officers have to recognize by themselves to avoid vendor A.

3. Objective of Thesis

The objective of this thesis is to develop a vendor selection tool for a bank that is easy to use, flexible, and effective, in a sense that the bank receives expected product/service under satisfactory price by applying Fuzzy Analytical Hierarchy Process (FAHP).

4. Literature Review

4.1) Related Theory

To match the right vendor with the task, appropriate tools are required. There are 2 types of methods to consider, which are qualitative methods and quantitative methods. For example service, support, technology, standard are classify as qualitative methods. While price, evaluation score, experience for instant are include in quantitative methods. There are many tools to help select the best vendor according to multi-criteria. The tradeoff between tangible factors, such as cost and intangible factors, such as quality, responsibility are necessary in order to select the best suppliers. In this thesis, we will review on potential tools for vendor selection.

4.2) Supplier Selection Criteria

In procurement department, the major task is to select the right vendor. One major aspect in this function is supplier selection criteria. They have to use their personal skill with accumulated experiences to match the right vendor with outsource requests. Dickson, the first researcher who studied supplier criteria selection problem, experimented this topic based on questionnaire to identify the

most suitable criteria for selecting the best supplier. He determined and analyzed what criteria should be used in the supplier selection process Dickson (1966). He came up with 23 important evaluation criteria methods. After that, Weber, Current and Benton (1991) reviewed 74 vendor selection criteria in manufacturing and retail environments reports (Weber, Current et al. 1991).They concluded that the list of criteria is growing in size and changing over time. For example, based on their 74 papers, criteria that often showed up are Price, Delivery, Quality, and Production capacity and location. However, the criteria have changed in the last five years' papers. Most of recent papers showed that vendor also considered vendor's warranties and claim policies, which did not appear in early papers. After Dickson and Weber, Current and Benton studies were more specific on certain topic from users. For example, the most popular service that many researchers are interested to study is third party logistic. Kasilingamr used factor analysis method to evaluate the criteria that affected the third party logistic selection decisions (Kasilingam 1998). He found that there were 4 factors that were commonly used, which were the perceived performance of logistics suppliers, the perception ability, the price, and the strategy and external environment. Those 4 criteria are mostly used as base criteria. However, there were also other criteria which will depend on each project's requirement.

4.3) Supplier Selection Criteria with ANALYTIC HIERARCHY PROCESS (AHP) Method

In 1990s, Saaty developed tools for management team called "Analytic Hierarchy Process (AHP)" (Saaty 1990). The idea of AHP methods used simple principles to structure problems in different layers. The problems are goals, criteria, sub-criteria and choices of suppliers respectively. This method has been used worldwide because of its accuracy and effectiveness of the results. In addition, the model is also easy to use as described below;

- The model uses comparative method to compare 2 criteria, reducing the complexity of too many different criteria from each request.

- The model uses flow chart to illustrate all criteria, making it easier to get big picture and understand connection between criteria.
- The model allows user to alter not only criteria upon requirements but also weight of each criterion. It is flexible to apply to all requirements easily.

Saaty conducts the AHP decision road map as shown in Figure 12: Steps followed in the analytic network decision process.

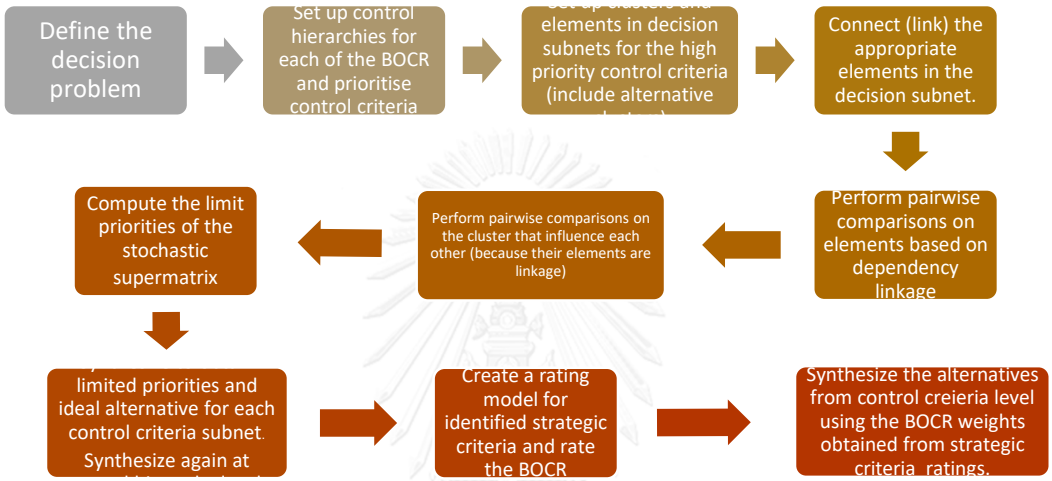

Figure 12: Steps followed in the analytic network decision process (Saaty 1990)

The vendor rating system helps identify the vendor's strengths and weaknesses, which are used for evaluation the most suitable vendor for the request. After Saaty study, AHP was recognized and used worldwide (Saaty and Vargas 2001). In 2007, Vijay concluded that the outsourcing activity was one of key success factors for the company (Wadhwa and Ravindran 2007). Therefore, he tried to adapt AHP in vendor selection. By using multi-objective optimization, he assumed that price, lead-time and quality are the most importance criteria. The paper concluded that a multi-objective technique gives various outcomes, which depends on decision maker. Moreover, the ability to simultaneously view results obtained by different techniques

gives greater flexibility to decision makers in choosing the best solution for the organization. One of the biggest issues in this paper is criteria.

There are many researchers who implement Analytic Hierarchy Process or AHP method to select outsourcing process. For example, in a case study of outsourcing a computer part researched by Wann-Yih Wu and his team (Wu, Sukoco et al. 2009). They separated the study in 2 parts. In the first part, they implemented AHP by selecting criteria according to its job requirement. As a result of AHP, they got the criteria global weight and vendor evaluation score. Their objective was not only to select the best vendor but also to appropriately allocate orders to suitable vendors. In the second part, they used criteria weight as a coefficient for objective function of the Mixed Integer Programming Model (MIP). They develop a MIP to find the optimum value by setting constrains and solving the equation. The result was optimum value with minimum cost and highest value. Their model is shown in the Figure 13: The integration model of AHP and MIP.

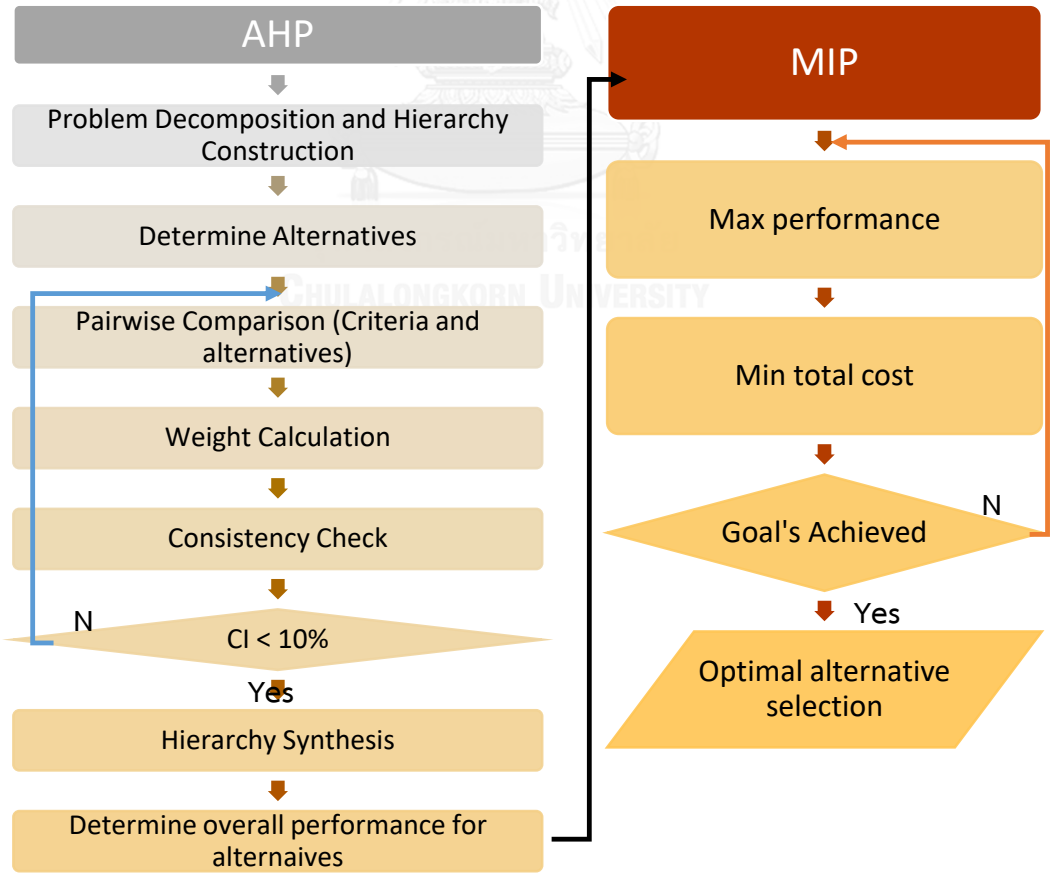

Figure 13: The integration model of AHP and MIP

(Wu, Sukoco et al. 2009)

The research was useful for considering both qualitative and quantitative factors with optimum vendors as a result. However, it is not practical for daily use as it is too complicated for officer to change criteria by themselves.

In 2012, Jianliang Peng applied AHP method in selecting supplier for logistic outsourcing for frozen food industry. He selected 4 main criteria which are cost, operational efficiency, service quality and technology level; sub-criteria are all included as shown in Figure 14: The evaluation index for logistic outsourcing for frozen food industry.

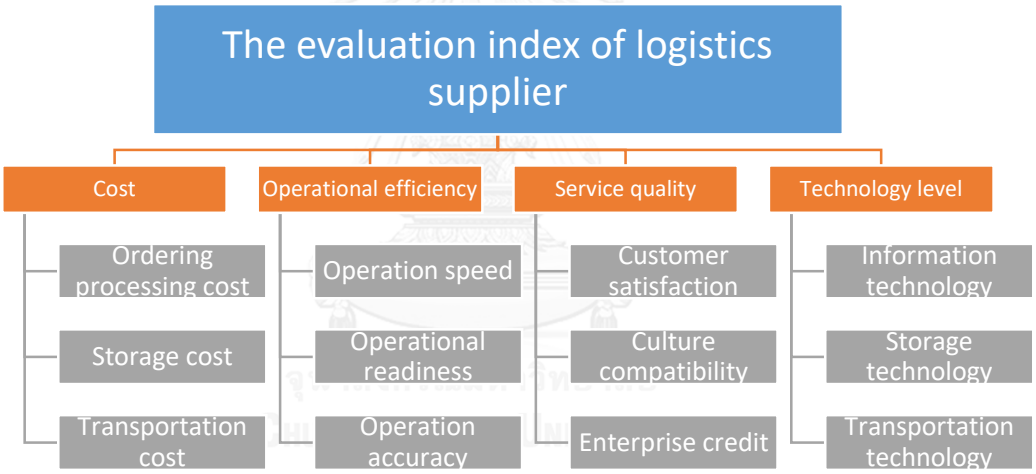

Figure 14: The evaluation index for logistic outsourcing for frozen food industry

After evaluation, criteria weight are as shown in Table 2: The weights and criteria for logistic outsourcing for frozen food industry;

Table 2: The weights and criteria for logistic outsourcing for frozen food industry

Criteria	Global Weight
Cost	**0.424**
Ordering processing cost	0.233
Storage cost	0.089
Transportation cost	0.102

Operational efficiency	**0.227**
Operation speed	0.038
Operational readiness	0.076
Operation accuracy	0.114
Service quality	**0.122**
Customer satisfaction	0.041
Culture compatibility	0.061
Enterprise credit	0.020
Technology level	**0.227**
Information technology	0.076
Storage technology	0.114
Transportation technology	0.038

Afterwards, scores are combined to compare logistic outsource supplier A, B and C together with each indicator. The calculation to sum up the score to select the best supplier for this case is shown in Table 2: The weights and criteria for logistic outsourcing for frozen food industry.

4.4) Supplier Selection Criteria with Fuzzy Analytic Hierarchy Process (Fuzzy AHP)

The Fuzzy Set Theory was introduced in 1965 by Zadeh (Zadeh 1965) to reduce uncertainty and ambiguity of expert's judgment. This concept was integrated with AHP, which was developed by Saaty (Saaty 1990). Cheng (Cheng 1997), Ruoning, Xu, and Zhai Xiaoyan (Ruoning and Xiaoyan 1992) used this concept to solve the selection problem. Basically, the Fuzzy AHP follows the AHP structure method while using fuzzy numbers in the calculation instead of real numbers.

The Fuzzy AHP was adopted and implemented in various fields such as operating system selection (Ballı and Korukoğlu 2009), hospital site selection (Vahidnia, Alesheikh et al. 2009), performance evaluation (Lee, Chen et al. 2008) or

planning and design (Hsieh, Lu et al. 2004). But in this section, only those that related to the supplier selection problem will be reviewed.

In 2013, Fuzzy AHP approach was used for supplier selection in a gear motor company (Ayhan 2013). This paper used 2 tools, namely Fuzzy TOPSIS model and Fuzzy AHP. The decisions obtained by the two tools were compared. It was found that the two tools came up with the same best vendor who, based on the tools, outperformed other vendors.

In 2014, applied Fuzzy AHP to the steel manufacturing industry in the supplier assessment and selection decisions. This paper used Fuzzy AHP in compliance with the collection of qualitative data and qualitative data for Fuzzy AHP supplier selection model. The study contained 3 levels of criterion model which are main-criteria, sub-criteria, sub-sub-criteria. After structure criterion in an AHP structure, they follow Fuzzy AHP theory to reach a result and check sensitivity of the model.

In 2016, Masoud Rahiminezhad Galankashi, Syed Ahmad Helmi, Pooria Hashemzahi (Galankashi, Helmi et al. 2016) developed a Mixed Balance Scorecard – Fuzzy AHP approach for supplier selection in automobile industry. They suggested BSC method in order to evaluate supplier performance then follow fuzzy AHP theory to select the supplier on difference perspective such as financial, customer, internal business and learning and growth. From the theoretical and methodological standpoints, to the best of our knowledge, this research also contributes to offer novel insights into automotive manufacturers for selecting their suppliers based on the exact measures since very few studies have been done before.

4.4.1) the fuzzy theory

Fuzzy set theory has proven advantages within vague, imprecise and uncertain contexts and it resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It was specially designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many decision problems. Fuzzy set theory implements classes and grouping of data with boundaries that are not sharply defined (i.e. fuzzy). Fuzzy set theory includes the fuzzy logic, fuzzy arithmetic, fuzzy

mathematical programming, fuzzy graph theory and fuzzy data analysis, usually the term fuzzy logic is used to describe all of these. The major contribution of fuzzy set theory is its capability of representing vague data.

A fuzzy set is characterized by a membership function, which assigns to each object a grade of membership ranging between 0 and 1. In this set the general terms such as 'large', 'medium' and 'small' each will be used to capture a range of numerical values. A fuzzy set is represented by putting a tilde '~' on a letter. If n1, n2 and n3, respectively, denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event then the triangular fuzzy number (TFN) can be denoted as a triplet (n1, n2, n3). A fuzzy number $\tilde{N}$ expresses the meaning of 'about N'. A TFN $\tilde{N}$ is shown in Figure 15: A triangular fuzzy number, N..

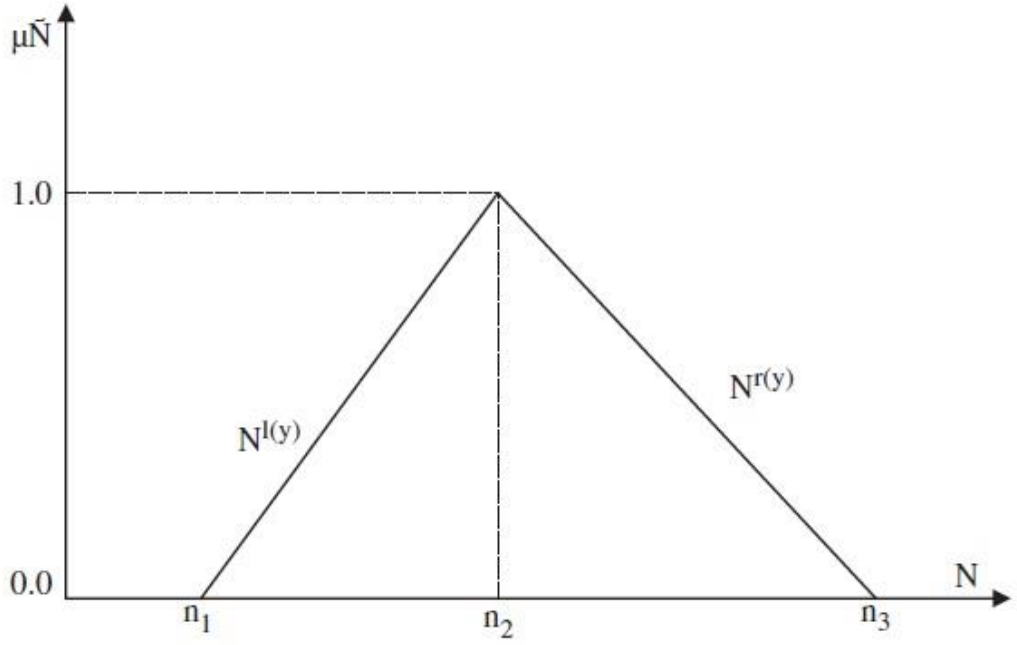

Figure 15: A triangular fuzzy number, N.

Some basic definitions of the fuzzy sets and fuzzy numbers after reviewing some of the past literatures (Zadeh 1965), (Buckley 1985), (Klir and Yuan 1995), (Ross and Donald 1995)) in this area are discussed in this section.

Definition 1: The membership function of a TFN which associated with a real number in the interval [0, 1] can be defined as:

$$\mu(x|\widetilde{N}) = \begin{cases} \frac{(x-n_1)}{(n_2-n_1)}, x \in [n_1, n_2] \\ \frac{(n_3-x)}{(n_3-n_2)}, x \in [n_2, n_3] \\ 0, otherwise \end{cases} \quad (1)$$

A fuzzy number can be given by its corresponding left and right representation of each degree of membership:

$$\widetilde{N}_1 = (N^{l(y)}, N^{r(y)}) \quad (2)$$

$= (n_1 + (n_2 - n_1)\, y,\ n_3 + (n_3 - n_2)\, y, \quad y \in [0, 1]$

Where l(y) and r(y) denote the left and right side representation of a fuzzy number respectively. A non-fuzzy number 'r' can be expressed as (r, r, r).

Definition 2: A fuzzy set $\widetilde{N}$ in the universe of discourse Y is defined as convex if and only if:

$$\mu(\gamma N_1 + (1-\gamma)N_2) \geq \min(\mu_x(N_1), \mu_x(N_2)) \quad (3)$$

For all N1, N2 in Y and all $\gamma \in [0, 1]$, where min denotes the minimum operator.

Definition 3: The height of a fuzzy set is the largest membership grade attained by any element in that set. A fuzzy set $\widetilde{N}$ in the universe of discourse Y is called normalized when the height of $\widetilde{N}$ is equal to 1.

Definition 4: A matrix $\widetilde{U}$ is called a fuzzy matrix if at least one element of it is a fuzzy number.

The fuzzy sum $\oplus$ and fuzzy subtraction $\ominus$ of any two triangular fuzzy numbers are also a triangular fuzzy number, but the multiplication $\otimes$ of any two triangular fuzzy numbers is only an approximate triangular fuzzy number. If $\widetilde{N}_1 = (n_{11}, n_{12}, n_{13})$ and $\widetilde{N}_2 = (n_{21}, n_{22}, n_{23})$ are two triangular fuzzy numbers then the operational laws of them can be expressed as follows:

$$\widetilde{N}_1 \oplus \widetilde{N}_2 = (n_{11} + n_{21}, n_{12} + n_{22}, n_{13} + n_{23}) \quad (4)$$

$$\widetilde{N}_1 \ominus \widetilde{N}_2 = (n_{11} - n_{21}, n_{12} - n_{22}, n_{13} - n_{23}) \quad (5)$$

$$\widetilde{N}_1 \otimes \widetilde{N}_2 = (n_{11}n_{21}, n_{12}n_{22}, n_{13}n_{23}) \quad (6)$$

$$\lambda \otimes \widetilde{N}_1 = (\lambda n_{11}, \lambda n_{12}, \lambda n_{13}),\ where\ \lambda > 0, \lambda \in R \quad (7)$$

$$\widetilde{N}_1^{-1} = \left(\frac{1}{n_{11}}, \frac{1}{n_{12}}, \frac{1}{n_{13}}\right) \quad (8)$$

The basic definitions and notations used in this section will be used throughout this paper until otherwise stated.

5. Proposed Methodology

This section will depict the process of applying FAHP in ranking the importance of all relevant factors. In generating the priorities in FAHP analysis, we need to decompose the decision making process into the steps shown in Figure 16: Fuzzy Analytic Hierarchy Process flowchart.

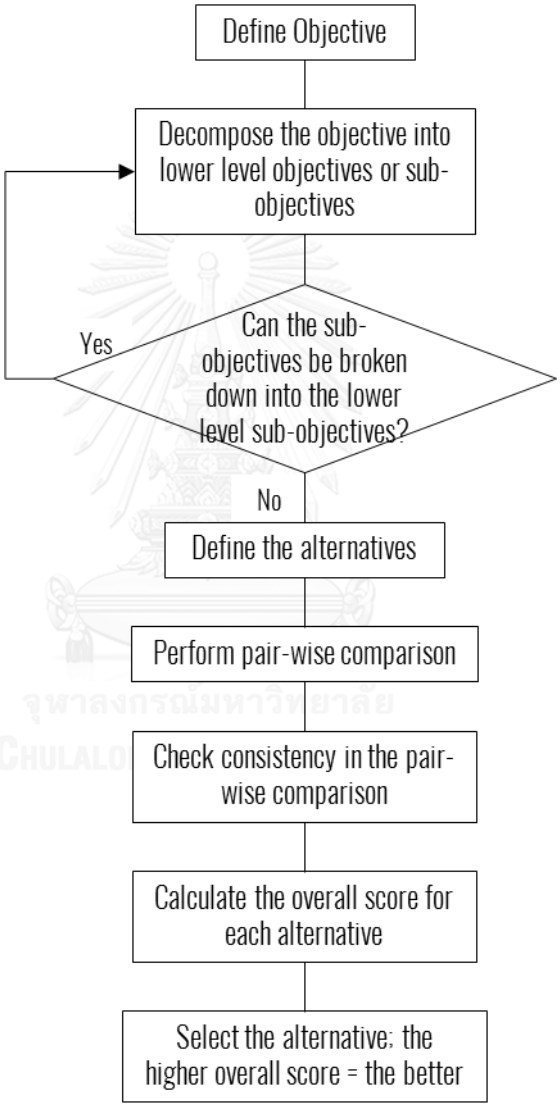

Figure 16: Fuzzy Analytic Hierarchy Process flowchart

1) First, we define the objective of the decision hierarchy. Then, we determine the main evaluation criteria and sub-criterion of each criterion as shown in Figure 17: Hierarchical Data Model.

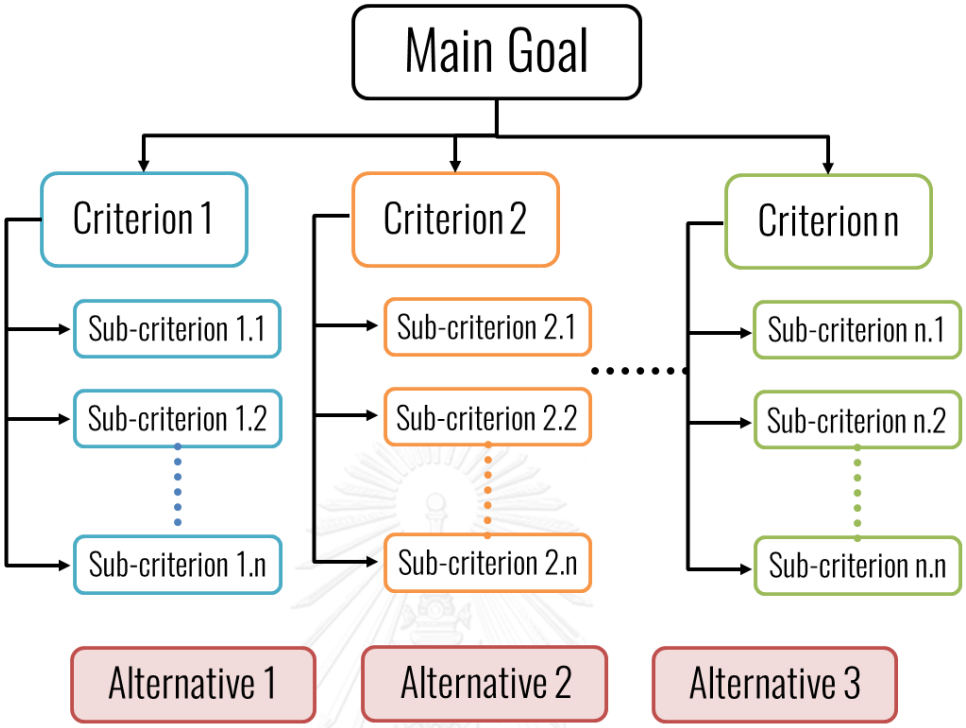

Figure 17: Hierarchical Data Model

2) Construct a set of pairwise comparison matrices. Each pairwise matric contain main criteria, sub-criteria or alternative. For example, the pairwise matric for main criteria consist of all the main selection criteria such as criterion 1, criterion 2, criterion 3 or pairwise matric for sub-criterion 1 is consist of sub-criterion1.1, sub-criterion 1.2 etc. There are 9-1-9 scale in the form which follow the Analytical Hierarchy Process form to collect the evaluation from user as shown in Table 4: Pairwise methods. The meaning of score as shown in Table 3: The evaluation score scale of absolute numbers as Fuzzy Analytical Hierarchy Process was implemented in the calculation process, the score from evaluation must be covert to fuzzy score as shown in Table 3: The evaluation score scale of absolute numbers and fuzzy number..

Table 3: The evaluation score scale of absolute numbers and fuzzy number.

INTENSITY OF IMPORTANCE	FUZZY SCORE	DEFINITION	EXPLANATION
1	(1,1,1)	Equally Important	Two activities contribute equally to the objective
2	(1,2,3)	Slightly important	
3	(2,3,4)	Moderately important	Experience and judgment slightly favor one activity over another
4	(3,4,5)	Exceed moderate	
5	(4,5,6)	Strong importance	Experience and judgment strongly favor one activity over another
6	(5,6,7)	Exceed strong	
7	(6,7,8)	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	(7,8,9)	Very, very strong	
9	(9,9,9)	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Table 4: Pairwise methods

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Total Cost																		Quality
Total Cost																		Delivery
Total Cost																		Management & Organization
Total Cost																		Financial
Quality																		Delivery
Quality																		Management & Organization
Quality																		Financial
Delivery																		Management & Organization
Delivery																		Financial
Management & Organization																		Financial

3) Use the priorities obtained from the comparisons to weigh the priorities in the level. Repeat this for every element. Then for each element in the level below, add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

3.1. The pairwise matrix is shown in equation 1 where $\widetilde{a_{ij}^{k}}$ indicates score of the k^{th} preference of i^{th} criterion over j^{th} criterion, via fuzzy triangular number. From example, $\widetilde{a_{12}^{1}}$ represents the score of the first preference of first criterion over second criterion which equal to (1, 1, 1).

$$\widetilde{A^{k}} = \begin{bmatrix} \widetilde{a_{11}^{k}} & \widetilde{a_{12}^{k}} & \dots & \widetilde{a_{1m}^{k}} \\ \widetilde{a_{21}^{k}} & \widetilde{a_{22}^{k}} & \dots & \widetilde{a_{2m}^{k}} \\ \dots & \dots & \dots & \dots \\ \widetilde{a_{n1}^{k}} & \widetilde{a_{n2}^{k}} & \dots & \widetilde{a_{nm}^{k}} \end{bmatrix} \quad (9)$$

3.2. If there are multiple decision makers, $\widetilde{a_{ij}^{k}}$ score in this case has to be the average value of all the decision makers' scores. Let *n* denote the number of decision makers. The new $\widetilde{a_{ij}^{k}}$ score are calculated by

$$\widetilde{a_{ij}} = \frac{\sum_{n=1}^{n} \widetilde{a_{ij}^{k}}}{n} \quad (10)$$

3.3. After averaging$\widetilde{a_{ij}}$, the pairwise matric is updated as shown in Equation 11.

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$$\tilde{A} = \begin{bmatrix} \widetilde{a_{11}} & \widetilde{a_{12}} & \dots & \widetilde{a_{1m}} \\ \widetilde{a_{21}} & \widetilde{a_{22}} & \dots & \widetilde{a_{2m}} \\ \dots & \dots & \dots & \dots \\ \widetilde{a_{n1}} & \widetilde{a_{n2}} & \dots & \widetilde{a_{nm}} \end{bmatrix} \quad (11)$$

3.4. According to Buckley (Buckley 1985), the fuzzy triangular means-values of a criterion is calculated as shown in Equation 12 While i= 1, 2,...., n.

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{a_{ij}}\right)^{1/n} \quad (12)$$

3.5. According the fuzzy triangular means in equation4, the mean value of each criterion is a fuzzy number. The fuzzy weight of each a criterion is calculate by next three sub steps.

3.5.1. Find the vector summation of each$\widetilde{r_i}$.

3.5.2. Find the (-1) power of summation vector by replacing the fuzzy triangular number; rank them in an increasing order.

3.5.3. To find the fuzzy weight of criterion i ($\widetilde{w_i}$), multiply each $\widetilde{r_i}$ with this reversed vector as shown in equation 5. While lw_i , mw_i , uw_i donate for the criterion weight in an increasing order.

$$\widetilde{w_i} = \widetilde{r_i} \otimes (\widetilde{r_1} \oplus \widetilde{r_2} \oplus \dots \oplus \widetilde{r_n})^{-1}$$
$$\widetilde{w_i} = (lw_i , mw_i , uw_i) \quad (13)$$

3.6. According equation 5, $\widetilde{w_i}$ are still fuzzy triangular score. Chou and Chang (Chou and Chang 2008) proposed the equation to de-fuzzified by using center of area method.

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (14)$$

3.7. Use the normalized weight to find the normalized weight of both criteria and alternatives. While N denote for the normalized weight.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (15)$$

After determining the normalized weight of each criteria, the consistency ratio can be calculated by equation 8, 9, 10, and 11 and its value should pass the score as shown in Table 5: The standard score for consistency ratio.

$$Consistency\ Vector = \frac{Weighted\ Sum}{Criteria\ Weights} \quad (16)$$

$$L = \frac{Sum\ of\ Consistency\ Vector}{n} \quad (17)$$

$$CI = \frac{(L-n)}{(n-1)} \quad (18)$$

$$CR = \frac{CI}{RI} \quad (19)$$

Table 5: The standard score for consistency ratio

Number of criteria	Standard score
3 Criteria	C.R. <= 0.05
4 Criteria	C.R. <= 0.08
More than 4 Criteria	C.R. <= 0.10

The following step will show the example of FAHP process.

1. Define the objective of the decision hierarchy as shown in Figure 18.

Figure 18: Hierarchical Data Model for commercial banking

2.

3. Table 6: The standard matrix for Analytic Hierarchy Process but in this process the score is still in the AHP form. It must be covert from AHP to Fuzzy AHP score as shown in Table 3: The evaluation score scale of absolute numbers and fuzzy number. and the final score shown in Table 7: The standard matrix for Fuzzy Analytic Hierarchy Process.

Table 6: The standard matrix for Analytic Hierarchy Process

	Total cost	Quality	Delivery	Mgt	Financial
Total cost	1	0.25	0.167	3	5
Quality	4	1	0.5	3	4
Delivery	6	2	1	6	7
Mgt	0.33	0.33	0.167	1	1
Financial	0.2	0.25	0.143	1	1

Table 7: The standard matrix for Fuzzy Analytic Hierarchy Process

	Total cost	Quality	Delivery	Mgt	Financial
Total cost	1,1,1	0.33,0.25,0.20	0.20,0.17,0.14	2,3,4	4,5,6
Quality	3,4,5	1,1,1	1,0.5,0.33	2,3,4	3,4,5
Delivery	5,6,7	1,2,3	1,1,1	5,6,7	6,7,8
Mgt	0.5,0.33,0.25	0.5,0.33,0.25	0.2,0.17,0.14	1,1,1	1,1,1
Financial	0.25,0.2,0.17	0.33,0.25,0.2	0.17,0.14,0.13	1,1,1	1,1,1

4. $\widetilde{r_i}$ Can calculated by step 3.5.1, using the multiply of each column then power by number of criteria which is 5 in this case.
   For example, $\widetilde{r_1}$ = (1*0.33*0.20*2*4)^1/5, (1*0.25*0.17*3*5)^1/5, (1*0.20*0.14*4*6)^1/5 =0.882, 0.910, 0.927
   $\widetilde{r_2}$ = 1.783, 1.888, 2.016
   $\widetilde{r_3}$ = 2.724, 3.471, 4.112
   $\widetilde{r_4}$ = 0.549, 0.450, 0.389
   $\widetilde{r_5}$ = 0.425, 0.372, 0.334
   Sum of $\widetilde{r_{total}}$ = 6.363, 7.091, 7.778
5. Power $\widetilde{r_{total}}$ with -1 and order it as an increasing order = 0.129,0.141, 0.157
6. Find each fuzzy weight criteria, $\widetilde{w_i}$ as mention 3.5.3
   $\widetilde{w_1}$ = (0.882*0.129), (0.910*0.141), (0.927*0.157) = 0.114, 0.128, 0.146

$\widetilde{w_2}$ = 0.230, 0.266, 0.317

$\widetilde{w_3}$ = 0.351, 0.489, 0.646

$\widetilde{w_4}$ = 0.071, 0.063, 0.061

$\widetilde{w_5}$ = 0.055, 0.052, 0.052

7. As $\widetilde{w_i}$ are fuzzy numbers, we have to de-fuzzified by using center of area method as mention in equation 6

M_1 = (0.114+ 0.128+ 0.146) /3 = 0.129

M_2 = 0.271

M_3 = 0.495

M_4 = 0.065

M_5 = 0.053

8. Lastly, N_i can calculated as mention in equation 7, which are

N_1 = 0.127

N_2 = 0.268

N_3 = 0.489

N_4 = 0.064

N_5 = 0.052

6. Application of Fuzzy AHP in the Procurement Process of the Banking Industry

This section will discuss the process of applying FAHP method in the procurement process of the Banking Industry. The method will be implemented in Excel. In this case, the objective is to determine the most suitable and reasonable supplier. For the banking industrial as mention before, there are several team that response for difference work task. To develop the criterion serve for all demand in the department. There are five evaluation mainly criterion namely total cost -price, quality – In this case, we consider both quality of product and service, delivery – how our supplier delivery both product and service to us , management and organization - The quality of management within organization , and financial – the company performance and capability in financial aspect. Apart from these five

criteria, additional points are added to supplier that is currently a customer of outsourcer. This score doesn't affect while evaluating the other five criteria and is added after five criteria and its sub-criteria are scored. The following table depicts the meaning of each criteria.

Table 8: The meaning of each criteria.

Criteria	Meaning
Total Cost	**Total price criteria.**
Quality	**Quality criteria.**
Company capability	The company workability such as modern machine, production capability to satisfying future increase in demand, standardized labor training routine, etc.
Quality of service	Degree of service-minded, service after sales, ease of information or knowledge transfer, etc.
Quality of product	High quality and standardized product, well-trained labor, etc.
Security control	Quality and number of security guards, control entree of people, technological surveillance to tackle crime, control excess of information by individual, etc.
Delivery	**The action of delivering products or services to buyer.**
Process plan	Clear defined objective and process plan, quantifiable, reasonable duration and applicability.
Compliance with due time	Able to complete the task in given amount of time.
Compliance with quality	Good quality of work.
Safety plan	Safety procedure during emergency issue including safety officer, tools such fire extinguisher or repairing equipment.
Management & Organization	**The quality of management within organization.**

Responsiveness	Able to response to demand from buyers including solving request or complaints from buyers.
Discipline	Able to follow the guidelines or rules according the signed agreement.
Environment	Stability of the organization in areas of factory, office, labor force, etc.
Technical Capability	Technological plan such as acquiring new technology for internal management and production for higher working output.
Facility Capability	Well planned resource management to create motivation within workforce.
Performance history	Historical data of organization performance on product delivery or service.
Risk Management	Able to assess risk by using external supplier.
Financial	**Cash flow and asset**
Company Profile	Company's investment, asset and cash flow.
Customer reference	Historical data on financial management of customer service.

All criteria was selected in order to cover all requirement from procurement department. While original version can construct and calculated by excel but the evaluator must understand the model. So we decide to create the excel programming by using VBA to make the model easy to use and understand which make everyone can use this model to selected the best suppliers.

How to use excel programming:

1). Input the following data

1.1) Tab 1: Criteria

1.1.1) Job name.

1.1.2) Choose criteria according objective.

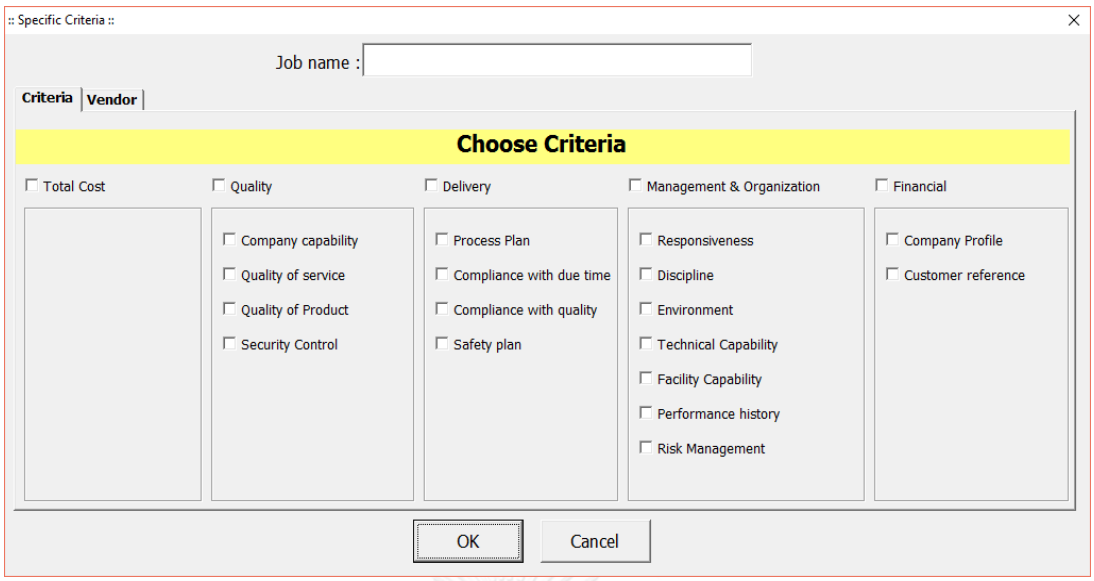

Figure 19: Excel programming- Criteria Selection

1.2) Tab 2: Vendor

1.2.1) Input vendor information (maximum of 10 sellers).

1.2.2) Choose whether vendor has customer relationship for extra point.

1.2.3) Input vendor's cost proposal.

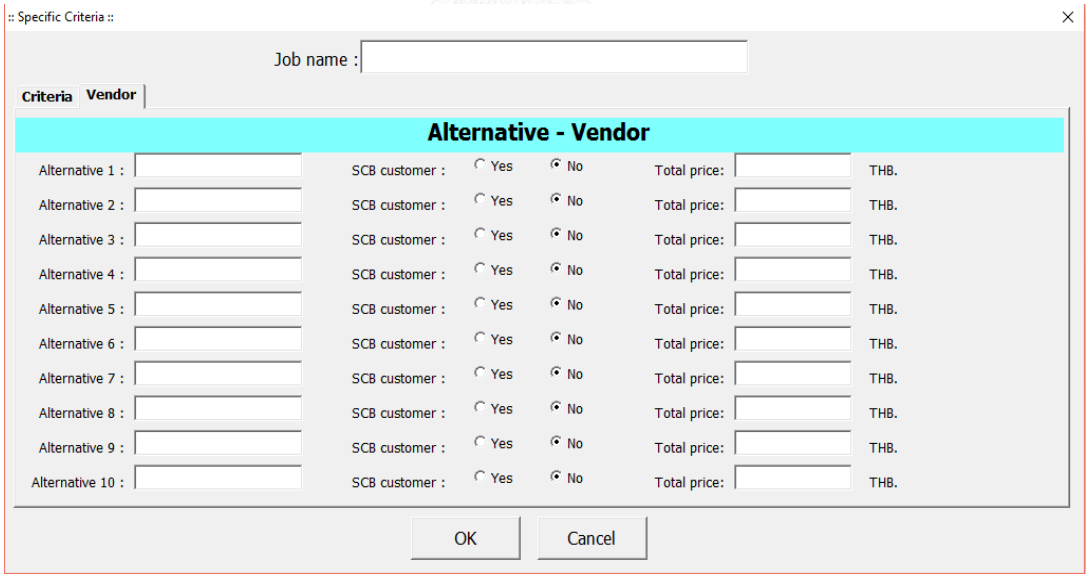

Figure 20: Excel programming- Vendor's Information

2). Evaluate each criteria and sub-criteria. There should post-evaluation after the evaluation is done to determine the consistency of scoring. If there is a lack of consistency, the process has to be redone.

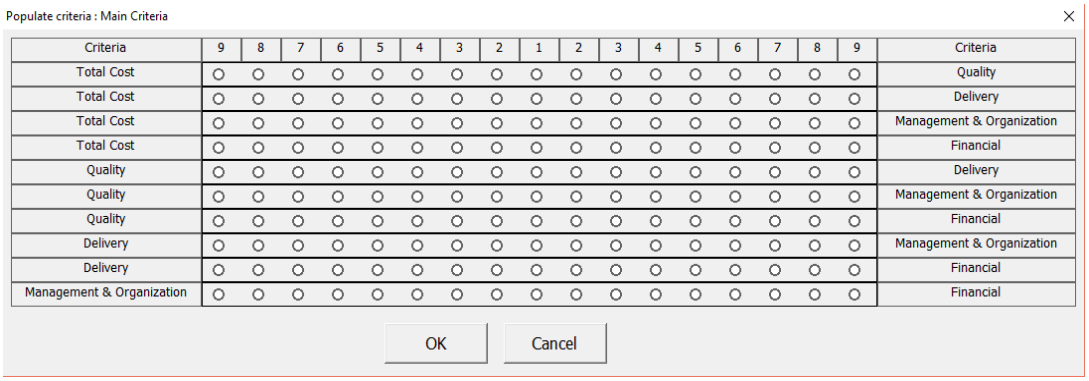

Figure 21: Excel programming- Criteria Scoring

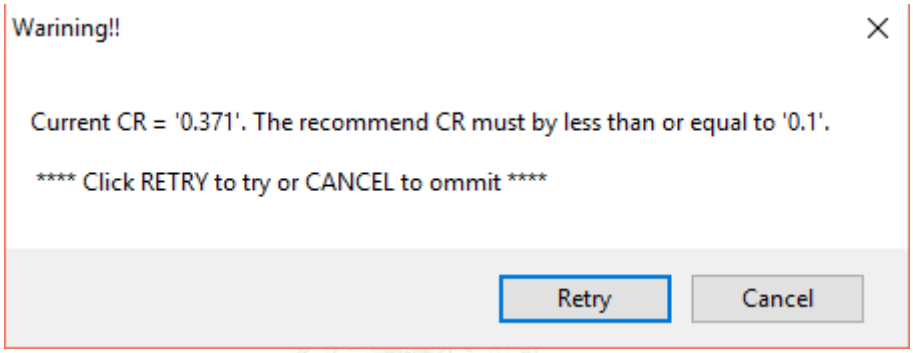

Figure 22: Excel Programming- Warning incase consistency index less than assigned value

3). After criteria evaluation, vendors will be scored in pairs for all criteria.

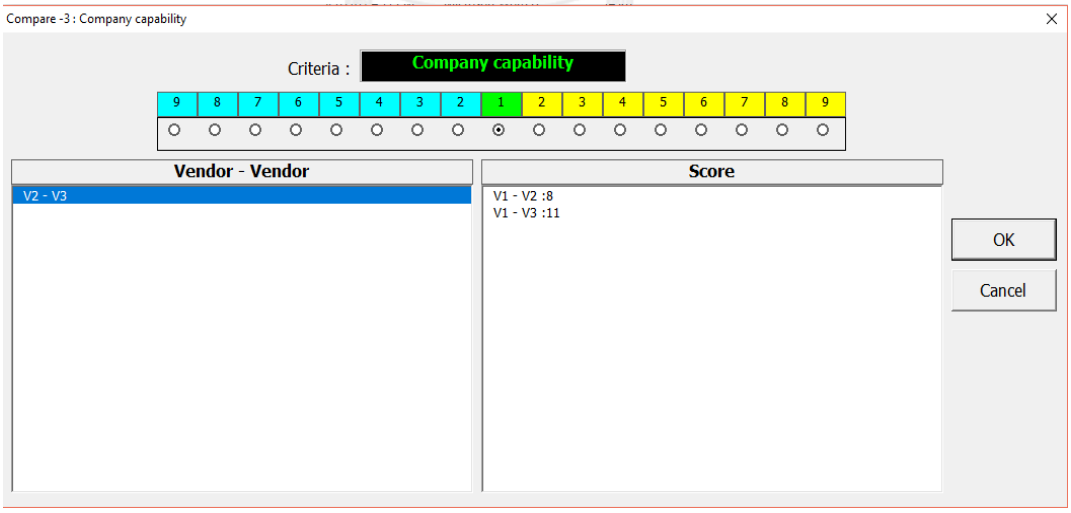

Figure 23: Excel programming- Vendor scoring for each criteria

4). The program will run such that the result will be the vendor with the best score.

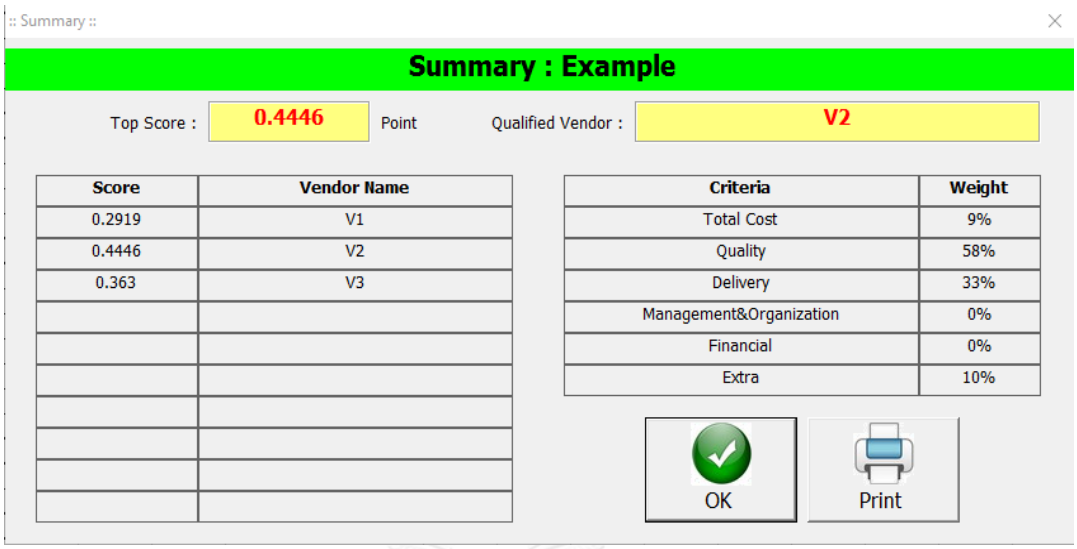

Figure 24: Excel programming- Summary

From the case study, bidding under contact name "Data center management" will take care of building, system and maintenance for commercial bank's computer center in Bangkok, Thailand. It is found that factors within the main criteria affecting the result are Total cost, Quality, Delivery, Management and organization and Financial.

During this bidding, there are three vendors namely Supplier A, Supplier B and Supplier C with price proposal of 28,000,000, 34,000,000 and 31,000,000 baht respectively; all suppliers are customer of the bank. The duration of the contract is three years. The following information, used with excel programming, are used to evaluate each supplier.

1. Fill in the information and criteria selection as shown in Figure 25: Case study- Choose criteria and Figure 26: Case study- insert supplier name and price.

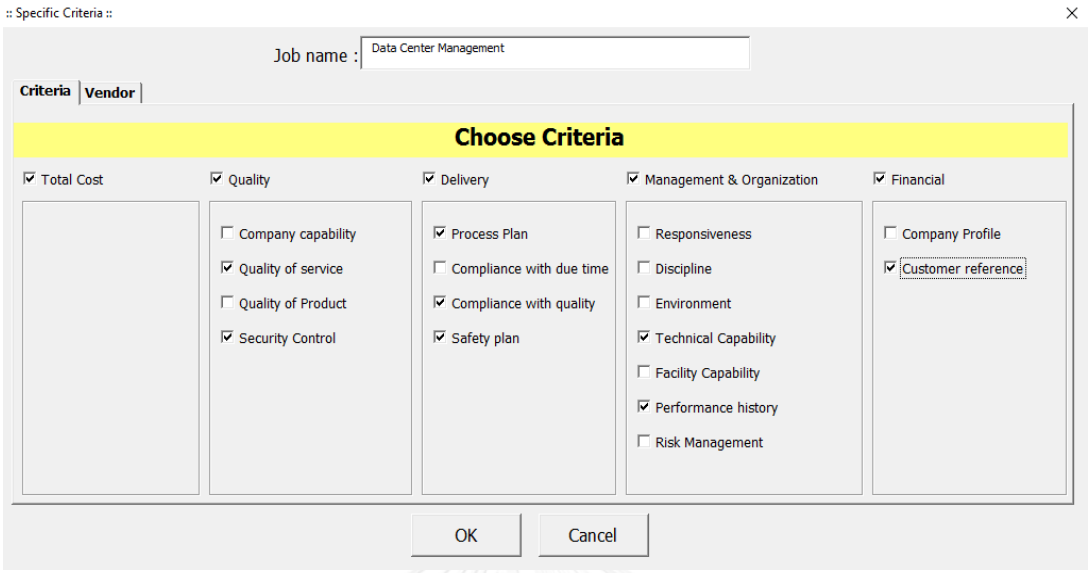

Figure 25: Case study- Choose criteria

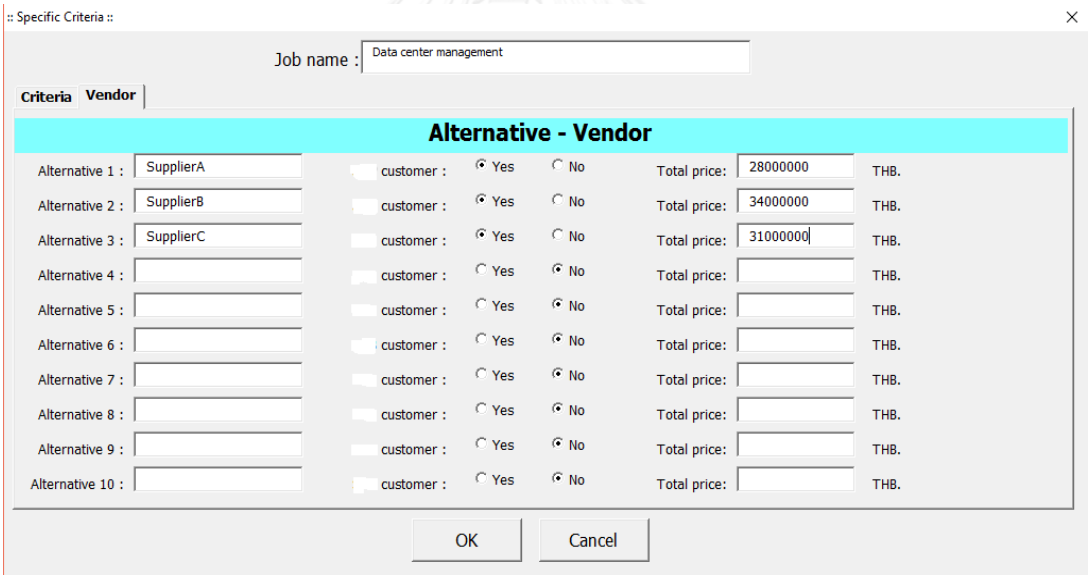

Figure 26: Case study- insert supplier name and price

2. Scoring each criteria and sub criteria by pairwise method to calculate each criteria weight as shown in figure 25-28.

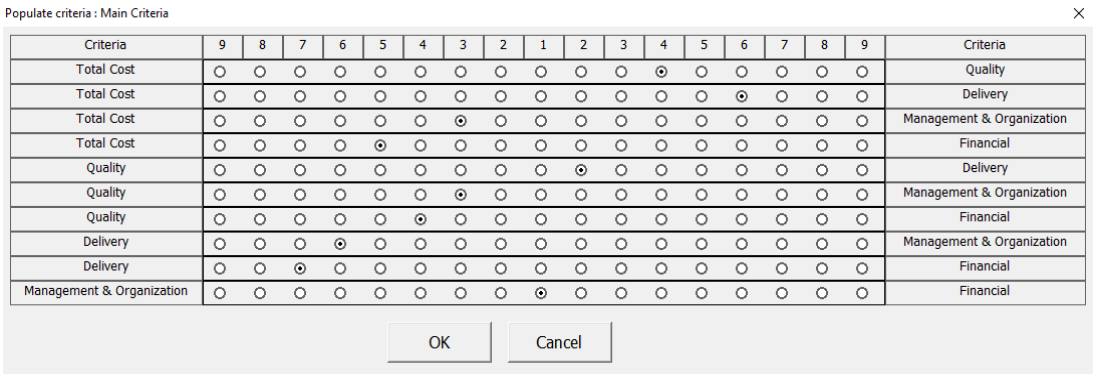

Figure 27: Case study- Main criteria scoring by pairwise metric

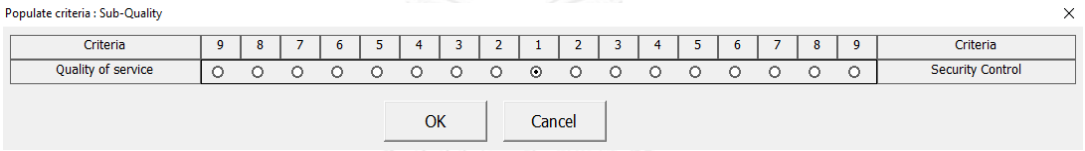

Figure 28: Case study- Sub criteria under quality scoring by pairwise metric

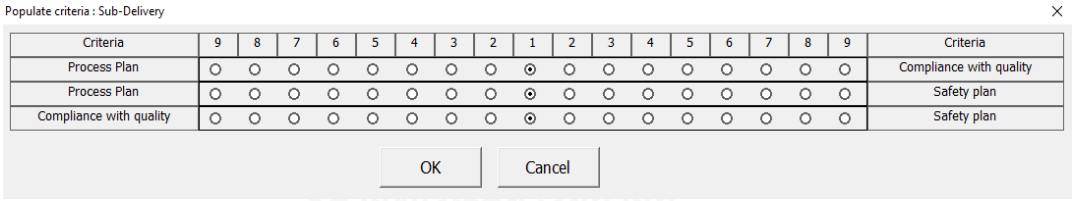

Figure 29: Case study- Sub criteria under delivery scoring by pairwise metric

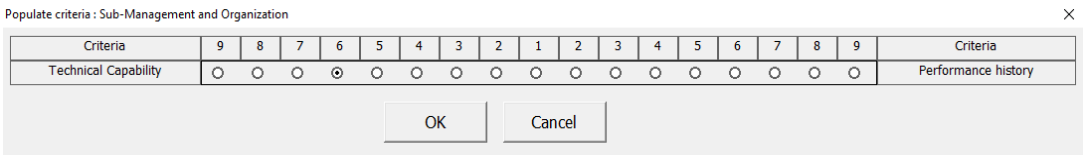

Figure 30: Case study- Sub criteria under Management and organization scoring by pairwise metric

3. Compare each supplier by pairwise for each criteria as shown in figure 31.

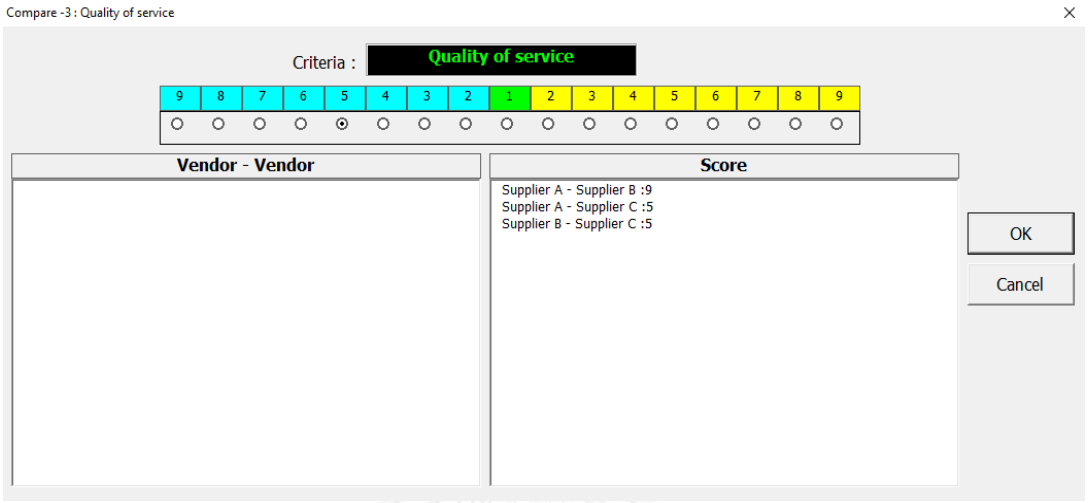

Figure 31: Case study- Evaluate each vendor under sub criteria quality of service

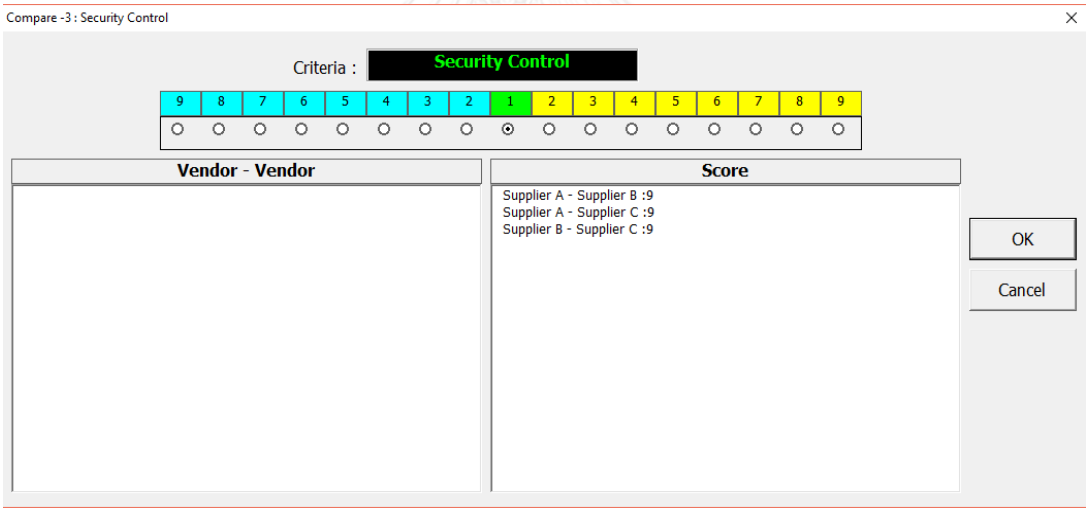

Figure 32: Case study- Evaluate each vendor under sub criteria security control

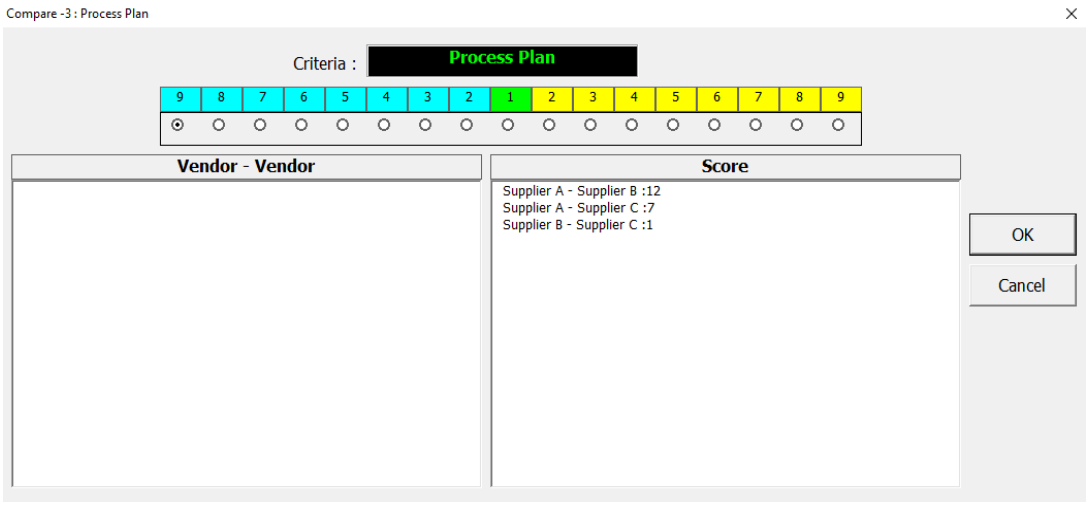

Figure 33: Case study- Evaluate each vendor under sub criteria process plan

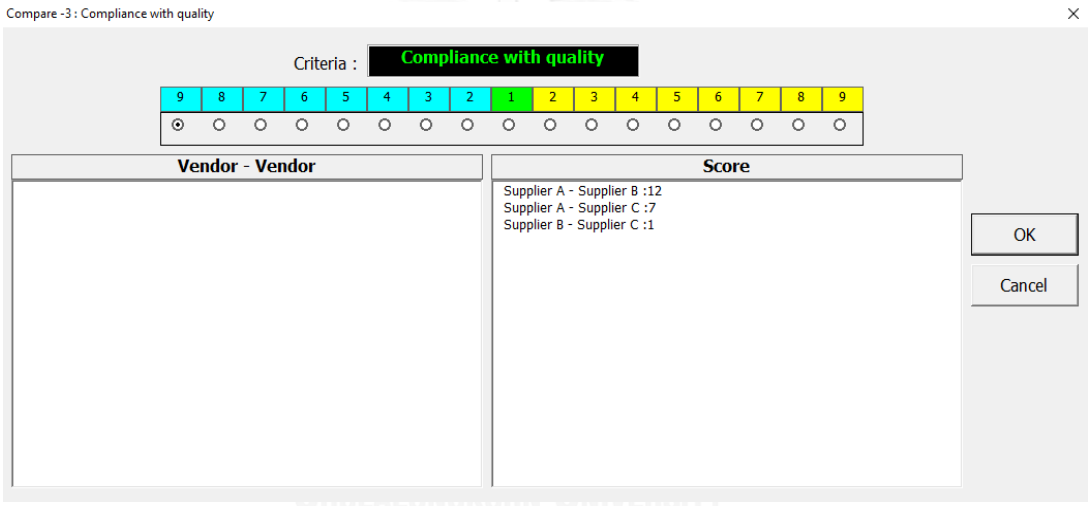

Figure 34: Case study- Evaluate each vendor under sub criteria compliance with quality

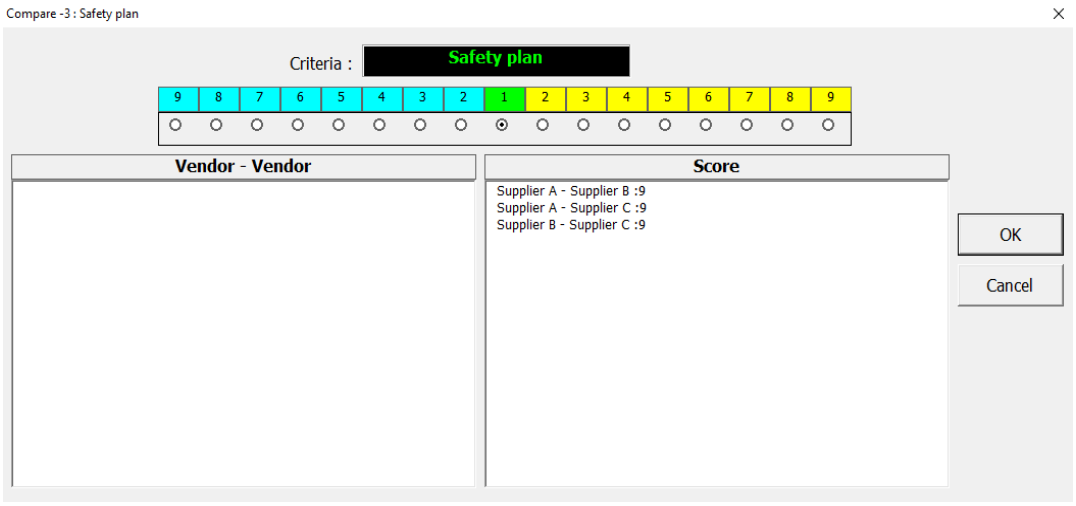

Figure 35: Case study- Evaluate each vendor under sub criteria safety plan

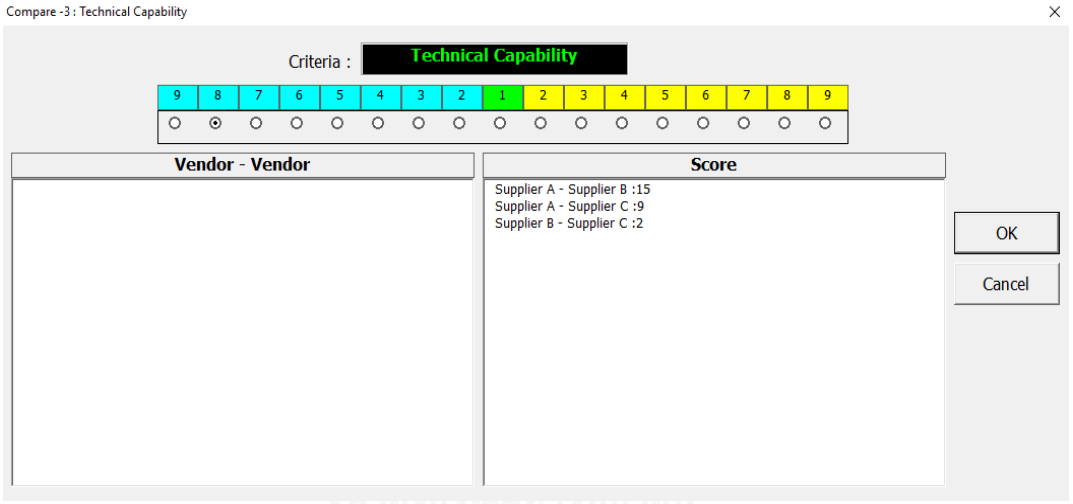

Figure 36: Case study- Evaluate each vendor under sub criteria technical capability

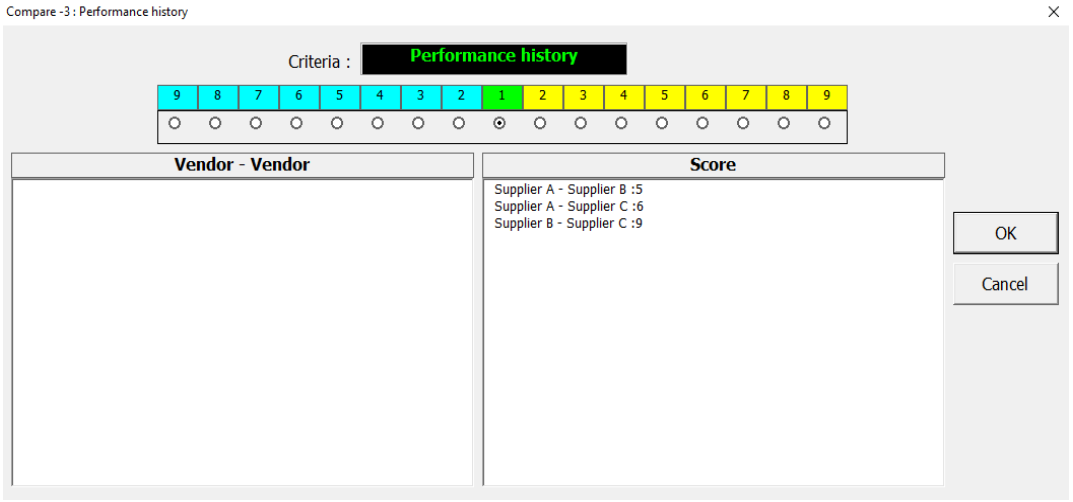

Figure 37: Case study- Evaluate each vendor under sub criteria performance history

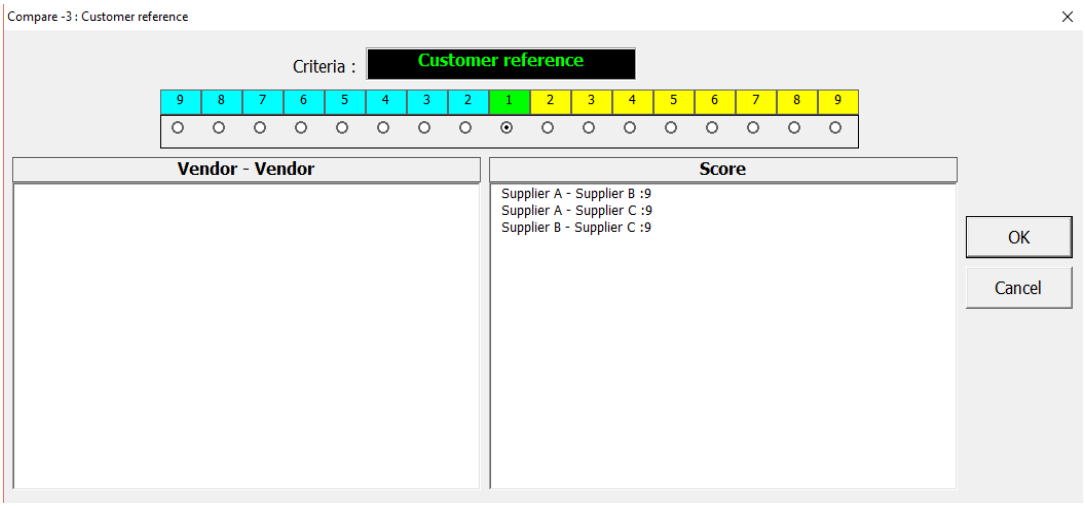

Figure 38: Case study- Evaluate each vendor under sub criteria

4. The result shown in Figure 39: Case study- Summary summarizes which supplier is the best supplier for this task with the weight of each criteria. Furthermore, the detail of each weight is collected in the excel sheet under name "Data keep" as shown in Table 9: Case study- Summary Detail.

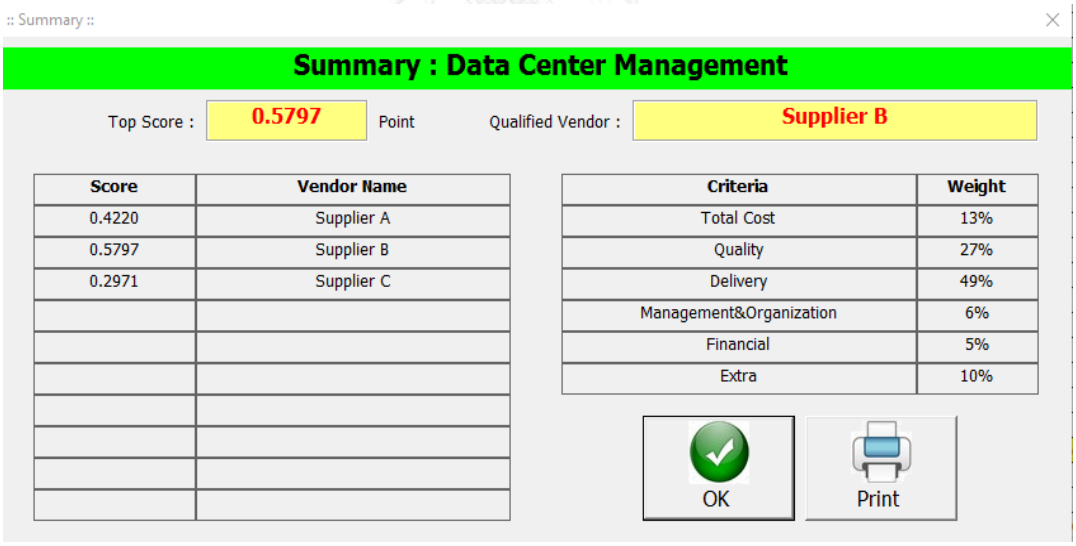

Figure 39: Case study- Summary

Table 9: Case study- Summary Detail

		Vendor 1	Vendor 2	Vendor 3		Score Vendor 1	Score Vendor 2	Score Vendor 3
Total Cost	0.1270	0.536	0.171	0.293		0.0681	0.0217	0.0372
Company capability	0.0000	0	0	0		0	0	0
Quality of service	0.1340	0.454	0.454	0.092		0.0608	0.0608	0.0123
Quality of Product	0.0000	0	0	0		0	0	0
Security Control	0.1340	0.333	0.333	0.333		0.0446	0.0446	0.0446
Process Plan	0.1628	0.199	0.726	0.075		0.0324	0.1182	0.0122
Compliance with due time	0.0000	0	0	0		0	0	0
Compliance with quality	0.1628	0.199	0.726	0.075		0.0324	0.1182	0.0122
Safety plan	0.1628	0.333	0.333	0.333		0.0542	0.0542	0.0542
Responsiveness	0.0000	0	0	0		0	0	0
Discipline	0.0000	0	0	0		0	0	0
Environment	0.0000	0	0	0		0	0	0
Technical Capability	0.0548	0.107	0.789	0.103		0.0059	0.0433	0.0056
Facility Capability	0.0000	0	0	0		0	0	0
Performance history	0.0092	0.691	0.149	0.160		0.0063	0.0014	0.0015
Risk Management	0.0000	0	0	0		0	0	0
Company Profile	0.0000	0	0	0		0	0	0
Customer reference	0.0520	0.333	0.333	0.333		0.0173	0.0173	0.0173
Extra	0.1000	1	1	1		0.1	0.1	0.1
						0	0	0
	1.0995	4.1850	5.0140	2.7970		0.4220	0.5797	0.2971

7. Sensitivity Analysis

The sensitivity analysis is the study of how the result will affect if we change input data. This study, we would like to analyze how the results are sensitive to the scores provided the evaluators, while the weights are kept unchanged. Because the sensitivity analysis cannot changed two dimension in the same period. To do this, we incrementally change the score by one unit either to the left and right of the current score. The results will consequently be observed and analyzed. Moreover, in some criteria, we completely changes the scoring. For example, for quality of service criteria. The original score are 1,-5,-5 but in case 19 we decide to scoring it equal to -3,-9,-5 to see how the score effect to the result. The score has been changed by each criteria is shown in table below.

Table 10: Sensitivity analysis – Quality of Service criteria

Criteria :	**Quality of service**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.134**	**Other Criteria Score**			**0.3612**	**0.5189**	**0.2848**				
	Score				Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.061	0.061	0.012	0.4222	0.5799	0.2968	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	-2	-5	-5	✗ 0.112													
Case 2	-2	-6	-5	✗ 0.091													
Case 3	-2	-6	-6	✗ 0.107													
Case 4	-2	-4	-5	✗ 0.150													
Case 5	-2	-4	-4	✗ 0.122													
Case 6	2	-5	-5	✗ 0.112													
Case 7	2	-6	-5	✗ 0.136													
Case 8	2	-6	-6	✗ 0.107													
Case 9	2	-4	-5	✗ 0.095													
Case 10	2	-4	-4	✗ 0.122													
Case 11	1	-6	-5	✓ 0.017	0.472	0.444	0.085	0.063	0.059	0.011	0.4242	0.5779	0.2958	Vendor 2	Vendor 1	Vendor 3	Same
Case 12	1	-6	-6	✓ 0.010	0.461	0.461	0.078	0.062	0.062	0.01	0.4232	0.5809	0.2948	Vendor 2	Vendor 1	Vendor 3	Same
Case 13	1	-6	-4	✓ 0.036	0.484	0.422	0.094	0.065	0.057	0.013	0.4262	0.5759	0.2978	Vendor 2	Vendor 1	Vendor 3	Same
Case 14	1	-4	-5	✓ 0.026	0.432	0.466	0.102	0.058	0.062	0.014	0.4192	0.5809	0.2988	Vendor 2	Vendor 1	Vendor 3	Same
Case 15	1	-4	-6	✓ 0.036	0.422	0.484	0.094	0.057	0.065	0.013	0.4182	0.5839	0.2978	Vendor 2	Vendor 1	Vendor 3	Same
Case 16	1	-4	-4	✓ 0.026	0.443	0.443	0.114	0.059	0.059	0.015	0.4202	0.5779	0.2998	Vendor 2	Vendor 1	Vendor 3	Same
Case 17	1	-5	-6	✓ 0.017	0.444	0.472	0.085	0.059	0.063	0.011	0.4202	0.5819	0.2958	Vendor 2	Vendor 1	Vendor 3	Same
Case 18	1	-5	-4	✓ 0.026	0.466	0.432	0.102	0.062	0.058	0.014	0.4232	0.5769	0.2988	Vendor 2	Vendor 1	Vendor 3	Same
Case 19	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.09	0.036	0.009	0.4512	0.5549	0.2938	Vendor 2	Vendor 1	Vendor 3	Same
Case 20	3	-3	-8	✓ 0.050	0.236	0.681	0.083	0.032	0.091	0.011	0.3932	0.6099	0.2958	Vendor 2	Vendor 1	Vendor 3	Same

From Table 10, it can be seen that, for the Quality of Service Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 1, -5, and -5, respectively. This score are compare between each vendor, in term of quality of service vendor 1 and 2 are equal quality while vendor 3 is less than both of them. For cases 1-18, the comparative scores were increased/decreased by at most one unit. Some scores may remain unchanged if at least one of other scores in that case was changed. For cases 19-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 11: Sensitivity analysis – security control criteria

Criteria :	**Security Control**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.134**	**Other Criteria Score**			**0.37740**	**0.53510**	**0.25250**				
	Score				Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	1	1	1	✓ 0.000	0.333	0.333	0.333	0.045	0.045	0.045	0.4224	0.5801	0.2975	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	-2	1	1	✗ 0.097													
Case 2	-2	-2	1	✗ 0.122													
Case 3	-2	-2	-2	✗ 0.222													
Case 4	-2	-2	2	✗ 0.222													
Case 5	-2	2	1	✗ 0.267													
Case 6	-2	2	-2	✗ 0.528													
Case 7	-2	2	2	✗ 0.222													
Case 8	1	-2	1	✗ 0.097													
Case 9	1	-2	-2	✗ 0.122													
Case 10	1	-2	2	✗ 0.267													
Case 11	1	2	1	✗ 0.097													
Case 12	1	2	-2	✗ 0.267													
Case 13	1	2	2	✗ 0.122													
Case 14	1	1	-2	✗ 0.097													
Case 15	1	1	2	✗ 0.097													
Case 16	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.061	0.061	0.012	0.4384	0.5961	0.2645	Vendor 2	Vendor 1	Vendor 3	Same
Case 17	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.09	0.036	0.009	0.4674	0.5711	0.2615	Vendor 2	Vendor 1	Vendor 3	Same
Case 18	-6	-9	1	✓ 0.022	0.785	0.115	0.100	0.105	0.015	0.013	0.4824	0.5501	0.2655	Vendor 1	Vendor 2	Vendor 3	Same
Case 19	3	9	5	✓ 0.050	0.072	0.177	0.751	0.01	0.024	0.101	0.3874	0.5591	0.3535	Vendor 2	Vendor 1	Vendor 3	Same
Case 20	1	-9	-5	✓ 0.043	0.511	0.419	0.07	0.068	0.056	0.009	0.4454	0.5911	0.2615	Vendor 2	Vendor 1	Vendor 3	Same

From Table 11, it can be seen that, for the Security Control Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 1, 1, and 1, respectively. This score are compare between each vendor, in term of security control vendor 1, 2 and 3 are equal quality. For cases 1-15, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring. For cases 16-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 12: Sensitivity analysis – process plan criteria

Criteria :	**Process Plan**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.1628**	**Other Criteria Score**			**0.3896**	**0.4615**	**0.2849**				
	Score				Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	4	-3	-9	✓ 0.041	0.199	0.726	0.075	0.032	0.118	0.012	0.4216	0.5795	0.2969	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	3	-3	-9	✓ 0.048	0.231	0.69	0.078	0.038	0.112	0.013	0.4276	0.5735	0.2979	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	3	-4	-9	✓ 0.041	0.251	0.679	0.07	0.041	0.111	0.011	0.4306	0.5725	0.2959	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	3	-4	-8	✗ 0.052													
Case 4	3	-2	-9	✗ 0.116													
Case 5	3	-2	-8	✗ 0.105													
Case 6	5	-3	-9	✗ 0.052													
Case 7	5	-4	-9	✗ 0.078													
Case 8	5	-4	-8	✗ 0.100													
Case 9	5	-2	-9	✗ 0.069													
Case 10	5	-2	-8	✗ 0.074													
Case 11	4	-4	-9	✗ 0.052													
Case 12	4	-2	-9	✗ 0.079													
Case 13	4	-4	-8	✗ 0.071													
Case 14	4	-2	-8	✗ 0.078													
Case 15	4	-4	-8	✗ 0.052													
Case 16	1	1	1	✓ 0.000	0.333	0.333	0.333	0.054	0.054	0.054	0.4436	0.5155	0.3389	Vendor 1	Vendor 2	Vendor 3	Same
Case 17	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.109	0.044	0.01	0.4986	0.5055	0.2949	Vendor 1	Vendor 2	Vendor 3	Same
Case 18	3	9	5	✓ 0.050	0.072	0.177	0.751	0.012	0.029	0.122	0.4016	0.4905	0.4069	Vendor 1	Vendor 2	Vendor 3	Same
Case 19	1	-9	-5	✓ 0.043	0.072	0.177	0.751	0.012	0.029	0.122	0.4016	0.4905	0.4069	Vendor 1	Vendor 2	Vendor 3	Same
Case 20	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.074	0.074	0.015	0.4636	0.5355	0.2999	Vendor 1	Vendor 2	Vendor 3	Same

From Table 12, it can be seen that, for the Process Plan Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 4, -3, and -9, respectively. This score are compare between each vendor, in term of process plan with quality vendor 2 has the better quality than vendor 1 while vendor 1 better vendor 3 respectively. For cases 1-15, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring. For cases 16-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 13: Sensitivity analysis – compliance with quality criteria

Criteria :	**Compliance with quality**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.1628**	**Other Criteria Score**			**0.3896**	**0.4615**	**0.2849**				
	Score				Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	4	-3	-9	✓ 0.041	0.199	0.726	0.075	0.032	0.118	0.012	0.4216	0.5795	0.2969	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	3	-3	-9	✓ 0.048	0.231	0.69	0.078	0.038	0.112	0.013	0.4276	0.5735	0.2979	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	3	-4	-9	✓ 0.041	0.251	0.679	0.07	0.041	0.111	0.011	0.4306	0.5725	0.2959	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	3	-4	-8	✗ 0.052													
Case 4	3	-2	-9	✗ 0.116													
Case 5	3	-2	-8	✗ 0.105													
Case 6	5	-3	-9	✗ 0.052													
Case 7	5	-4	-9	✗ 0.078													
Case 8	5	-4	-8	✗ 0.100													
Case 9	5	-2	-9	✗ 0.069													
Case 10	5	-2	-8	✗ 0.074													
Case 11	4	-4	-9	✗ 0.052													
Case 12	4	-2	-9	✗ 0.079													
Case 13	4	-4	-8	✗ 0.071													
Case 14	4	-2	-8	✗ 0.078													
Case 15	4	-4	-8	✗ 0.052													
Case 16	1	1	1	✓ 0.000	0.333	0.333	0.333	0.054	0.054	0.054	0.4436	0.5155	0.3389	Vendor 1	Vendor 2	Vendor 3	Same
Case 17	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.109	0.044	0.01	0.4986	0.5055	0.2949	Vendor 1	Vendor 2	Vendor 3	Same
Case 18	3	9	5	✓ 0.050	0.072	0.177	0.751	0.012	0.029	0.122	0.4016	0.4905	0.4069	Vendor 1	Vendor 2	Vendor 3	Same
Case 19	1	-9	-5	✓ 0.043	0.072	0.177	0.751	0.012	0.029	0.122	0.4016	0.4905	0.4069	Vendor 1	Vendor 2	Vendor 3	Same
Case 20	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.074	0.074	0.015	0.4636	0.5355	0.2999	Vendor 1	Vendor 2	Vendor 3	Same

From Table 13, it can be seen that, for the Compliance With Quality Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 4, -3, and -9, respectively. This score are compare between each vendor, in term of compliance with quality vendor 2 has the better quality than vendor 1 while vendor 1 better vendor 3 respectively. For cases 1-15, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring. For cases 16-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 14: Sensitivity analysis – safety plan criteria

Criteria :	**Safety plan**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.1628**	**Other Criteria Score**			**0.3678**	**0.5255**	**0.2429**				
	Score				Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	1	1	1	✓ 0.000	0.333	0.333	0.333	0.054	0.054	0.054	0.4218	0.5795	0.2969	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	-2	1	1	✗ 0.097							0.3678	0.5255	0.2429	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	-2	-2	1	✗ 0.122							0.3678	0.5255	0.2429	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	-2	-2	-2	✗ 0.222													
Case 4	-2	-2	2	✗ 0.222													
Case 5	-2	2	1	✗ 0.267													
Case 6	-2	2	-2	✗ 0.528													
Case 7	-2	2	2	✗ 0.222													
Case 8	1	-2	1	✗ 0.097													
Case 9	1	-2	-2	✗ 0.122													
Case 10	1	-2	2	✗ 0.267													
Case 11	1	2	1	✗ 0.097													
Case 12	1	2	-2	✗ 0.267													
Case 13	1	2	2	✗ 0.122													
Case 14	1	1	-2	✗ 0.097													
Case 15	1	1	2	✗ 0.097													
Case 16	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.074	0.074	0.015	0.4418	0.5995	0.2579	Vendor 2	Vendor 1	Vendor 3	Same
Case 17	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.109	0.044	0.01	0.4768	0.5695	0.2529	Vendor 2	Vendor 1	Vendor 3	Same
Case 18	-6	-9	1	✓ 0.022	0.785	0.115	0.100	0.128	0.019	0.016	0.4958	0.5445	0.2589	Vendor 2	Vendor 1	Vendor 3	Same
Case 19	3	9	5	✓ 0.050	0.072	0.177	0.751	0.012	0.029	0.122	0.3798	0.5545	0.3649	Vendor 2	Vendor 1	Vendor 3	Same
Case 20	1	-9	-5	✓ 0.043	0.511	0.419	0.07	0.083	0.068	0.011	0.4508	0.5935	0.2539	Vendor 2	Vendor 1	Vendor 3	Same

From Table 14, it can be seen that, for the Safety Plan Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 1, 1, and 1, respectively. This score are compare between each vendor, in term of safety plan vendor 1, 2 and 3 are equal quality. For cases 1-15, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring. For cases 16-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 15: Sensitivity analysis – safety plan criteria

Criteria :	**Technical Capability**																	
		CR Score	**<=**		**0.05**	**Criteria Weight**		**0.0548**	**Other Criteria Score**			**0.4161**	**0.5364**	**0.2915**				
	Score					Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score		Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	7	1	-8	✓	0.009	0.107	0.789	0.103	0.006	0.043	0.006	0.4221	0.5794	0.2975	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	6	1	-8	✓	0.017	0.117	0.776	0.106	0.006	0.043	0.006	0.4221	0.5794	0.2975	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	6	-2	-8	✗	0.079							0.4161	0.5364	0.2915	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	6	-2	-9	✗	0.069													
Case 4	6	-2	-7	✗	0.090													
Case 5	6	2	-8	✗	0.147													
Case 6	6	2	-9	✗	0.167													
Case 7	6	2	-7	✗	0.126													
Case 8	8	1	-8	✓	0.007	0.100	0.801	0.100	0.005	0.044	0.005	0.4211	0.5804	0.2965	Vendor 2	Vendor 1	Vendor 3	Same
Case 9	8	-2	-8	✗	0.102													
Case 10	8	-2	-9	✗	0.086													
Case 11	8	-2	-7	✗	0.121													
Case 12	8	2	-8	✗	0.102													
Case 13	8	2	-9	✗	0.116													
Case 14	8	2	-7	✗	0.090													
Case 15	7	2	-8	✗	0.090													
Case 16	7	2	-9	✗	0.076													
Case 17	7	2	-7	✗	0.103													
Case 18	7	2	-8	✗	0.121													
Case 19	7	2	-9	✗	0.136													
Case 20	7	2	-7	✗	0.103													

From Table 15, it can be seen that, for the Technical Capability Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 7, 1, and -8, respectively. This score are compare between each vendor, in term of technical capability vendor 2 has the better quality than vendor 1 and 3 while vendor 1 and 3 have the same quality. For cases 1-20, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring but Some scores may remain unchanged if at least one of other scores in that case was changed. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 16: Sensitivity analysis – performance history criteria

Criteria :	**Performance history**																
		CR Score	**<=**		**0.05**	**Criteria Weight**		**0.0092**	**Other Criteria Score**			**0.4157**	**0.5783**	**0.2956**			
	Score					Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score		Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	-5	-4	1	✓	0.026	0.691	0.149	0.160	0.006	0.001	0.001	0.4217	0.5793	0.2966	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	-6	-4	1	✓	0.036	0.710	0.135	0.155	0.006	0.001	0.001	0.4217	0.5793	0.2966	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	-6	-5	1	✓	0.017	0.732	0.13	0.138	0.007	0.001	0.001	0.4227	0.5793	0.2966	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	-6	-5	-2	✗	0.136													
Case 4	-6	-5	2	✗	0.091													
Case 5	-6	-3	1	✗	0.081													
Case 6	-6	-3	-2	✗	0.267													
Case 7	-6	-3	2	✗	0.091													
Case 8	-4	-4	1	✓	0.026	0.667	0.167	0.167	0.006	0.002	0.002	0.4217	0.5803	0.2976	Vendor 2	Vendor 1	Vendor 3	Same
Case 9	-4	-5	1	✓	0.026	0.691	0.16	0.149	0.006	0.001	0.001	0.4217	0.5793	0.2966	Vendor 2	Vendor 1	Vendor 3	Same
Case 10	-4	-5	-2	✗	0.095													
Case 11	-4	-5	2	✗	0.150													
Case 12	-4	-3	1	✓	0.047	0.633	0.174	0.193	0.006	0.002	0.002	0.4217	0.5803	0.2976	Vendor 2	Vendor 1	Vendor 3	Same
Case 13	-4	-3	-2	✗	0.179													
Case 14	-4	-3	2	✗	0.105													
Case 15	-5	-5	1	✓	0.016	0.714	0.143	0.143	0.007	0.001	0.001	0.4227	0.5793	0.2966	Vendor 2	Vendor 1	Vendor 3	Same
Case 16	-5	-5	-2	✗	0.112													
Case 17	-5	-5	2	✗	0.112													
Case 18	-5	-3	1	✗	0.060													
Case 19	-5	-3	-2	✗	0.222													
Case 20	-5	-3	2	✗	0.093													

From Table 16, it can be seen that, for the Performance History Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are -5, -4, and 1, respectively. This score are compare between each vendor, in term of technical capability vendor 1 has the better quality than vendor 2 and 3 while vendor 2 and 3 have the same quality. For cases 1-20, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring but Some scores may remain unchanged if at least one of other scores in that case was changed. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

Table 17: Sensitivity analysis – customer reference criteria

Criteria :	**Customer reference**																
		CR Score	**<=**	**0.05**	**Criteria Weight**		**0.0520**	**Other Criteria Score**			**0.4047**	**0.5624**	**0.2798**				
Score					Quality of service			Score			Sum score			Rank			Result
	Pair 1-2	Pair 1-3	Pair 2-3	CR Score	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	Vendor 1	Vendor 2	Vendor 3	1	2	3	
Original Score	1	1	1	✓ 0.000	0.333	0.333	0.333	0.017	0.017	0.017	0.4217	0.5794	0.2968	Vendor 2	Vendor 1	Vendor 3	Original
Case 1	-2	1	1	✗ 0.097							0.4047	0.562	0.2798	Vendor 2	Vendor 1	Vendor 3	Same
Case 2	-2	-2	1	✗ 0.122							0.4047	0.562	0.2798	Vendor 2	Vendor 1	Vendor 3	Same
Case 3	-2	-2	-2	✗ 0.222													
Case 4	-2	-2	2	✗ 0.222													
Case 5	-2	2	1	✗ 0.267													
Case 6	-2	2	-2	✗ 0.528													
Case 7	-2	2	2	✗ 0.222													
Case 8	1	-2	1	✗ 0.097													
Case 9	1	-2	-2	✗ 0.122													
Case 10	1	-2	2	✗ 0.267													
Case 11	1	2	1	✗ 0.097													
Case 12	1	2	-2	✗ 0.267													
Case 13	1	2	2	✗ 0.122													
Case 14	1	1	-2	✗ 0.097													
Case 15	1	1	2	✗ 0.097													
Case 16	1	-5	-5	✓ 0.016	0.454	0.454	0.092	0.024	0.024	0.005	0.4287	0.5864	0.2848	Vendor 2	Vendor 1	Vendor 3	Same
Case 17	-3	-9	-5	✓ 0.049	0.669	0.268	0.064	0.035	0.014	0.003	0.4397	0.5764	0.2828	Vendor 2	Vendor 1	Vendor 3	Same
Case 18	-6	-9	1	✓ 0.022	0.785	0.115	0.100	0.041	0.006	0.005	0.4457	0.5684	0.2848	Vendor 2	Vendor 1	Vendor 3	Same
Case 19	3	9	5	✓ 0.050	0.072	0.177	0.751	0.004	0.009	0.039	0.4087	0.5714	0.3188	Vendor 2	Vendor 1	Vendor 3	Same
Case 20	1	-9	-5	✓ 0.043	0.511	0.419	0.07	0.027	0.022	0.004	0.4317	0.5844	0.2838	Vendor 2	Vendor 1	Vendor 3	Same

From Table 17, it can be seen that, for the Customer Reference Criteria, the Original Scores, which are the comparative scores between vendors 1 and 2, vendors 1 and 3, and vendors 2 and 3, currently are 1, 1, and 1, respectively. This score are compare between each vendor, in term of safety plan vendor 1, 2 and 3 are equal quality. For cases 1-15, the comparative scores were increased/decreased by at most one unit. The score do not pass consistency ratio so the evaluator have to re-scoring. For cases 16-20, the scores were significantly changed from the current ones. The purpose of doing this is to see how sensitive the results are if the scores do deviate far off from the original ones.

The sensitivity analysis results show that if we changed the criteria case by case, it would not affect to the result. But if the supplier performance changed, the evaluated score would change and it will change the result.

9. Software Test

The FAHP-based Vendor Selection Software must be evaluated with the company real case study. In this thesis, we decided to compare the result of selecting vendors using PPR method and the FAHP-based Vendor Selection Software. The test was administered by the procurement department of the bank. Three procurement cases were tested as follows:

1. Fire Door & Barrier For Stairways And Fireman's Lift Lobbies Renovation
2. Data Entry Management
3. Learning Center Renovation

8.1) Test 1: Renovated Fire Door & Barrier for Stairways and Fireman's Lift Lobbies

The fire door & barrier for stairways and fireman’s lift lobbies renovation is the project responsible by the building team. The scope of work is to replace new doors with fire-alarm system include test-run the system. They have 3 offers from 3 vendors for this project: Vendor 1, Vendor 2, and Vendor3. The criteria score weighting using PPR method is Team Experience- 20%, Safety- 20%, Specification-

40%, Company Profile & Customer Reference- 10%, Performance Rating- 10% and Extra point- 10%. The total offer prices of these 3 vendors are 310 million Baht, 302 million Baht and 305 million Baht respectively. With the PPR method, vendor1 was selected and their performance was satisfactory. In comparison, FAHP-based Vendor Selection Software criteria is more elaborate and specific. The criteria selected are shown in Figure 40 which is Total Cost, Quality of Service, Quality of Product, Security Control, Process Plan, Compliance with Quality, Safety Plan, Technical Capability, Performance History, Company Profile and Customer Reference.

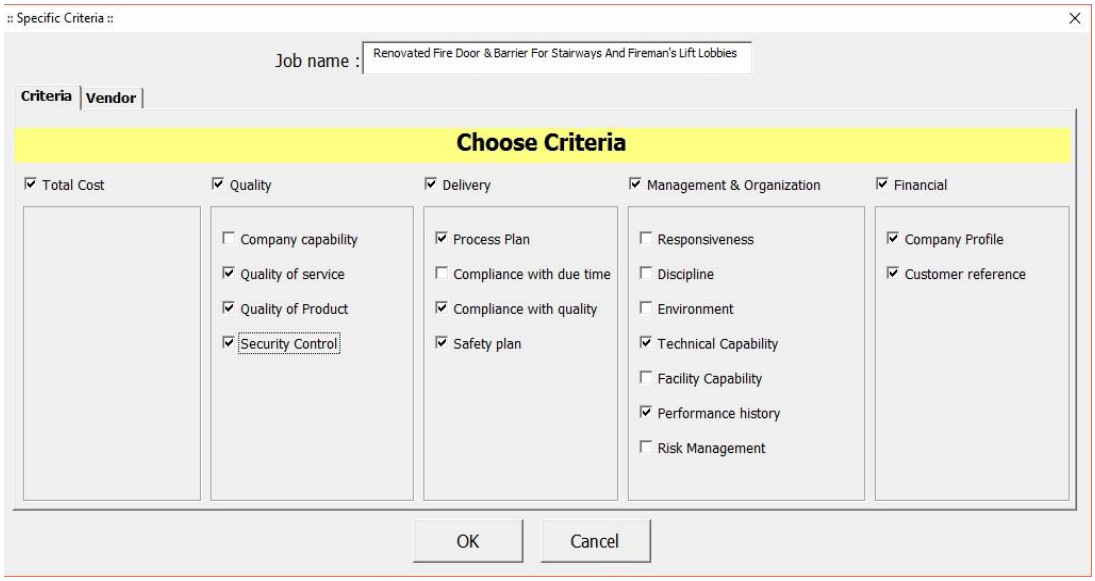

Figure 40: Case study renovated fire door & Barrier for Stairways and Fireman's Lift Lobbies criteria from excel programming.

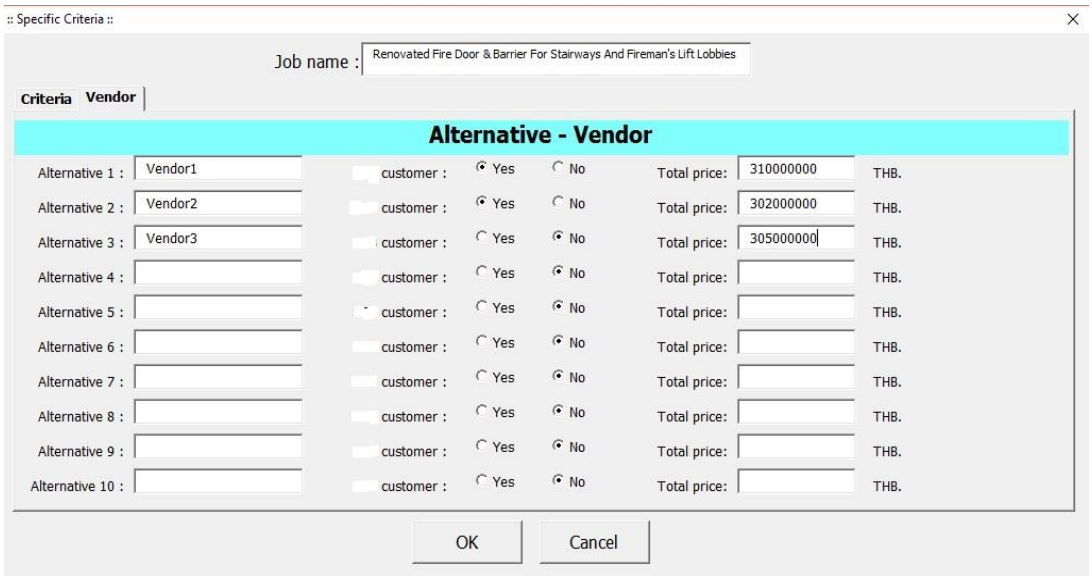

Figure 41: Case study renovated fire door & Barrier for Stairways and Fireman's Lift Lobbies information input from excel programming.

After calculating in the excel programming, the criteria score weighting is Total cost 25%, Quality 35%, Delivery 28%, Management &Organization 7%, Financial 5% and Extra point 10%. The FAHP-based Vendor Selection Software also suggest choosing Vendor 1 who has the best score for this project as shown in Figure 42: Case study fire door & Barrier for Stairways and Fireman's Lift Lobbies Renovation summary from excel programming. and Figure 43: Case study fire door & Barrier for Stairways and Fireman's Lift Lobbies Renovation scoring detail from excel programming.. The result from the program is aligned with PPR ratio.

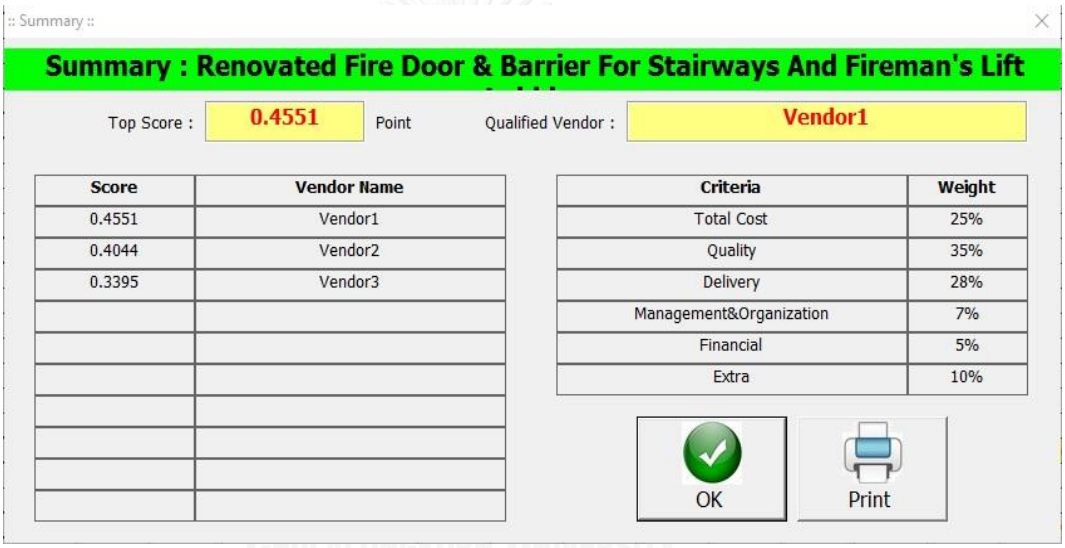

Figure 42: Case study fire door & Barrier for Stairways and Fireman's Lift Lobbies Renovation summary from excel programming.

		Vendor 1	Vendor 2	Vendor 3		Score Vendor 1	Score Vendor 2	Score Vendor 3
Total Cost	0.2470	0.333	0.333	0.333		0.0823	0.0823	0.0823
Company capability	0.0000	0	0	0		0	0	0
Quality of service	0.1159	0.167	0.667	0.167		0.0194	0.0773	0.0194
Quality of Product	0.1159	0.742	0.181	0.076		0.086	0.021	0.0088
Security Control	0.1159	0.209	0.085	0.705		0.0242	0.0099	0.0817
Process Plan	0.2096	0.333	0.333	0.333		0.0698	0.0698	0.0698
Compliance with due time	0.0000	0	0	0		0	0	0
Compliance with quality	0.0000	0	0	0		0	0	0
Safety plan	0.0714	0.181	0.076	0.742		0.0129	0.0054	0.053
Responsiveness	0.0000	0	0	0		0	0	0
Discipline	0.0000	0	0	0		0	0	0
Environment	0.0000	0	0	0		0	0	0
Technical Capability	0.0104	0.751	0.177	0.072		0.0078	0.0018	0.0008
Facility Capability	0.0000	0	0	0		0	0	0
Performance history	0.0626	0.333	0.333	0.333		0.0208	0.0208	0.0208
Risk Management	0.0000	0	0	0		0	0	0
Company Profile	0.0130	0.571	0.373	0.057		0.0074	0.0048	0.0007
Customer reference	0.0380	0.643	0.298	0.058		0.0245	0.0113	0.0022
Extra	0.1000	1	1	0		0.1	0.1	0
						0	0	0
	1.0997	5.2630	3.8560	2.8760		0.4551	0.4044	0.3395

Figure 43: Case study fire door & Barrier for Stairways and Fireman's Lift Lobbies Renovation scoring detail from excel programming.

8.2) Test 2: Data Entry Management

The Data Entry Management is the project of building team. The scope of work is to managed resources who response for input the data of clients for loan department in the bank with 3 years contract. They have 3 offers from 3 vendors for this project: Vendor W, Vendor X, and Vendor Y. The criteria score weighting using PPR method is Service& Support- 45%, Company Profile- 30%, Security Control - 25 and Extra point- 10%. The total offer prices of these 3 vendors are 190 million Baht, 200 million Baht and 210 million Baht respectively. With the PPR method, vendor X was selected and their performance was satisfactory. In comparison, The FAHP-based Vendor Selection Software criterion is more elaborate and specific. The criteria selected are shown in Figure 44 which is Total Cost, Quality of Service, Quality of Product, Security Control and Company Profile.

Figure 44: Case study Data Entry Management criteria from excel programming.

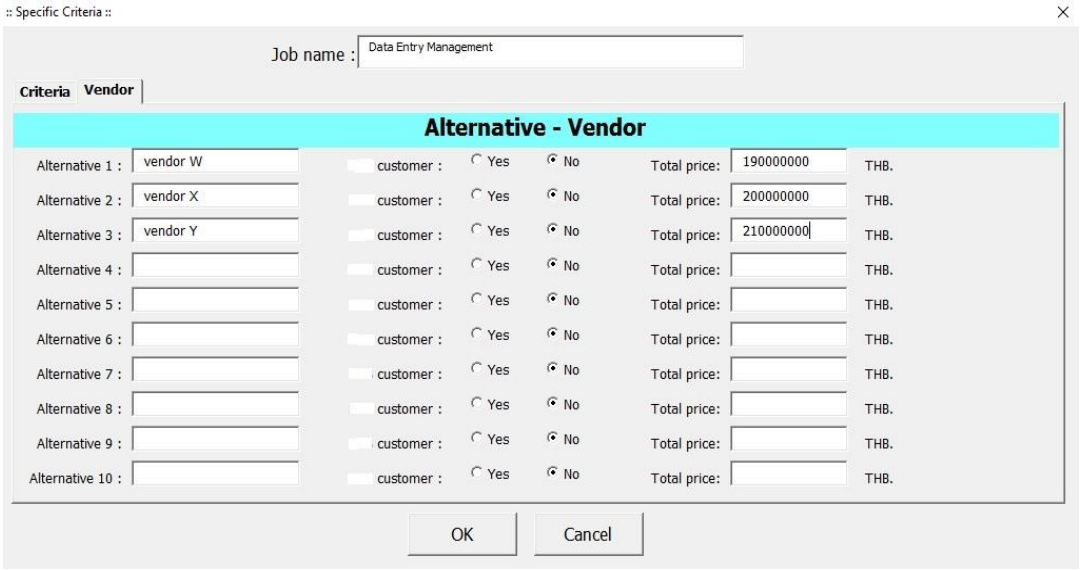

Figure 45: Case study Data Entry Management information input from excel programming.

After calculating in The FAHP-based Vendor Selection Software, the criteria score weighting is Total cost- 66%, Quality- 26%, Financial- 8% and Extra point- 10%. The FAHP-based Vendor Selection Software suggest choosing vendor X who has the best score for this project as shown in Figure 46: Case study Data Entry Management summary from excel programming. and Figure 47: Case study Data Entry Management scoring detail from excel programming. The result from the program difference from the PPR ratio due to weighted criteria are not the same. The result from the new

program suggests Vendor X to be selected on the project as it has the best score from the new set of criteria. The differences on set of criteria have impact on the selected vendor. The new set of criteria has only 66% on weight of "total cost" instead of 100% from PPR ratio. As we reduce importance of "Total cost", we allocate weight to other criteria such as quality, financial etc. to be better match with each project requirement.

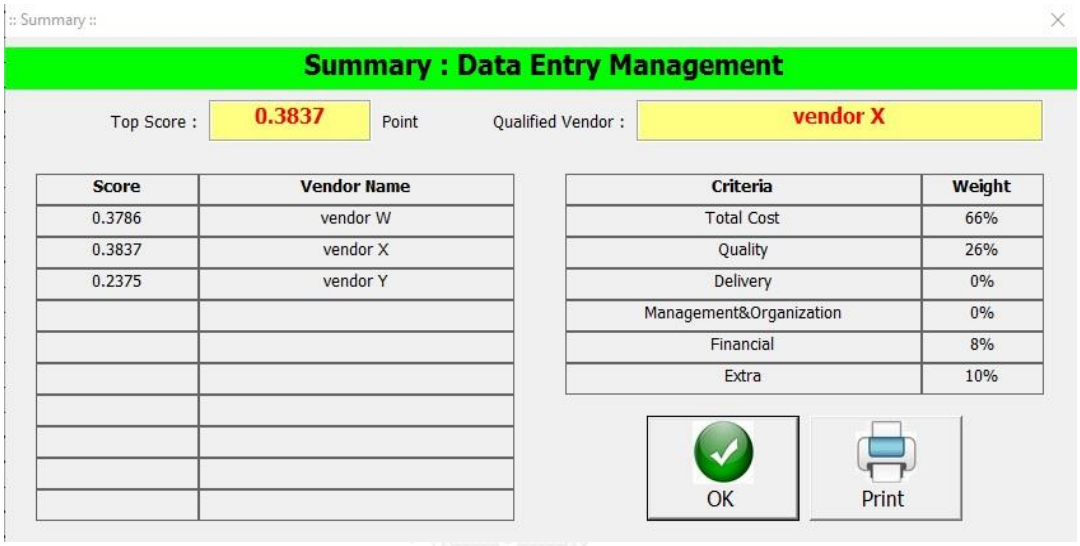

Figure 46: Case study Data Entry Management summary from excel programming.

		Vendor 1	Vendor 2	Vendor 3		Score Vendor 1	Score Vendor 2	Score Vendor 3
Total Cost	0.6580	0.404	0.326	0.27		0.2658	0.2145	0.1777
Company capability	0.0000	0	0	0		0	0	0
Quality of service	0.1120	0.257	0.637	0.106		0.0288	0.0714	0.0119
Quality of Product	0.1120	0.257	0.637	0.106		0.0288	0.0714	0.0119
Security Control	0.0387	0.333	0.333	0.333		0.0129	0.0129	0.0129
Process Plan	0.0000	0	0	0		0	0	0
Compliance with due time	0.0000	0	0	0		0	0	0
Compliance with quality	0.0000	0	0	0		0	0	0
Safety plan	0.0000	0	0	0		0	0	0
Responsiveness	0.0000	0	0	0		0	0	0
Discipline	0.0000	0	0	0		0	0	0
Environment	0.0000	0	0	0		0	0	0
Technical Capability	0.0000	0	0	0		0	0	0
Facility Capability	0.0000	0	0	0		0	0	0
Performance history	0.0000	0	0	0		0	0	0
Risk Management	0.0000	0	0	0		0	0	0
Company Profile	0.0790	0.536	0.171	0.293		0.0423	0.0135	0.0231
Customer reference	0.0000	0	0	0		0	0	0
Extra	0.1000	0	0	0		0	0	0
						0	0	0
	1.0997	1.7870	2.1040	1.1080		0.3786	0.3837	0.2375

Figure 47: Case study Data Entry Management scoring detail from excel programming.

8.3) Test 3: Learning Center Renovation.

The Learning Center Renovation is the project of building team. The scope of work is to renovate learning center with interior decoration work and system work or Mechanical, Electrical, Plumbing (MEP). They have 10 offers from 10 vendors for this project: vendor1, vendor2, vendor3, vendor4, vendor5, vendor6, vendor7, vendor8, vendor9 and vendor 10. But in this case, vendor8 does not meet the requirement for technical support. So they would not allow to award this vendor. The criteria score weighting using PPR method is Team Experience- 30%, Safety- 30%, Performance Rating- 40% and Extra point- 10%. The total offer prices of these 10 vendors are between 20 – 26 million Baht. With the PPR method, vendor 7 was selected and their performance was not satisfactory. In comparison, The FAHP-based Vendor Selection Software criterion is more elaborate and specific. The criteria selected are shown in Figure 48 which are Total Cost, Quality of Service, Quality of Product, Security Control, Process Plan, Compliance with Quality, Safety Plan, Technical Capability, Performance History, Company Profile, and Customer Reference.

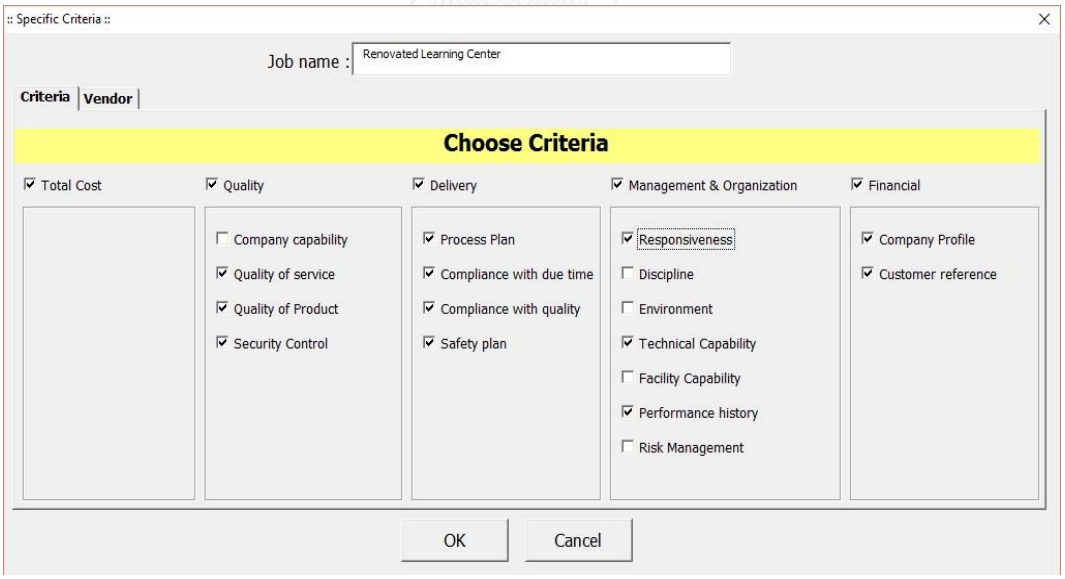

Figure 48: Case study Learning Center Renovation criteria from excel programming

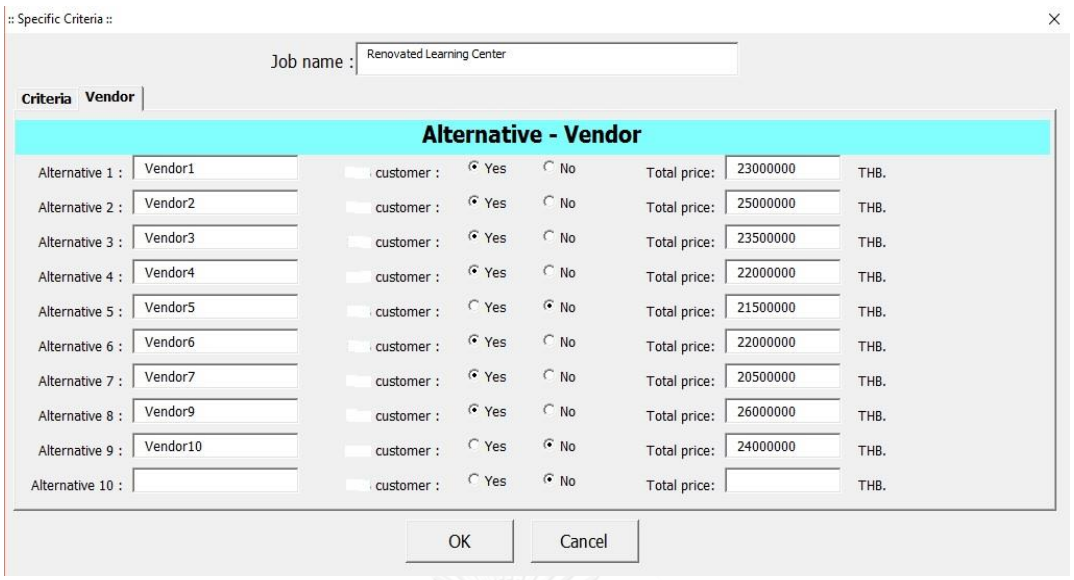

Figure 49: Case study Learning Center Renovation information input from excel programming.

After calculating in The FAHP-based Vendor Selection Software, the criteria score weighting is Total cost- 12%, Quality- 50%, Delivery- 27%, Management & Organization- 6%, Financial- 5% and Extra point- 10%. The excel programming suggest choosing vendor 1 who has the best score for this project as shown in Figure 50: Case study Learning Center Renovation summary from excel programming.. The result from the program is different from the result from the PPR ratio method due to weighted criteria are not the same. The result from the new program suggests Vendor 1 to be selected on the project as it has the best score from the new set of criteria. The differences on set of criteria have impact on the selected vendor. The new set of criteria has only 12% on weight of "total cost" instead of 100% from PPR ratio. As we reduce importance of "Total cost", we allocate weight to other criteria such as quality, delivery, Management& Organization, financial etc. to be better match with each project requirement

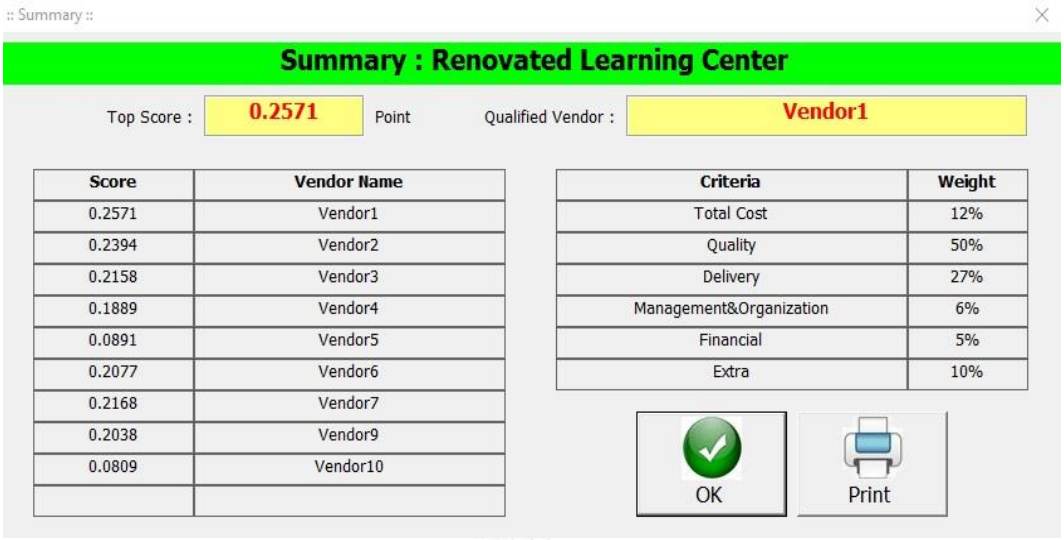

Figure 50: Case study Learning Center Renovation summary from excel programming.

8.4) Limitations of The FAHP-based Vendor Selection Software

The FAHP-based Vendor Selection Software can be improved as follows:

1. The calculation in excel programming can be improved by using multiple evaluators. The calculation method of "multiple evaluators" is described in fuzzy theory part. By using multiple evaluators will reflect more reliable Fuzzy score resulting in the model will be more reliable.

2. This thesis tried to standardize the selecting criteria because one of the bank's requirements is that the model should be able to implement to all types of purchasing. However, each purchasing requires difference set of selection criteria. Therefore, the result can be improved by preparing back-up sheet for scoring-criteria that they selected or developing another program to make sub-sub criteria flexible.

10. Summary

The FAHP-based Vendor Selection Software is alternative tool for commercial bank due to dramatically increase in competition in the commercial banking industry, the banks have to adapt themselves to survive and be able to compete in the market. The Fuzzy Analytical Hierarchy Process (FAHP) encompasses both qualitative and quantitative components that will seek for the most suitable supplier for the task.

Fuzzy in the term FAHP represents the uncertain element in the process of quantifying the decision factors that are usually qualitative. These factors include quality, delivery, management policy and etc. With this feature, the procurement department of the bank can evaluate supplier solicit preferences of those qualitative decision factors from the buyer and interpret them to quantitative measures with more accuracy. This program gives opportunity for non-experience employee to perform as an experience one and will support all general criterions which are prioritize by expert procurement team. With support of program, new employee can reduce training time and increase efficiency because the program will provide default criterion and template as a time saver.

From case study, the result showed that supplier with the lowest price was not necessarily chosen. The result from the program shows that the higher price supplier with better performance can also win the task. Based on our case, the criteria weighted of total cost, quality, delivery time, management & organization, financial criteria, and extra bonus are 13%, 27%, 47%, 6%, 5%, and 10% respectively. This procurement values delivery time and quality the most. Due to these factors, supplier B has the best score with 0.5797 and supplier A and c with score 0.4220 and 0.2971 respectively. Therefore, the evaluation result suggests that supplier B should win the task with the highest score of 0.5797, despite its highest price at 34 million baths. While supplier A, which has the lowest price, does not win the task due to its lower performance in other criteria.

To be more confident with the result, we develop the sensitivity analysis with bank procurement department and it was implemented to identify the effect of human judgment. The sensitivity analysis results from the study showed that even if the input scores have some small incremental changed, the result remains unchanged.

In conclusion, we have tested the tools together with the sensitivity analysis with the case study bank procurement department. The results are satisfied as it allows the department to have better decisions, improve the selected supplier, easy for staffs to use, etc.

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APPENDIX

Example of the evaluation sheet

Description	BRAND	Vendor1		Vendor2		Vendor3	
	Full Score	Score	Weight	Score	Weight	Score	Weight
1. Team Experience (Weight 20%)	**110.00**	**100.00**	**18.18%**	**96.00**	**17.45%**	**68.00**	**12.36%**
1.1 บุคลากรภายในบริษัท							
1.1.1 จำนวนบุคลากรรวมของบริษัท สำหรับการติดตั้งประตูทนไฟ	For Reference	83 Persons		30 Persons		30 Persons	
1.2 จำนวนบุคลากรสำหรับการผลิตและติดตั้ง							
1.2.1 Project Manager	10.00	8.00	8.00%	10.00	10.00%	8.00	8.00%
		1 Person		2 Persons		1 Person	
1.2.1.1 ประสบการณ์การทำงาน (ปี)	10.00	10.00	10.00%	10.00	10.00%	10.00	10.00%
1.2.2 หัวหน้าควบคุมงาน	10.00	10.00	10.00%	10.00	10.00%	6.00	6.00%
		3 Persons		1 Person		1 Person	
1.2.2.1 ประสบการณ์การทำงาน (ปี)	10.00	10.00	10.00%	10.00	10.00%	6.00	6.00%
		16 / 30 / 8 Years		19 Years		2 Years	
1.2.3 จำนวนเจ้าหน้าที่ความปลอดภัย (Safety) (จป. เทคนิค)	10.00	8.00	8.00%	8.00	8.00%	8.00	8.00%
		1 Person		1 Person		1 Person	
1.2.3.1 ประสบการณ์การทำงาน (ปี)	10.00	10.00	10.00%	10.00	10.00%	4.00	4.00%
		16 Years		1 Year		1 Year	
1.2.4 จำนวนเจ้าหน้าที่ความปลอดภัย (Safety) (จป. วิชาชีพ สำหรับงานความเสี่ยงสูง)	10.00	8.00	8.00%	8.00	8.00%	0.00	0.00%
		1 Person		1 Person		N/A	
1.2.4.1 ประสบการณ์การทำงาน (ปี)	10.00	10.00	10.00%	4.00	4.00%	0.00	0.00%
		30 Years		1 Year		N/A	
1.2.5 Maximum worker (สำหรับโครงการนี้)		60 Persons		24 Persons		30 Persons	
1.3 การรับประกัน	10.00	8.00	8.00%	10.00	10.00%	8.00	8.00%
		2 Years		Install 2 Years, Material 5 Years		2 Years	
1.4 SLA (service level agreement) ในการดำเนินการแก้ไข กรณี บานประตู, Hardware หรืออุปกรณ์อื่นๆ มีปัญหา หรือ กรณีที่การติดตั้งเกิดชำรุดหลังการติดตั้ง (ในระยะเวลารับประกัน)	10.00	10.00	10.00%	8.00	8.00%	10.00	10.00%
		24 Hrs.		24 – 48 Hrs.		24 Hrs.	
1.5 ระยะเวลาดำเนินการ ทั้งโครงการ	10.00	8.00	8.00%	8.00	8.00%	8.00	8.00%
2. Safety (Weight 20%)	**100.00**	**26.00**	**5.20%**	**16.00**	**3.20%**	**66.00**	**13.20%**
2.1 Safety Record Accident Frequency rate	10.00	0.00	0.00%	0.00	0.00%	0.00	0.00%
		Year 2013, 2014, 2015 = 0 / No Document support		Year 2013, 2014, 2015 = 0 / No Document support		No Safety Record	
2.2 Have a policy statement for safety and health?	10.00	0.00	0.00%	0.00	0.00%	10.00	10.00%
		No Document support		No Document support		Have	
2.3 Appoint a designated Safety Officer(s)/safety and health	10.00	8.00	8.00%	8.00	8.00%	8.00	8.00%
		Yes = 1 Item		Yes = 1 Item		Yes = 1 Item	
2.4 Have the safety officers registered in Company as regulation required. (Professional, Adv. Technical, Advance, Supervisor, Management)	10.00	10.00	10.00%	0.00	0.00%	10.00	10.00%
		Have		No / No Document support		Have	
2.5 Have the written procedures of safe working, e.g., scaffolding, crane usage?	10.00	8.00	8.00%	8.00	8.00%	8.00	8.00%
		Yes, base on Owner		Yes, base on Owner		Yes, base on Owner	
2.6 Senior management periodically inspect safety, health and environment of work-sites?	10.00	0.00	0.00%	0.00	0.00%	0.00	0.00%
		No / No Document support		No / No Document support		No	
2.7 Have annual plan / objectives about safety, health and environment?	10.00	0.00	0.00%	0.00	0.00%	10.00	10.00%
		No / No Document support		No / No Document support		Yes	
2.8 Provide a safety, health and environment induction training for employees?	10.00	0.00	0.00%	0.00	0.00%	0.00	0.00%
		No / No Document support		No / No Document support		No training record	
2.9 Have the inspection program for your machine, equipments, and tools?	10.00	0.00	0.00%	0.00	0.00%	10.00	10.00%
		No / No Document support		No / No Document support		Yes	
2.10 Have the procedure for reporting, investigating the accidents / incidents?	10.00	0.00	0.00%	0.00	0.00%	10.00	10.00%
		No / No Document support		No / No Document support		Yes	
3. Specification (Weight 40%)	**50.00**	**50.00**	**40.00%**	**44.00**	**35.20%**	**26.00**	**20.80%**
3.1 Brand ประตูทนไฟ		**CLASSIC STEEL**		**SPR**		**Diamond Door**	
3.1.1 การทดสอบมาตรฐานที่ได้รับสำหรับประตูทนไฟ กรณีที่มีหนังสือผลการทดสอบมาตรฐาน (โปรดระบุ UL 10C หรือ BS 476 Part 20 and 22, ระบุขนาดประตู และปีที่ได้รับหนังสือรับรอง)	10.00	10.00	10.00%	10.00	10.00%	8.00	8.00%
		UL 10C		UL 10C / BS476		BS476	
3.1.2 ขนาดที่ได้รับการรับรอง (ครอบคลุม ขนาดที่ทางธนาคารต้องการ)		> 3 Sizes		> 3 Sizes		1 Size	
3.1.3 วัน เดือน ปี ที่ได้รับการรับรอง		Certificate issued < 3 Years		Certificate issued < 3 Years		Certificate issued > 3 Years	

3.2 วัสดุ และอุปกรณ์ที่นำเสนอสำหรับโครงการนี้							
3.2.1 อัตราการทนไฟ หมายความรวมถึง คุณสมบัติทนไฟ Integrity (อัตราการทนไฟ 2 ชั่วโมง) และคุณสมบัติ ความเป็นฉนวน Insulation (ไม่น้อยกว่า 30 นาที) ไม่น้อยกว่าที่กำหนด	10.00	10.00	10.00%	6.00	6.00%	10.00	10.00%
		ทนไฟ 3 ชั่วโมง / Insulation 30 นาที		2 Hr for Door+panel and 3 Hr. for Door Insulation 12 – 45 minutes (varies by size)		ทนไฟ 4 Hr. / Insulation 31 – 33 minute	
3.2.2 Self Closing Device หรือ Door Closer ต้องเป็น ชนิด Concealed Type, Heavy or Extra Duty และ Hydraulically Controlled Operation With Adjustable Force Port เหมาะกับ วัสดุที่ทำเป็นบานประตู และลักษณะการใช้งานเช่น ปกติเปิดค้าง รวมถึง ขนาดและน้ำหนักบานประตู โดยให้ ติดตั้งด้านปลอดภัย และสามารถปิดได้ไม่น้อยกว่า 90 องศา หรือไม่น้อยกว่า 180 องศา หรือขนาด มม การเปิดบานประตู ที่กำหนด ไม่ยอมให้ใช้ชนิดแบบที่สามารถเปิดค้าง (Non-Hold Open Feature)	10.00	10.00	10.00%	10.00	10.00%	0.00	0.00%
		Door Closer เป็นชนิด Surface Mounting เนื่องจากประตูทนไฟไม่สามารถเปลี่ยนแปลงโครงสร้างสำหรับติด Door Closer ชนิด Concealed Type ซึ่งต้องเจาะช่องประตูสำหรับฝังในบาน)		Mortise lock / UL		No submitted information	
3.2.3 ประตูทนไฟที่มีอัตราการทนไฟไม่เกิน 2 ชั่วโมง ยอมให้มีช่องมองผ่านประตูได้ (Vision Panel) ช่องมองผ่านต้องทำด้วยกระจกเสริมเส้นลวดโลหะ (Wire Glass) โดยมีขนาดไม่เกินตามมาตรฐานการผลิตที่ได้รับการรับรองจาก มาตรฐานที่กำหนด	10.00	10.00	10.00%	8.00	8.00%	8.00	8.00%
		Comply / ทนไฟ เกิน 2 ชั่วโมง / กระจก UL / 45-60 min		ทนไฟ 2 hr บาน+กระจก / BS		กระจกทนความร้อน 1000C ช่องกระจก 20*70 cm BS 476 จากจฬฟ้า	
3.2.4 บาร์ผลักที่ใช้กับประตูทนไฟ ต้องเป็นชนิด Fire Exit Hardware พร้อมติด Label Rating ที่บาร์ผลักที่มีการทดสอบตามมาตรฐาน UL 10C ไม่น้อยกว่าอัตราการทนไฟของประตูทนไฟที่ติดตั้ง กรณีเป็นบานคู่ต้องติดตั้งบาร์ผลัก ทั้งสองบาน หรือกำหนดเป็นอย่างอื่นในแบบ และต้องเป็นชนิด Top and Bottom Vertical Rod ทั้งสองบาน	10.00	10.00	10.00%	10.00	10.00%	0.00	0.00%
		Exit hardware : UL 3 hr		Exit hardware : UL		คานผลัก และ lever เป็น Max star : No Certificate	
4. Company Profile & Customer Reference (V	**40.00**	**40.00**	**10.00%**	**38.00**	**9.50%**	**18.00**	**4.50%**
4.1 Company Profile							
4.1.1 จำนวนปีที่ดำเนินธุรกิจ	10.00	10.00	10.00%	10.00	10.00%	10.00	10.00%
4.1.2 ทุนที่ชำระแล้ว	10.00	10.00	10.00%	10.00	10.00%	4.00	4.00%
		WORK PATH = 7.5 MB		CHOKRUNGREUNG = 5 MB		FASTTECH = 5 MB	
		PCJ = 50 MB		SPR = 50 MB		DIAMOND DOOR = 4 MB	
4.2 Customer Reference							
4.2.1 ผลงานที่ผ่านมาในระยะเวลา 5 ปี เฉพาะที่เกี่ยวข้องกับประตูทนไฟ (ระบุจำนวนผลงาน พร้อมกรอกรายละเอียด list รายชื่อผลงานใน sheet Ref)		มากกว่า 100 โครงการ		30 Projects		176 Projects	
4.2.2 มูลค่างานรวม 5 ปี ที่ เฉพาะที่เกี่ยวข้องกับประตูทนไฟ (ระบุมูลค่ารวมผลงานทั้งหมด พร้อมกรอกรายละเอียดผลงานใน sheet Ref)	10.00	10.00	10.00%	8.00	8.00%	4.00	4.00%
		290 MB		188 MB		86.20 MB	
4.2.3 มูลค่างานที่เคยรับสูงสุดจำนวน 5 อันดับ ของผลงาน เฉพาะที่เกี่ยวข้องกับประตูทนไฟ		1. EMI ENGINEERING PTE LTD / 8.7 MB 2. - MENAM RESIDENCES / บริษัท แม่น้ำ เรสซิเดนท์ จำกัด / 4.6 MB 3. - NBCC 2 / การไฟฟ้าฝ่ายผลิต / 3.8MB 4. TWIN CENTRO / SHWE TAUNG DEVELOPMENT CO., LTD. / 3.1 MB 5. GRAPHICS TEXTILES FACTORY / GRAPHICS TEXTILES LTD / 2.7MB 6. CIRCLE II / บริษัท เฟรเกรนท์ พร็อพเพอร์ตี้ จำกัด / 2.9MB 7. HILL TOP / HILL TOP		1. ปรับปรุงปตท.สนญ./ ปตท / 2MB. 2. ปตท.วังน้อย/ปตท / 5MB 3. circle คอนโด/ฟาร์แกรนด์ / 6MB 4. โรงแรมอมารี หัวหิน/อมารี / 5MB 5. โรงงานหลินหลง/หลินหลง / 7MB 6. รงงานอีโยร์/อีโยร์ / 5MB		1.แมกโนเลีย 2. เอ็มควอเทีย 3. จีแลนด์ 4. สถบัน ปตท. 5. SCG	
4.2.4 ผลงานที่ผ่านมาในระยะเวลา 5 ปี ผลงานอื่นๆ เช่น งานก่อสร้าง, งานปรับปรุงตกแต่ง ที่มีมูลค่าตั้งแต่ 10 ล้านบาทขึ้นไป เป็นต้น		8 Project		8 Projects		None (No Project more than 10MB) (18 Projects reference 2 – 8 MB for each of project)	
4.2.5 มูลค่างานรวม 5 ปี ผลงานอื่นๆ เช่น งานก่อสร้าง, งานปรับปรุงตกแต่ง ที่มีมูลค่าตั้งแต่ 10 ล้านบาทขึ้นไป เป็นต้น	10.00	10.00	10.00%	10.00	10.00%	0.00	0.00%
		197.27 MB		242.42 MB		None	
4.2.6 มูลค่างานที่เคยรับสูงสุดจำนวน 5 อันดับ ของผลงาน 5 ปี ผลงานอื่นๆ เช่น งานก่อสร้าง, งานปรับปรุงตกแต่ง ที่มีมูลค่าตั้งแต่ 10 ล้านบาทขึ้นไป เป็นต้น		1. งานปรับปรุงสำนักงานห้องค้าเงิน ชั้น 12BC / ธนาคารไทยพาณิชย์ / 51 ล้านบาท 2. งานปรับปรุง ศูนย์ฝึกอบรมหาดตะวันรอน / ธนาคารไทยพาณิชย์ / 42 ล้านบาท 3. งานปรับปรุง ชั้น 8 สำนักงานใหญ่ / ธนาคารไทยพาณิชย์ / 28 ล้านบาท 4. งานปรับปรุงพื้นที่ ชั้น 4 Tower A / ธนาคารไทยพาณิชย์ / 22.42 ล้านบาท 5. งานปรับปรุง CALL CENTER / ธนาคารไทย		1.สำนักงานยูเนสโก อาคารหม่อมหลวงปิ่น มาลากุล / 67.7MB 2.NIDA อาคาร 6 / 39.3MB 3.สวทช อาคารกลุ่มนวัตกรรม 2 / 39.1MB 4. GHB อาคาร 2 ชั้น 1 / 39.7MB 5.GSB วิทยาลัยอาชีวศึกษาสมโภช 99ปี สงขลา / 18.7MB		None (No Project more than 10MB) (16 Projects reference 2 – 8 MB for each of project)	

5. Performance Rating (Weight 10%)	**70.00**	**46.00**	**6.58%**	**45.00**	**6.40%**	**47.67**	**6.93%**
5.1 Q = Weight 40%	**40.00**	**26.17**	**26.17%**	**26.00**	**26.00%**	**26.00**	**26.00%**
5.1.1 การติดต่อสื่อสารและประสานงาน	5.00	3.50	3.50%	3.75	3.75%	300.00%	3.00%
5.1.2 ความรับผิดชอบเอาใจใส่ในงาน	5.00	3.67	3.67%	3.75	3.75%	300.00%	3.00%
5.1.3 วัสดุและอุปกรณ์ตรงตามมาตรฐาน	5.00	3.33	3.33%	3.25	3.25%	366.67%	3.67%
5.1.4 ความชำนาญการของช่าง	5.00	3.33	3.33%	3.00	3.00%	333.33%	3.33%
5.1.5 คุณภาพของผู้ควบคุมงาน	5.00	3.00	3.00%	3.00	3.00%	333.33%	3.33%
5.1.6 คุณภาพของงาน (ความปราณีตของงาน, ความเรียบร้อย, ความสวยงาม)							
5.1.6.1 ID คุณภาพของงาน (ความปราณีตของงาน, ความเรียบร้อย, ความสวยงาม)	5.00	3.00	3.00%	3.25	3.25%	300.00%	3.00%
5.1.6.2 ME คุณภาพของงาน (ความปราณีตของงาน, ความเรียบร้อย, ความสวยงาม)	5.00	3.67	3.67%	3.25	3.25%	366.67%	3.67%
5.1.7 ปริมาณข้อบกพร่องในงาน (defect)	5.00	2.67	2.67%	2.75	2.75%	300.00%	3.00%
5.2 T = Weight 40%	**20.00**	**13.33**	**26.67%**	**13.00**	**26.00%**	**14.00**	**28.00%**
5.2.1 การจัดจำนวนคนได้เหมาะสมกับงาน	5.00	3.17	3.17%	3.00	3.00%	3.00	3.00%
5.2.2 การตรงต่อเวลาและความพร้อมในการเข้าทำงาน	5.00	3.33	3.33%	3.50	3.50%	4.00	4.00%
5.2.3 ความสามารถในการส่งมอบงานได้ตรงตามกำหนดเวลา	5.00	3.17	3.17%	3.25	3.25%	4.00	4.00%
5.2.4 ความรวดเร็วในการให้บริการเมื่อได้รับแจ้งเหตุ, แก้ไข defect	5.00	3.67	3.67%	3.25	3.25%	3.00	3.00%
5.3 S = Weight 20%	**10.00**	**6.50**	**13.00%**	**6.00**	**12.00%**	**7.67**	**15.33%**
5.3.1 การปฏิบัติตามกฎระเบียบของอาคารและสถานที่	5.00	3.17	3.17%	3.00	3.00%	4.00	4.00%
5.3.2 การคำนึงถึงความปลอดภัยในการทำงาน	5.00	3.33	3.33%	3.00	3.00%	3.67	3.67%
Total Item 1 – 5 (Weight 100%)	**370.00**	**262.00**	**79.96%**	**239.00**	**71.75%**	**225.67**	**57.79%**
6. Main Financial (Weight 10%)	**40.00**	**10.00**	**2.50%**	**10.00**	**2.50%**	**0.00**	**0.00%**
6.1 Main Financial	10.00	6.00	6.00%	6.00	6.00%	0.00	0.00%
		SCB		SCB		None	
6.2 Loan customer Credit	10.00	0.00	0.00%	0.00	0.00%	0.00	0.00%
6.3 Bank account (Saving, Deposit, Fix Deposit, Current)	10.00	4.00	4.00%	4.00	4.00%	0.00	0.00%
		Current, Saving		Current account 7,000,000		None	
6.4 Payroll	10.00	0.00	0.00%	0.00	0.00%	0.00	0.00%
Total Item 1 – 5 (Weight 110%)	**410.00**	**272.00**	**82.46%**	**249.00**	**74.25%**	**225.67**	**57.79%**

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