European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 02, 2020

Prioritizing the Dengue Epidemic Mitigation Strategy Using Fuzzy TOPSIS Approach

Norhaslinda Zainal Abidin[*a], Ibnu Affan Jaafar[b], Antoni Wibowo[c], Azatuliffah Alwi[d]

[a]*Institute of Strategic Industrial Decision Modeling, School of Quantitative Sciences, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia*
[b,d] *School of Quantitative Sciences, College of Arts and Sciences, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia*
[c]*Computer Science Department, BINUS Graduates Program – Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*

[*]nhaslinda@uum.edu.my, ibnu@gmail.com, anwibowo@binus.edu, azatuliffah@uum.edu.my

Abstract

Dengue virus had become the dominant mosquito-borne disease that has rapidly spread in the world including Malaysia. Thus, controlling *Aedes* mosquito through the effective dengue control strategy had become the focus of government in controlling the spread of dengue virus. The aim of this paper is to prioritize the dengue control activities focuses on epidemic mitigation strategy. This strategy emphasizes on preventing the outbreak by implementing the high-impact activities at the beginning of outbreak period. The prioritized Fuzzy Technique for Order of Preference (FTOPSIS) model was developed based on the four dengue control activities namely fogging and larvaciding, premise inspection, public education and vector surveillance. Finding from the analysis shows that fogging and larvaciding, and premise inspection were the two appropriate controlling activities for epidemic mitigation strategy. As a conclusion, the FTOPSIS model provide a beneficial guidance to the health authorities in Malaysia on the most to the least importance factors should be given priority for the dengue control under epidemic mitigation strategy.

Keywords: FTOPSIS, Dengue control activity, Epidemic mitigation strategy, Prioritization

1. INTRODUCTION

Dengue is a mosquito-borne disease cause by a single stranded virus that transmitted from one human to another through the contact with infectious mosquito known as a vector (Brachman, 1996; Centers for Disease Control and Prevention, 2010). The common mosquito vector for dengue virus are adult female *Aedes Aegypti* and *Aedes Albopictus* (Brady et al., 2013). Practically, dengue control strategy aims in reducing the population size of *Aedes* mosquito which act as a carrier for the dengue virus. However, issues such as the use of single strategy, the absent of climate-driven strategy and infrequent assessment for dengue control strategy had contributed to the ineffectiveness of these control strategy. Government will continue to rely on controlling *Aedes* mosquito even after an effective vaccine is available due to combination of both vaccine and controlling mosquito *Aedes* shows a successful result in controlling dengue (Beier et al., 2008; Achee et al. 2015).

To date, Malaysia is still practicing a single strategy known as passive dengue surveillance system for controlling *Aedes* mosquito (Cheah et al., 2014). Based on this strategy, health practitioners are required to report within 24 hours from the initial encountered with the dengue infected people. The purpose is to notify the district health departments for further action such as investigation and implementation of chemical fogging and premise inspections (Packierisamy et al., 2015). However, depending on this strategy alone is not enough as dengue virus spread faster in the wider area in short period of time (Manorea, Hickmanna, Xub, Wearing & Hymanb, 2015). Thus, any delay in the notification process will slow down the implementation of the control activities and this result to the slow response in controlling the spread of dengue virus.

Dengue trend in Kedah

Kedah consist of twelve districts that covers over 9,425 km² of land in Northwestern part of Peninsular Malaysia. Known as the "rice bowl" of Malaysia, Kedah economies are mainly driven by agriculture, industrial and tourism (Mapjabil et al., 2010). The total population in Kedah had increase steadily for the past few years, from 1.99 million people in 2012 to 2.16 million people in 2018 (Department of Statistics, 2018). In general, Kedah experience significant amount of rainfall throughout the year which classified Kedah as an equatorial rainforest and fully humid state (Nurul Nadbrcfah Aqilah & Sobri, 2011). To get a grip on climate condition in Kedah, the seasons are divided into Southwest Monsoon (SW), Northeast Monsoon (NE) and Inter Monsoon (IE) seasons. During NE monsoon, there are widespread of heavy rainfall that lasted for days whereas SW normally signifies opposite climate condition than NE which represent drier weather. On the other hand, the transition period between the monsoons is known as the Inter Monsoon season (Cheong et al., 2013).

One of the visible impacts of climate changes in Kedah is on the growth of dengue reported cases. Based on the Figure 1, the early period of 2013 and 2014 had shown an increase of dengue trend from the first week to third week. However, the number of cases drops for the following week. The cases in 2014 continue to rise dramatically than cases in 2013 between the periods 19th to 27th. The trend for both years reaches its peak at 25th week with 31 cases for 2013 and 60 reported cases for 2014. However, the cases decrease to 19 cases in 2013 and 15 cases in 2014 for 27th week. The increase number of dengue infected people had resulted in higher hospitalization and death rate. From the total cases, two percent of the patient admitted to the hospital suffered from Dengue Hemorrhagic Fever (DHF) which led to one death in 2013 and seven deaths in 2014 (Ministry of Health Malaysia, 2015).

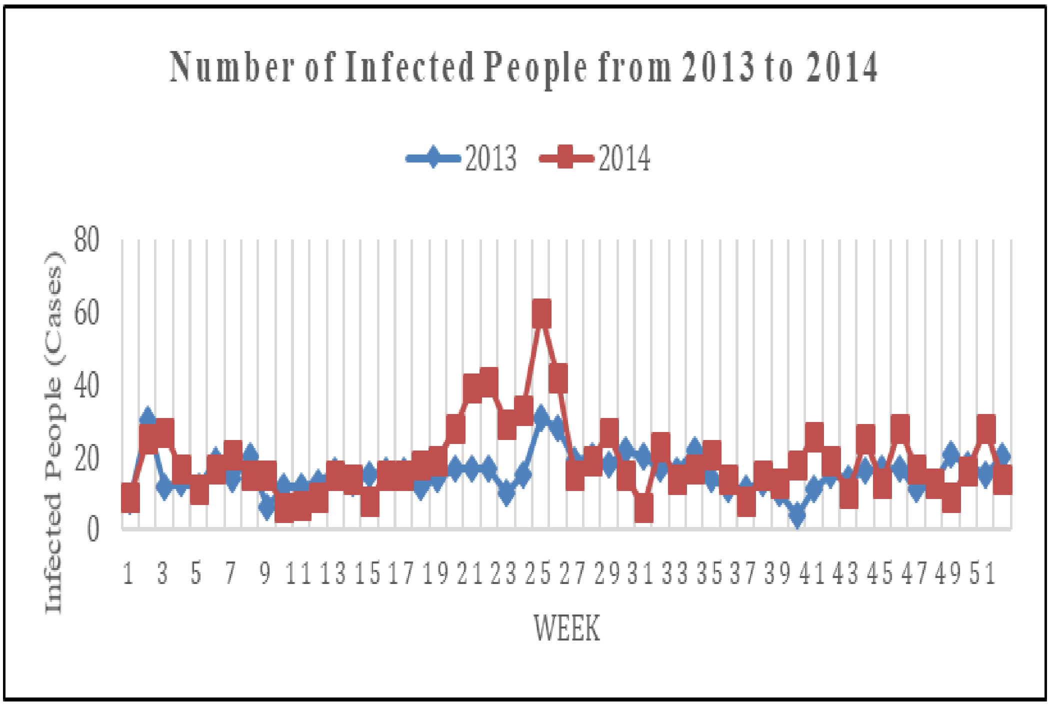

Fig. 1. Number of infected people based on dengue cases reported in Kedah between 2013 and 2014 (Source: Ministry of Health Malaysia, 2015)

To date, there is no consensus has been reached regarding the dengue control strategy that can be most effectively implemented to manage the impact of climate change towards prevention of dengue virus transmission. For the past decade, various profound literatures was studied on the different climate variations and its influence to the dengue outbreak problem (Degallier et al., 2010; Ibrahim et al., 2011; Lowe et al., 2013; Munasinghe, Premaratne & Fernando, 2013; Shi et al., 2016; Ramadona et al., 2016). However, these studies only focused on developing an early warning system that allow decision makers to identify the possible time for the outbreak rather than identifying what is the best control activity to be applied during those period (Degallier et al., 2010; Lowe et al., 2013; Shi et al., 2016). Based on our reviewed, there is a lack of study which is available to be used as a reference for this research that focuses on climate change adaptation strategy in the dengue context. This information is important to allow early preparedness and timely preventative measures that give essential advantages for preventing and controlling the dengue outbreak based on climate seasons. In line with this issue, the aim of this paper is to develop a Fuzzy TOPSIS model to prioritize the best controlling strategy should be practise for epidemic mitigation strategy.

The arrangement of the paper as follows. The next section focus on the review of studies related to dengue control activities and strategies, and Multi Criteria Decision Making (MCDM) methods applied in ranking factors. It is followed by methodology section, and continue with results and discussion section. Finally, the conclusion will end the paper.

2. LITERATURE REVIEW

2.1 Dengue control activities

Theoretically, dengue virus is transmitted by mosquito vector of adult female from mosquito species of *Aedes aegypti* and *Aedes albopictus* (Brady et al., 2013). To eliminate or reduce these mosquito species, this can be done through practicing the dengue control activities (WHO, 2015). For each country, controlling the dengue virus is depending on the resources that the country has and based on their geographical areas (Chang et al., 2011). In Malaysia, Ministry of Health Malaysia is responsible to lead a dengue control and prevention programs that work together with other government agencies that include federal, state and district level agencies and non-government organization (Ong, 2016). Currently, there are only four official dengue control activities namely fogging and larvaciding, premise inspection, public education and vector surveillance have been practiced in Malaysia.

Fogging and larvaciding are defined as insecticides technique that concentrate on killing mosquito in pupae, larvae and adult stages (Amal et al., 2011). Fogging is conducted in the outdoor areas using vehicles-mounted equipment that target adult mosquito population (Bonds, 2012). The effectiveness of fogging activity was presented in the study by Amal et al., (2011) who conducted a research for 16 weeks that showed a reduction of 3.5% in the mean larval count for indoor and outdoor was recorded through fogging activity. However, mosquito may developed insecticide resistance if fogging is conducted regularly (Bonds, 2012). On the other hand, larviciding treatment in a potable water known as temephos is applied to eliminate the larva and pupae mosquito (Ong, 2016). The success of larviciding treatment depends heavily on the involvement of the public (Antonio-Nkondjio et al., 2018). However, the practice of larvaciding treatment in Malaysia is recorded low with only 18% from the total respondent who involved with this treatment (Al-Dubai, 2013).

Vector surveillance defined as a warning system for dengue outbreak through monitoring process of mosquito *Aedes* (Horstick, Runge-Ranzinger, Nathan & Kroeger, 2010). Among the role of vector surveillance are to identify the possibility of dengue outbreaks (Sanchez et al., 2006), monitor the impact of dengue control activities (Favier et al., 2006), and provide evidence on the spread of dengue virus (Ritchie et al., 2006). However, despite the versatile role of vector surveillance, the reliability of this activity still need to be improved due to its ineffectiveness to predict a dengue outbreak in a low rate of herd immunity (Koh et al., 2008). Therefore, other control activities such as premise inspection should be conducted together with vector surveillance activity.

Premise inspection is an activity carried out by public health worker to find any potential and existing breeding site for the mosquito (Ong, 2016). Three widely used indicators for premise inspection activity named as Aedes Index (AI), Container Index (CI) and Breteau Index (BI) (Mahmud, Mutalip, Lodz & Shahar, 2018). AI is used to calculate the percentage of house with the present of larvae or/and pupae. On the other hand, CI is the percentage of container (that can hold water) with the present of larvae or/and pupae. Meanwhile, BI is the number of container that positive with larvae and/or pupae per 100 inspected houses. In Malaysia, the Ministry of Health has set the standard percentage of 1% for AI, 5% for BI and 10% for CI for these indicators (Mahmud et al., 2018). During this inspection, the authorities will also educate the owner on how to carry out the dengue prevention activities. However, stubborn owner will be enforced with Destruction of Disease Bearing Insects Act 1995 which result in court action (Ong, 2016). The poor attitude of public in cooperating with dengue prevention measures will become major setbacks in the national campaign against dengue.

Another dengue control activities that officially has been practiced in Malaysia is public education campaign. This activity aiming to gain support and cooperation from the public regarding the control strategy towards reducing and eliminating the mosquito *Aedes* (Ong, 2016). This support is important because most of the dengue epidemic zone are located in the urban residential area (Chandren et al., 2015). Among the health education campaign related to the dengue are talks, dialogues, exhibitions, demonstration of the use of Abate, film shows, small group discussions, public announcements and poster distributions (Ong, 2016). Throughout the years, several campaign had been organized by the ministry and local authorities including the 1997 anti-dengue campaign, media campaign in conjunction with SUKOM 1998 and National Anti-mosquito and Cleanliness Campaign (Ewe, 2000). Other than campaign, the Ministry of Malaysia had introduced a more direct approach to encourage public participations by organizing a community-based activity called Communication for Behavioral Impact (COMBI). COMBI is an approach originated from WHO that is design to encourage social mobilization and communication programs in a community for communicable diseases prevention and control (Suhaili et al., 2004). COMBI had been proven effective to increase public understanding and cooperation towards the control and prevention of communicable disease not only in Malaysia but also in Bangladesh, India and Kenya (Hod et al., 2013).

2.2 Dengue Control Strategies

Currently, Malaysia practices a single dengue control strategy known as passive dengue surveillance system (Sazali et al., 2014). Based on this strategy, all health practitioners are required to report dengue infected people within 24 hours from the initial encountered with the virus. The next process include notification from the state health department to district health department for investigation and implementation of the necessary prevention activities (Packierisamy et al., 2015). This strategy is used as a surveillance system for dengue outbreak in countries with a low epidemic trends (Runge-Ranzinger et al., 2014). However, the challenges of this strategy is the reporting time from the initial encountered with the virus is slow and the credibility of data being gathered using this strategy is often questions by the authorities (Runge-Ranzinger et al., 2014).

The second strategy named as sustain management strategy. This strategy focusses on applying controlling activities at everyday basis such as indoor spraying with residual insecticides to kill adult mosquitoes (Achee et al., 2015). The other proposed dengue control activities for sustain management strategy include larvaciding treatment, container removals, public education campaign, environment and legislation (Tun-Lin et al., 2009; Vanlerberghe et al., 2009; Arunachalam et al., 2012). However, currently, there is no specific dengue control activities that exclusively recommended for sustain management strategy (Achee et al., 2015).

Finally, epidemic mitigation strategy emphasizes on preventing the outbreak by implementing high-impact activities at the beginning of the outbreak period (Achee et al., 2015). Among the suggested dengue control activities for epidemic mitigation strategy are fogging, indoor insecticide and the use of bed nets (Amal et al., 2011; Achee et al., 2015; Antonio-Nkondjio et al., 2018). The objective for this strategy is to prevent the *Aedes* mosquito from accumulated to critical level. This strategy is usually applied during epidemic period which favor the growth of mosquito *Aedes* the most. Similar to the sustain management strategy, there is no consent on the specific dengue control activities that were recommended for epidemic mitigation strategy due to the lack of reliable data (Achee et al., 2015).

2.3 Multi Criteria Decsion Making Methods for Ranking the Factors

Multi Criteria Decision Making (MCDM) is an approach of solving multi criteria problems for obtaining the appropriate alternative that involve process such as evaluation and comparison between the alternatives (Ozturk & Ozcelik, 2014). MCDM provides a decision support tools to assist decision makers in the selection of alternatives under the influence of criterion through a decision hierarchy. In general, MCDM deal with alternative that are evaluated under a set of criteria by a single or a group of decision makers (Triantaphyllou & Shu, 1998). Decision maker is an individual that are knowledgeable in the area of their interest. Their judgements, weighting and opinions are essential in determining the value for criteria and alternatives (Chen, 2000). The general decision hierarchy for MCDM approach is presented in Figure 2.

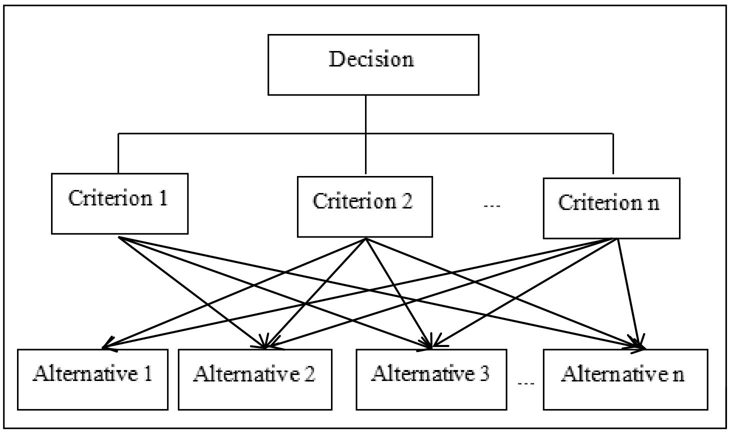

Fig. 2. Decision hierarchy of MADM

One of the available methods in MADM is The Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). The purpose of TOPSIS is to choose alternative that have the shortest distance from the positive ideal solution while having the farthest distance of the negative ideal solution. TOPSIS is often used in the selection of complex and uncertain scenarios. For example, TOPSIS was used in the selection of possible management that will increase the performance of reservoir through three indicators namely reliability, resiliency and vulnerability (Srdjevic & Medeiros, 2004). Other similar research done by Salmeron, Vidal and Mena (2012) integrated TOPSIS, fuzzy cognitive map and Delphi approach in selecting the appropriate scenario that concern with human explicit and tacit knowledge. However, there is lack of research on TOPSIS applied in the dengue case study. The most recent work is by Ermatita and Febry (2017) adopted TOPSIS and association rule method to develop a decision support system for prioritizing a risk factor for dengue epidemic.

In the real problem, most of the expert judgements are consider ambiguous due to the sufficient, uncertainties, subjectivity, and the unavailability of numerical data (Chen, 2000). Dengue studies in particular, involved with uncertainties that result in environmental factors (Torres et al., 2014). Instead of giving evaluation in numerical value, decision makers tends to express their opinions based on their experience through language variables. Therefore, the extension of TOPSIS under fuzzy environment known as Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (FTOPSIS) was proposed by Chen (2000). The general concept of FTOPSIS highlighted the importance of giving weightage on criteria and ratings on alternatives by using linguistic variable (Chen, 2000).

3. METHODOLOGY

The steps involved for the development of FTOPSIS model as shown in Figure 3. The explanation for each steps are as follows:

Step 1: In this step, the criteria and alternative used in this research were determined. For this study, the criteria are economics, effectiveness and environment which are adopted from the studies by Ong (2016). On the other hand, alternatives represent the four control activities namely fogging and larvaciding, premise inspection, public education and vector surveillance. The information on these control activities are obtained from the study by Packierisamy et al., (2015) and Ong (2016). Detail explanations for both criteria and alternatives are provided in Table 1.

Table 1. Description on the criteria and alternative used in the model.

		Label	Description
Criteria (E)	Environment	E1	The capability of control activities to effect on surroundings, visual, biodiversity and public acceptance.
	Economics	E2	The spending money allocates to equipment, personnel and vehicles maintenance to conduct the control activities.
	Effectiveness	E3	The impact of control activities towards reducing the number of mosquito population either in larvae or adult state.

Alternatives (A)	Fogging & larvaciding	A1	Use to target adult mosquito through thermal fogging and Ultra Low Volume (ULV) fogging. The thermal fogging use heat in the fogging process while ULV fogging use cold fogging technique.
	Premise inspection	A2	Source reduction approach that target house and premises from larvae or pupae through the enforcement of Destruction of Disease Bearing Insects Act 1995.
	Public education	A3	Health education campaign including talks, dialogues, exhibitions, demonstration of the use of Abate, film shows, small group discussions, public announcements and poster distributions.
	Vector surveillance	A4	Part of entomological surveillance that used to determine changes in the geographical distribution and density of vector population over time.

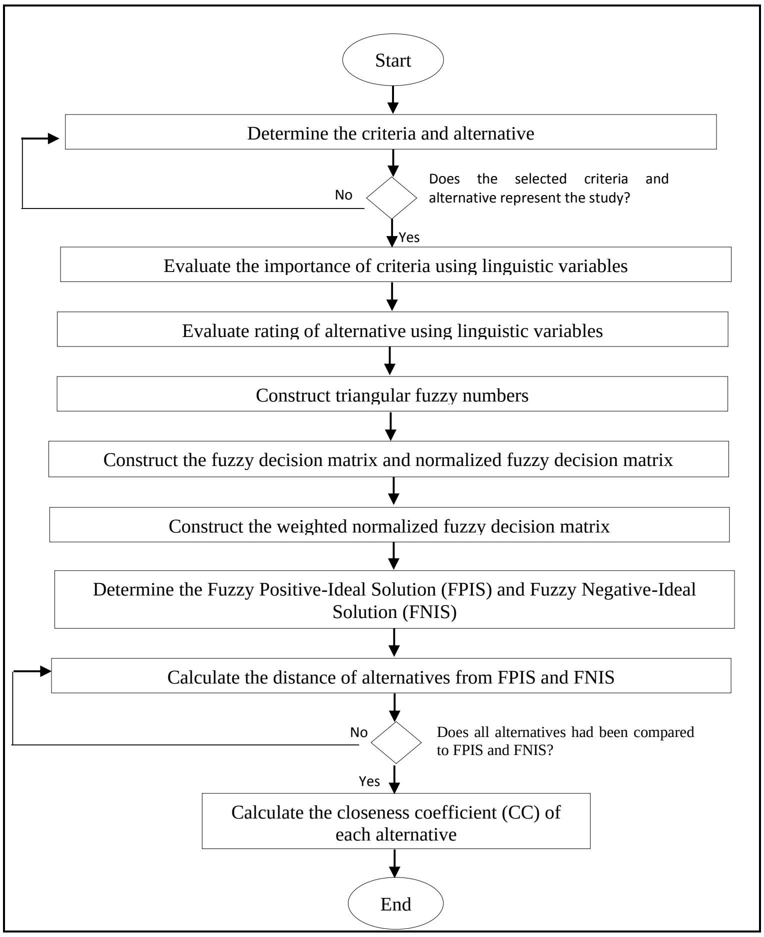

Fig. 3. FTOPSIS modelling process (adapted from Chen, 2000)

The chosen criteria and alternatives are combined to form a decision hierarchy. The constructed decision hierarchies for this research is presented in Figure 4. Once the constructed decision hierarchy has been developed, the expert then prioritizes the control strategy. This strategy aims to prevent mosquito *Aedes* from accumulate to critical level through implementing high-impact activities at the beginning of outbreak period.

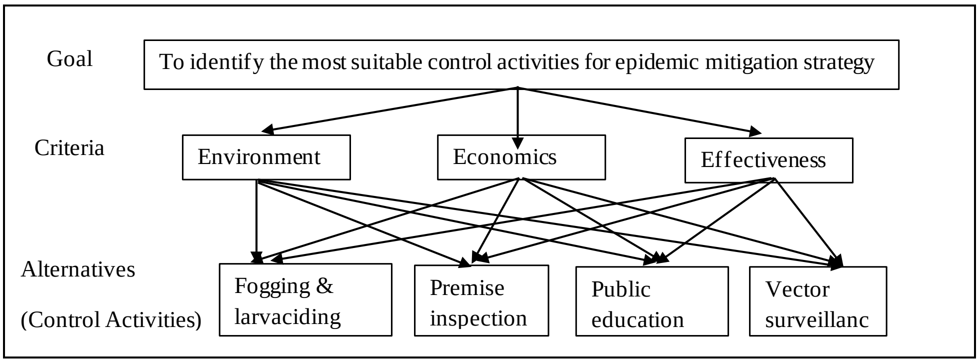

Fig. 4. The constructed decision hierarchy for epidemic mitigation strategy

Step 2: In this step, expert evaluated the importance of criteria and weighting the alternative using linguistic variables adopted from the study by Chen (2000). The linguistic variables for this research are presented in Table 2. These linguistic variables were used to evaluate the importance of the environment, economics and effectiveness criteria for nd epidemic mitigation strategy. The value represents the position in a triangular fuzzy number. For example, Let $\tilde{m} = (m_1, m_2, m_3)$. The value of $\tilde{m}$ lies between 0 to 1 where m_1 represents smallest likely value, m_2 the most probable value, and m_3 the largest possible value of any fuzzy events. After that, these linguistic variables were converted into fuzzy numbers. These fuzzy numbers were used throughout the process.

Table 2. Linguistic variables for the importance weight of each criterion (Source: Chen, 2000).

Very low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1, 0.3)
Medium low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium high (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very high (VH)	(0.9, 1.0, 1.0)

Step 3: In this step, linguistic variables as presented in Table 3 was used to rate the four dengue controlling activities which are fogging and larvaciding, premise inspection, vector surveillance and public education based on the criteria of environment, economics and effectiveness.

Table 3. Linguistic variables used for the rating process (Source: Chen, 2000).

Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

Step 4: In this step, linguistic variables used in Table 2 and Table 3 were converted into triangular fuzzy numbers using the notation of $X_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $W_j = (W_{j1}, W_{j2}, W_{j3})$.

Step 5: In this step, a fuzzy decision matrix and the normalized fuzzy decision matrix was constructed based on the Equation 1 and Equation 2.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (1)$$

$$\tilde{w} = [\tilde{w}_1 \quad \tilde{w}_2 \quad \cdots \quad \tilde{w}_n] \quad (2)$$

Where $\tilde{x}_{ij}$, $\forall i$, j and $\tilde{w}_j$, $j = 1, 2, \ldots, n$ are linguistic items. These linguistic variables can be described by triangular fuzzy numbers $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$. Next, the normalized fuzzy decision matrix was constructed. In this process, linear scale transformation was used to avoid the complexity in the traditional TOPSIS procedure and to preserve the ranges to [0, 1]. The normalized fuzzy decision matrix denoted by $\tilde{\boldsymbol{R}}$ can be obtained as shown in Equation 3.

$$\tilde{\boldsymbol{R}} = [\tilde{r}_{ij}]_{m \times n} \quad (3)$$

The calculation for the normalized fuzzy decision matrix is shown in Equation 4 to Equation 7.

$$\tilde{r}_{ij} = \left[\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+},\right], j \in B; \quad (4)$$

$$\tilde{r}_{ij} = \left[\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right], j \in C; \quad (5)$$

$$c_j^+ = \frac{max}{i} C_{ij}, j \in B; \quad (6)$$

$$a_j^- = \frac{min}{i} a_{ij}, j \in C; \quad (7)$$

where B and C are the set of benefit attributes and cost attributes respectively. A maximum value is set for the benefit attribute and a minimum value is set for the cost attribute.

Step 6: In this step, the weighted normalized fuzzy decision matrix is constructed based on the Equation 8.

$$\tilde{\boldsymbol{V}} = [\tilde{v}_{ij}]_{m \times n} \quad (8)$$

where $\tilde{v}_{ij} = \tilde{r}_{ij} (.) \tilde{w}_j$

Step 7: In this step, the constructed weighted normalized fuzzy decision matrix contains elements that are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0,1]. Then, the value of Fuzzy Positive-Ideal Solution (FPIS, A^+) and Fuzzy Negative-Ideal Solution (FNIS, A^-) which adapted from Chen (2000) is presented in Equation 9 and Equation 10 respectively.

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots \tilde{v}_n^+) \quad (9)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots \tilde{v}_n^-) \quad (10)$$

Based on Chen (2000), the value for Fuzzy Positive-Ideal Solution is $\tilde{v}_j^+$= (1.0, 1.0, 1.0) and Fuzzy Negative-Ideal Solution is $\tilde{v}_j^-$= (0.0, 0.0, 0.0).

Step 8: In this step, the distance of each alternative from FPIS (d_i^+) and FNIS (d_i^-) were calculated. The distance is to measure how close the alternative with ideal (FPIS, A^+) and non-ideal solution (FNIS, A^-) where $i = 1,2, \dots, m$ and $j = 1,2, \dots, n$. The formula for calculation is shown in Equation 11 and Equation 12 as follows:

$$d_i^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^+\right), i = 1,2, \dots, m \text{ and } j = 1,2, \dots, n \quad (11)$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right), i = 1,2, \dots, m \text{ and } j = 1,2, \dots, n \quad (12)$$

where $d\left(\tilde{v}_{ij}, \tilde{v}_j^+\right)$ and $d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right)$ is the measurement of distance between two fuzzy numbers.
Step 9: In this step, the closeness coefficient (CC) of each alternative was calculated using the Equation 13. Then, the alternatives where rank from the smaller to the bigger value.

$$CC_i = \frac{d_i}{(d_i^+ + d_i^-)}, \ i = 1,2, \dots, m. \quad (13)$$

As a summary, result obtain from the analysis of FTOPSIS model was used to rank the dengue control activities from the most suitable to the least suitable for epidemic mitigation strategy.

4. RESULT AND DISCUSSION

The result of FTOPSIS analysis for epidemic mitigation strategy are presented in Table 4 to Table 7. Referring to Table 4, result shows that effectiveness were the most important criteria for epidemic mitigation strategy. Meanwhile, environment and economic criteria are labelled as *Medium* in terms of its importance. Based on Table 5, most of the dengue control activities were rate with the range value of rating from *Fair*, *Medium Good* and *Good* for environment, economics and effectiveness criteria. However, only public education had been rated as *Medium Poor* for its effectiveness. In contrast, fogging and larvaciding and premise inspection had been rated with *Good* for its effectiveness in epidemic mitigation strategy. Based on Table 6, the highest CC value is premise inspection with 0.5483 followed by fogging and larvaciding activity with 0.4506. The third highest CC value is vector surveillance with 0.3445 which have slight difference with public education activity that have CC value of 0.3359.

Based on the CC value, the ranking of control activity is presented in the Table 7. The finding shows that premise inspection is the first rank followed by fogging & larvaciding, vector surveillance and public education in the second, third and fourth rankings. This is because, these two activities yield faster result and it is proven effective in reducing the number of mosquito in shorter period of time. On the other hand, vector surveillance and public education would have a less effect on dengue control. This is because vector surveillance only functioning as a tool to alert the vector control team regarding the *Aedes* mosquito. Meanwhile, the objective of public education is to educate society on the importance of keeping the residential area free from the *Aedes* mosquito breeding area and the result could be observed in the long run. For these reasons, vector surveillance and public education is less appropriate for epidemic mitigation strategy.

Table 4. The importance weight of criteria for epidemic mitigation strategy

Criteria	Linguistic Variables
Environment	Medium
Economics	Medium
Effectiveness	Very High

Table 5. The ratings of control activities under epidemic mitigation strategy

Criteria	Control activities	Linguistic Variables
Environment	Fogging & larvaciding	Fair
	Premise inspection	Medium Good
	Public education	Good
	Vector surveillance	Fair
Economics	Fogging & larvaciding	Fair
	Premise inspection	Medium Good
	Public education	Good
	Vector surveillance	Good
Effectiveness	Fogging & larvaciding	Good
	Premise inspection	Good
	Public education	Medium Poor
	Vector surveillance	Fair

Table 6. The distance of control activity from FPIS (A*), FNIS (A-) and the value of closeness coefficient (CC) under epidemic mitigation strategy

Control activity	A*	A-	CC value
Fogging & larvaciding	0.5747	0.4714	0.4506
Premise inspection	0.4518	0.5485	0.5483
Public education	0.6002	0.3036	0.3359
Vector surveillance	0.5900	0.3100	0.3445

Table 7. The ranking of control activity under epidemic mitigation strategy

Control activity	Rank
Fogging & larvaciding	2
Premise inspection	1
Public education	4
Vector surveillance	3

5. CONCLUSION AND FUTURE RESEARCH

In this study, a FTOPSIS model was developed to priotize the four dengue controlling strategies namely fogging & larvaciding, premise inspection, public education, and vector surveillance based on the criteria of effectivess, economics and environment. The result shows that premise inspection and fogging and larvaciding activities are the two most appropriate control activities for epidemic mitigation strategy. It is followed by vector surveillance and public education. For future research, other alternatives of dengue control activities such as biological control, attractant trap, genetic modified mosquito and bacterium *wolbachia pipientis* that were not officially practice at the time of this study being conducted should also be included in the model for the better representation of the real dengue system.

ACKNOWLEDGEMENT

The authors wish to thank the Universiti Utara Malaysia (UUM) in funding this study under Geran Penjanaan (S/O Code-13874) and Research and Innovation Management Centre (RIMC), UUM for the administration of this study.

SOURCE(S) OF SUPPORT: Nil

CONFLICTING INTEREST: There Is No Conflict Of Interest Between Authors**.**

REFERENCES

Achee, N. L., Gould, F., Perkins, T. A., Reiner, R. C., Morrison, A. C., Ritchie, S. A., Gubler, D. J., Teyssou, R., & Scott, T. W. (2015). A Critical Assessment of Vector Control for Dengue Prevention. *PLoS Neglected Tropical Diseases*, *9*(5), 1–19. https://doi.org/10.1371/journal.pntd.0003655

Al-Dubai, S. (2013). Factors affecting dengue fever knowledge, attitudes and practices among selected urban, semi-urban and rural communities in Malaysia. *Southeast Asian J …*, *44*(1), 37–49. http://www.tm.mahidol.ac.th/seameo/2013-44-1-full/6-5403-10.pdf

Amal, A. R., Malina, O., Rukman, A. H., Zasmy, U. N., Omar, A. W., & Norhafizah, M. (2011). The impact of preventive fogging on entomological parameters in a university campus in malaysia. *Malaysian Journal of Medicine and Health Sciences*, *7*(1), 9–15.

Antonio-Nkondjio, C., Sandjo, N. N., Awono-Ambene, P., & Wondji, C. S. (2018). Implementing a larviciding efficacy or effectiveness control intervention against malaria vectors: Key parameters for success. *Parasites and Vectors*, *11*(1), 1–12. https://doi.org/10.1186/s13071-018-2627-9

Arunachalam, N., Tyagi, B. K., Samuel, M., Krishnamoorthi, R., Manavalan, R., Tewari, S. C., Ashokkumar, V., Kroeger, A., Sommerfeld, J., & Petzold, M. (2012). Community-based control of *Aedes aegypti* by adoption of eco-health methods in Chennai City, India. *Pathogens and Global Health*, *106*(8), 488–496. https://doi.org/10.1179/2047773212Y.0000000056

Beier, J. C., Keating, J., Githure, J. I., Macdonald, M. B., Impoinvil, D. E., & Novak, R. J. (2008). Integrated vector management for malaria control. *Malaria Journal*, *10*, 1–10. https://doi.org/10.1186/1475-2875-7-S1-S4

Bonds, J. A. S. (2012). Ultra-low-volume space sprays in mosquito control: A critical review. *Medical and Veterinary Entomology*, *26*(2), 121–130. https://doi.org/10.1111/j.1365-2915.2011.00992.x

Chandren, J. R., Wong, L. P., & AbuBakar, S. (2015). Practices of Dengue Fever Prevention and the Associated Factors among the Orang Asli in Peninsular Malaysia. *PLoS Neglected Tropical Diseases*, *9*(8), e0003954. https://doi.org/10.1371/journal.pntd.0003954

Chang, M. S., Christophel, M., Gopinath, D., & Abdur, R. (2011). Challenges and future perspective for dengue vector control in the Western Paci fi c Region. *Western Pacific Surveillance and Response Journal*, *2*(2), 1–8. https://doi.org/10.5365/wpsar.2010.1.1.012

Cheah, W. K., Ng, K. S., Marzilawati, A., & Lum, L. C. S. (2014). A Review of Dengue Research in Malaysia. *Med J Malaysia*, *69*, 59–67.

Chen, C.-T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets and Systems*, *114*(1), 1–9. https://doi.org/10.1016/S0165-0114(97)00377-1

Cheong, Y., Burkart, K., Leitão, P., & Lakes, T. (2013). Assessing Weather Effects on Dengue Disease in Malaysia. *International Journal of Environmental Research and Public Health*, *10*(12), 6319–6334. https://doi.org/10.3390/ijerph10126319

Degallier, N., Favier, C., Menkes, C., Lengaigne, M., Ramalho, W. M., Souza, R., Servain, J., & Boulanger, J. P. (2010). Toward an early warning system for dengue prevention: Modeling climate impact on dengue transmission. *Climatic Change*, *98*(3), 581–592. https://doi.org/10.1007/s10584-009-9747-3

Department of Statistics, M. (2016). *Kedah*. Department of Statistic Malaysia. https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=M25ucnhaYUMwbjFwc3hhWkhrQ2tIUT09

Ermatita, & Febry, F. (2017). Implementation of association rule method and topsis method to decision support system for determining epidemic dengue based on risk factors association. *Journal of Theoretical and Applied Information Technology*, *95*(7), 1418–1424. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85017574719&partnerID=40&md5=53cdba0d1cd7843cb8ce76ee02648207

Ewe, E. (2000). Behavioural Interventions in Dengue Control in Malaysia. In F. Kin, K. Y. LIm, & V. Devi (Eds.), *Health Education in Dengue Control* (pp. 27–35). Universiti Sains Malaysia.

Hod, R., Othman, H., Jemain, N. A., Sahani, M., Udin, K., Ali, Z. M., Choy, E. A., & Zailiza Suli. (2013). The COMBI Approach in Managing Dengue Cases in an Urban. *International Journal of Public Health Research*, *3*(2), 347–352.

Horstick, O., Runge-Ranzinger, S., Nathan, M. B., & Kroeger, A. (2010). Dengue vector-control services: How do they work? A systematic literature review and country case studies. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *104*(6), 379–386. https://doi.org/10.1016/j.trstmh.2009.07.027

Ibrahim, A., Azan, N., Zin, M., & Ashaari, N. S. (2011). Simulation Model for Predicting Dengue Fever Outbreak. *World Academiy of Science, Engineering and Technology*, *59*, 67–69.

Lowe, R., Bailey, T. C., Stephenson, D. B., Jupp, T. E., Graham, R. J., Barcellos, C., & Carvalho, M. S. (2013). The development of an early warning system for climate-sensitive disease risk with a focus on dengue epidemics in Southeast Brazil. *Statistics in Medicine*, *32*(5), 864–883. https://doi.org/10.1002/sim.5549

Mahmud, M. A. F., Mutalip, M. H., Lodz, N. A., & Shahar, H. (2018). Study on key Aedes spp breeding containers in dengue outbreak localities in Cheras district, Kuala Lumpur. *International Journal of Mosquito Research*, *5*(2), 23–30.

Mapjabil, J., Yusof, N., & Mat Jusoh, A. T. (2010). TRANSFORMATION OF ECONOMIC DEVELOPMENT IN THE STATE OF KEDAH : HISTORICAL PERSPECTIVE. *Prosiding Perkem V*, *2*, 171–181.

Ministry of Health Malaysia. (2015). *Health Facts 2015* (pp. 1–2). http://vlib.moh.gov.my/cms/content.jsp?id=com.tms.cms.document.Document_ef876440-a0188549-82a26f00-e6a36876

Nurul Nadrah Aqilah, T., & Sobri, H. (2011). The Projection Of Future Rainfall Change Over Kedah, Malaysia With The Statistical Downscaling Model. *Malaysian Journal of Civil Engineering*, *23*(2), 67–79.

Ong, S.-Q. (2016). Dengue Vector Control in Malaysia: A Review for Current and Alternative Strategies. *Sains Malaysiana*, *45*(5), 777–785. http://www.ukm.my/jsm/pdf_files/SM-PDF-45-5-2016/14 Song-Quan Ong.pdf

Packierisamy, P. R., Ng, C.-W., Dahlui, M., Inbaraj, J., Balan, V. K., Halasa, Y. A., & Shepard, D. S. (2015). Cost of Dengue Vector Control Activities in Malaysia. *The American Journal of Tropical Medicine and Hygiene*, *93*(5), 1020–1027. https://doi.org/10.4269/ajtmh.14-0667

Runge-Ranzinger, S., McCall, P. J., Kroeger, A., & Horstick, O. (2014). Dengue disease surveillance: An updated systematic literature review. *Tropical Medicine and International Health*, *19*(9), 1116–1160. https://doi.org/10.1111/tmi.12333

Sazali, M., Samino, S., & Leksono, A. S. (2014). Attractiveness test of attractants toward dengue virus vector (Aedes aegypti) into lethal mosquiTrap modifications (LMM). *Nternational Journal of Mosquito Research*, *1*(4), 47–49.

Shi, Y., Liu, X., Kok, S. Y., Rajarethinam, J., Liang, S., Yap, G., Chong, C. S., Lee, K. S., Tan, S. S. Y., Chin, C. K. Y., Lo, A., Kong, W., Ng, L. C., & Cook, A. R. (2016). Three-month real-time dengue forecast models: An early warning system for outbreak alerts and policy decision support in Singapore. *Environmental Health Perspectives*, *124*(9), 1369–1375. https://doi.org/10.1289/ehp.1509981

Suhaili, M. R., Hosein, E., Mokhtar, Z., Ali, N., Palmer, K., & Isa, M. (2004). Applying Communication-for-Behavioural-Impact (COMBI) in the Prevention and Control of Dengue in Johor Bahru, Johore, Malaysia. *Dengue Bulletin*, *28*, 39–43.

Torres, C., Barguil, S., Melgarejo, M., & Olarte, A. (2014). Fuzzy model identification of dengue epidemic in

Colombia based on multiresolution analysis. *Artificial Intelligence in Medicine*, *60*(1), 41–51. https://doi.org/10.1016/j.artmed.2013.11.008

Triantaphyllou, E., & Shu, B. (1998). Multi-criteria decision making: an operations research approach. *Encyclopedia of Electrical and Electronics Engineering*, *15*, 175–186. http://univ.nazemi.ir/mcdm/Multi-Criteria Decision Making.pdf

Tun-Lin, W., Lenhart, A., Nam, V. S., Rebollar-Téllez, E., Morrison, A. C., Barbazan, P., Cote, M., Midega, J., Sanchez, F., Manrique-Saide, P., Kroeger, A., Nathan, M. B., Meheus, F., & Petzold, M. (2009). Reducing costs and operational constraints of dengue vector control by targeting productive breeding places: A multi-country non-inferiority cluster randomized trial. *Tropical Medicine and International Health*, *14*(9), 1143–1153. https://doi.org/10.1111/j.1365-3156.2009.02341.x

Vanlerberghe, V., Toledo, M. E., Rodríguez, M., Gomez, D., Baly, A., Benitez, J. R., & Van Der Stuyft, P. (2009). Community involvement in dengue vector control: Cluster randomised trial. *BMJ (Online)*, *338*(7709), 1477–1479. https://doi.org/10.1136/bmj.b1959

WHO. (2015). *About WHO*. http://www.who.int/about/en/