การเลือกคอมพิวเตอร์วางตักที่ดีสุดสำหรับวัตถุประสงค์ด้านการศึกษา โดยใช้เทคนิคการตัดสินใจแบบผสมผสาน

Selection of the Best Laptop for Educational Purposes using Hybrid Decision Making Technique

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บทคัดย่อ

ปัจจุบันนี้คอมพิวเตอร์วางตักได้เข้ามามีบทบาทสำคัญในโลกปัจจุบัน เช่น ด้านวิทยาสาสตร์ ธุรกิจ การแพทย์ และด้านโลจิสติกส์ คอมพิวเตอร์วางตักช่วยให้การดำเนินชีวิตสะควกสบายขึ้น เนื่องจาก คอมพิวเตอร์วางตักมีประสิทธิภาพสูง น้ำหนักเบา และการเคลื่อนย้ายสะควก อย่างไรก็ตามปัญหา การเลือกซื้อ คอมพิวเตอร์วางตักสำหรับวัตถุประสงค์ด้านการศึกษาเป็นปัญหาหนึ่งที่มีความซับซ้อนและ ยากต่อการตัดสินใจสำหรับนักศึกษา เนื่องจากต้องพิจารณาปัจจัยที่เกี่ยวข้องหลายปัจจัยพร้อมกัน ดังนั้น การเลือกเครื่องมือช่วยในการตัดสินใจที่เหมาะสมจึงเป็นสิ่งจำเป็น งานวิจัยนี้นำเสนอเครื่องมือช่วยในการตัดสินใจสำหรับปัญหาการเลือกซื้อคอมพิวเตอร์วางตักเพื่อวัตถุประสงค์ด้านการศึกษาโดยใช้ เทกนิกการตัดสินใจแบบผสมผสานซึ่งเป็นการผสมผสานกันระหว่างกระบวนการลำดับชั้นวิเคราะห์ เชิงวิภัชนัยและเทคนิกที่อบซิสเชิงวิภัชนัย โดยมีปัจจัยที่เกี่ยวข้องดังนี้ ความจุของฮาร์คดิสก์ ความจุของ แรม ความเร็วของซีพียู ขนาดจอ ความเชื่อมั่นของยี่ห้อ การรับประกันสินค้า น้ำหนัก และราคา ผลการวิจัย พบว่า การรับประกันสินค้า ความเร็วของซีพียู กวามจุของแรมน้ำหนักและราคาเป็นปัจจัยที่มีความสำคัญ สูงสุดห้าอันดับแรก ในส่วนของผลการเลือกคอมพิวเตอร์วางตักสำหรับวัตถุประสงค์ด้านการศึกษาที่ดีที่สุด คือ โมเคล NC2 (น้ำหนัก = 0.112) ตามด้วยโมเคล NC1 (น้ำหนัก = 0.091) โมเคล NC3 (น้ำหนัก = 0.088) และ โมเคล NC4 (น้ำหนัก = 0.087) ตามลำดับ

คำสำคัญ: กระบวนการลำดับชั้นวิเคราะห์เชิงวิภัชนัย, เทคนิคท็อบซิสเชิงวิภัชนัย, ปัญหาการตัดสินใจ แบบหลายเกณฑ์, คอมพิวเตอร์วางตัก

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ABSTRACT

Today, laptops play an important role in the world. They have a great effect on science, education, business, medicine, logistics, etc. The laptop makes human life easier through its ability, portability and mobility. However, a lot of criteria are influential in the selection of a laptop due to the technological and global competitive changes happening today, and so making a choice is becoming harder. This research used the hybrid decision making technique which hybridizes fuzzy AHP and fuzzy TOPSIS to compare each laptop for educational purposes based on the following criteria: Capacity of hard disk, RAM capacity, CPU speed, Screen size, Brand reliability, Warranty, Weight, and Price. The results of this study showed that Warranty (weight=0.22), Speed (weight=0.18), RAM capacity (weight=0.12), Weight (weight=0.12) and Price (weight=0.11) were ranked as the top five most influential decision criteria. The results of selecting the best laptop results indicated that Model NC2 (weight=0.112) provided the best laptops for educational purposes, followed by Model NC1 (weight=0.091), Model NC3 (weight=0.088) and Model NC4 (weight=0.087).

Key words: fuzzy analytic hierarchical process, fuzzy TOPSIS, multi-criteria decision making problem, laptop

INTRODUCTION

In today's world, laptops have become an important electronic device for almost everyday use for individuals of every age, and are essential in almost all business dealings because of their ability, mobility, and portability (Srichetta and Thurachon, 2012; Adalı and Işık, 2017). Nowadays the laptop plays an important role in education. The students collect their educational informative materials through Google, and download them into their laptop. In addition, in the era of science everyone should know about the usages of various software and programs that make life easier. So, everyone

must buy a laptop for his education because he can read necessary books from the laptop and also learn about the software that is needed for his student life and job life. Laptop is one of the electronic devices for the students because of educational purpose. They utilize it to obtain notes, books, internet access, communication, entertainment and other purposes. Therefore, choosing an effective laptop that suits the needs of students is essential. In the market, there are numerous laptops with different features and brands. They also seem same to each other. So the selection of an effective laptop that suits the needs of students is essential but also the

difficult problem. When students and buyers need to buy a computer for their use, they can't decide which laptop they should buy because there are numerous laptops with different brands and features, and they have to face a variety of types of laptop, so it is difficult to compare the alternatives. Hence, the laptop selection problem for educational purposes, which is one of multi-criteria decision making problems (MCDM problems), is needed to choose a suitable technique for solving this problem in this case.

In the past, many researchers have used the MCDM techniques for selecting the best laptop for various purposes. For example, McMullen (McMullen, 2000) used Data Envelopment Analysis (DEA) in choosing the efficient laptops. Srichetta (Srichetta and Thurachon, 2012) used AHP technique in evaluating and selecting laptop for determining the significant factor in selecting the best laptop. The results indicated that CPU speed was ranked as the first criteria in the selection of laptops. Lakshmi (Lakshmi et al., 2015) used Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in choosing the best laptop. Tampi (Tampi et al., 2016) have proposed the consumer decision making in selecting laptop using Analytical Hierarchy Process (AHP) technique.

In their study, physical appearance, price and speed were selected as the relevant criteria in selecting laptop. The results indicated that speed was the ranked as the most important factor in the selection of laptop. Adalı (Adalı and Işık, 2017)

proposed the multi-objective decision making methods based on MULTIMOORA and MOOSRA for the laptop selection problem.

According to the literature review, MCDM problems are divided into multi-attribute decision making (MADM) and multi-objective decision making (MODM) problems. Although the Fuzzy AHP is a powerful and flexible technique to solve MADM problems, ranking of the Fuzzy AHP technique is rather imprecise. A distinguishing feature of Fuzzy TOPSIS is that it is easy to understand and it can be used to rank the alternatives effectively. Hence, in order to take advantage of the strengths of the techniques detailed in the literature, while overcoming their weaknesses, selecting the hybrid MADM technique (combining Fuzzy AHP and Fuzzy TOPSIS) will enhance the confidence of students in choosing the best of the laptops for educational purposes.

The multi-criteria decision making problems (MCDM problems) are divided into multi-attribute decision making (MADM) and multi-objective decision making (MODM) problems. There are several traditional MADM tools which are applied to handle the MADM problems, such as the preference ranking organization method for enrichment of evaluations (PROMETHEE) (Vetschera and de Almeida, 2012; Veza *et al.*, 2015; Vulević and Dragović, 2017), hierarchical additive weighting, elimination and choice expressing reality (ELECTRE) (Teixeira de Almeida, 2007; Haurant *et al.*, 2011; Petrović

et al., 2014), technique for order preference by similarity to an ideal solution (TOPSIS) (Behzadian et al., 2012; Shukla et al., 2017; Srirangan and Sathiya, 2017) and analytical hierarchy process (AHP) (Uyan, 2013; Singh and Nachtnebel, 2016; Azizkhani et al., 2017). However, the AHP and TOPSIS techniques are often suggested for solving MADM problems in the literature, because they are flexible and powerful tools for handling both qualitative and quantitative data (Ünal and Güner, 2009). The traditional MADM tools still cannot reflect the human thinking style, and it is difficult in that it applies an exact value to express the decision maker's opinion in a comparison of alternatives, and the traditional tools are often criticized due to its use of an unbalanced scale of judgments. Later, the fuzzy set theory of Zadeh (Zadeh, 1965) was developed in order to overcome this weak point for solving MADM problems. Nowadays this theory is widely used to combine the traditional MADM tools for solving MADM problems instead of traditional MADM tools as shown in the literature (Wang, 2014; Chen et al., 2015; Beşikçi et al., 2016; Chiu and Hsieh, 2016; Meethom and Triwong, 2016; Dožić et al., 2017; Jayawickrama et al., 2017; Walczak and Rutkowska, 2017; Wichapa and Khokhajaikiat, 2018). The Fuzzy AHP is a powerful and popular technique for solving MADM problems with many alternatives, and it can also select the best one when the decision maker has multiple criteria (Huang et al., 2008; Wichapa and Khokhajaikiat, 2017a). Its main

advantages are handling various criteria, being easy to understand, and effectively handling both qualitative and quantitative data. However, disadvantages of Fuzzy AHP are that consistency is difficult to achieve when the criteria and alternatives are many, and ranking of the Fuzzy AHP technique is rather imprecise. Advantages of Fuzzy TOPSIS are as follows: (1) it can measure the distance of the alternatives form the ideal solution; (2) it can obtain the result which is closest to the ideal solution; (3) it is easy to use and understandable. Because of the weaknesses of Fuzzy AHP technique is that ranking of this technique is rather imprecise, a group of researchers (Patil and Kant, 2014, Shukla et al., 2014) have proposed using combined Fuzzy AHP and Fuzzy TOPSIS/ TOPSIS to solve the MADM problems. Hence, the integration of Fuzzy AHP and Fuzzy TOPSIS models is reasonable to solve the MADM problems.

The laptop selection problem for educational purpose is a MADM problem because there are several factors such as price, speed and warranty period, including both tangible and intangible factors that must be considered together. Therefore, one of the most essential difficulties to address this complicated problem is to select a suitable technique for evaluating the complicated criteria, because during the decision making process the experts may be imprecise. In order to handle the vague data involved in this problem, the integration of Fuzzy AHP and Fuzzy TOPSIS techniques is reasonable for use to solve the MADM problems in this case.

METHODOLOGY

The solution approach for laptop selection problem consists of the following stages: (i) the first phase of this paper is to use the Fuzzy AHP for evaluating the priority weights of main criteria in Level 1 and alternatives in Level 2 and (ii) finally, Fuzzy TOPSIS is used to rank the alternatives in order.

The details of selecting the best laptop using the hybrid MADM technique are as follows:

- 1) Define the most important criteria for selection of the best laptop for educational purposes;
- 2) Evaluate the priority weights for each element in Level 1 and Level 2 using Fuzzy AHP;
- 3) Rank the alternatives using Fuzzy TOPSIS and
- 4) Select the best laptop for educational purposes.

The first step is to define the most important criteria for selection of the best laptop for educational purposes, and determining candidate alternatives is considered by using previous research and experts' opinion. Next, these criteria and candidate alternatives are decomposed into a multi-level hierarchical structure. The second step is to evaluate the priority weights of elements in each level using Fuzzy AHP. The third step is to use Fuzzy TOPSIS for ranking the alternatives. The final step is to choose the best laptop for educational purposes from the hybrid MADM technique.

1. Fuzzy AHP

From the literature reviewed, Fuzzy AHP is a flexible and powerful tool to solve MADM problems. Hence, using Fuzzy AHP should give a suitable approach to evaluate the priority weights of elements in the multi-level hierarchical structure. In this paper, we evaluated the priorities weights of elements in each level using the geometric means method of Buckley (Buckley, 1985) and Buckley et al. (Buckley et al., 2001). The fuzzy arithmetic operations on triangular fuzzy numbers (TFNs) have been shown in literature (Chen et al., 2015; Dožić et al., 2017; Wichapa and Khokhajaikiat, 2017a; Wichapa and Khokhajaikiat, 2017b; Wichapa and Khokhajaikiat, 2018). triangular fuzzy numbers will be used in order to compare a priority scale between elements as shown in Table 1.

1.1 Construct the hierarchy

The relevant criteria and candidate alternatives for selecting the best laptop can be defined by asking questions to experts and reviewing the related literature. After that, these elements are decomposed into a multi-level hierarchical structure, as shown in Figure 1. At level "0", the goal is to choose the best laptop for educational purposes. At level "1", the main criteria are C1, C2, C3, and at level "2", the candidate laptops are NC1, NC2, NC3 and NC4.

(TFNs)	Definition
(1,1,1)	Equal
(2,3,4)	Moderate
(4,5,6)	Strong
(6,7,8)	Very strong
(8,9,9)	Extreme

Table 1 The comparison scale of TFNs

The steps of the Fuzzy AHP for solving the MADM problems are as follows.

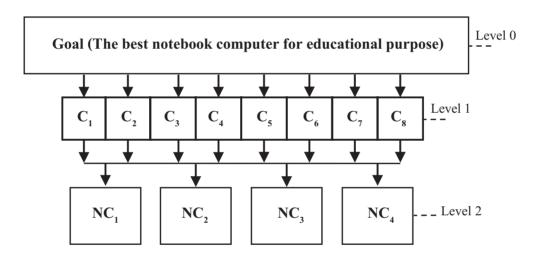


Figure 1 A hierarchy for selecting the best laptop for educational purposes

1.2 Construct the comparison matrices

The comparison matrices of each decision maker k can be constructed using triangular fuzzy numbers in Table 1. After that, combining the comparison matrices from all decision makers using the fuzzy geometric mean method in the literature (Meixner, 2009; Dong and Cooper, 2016; Wichapa and Khokhajaikiat, 2017a; Wichapa and Khokhajaikiat, 2018) is as shown in Equation (1).

$$\widetilde{A} = (\prod_{i=1}^{K} \widetilde{a}_{ijk})^{1/K} \tag{1}$$

where \widetilde{A} is a aggregated pair-wise comparison matrix of all decision makers, and $\widetilde{a}_{ijk} = (l_{ijk}, m_{ijk}, u_{ijk})$ is the TFNs of the kth decision maker.

1.3 Estimate priority weights

The priority weights of each level will be estimated by the geometric means method of Buckley (Buckley, 1985) and Buckley *et al.* (Buckley *et al.*, 2001) by

$$\widetilde{r}_i = (\prod_{j=1}^n p_{ij})^{1/n} \tag{2}$$

where p_{ii} is an aggregated fuzzy number, and

$$\widetilde{w}_i = \widetilde{r}_i \otimes (\sum_{i=1}^n \widetilde{r}_i)^{-1}, i = 1, 2,, n$$
(3)

The fuzzy priority weights (\widetilde{w}_i) can be converted to crisp priority weights using Equation (4) (Tsaur *et al.*, 2002; Meixner, 2009).

$$d\widetilde{\mathfrak{f}}a_{ii} = \lfloor (u_{ii} - l_{ii}) + (m_{ii} - l_{ii}) \rfloor / 3 + l_{ii} \ \forall i, \ \forall j \ (4)$$

1.4 Check CR values

- Defuzzify aggregated comparison matrix and then multiply the crisp comparison matrix by the crisp priority weight vector.
- 2) Divide the weighted sum vector with criterion weight in step 1; average weighted sums (\overline{w}_i) will be obtained for each row i for the calculation in this step.
 - 3) Compute λ max by Equation (5).

$$\lambda_{\max} = \sum_{j=1}^{n} \overline{w} / n \tag{5}$$

4) Compute the consistency index (CI) and CR by Equations (6) to (7) respectively.

$$CI = (\lambda_{\text{max}} - n)/(n-1)$$
(6)

$$CI = CI / RI \le 0.10 \tag{7}$$

A *CR* value of 0.10 or less is accepted as a good consistency measure. If the value exceeds 0.10, it is indicative of inconsistent judgment, and it should be revised.

2. Fuzzy TOPSIS

TOPSIS is a classic MADM technique developed by Hwang and Yoon (Hwang and Yoon, 1981). It is based on the concept that the

selected alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). Although the TOPSIS technique has a long history for solving MADM problems, it seems that since the origin of fuzzy set theory of Zadeh (1965) in management sciences, this theory is often integrated with the traditional TOPSIS technique to apply in real word problems. The first application of the Fuzzy TOPSIS technique was made by Chen (Chen, 2000) in a system analysis engineer's selection problem. Nowadays the Fuzzy TOPSIS technique has been widely applied to solve MADM problems instead of traditional TOPSIS. In this paper, the steps of the Fuzzy TOPSIS are described as follows.

2.1 Construct the fuzzy decision matrix

Given m alternatives, n criteria, a typical fuzzy multi-criteria group decision-making problem can be expressed in matrix format as

$$D = \begin{bmatrix} C_1 & C_2 & \dots & C_n \\ A_1 & \widetilde{\chi}_{11} & \widetilde{\chi}_{12} & \dots & \widetilde{\chi}_{1n} \\ \widetilde{\chi}_{21} & \widetilde{\chi}_{22} & \dots & \widetilde{\chi}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ A_m & \widetilde{\chi}_{m1} & \widetilde{\alpha}_{m2} & \dots & \widetilde{\chi}_{mn} \end{bmatrix}$$
(8)

where A_1, A_2, \ldots, A_m are the alternatives to be chosen, C_1, C_2, \ldots, C_n denote the evaluation criteria and \widetilde{x}_{ij} represents the fuzzy rating of alternative A_i with respect to criterion C_j .

2.2 Normalize the fuzzy decision matrix

This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. If denotes the normalized fuzzy decision matrix, then

$$\widetilde{R} = [\widetilde{r}_{ii}] \ i = 1, 2, ..., m; j = 1, 2, ..., n$$
 (9)

where

$$\widetilde{r}_{ij} = \frac{a_{ij}}{c^*_{j}}, \frac{b_{ij}}{c^*_{j}}, \frac{c_{ij}}{c^*_{j}}$$

$$and c^*_{j} = \max(c_{ij})(benefit \ criteria) \tag{10}$$

$$\widetilde{r}_{ij} = \frac{a_{-j}^{-}}{c_{ij}} \cdot \frac{a_{-j}^{-}}{b_{ij}} \cdot \frac{a_{-j}^{-}}{a_{ij}}$$
and $a_{-j}^{-} = \max(a_{ij})(\cos t \ criteria)$ (11)

2.3 Construct the weighted normalized matrix

Considering the different fuzzy weight of each criterion, the weighted normalized decision matrix can be computed by multiplying the fuzzy weights of evaluation criteria and the values in the normalized fuzzy decision matrix. The weighted normalized decision matrix \tilde{v} is defined as

$$\widetilde{V} = \left[\widetilde{v}_{ij}\right]_{mxn} \tag{12}$$

$$\widetilde{v}_{ij} = \widetilde{w}_j \otimes r_{ij} \tag{13}$$

where \widetilde{w}_j represents the fuzzy weights of criteria from using the FAHP technique.

2.4 Determine the FPIS and FNIS

Because the positive TFNs are included in the interval [0, 1], the fuzzy ideal solution $(FPIS, A^+)$ and fuzzy negative ideal solution $(FNIS, A^-)$ hence can be defined as

$$A^{+} = (\widetilde{v}_{1}^{+}, \widetilde{v}_{2}^{+}, \dots, \widetilde{v}_{n}^{+}) \tag{14}$$

$$A^{-} = (\widetilde{v}_{1}, \widetilde{v}_{2}, \dots, \widetilde{v}_{n})$$
 (15)

where
$$\tilde{v}_{j}^{+} = (1, 1, 1)$$
 and $\tilde{v}_{j}^{-} = (0, 0, 0), j = 1, 2, 3, ..., n$.

2.5 Calculate the distance d_i^+ and d_i^-

The distance d_i^+ and d_i^- of alternatives from FPIS and FNIS can be derived respectively as

$$d_i^+ = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^+) \tag{16}$$

$$d_i^- = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^-)$$
 (17)

Chen (Chen, 2000) introduced a vertex method to calculate the distance between two TFNs. If $\widetilde{x} = (a_1, b_1, c_1)$, $\widetilde{y} = (a_2, b_2, c_2)$ are two TFNs then

$$d(\widetilde{x}, \widetilde{y}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_1)^2 + (c_1 - c_2)^2]}$$
 (18)

2.6 Rank of the alternatives

Once the closeness coefficient weight of each alternative (ccw_i) is determined, the ranking order of all alternatives can be obtained, allowing the decision makers to select the most feasible alternative. The closeness coefficient weight of each alternative is calculated as

$$ccw_i = \frac{d_i^-}{\left(d_i^+ + d_i^-\right)} \tag{19}$$

Obviously, a large value of index ccw_i indicates that the alternative is closest to the FPIS and farthest from the FNIS, and then this alternative will get a high ranking order.

Application

To demonstrate the applicability of the hybrid MADM technique which hybridizes the Fuzzy AHP and Fuzzy TOPSIS techniques in solving MADM problems, a real case study is considered. The steps of calculation are as follows.

1. Construct the hierarchy

In the case study, the original hierarchical structure of the laptop selection problem has been constructed composed of three levels as illustrated in Figure 1. On the top of the hierarchical structure (Level 0), the goal is to select the best laptop for educational purposes. In the middle section of the problem (Level 1), the criteria are chosen based on the students requirements and how they need the product to buy. We have surveyed around 100 students of Kalasin University because they face the problem of choosing best laptop when they want to buy a laptop for their educational purpose. The survey was done by asking questions to the students. Finally, a primary data, eight decision criteria, namely Capacity of hard disk (C_1) (in GB), RAM capacity (C₂) (in GB), CPU speed (C₃) (in GHz), Screen size (C₄) (in inches), Brand reliability (C₅), Warranty (C₆) (in years), Weight

 (C_7) (in kg), and Price (C_8) (in Baht), was collected by survey method that is provided below in the Table 2. The best notebook is selected based on these decision criteria. Finally, at the bottom level (Level 2), this level provides the list of well-known products of laptops in Thailand such as ACER, ASUS, DELL and LENOVO. Four up-to-date models of each product offered in 2017 are also provided. Their common features are running ≥ core i5 processors, having $\leq 20,000$ baht price, having ≥ 2.0 GHz CPU speed and having ≥ 1 year warranty period. Necessary data were collected from website https://notebookspec.com. If any model did not meet the prerequisites, it was not considered in this study. Hence, four alternatives (models of laptops) were determined as the candidate alternatives, namely NC₁, NC₂, NC₃ and NC₄. The information of each model of candidate alternatives is shown in Table 2.

 Table 2
 The information of each model of laptops

	Number of Student				
Criteria	who select the criterion	NC_1	NC_2	NC ₃	NC_4
	as their first choice				
Capacity of hard disk (C_1)	10	500 GB	1000 GB	1000 GB	1000 GB
RAM capacity (C ₂)	18	4 GB DDR4	4 GB DDR4	4 GB DDR4	8 GB DDR4
CPU speed (C ₃)	20	2.5 -3.10 GHz	2.5 -3.10 GHz	2.5 -3.10 GHz	2.3 -2.8 GHz
Screen size (C ₄)	6	15.6 inches	15.6 inches	14 inches	13.3 inches
Brand reliability (C_5)	13	6,6	7,7	8,8	8,7
Warranty (C ₆)	15	2 years	2 years	1 years	1 years
Weight (C ₇)	6	$2.20\mathrm{kg}$	$2.00\mathrm{kg}$	1.77 kg	1.70 kg
Price (C ₈)	12	19,900 baht	18,990 baht	19,900 baht	19,900 baht
Total	100				

2. Construct the pair-wise comparison matrices

Fuzzy pair-wise comparison matrices were constructed from the six decision makers who have good computer skills and are also teachers at Kalasin University in computer engineering and computer science fields, using the comparison

scale of Fuzzy AHP, as shown in Table 1. After that, the fuzzy pair-wise comparison matrices of each decision maker were aggregated into a Fuzzy AHP combined matrix (\widetilde{A}) using equation (1), shown in Table 3.

 Table 3
 The combined matrix based on Fuzzy AHP

Combined	C1	C2	С3	C4	C5	С6	С7	C8	$\widetilde{r_i}$	\widetilde{w}_i	w_i	CR
-	(1.00,	(0.30,	(0.23,	(0.61,	(0.28,	(0.22,	(0.30,	(0.37,	(0.36,	(0.03,		
C1	1.00,	0.43,	0.30,	0.70,	0.39,	0.28,	0.37,	0.50,	0.47,	0.05,	0.06	
	1.00)	0.76)	0.43)	0.87)	0.66)	0.39)	0.76)	0.80)	0.68)	0.11)		
	(1.32,	(1.00,	(0.39,	(1.06,	(0.64,	(0.31,	(0.80,	(0.87,	(0.73,	(0.06,		
C2	2.35,	1.00,	0.53,	1.78,	0.87,	0.46,	1.00,	1.32,	1.02,	0.12,	0.12	
	3.37)	1.00)	0.87)	2.70)	1.25)	0.87)	1.25)	1.78)	1.45)	0.23)		
	(2.35,	(1.15,	(1.00,	(0.92,	(1.15,	(0.64,	(1.00,	(1.15,	(1.10,	(0.09,		
C3	3.37,	1.89,	1.00,	1.64,	1.64,	0.87,	1.74,	1.89,	1.63,	0.19,	0.18	
	4.37)	2.55)	1.00)	2.55)	2.05)	1.25)	2.41)	2.55)	2.14)	0.34)		
	(1.15,	(0.46,	(0.39,	(1.00,	(0.46,	(0.32,	(0.49,	(0.52,	(0.54,	(0.05,		
C4	1.43,	0.64,	0.61,	1.00,	0.56,	0.40,	0.61,	0.76,	0.70,	0.08,	0.08	
	1.64)	0.94)	1.08)	1.00)	0.76)	0.56)	0.87)	1.25)	0.97)	0.16)		0.05
	(1.52,	(0.61,	(0.49,	(1.32,	(1.00,	(0.37,	(0.61,	(0.80,	(0.76,	(0.06,		0.05
C5	2.55,	0.80,	0.61,	1.78,	1.00,	0.49,	0.92,	1.00,	1.00,	0.11,	0.11	
	3.57)	1.08)	0.87)	2.17)	1.00)	0.76)	1.35)	1.25)	1.32)	0.21)		
	(2.55,	(1.15,	(0.80,	(2.05,	(1.15,	(1.00,	(1.15,	(1.22,	(1.29,	(0.11,		
C6	3.57,	2.17,	1.15,	2.70,	1.89,	1.00,	2.17,	1.93,	1.93,	0.22,	0.22	
	4.57)	3.18)	1.55)	3.31)	2.55)	1.00)	3.18)	2.86)	2.54)	0.41)		
	(1.32,	(0.80,	(0.42,	(1.15,	(0.64,	(0.31,	(1.00,	(0.87,	(0.74,	(0.06,		-
C7	2.35,	1.00,	0.57,	1.89,	0.87,	0.46,	1.00,	1.15,	1.02,	0.12,	0.12	
	3.37)	1.25)	1.00)	2.55)	1.25)	0.87)	1.00)	1.43)	1.42)	0.23)		
	(1.25,	(0.64,	(0.39,	(1.00,	(0.64,	(0.38,	(0.84,	(1.00,	(0.71,	(0.06,		-
C8	2.00,	0.84,	0.53,	1.52,	0.87,	0.58,	1.00,	1.00,	0.95,	0.11,	0.11	
	2.67)	1.19)	0.87)	1.93)	1.25)	0.93)	1.19)	1.00)	1.28)	0.21)		

3. Estimate priority weights

As seen in Table 3, the weights of each element in level 1 were calculated using equations (2-7). Finally, the priority weights of each element in level 2 were computed by Excel 2007.

4. Construct the fuzzy decision matrix

After obtaining the weights of all elements in each level, these priority weights will be taken into Equation (8), and the fuzzy decision matrix based on Fuzzy TOPSIS is shown in Table 4.

5. Construct the weighted normalized decision matrix

Considering the different fuzzy weight of each criterion, the normalized fuzzy decision

matrix can be computed using Equation (9), Equation (10) and Equation (11). The normalized fuzzy decision matrix (\tilde{R}) is defined as shown in Table 5. After that, the weighted normalized decision matrix can be computed by multiplying the fuzzy weights of evaluation criteria and the values in the normalized fuzzy decision matrix. The weighted normalized decision matrix \tilde{A} is defined using Equations (12) to (13) as shown in Table 6.

As seen in Table 3, crisp priority weights for each criterion (w_i or weight) are shown that Warranty (weight = 0.22), Speed (weight = 0.18), RAM capacity (weight = 0.12), Weight (weight = 0.12) and Price (weight = 0.11) are ranked as the top five most influential decision criteria, CR < 0.10.

 Table 4
 Fuzzy decision matrix based on Fuzzy TOPSIS

	C1	C2	С3	C4	C5	C6	C 7	C8
	(0.08,	(0.13,	(0.25,	(0.31,	(0.05,	(0.26,	(0.06,	(0.13,
NC ₁	0.11,	0.17,	0.30,	0.40,	0.07,	0.38,	0.10,	0.17,
	0.19)	0.22)	0.36)	0.52)	0.10)	0.52)	0.19)	0.22)
	(0.21,	(0.13,	(0.25,	(0.31,	(0.10,	(0.26,	(0.08,	(0.31,
NC_2	0.28,	0.17,	0.30,	0.40,	0.15,	0.38,	0.16,	0.50,
	0.38)	0.22)	0.36)	0.52)	0.24)	0.52)	0.33)	0.74)
	(0.21,	(0.13,	(0.25,	(0.10,	(0.29,	(0.09,	(0.14,	(0.13,
NC ₃	0.28,	0.17,	0.30,	0.14,	0.39,	0.13,	0.28,	0.17,
	0.38)	0.22)	0.36)	0.22)	0.52)	0.18)	0.55)	0.22)
	(0.23,	(0.31,	(0.07,	(0.04,	(0.29,	(0.09,	(0.24,	(0.13,
NC_4	0.32,	0.50,	0.10,	0.05,	0.39,	0.13,	0.47,	0.17,
	0.43)	0.74)	0.15)	0.08)	0.52)	0.18)	0.83)	0.22)

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	C1	C2	С3	C4	C5	C6	C7	C8
	(0.18,	(0.18,	(0.68,	(0.59,	(0.09,	(0.50,	(0.07,	(0.18,
NC_1	0.26,	0.22,	0.83,	0.77,	0.13,	0.72,	0.12,	0.22,
	0.45)	0.30)	1.00)	1.00)	0.19)	1.00)	0.23)	0.30)
	(0.49,	(0.18,	(0.68,	(0.59,	(0.20,	(0.50,	(0.10,	(0.42,
NC_2	0.66,	0.22,	0.83,	0.77,	0.29,	0.72,	0.19,	0.67,
	0.88)	0.30)	1.00)	1.00)	0.45)	1.00)	0.40)	1.00)
	(0.49,	(0.18,	(0.68,	(0.19,	(0.55,	(0.18,	(0.17,	(0.18,
NC_3	0.66,	0.22,	0.83,	0.27,	0.75,	0.24,	0.34,	0.22,
	0.88)	0.30)	1.00)	0.42)	1.00)	0.35)	0.67)	0.30)
	(0.53,	(0.42,	(0.20,	(0.08,	(0.55,	(0.18,	(0.30,	(0.18,
NC_4	0.75,	0.67,	0.28,	0.10,	0.75,	0.24,	0.56,	0.22,
	1.00)	1.00)	0.42)	0.14)	1.00)	0.35)	1.00)	0.30)

 Table 5
 Normalized decision matrix based on Fuzzy TOPSIS

 Table 6
 Weighted normalized decision matrix based on Fuzzy TOPSIS

	C1	C2	С3	C4	C5	C6	C 7	C8
	(0.01,	(0.01,	(0.06,	(0.03,	(0.01,	(0.05,	(0.00,	(0.01,
NC_1	0.01,	0.03,	0.16,	0.06,	0.01,	0.16,	0.01,	0.02,
	0.05)	0.07)	0.34)	0.16)	0.04)	0.41)	0.05)	0.06)
	(0.01,	(0.01,	(0.06,	(0.03,	(0.01,	(0.05,	(0.01,	(0.03,
NC_2	0.03,	0.03,	0.16,	0.06,	0.03,	0.16,	0.02,	0.07,
	0.10)	0.07)	0.34)	0.16)	0.10)	0.41)	0.09)	0.21)
	(0.01,	(0.01,	(0.06,	(0.01,	(0.04,	(0.02,	(0.01,	(0.01,
NC_3	0.03,	0.03,	0.16,	0.02,	0.09,	0.05,	0.04,	0.02,
	0.10)	0.07)	0.34)	0.07)	0.21)	0.14)	0.15)	0.06)
	(0.02,	(0.03,	(0.02,	(0.00,	(0.04,	(0.02,	(0.02,	(0.01,
NC_4	0.04,	0.08,	0.05,	0.01,	0.09,	0.05,	0.07,	0.02,
	0.11)	0.23)	0.14)	0.02)	0.21)	0.14)	0.23)	0.06)

As seen in Table 4, this is the fuzzy decision matrix of candidate alternatives with respect to criteria/factors, C_1^* = 0.43, C_2^* = 0.74, C_3^* = 0.36, C_4^* = 0.52, C_5^* = 0.52, C_6^* = 0.52, C_8^* = 0.74 and

As seen in Table 5, this is the normalized decision matrix of candidate alternatives with respect to criteria. The various attribute dimensions

in Table 7 were transformed into non-dimensional attributes.

As seen in Table 6, the weighted normalized decision matrix was computed by multiplying the weights of evaluation criteria based on Fuzzy AHP and the normalized decision matrix in Table 5.

6. Define the ranking of the candidate alternatives

Now, using Equations (14) to (19), the ranking of alternatives are evaluated. The results and final ranking of alternatives are shown in Table 7. Besides, the ranking of alternatives was compared with FAHP-only, as shown in Table 8.

Table 7 depicts the final results of this investigation. This table also gives ideas about the best laptop that a student can buy for his/her educational purposes. A higher value of cc_i is a better alternative. Hence, NC_2 is best laptop based on CC_i value.

As seen in Table 8, the solutions can provide best laptop for educational purpose with maximum

value of final priority weight (weight using Fuzzy AHP = 0.30 and weight using Hybrid model =0.112). The rest of alternatives are slightly different weights. Therefore, this model can guide to the selection of best laptop for educational purpose by considering relevant decision factors/criteria simultaneously. In addition, the decision makers believe that our work can provide essential support for decision makers in the assessment of laptop selection problems; in this case study and others, and they also believe that the proposed methodology can be applied to other complex problems.

Table 7 The final evaluation and ranking of alternative locations

	di^{+}	di -	CC_i	Rank
NC_1	7.41	0.74	0.091	2
NC_2	7.28	0.92	0.112	1
NC_3	7.43	0.72	0.088	3
NC_4	7.45	0.71	0.087	4

Table 8 Comparison of Fuzzy AHP and Fuzzy AHP - TOPSIS models

Alternatives	Ranking by Fuzzy AHP	Ranking by Hybrid model
	(final weight)	(closeness coefficient weight)
NC_1	3 (0.23)	2(0.091)
NC_2	1 (0.30)*	1(0.112)*
NC ₃	4 (0.23)	3 (0.088)
NC_4	2 (0.25)	4(0.087)

CONCLUSIONS

This paper presents a hybrid decision making technique to choose a suitable laptop model for educational purposes. Firstly, define most important criteria for selection of the best laptop for educational purposes from the student requirements. The decision criteria identified in this case study are Capacity of hard disk (C₁) (in GB), RAM capacity (C2) (in GB), CPU speed (C_3) (in GHz), Screen size (C_4) (in inches), Brand reliability (C₅), Warranty (C₆) (in years), Weight (C_7) (in kg), and Price (C_9) (in Baht). Secondly, evaluate the priority weights for each element in Level 1 and Level 2 using Fuzzy AHP. Next, rank the alternatives using Fuzzy TOPSIS. Finally, select the best laptop for educational purposes. The results show that Warranty, Speed, RAM capacity, Weight and Price are ranked as the top five influential decision criteria in this study. In the best laptop result, NC_2 (weight = 0.112) becomes the best laptop for educational purposes, followed by NC_1 (weight = 0.091), NC_3 (weight = 0.088) and NC_4 (weight = 0.087). The major advantages of the proposed methodology are that the hybrid decision making technique can guide selection of a best laptop for educational purposes by considering subjective and objective criteria simultaneously. This proposed approach is simple but powerful, and is flexible for decision makers to limit costs and other relevant criteria. Therefore, it is believed that this approach should be more valuable and applicable for solving MCDM problems in other cases.

For future research, the authors suggest the other multi-criteria approaches such as MOORA, fuzzy PROMETHEE, fuzzy TOPSIS and other hybrid decision making techniques to be used and compared in justification of the laptop selection problem. This research can also be extended by incorporating additional decision criteria and alternatives. Hence, the proposed methodology can be applied to other multi-criteria decision problems.

ACKNOWLEDGEMENTS

The authors are very grateful to the Department of Industrial Technology, Kalasin University for supporting this research. The authors would like to express sincere gratitude to those experts who provided valuable time and information for this research, but whose names unfortunately cannot be revealed because of the confidentiality agreement. Finally, the authors would like to thank the reviewers for their valuable comments and recommendations which enabled the improvement of the quality of this paper.

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