Dengue Hemorrhagic Fever Prevention and Control: DHF-Solve Model using Linebot-Application and GIS

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Abstract
Dengue hemorrhagic fever (DHF) poses a significant health challenge in Thailand, highlighting the need for a better understanding of its transmission and characteristics. Innovation and technology are essential for effective prevention and control measures. This research article centres on developing a model to prevent and control DHF, utilising the DHF-Solve model, a Linebot, and Geographic Information Systems (GIS). The research was conducted in four phases. Phase 1 focused on identifying risk factors and high-risk areas for DHF. Phase 2 examined the factors influencing people's behaviours regarding DHF prevention and control. Phase 3 was dedicated to developing the model, while Phase 4 assessed its effectiveness. The research employed various tools, including GIS, questionnaires, Linebot, assessment forms, and primary and secondary data collection. Risk areas were identified through frequency and weighting techniques as well as descriptive statistical analysis. The factor that most significantly influenced behaviour was people's perception of DHF, which received an average score of 4.19. The findings from the model development indicated that the DHF-Solve Linebot is an effective management and control system for DHF. It features six menus accessible through the Line Official Account (LOA) and can function as a real-time platform. This Linebot incorporates AI chatbot commands and GIS technology, which proved to be the most effective in terms of promptness and responsiveness. It has demonstrated the potential to reduce morbidity rates during two outbreak generations. Therefore, this model effectively addresses the issue of DHF and should be implemented as a response mechanism in emergencies where DHF outbreaks may arise.

Keywords: DHF, Geographic Information System, Linebot, Prevention and Control

1. Introduction

Dengue Hemorrhagic Fever (DHF) is a viral infection caused by the dengue virus, transmitted by Aedes mosquitoes. It has become a significant public health concern worldwide, particularly in tropical countries like Thailand. In 2023, Thailand experienced a substantial outbreak of DHF, resulting in numerous fatalities. This outbreak followed a period of relative calm after the resolution of the COVID-19 pandemic [1]. The disease's resurgence can be linked to reduced immunity within the population and increased risk factors such as transportation, population movement, labour, and economic activities during the post-COVID-19 recovery phase [2]. Additionally, Thailand's topography and climate create an ideal environment for Aedes mosquitoes, heightening the epidemic risk [3].

On November 21, 2023, a report from the Department of Disease Control in Thailand indicated that the morbidity rate was 206.52 cases per 100,000 population, resulting in 147 deaths and a mortality rate 71.18. Chaiyaphum Province experienced a notably higher morbidity rate compared to the previous year, reaching 157.89 cases per 100,000 people, with three recorded deaths. This trend is concerning, especially as it emerges toward the end of the rainy season 2023 [4].

It is essential to emphasize the ongoing threat of DHF in Chaiyaphum Province, which can be attributed to ineffective disease prevention and control measures [5]. Given the seriousness of the situation, it is essential to address the DHF issue while strictly adhering to the Ministry of Public Health guidelines.

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This should focus on rapid and effective prevention and control measures, timely detection of events, accurate information reporting, and proper management strategies, all of which are crucial for effective disease control. However, a comprehensive model for timely event detection, information reporting, and risk analysis has yet to be developed [6]. Such a model must align with the Ministry of Public Health's guidelines while remaining cost-effective. According to existing literature, Linebot technology is a valuable tool for disease control. It facilitates supervision and monitoring while streamlining application processes by disease prevention models. When integrated with Geographic Information Systems (GIS) and enhanced by Artificial Intelligence (AI) technology, the efficiency of disease control efforts is significantly improved [7].

GIS, a branch of information technology, has been extensively utilised in public health management at various levels [8]. It is a more effective method of disease control, playing a crucial role in decision-making for disease prevention. Additionally, GIS enhances operational efficiency across all aspects of public health management [9]. Despite the significance of effective disease control, current measures are often inefficient and lack systematic management. As a result, outbreaks are not effectively controlled, allowing diseases to spread and worsen. This study proposes developing a model for preventing and controlling DHF using Linebot technology integrated with Geographic Information Systems (GIS). The goal is to efficiently manage and address dengue fever by leveraging modern technology for ease of use, speed, and cost-effectiveness, ultimately ensuring rapid and effective disease control. The objectives of the study are as follows:

- To identify risk factors and high-risk areas for DHF using GIS
- To examine the factors influencing individuals' behaviours regarding DHF prevention and control
- To develop a model for DHF control that integrates GIS with Linebot technology
- To evaluate the effectiveness of the proposed model

2. Study Area

Chaiyaphum Province is in the northeastern region of Thailand, at 631 feet above sea level. It is approximately 332 kilometres from Bangkok by car. It covers an area of about 12,778.3 square kilometres, or 7,986,429 rai, which accounts for 7.9 per cent of the region's total area and 2.5 percent of the country. This makes it the third-largest province in the northeastern region and the seventh-largest in Thailand. The province shares borders with several neighboring provinces: Khon Kaen and Phetchabun to the north, Khon Kaen and Nakhon Ratchasima to the east, Nakhon Ratchasima to the south, and Lopburi and Phetchabun to the west. Chaiyaphum Province is situated at a latitude of 15.8040° North and a longitude of 102.0310° East. The general topography of Chaiyaphum consists of forests and mountains, which comprise 31.5 per cent of its total area. The remaining area is a plateau, with a central flat region with forests and mountain ranges stretching east to west. Notable mountain ranges in the province include Phu E-Thao, Phu Laen Kha, and Phu Phang Hei. Chaiyaphum Province experiences a hot and humid climate characterized by a tropical monsoon climate with three distinct seasons. The duration of each season may vary depending on the weather conditions from year to year. Winters can be cold, summers are sweltering, and the rainy season alternates with a dry season, with each season clearly defined within the year.

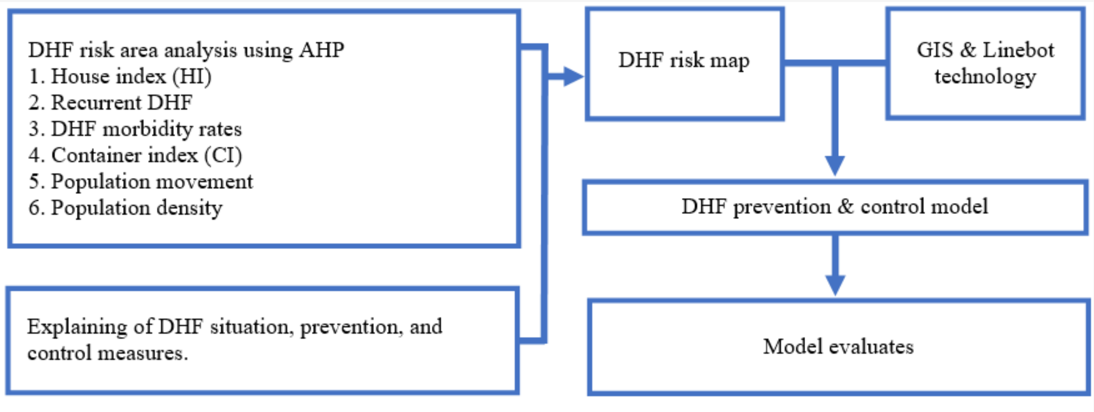

Figure 1: Conceptual framework for the study

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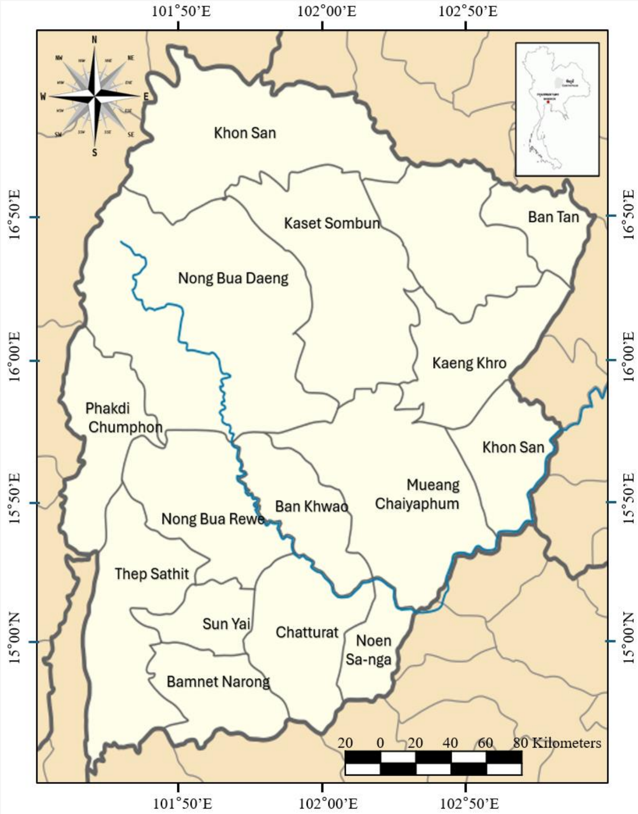

Figure 2: Chaiyaphum province of Thailand

3. Methods

This study was development research divided into 4 phases as depicts in Figure 1.

3.1 Phase 1: DHF Risk Areas Analysis

3.1.1 Methodology

Step 1: Conduct a comprehensive review of relevant literature and research to identify factors influencing the incidence of DHF in Chaiyaphum Province (Figure 2) and select appropriate factors for analysis.

Step 2: Several key steps involve analysing and managing data related to the factors that influence the incidence of DHF. First, it is essential to assign weights to the scores of the selected factors. Next, the data should be categorised into groups. Lastly, scores should be applied based on predefined criteria. The scoring criteria are as follows: a score of 1 indicates that the factor has the most negligible impact, a score of 2 represents a moderate impact, and a score of 3 signifies that the factor has the most significant impact.

Step 3: Assess the impact of various factors on the incidence of DHF by first assigning a weight to each factor score (Weighting) and then rating each factor score (Rating). This assessment is based on experts' opinions on DHF prevention and control from 16 districts, with three individuals consulted per district, totaling 48 participants. Assign weights to the scores of each factor on a scale from 1 to 10 and subsequently adjust these scores to a uniform range of 0 to 1. Finally, incorporate the adjusted scores into an equation. The weights are determined using the Analytic Hierarchy Process (AHP). These adjusted scores will then be utilised in an equation reflecting the varying importance of each factor based on expert opinions, as detailed in Table 3.

The Multiple Criteria Analysis (MCA) of the following steps:

- Criteria evaluation: Criteria scores for each factor were set, with each factor being ranked or scored according to its relevance, assigning scores from 1 to 3 based on the risk level of each area.
- Weight assignment: Weighting techniques, such as Analytic Hierarchy Process (AHP), were used to assign weights to each factor based on its importance.
- Map overlay: The data of each factor, which had been assigned scores and weights, were overlaid to create DHF risk area map. Then, the total score was calculated by multiplying each factor's score by its assigned weight.

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- Score aggregation: The score of each area was calculated based on the scores and weights of the factors that had been overlaid, resulting in the final score or suitability value for each area by aggregating all related factors.
- Final map generation: The analysis results were displayed through a map created from the total scores calculated in the previous steps. The result map used different colors to indicate the suitability levels of each area.

The process of assigning weights using the Analytic Hierarchy Process (AHP) for risk area analysis consists of the following steps, as detailed in Table 2.

- Define the main criteria. Identify all factors relevant to the risk area analysis.
- Create a hierarchical structure. Organize the criteria into a hierarchy, starting with the primary goal at the top and then sub-criteria at lower levels.
- Develop the pairwise comparison matrix. Conduct pairwise comparisons of all criteria in a comparison matrix, assigning scores based on their relative importance. Each pair is compared individually, and these scores are informed by expert input or experiential data to ensure accuracy.
- Calculate weights from the pairwise comparison matrix. Once the pairwise comparison matrix is completed, calculate the relative weight of each factor by averaging each row. This method helps derive weights that reflect each factor's importance.

Calculate a total score value during data analysis and categorize the risk of DHF outbreaks accordingly.

$$S = \sum_{i=1}^{n} R_i W_i$$

Equation 1

Where:

S = DHF risk
R_i = DHF risk-influencing of i^{th} factor
W_i = Criteria weight for i^{th} factor
i = factor number
n = Total numbers of influencing factors

Step 4: Utilize ArcGIS software to create a map that illustrates the risk of DHF in Chaiyaphum Province. Conduct a geostatistical analysis to explore the spatial relationships among the identified risk factors. The research tools used included the ArcGIS program and a questionnaire designed to gather expert opinions on the factors influencing the incidence of DHF in Chaiyaphum Province.

3.1.2 Data collection

Primary data was collected by distributing a questionnaire to 48 local experts. The responses were thoroughly reviewed for completeness and accuracy before analysis. Additionally, secondary data was gathered from various agencies that compiled relevant information, including data on recurring outbreak areas, morbidity rates, and population movement and density.

3.1.3 Data analysis

The analysis of opinion data utilised descriptive statistics, including frequency, mean, and standard deviation, to examine the factors influencing the incidence of DHF in Chaiyaphum Province. ArcGIS was employed to assess areas at risk for DHF, and it involved several vital steps.

- Data scores. Scores were calculated for each factor class to rank the risk of DHF. These scores were then incorporated into a specified equation.
- Division of DHF risk levels. The DHF risk areas were categorized into low-risk, medium-risk, and high-risk areas.
- Map preparation. Maps were created to illustrate the incidence of each factor. These maps were developed using geospatial attribute analysis.
- They provide a comprehensive map depicting areas at risk for DHF, categorised according to each location's risk level.

3.2 Phase 2: Discuss the Factors Affecting the Population's Behaviour in Chaiyaphum Province Regarding the Prevention and Control of DHF

The study population comprised 1,118,750 individuals from Chaiyaphum Province [10]. A total of 455 heads of households or household representatives who had been living in the province for at least six months were included in the sample. The sample size was calculated using a formula for estimating proportions in a small population, with a confidence level of 95% [11]. To account for the possibility of incomplete data, the sample size was increased by 20%. Participants were selected through a combination of multi-stage random sampling and simple random sampling, ensuring that the proportions corresponded to each district.

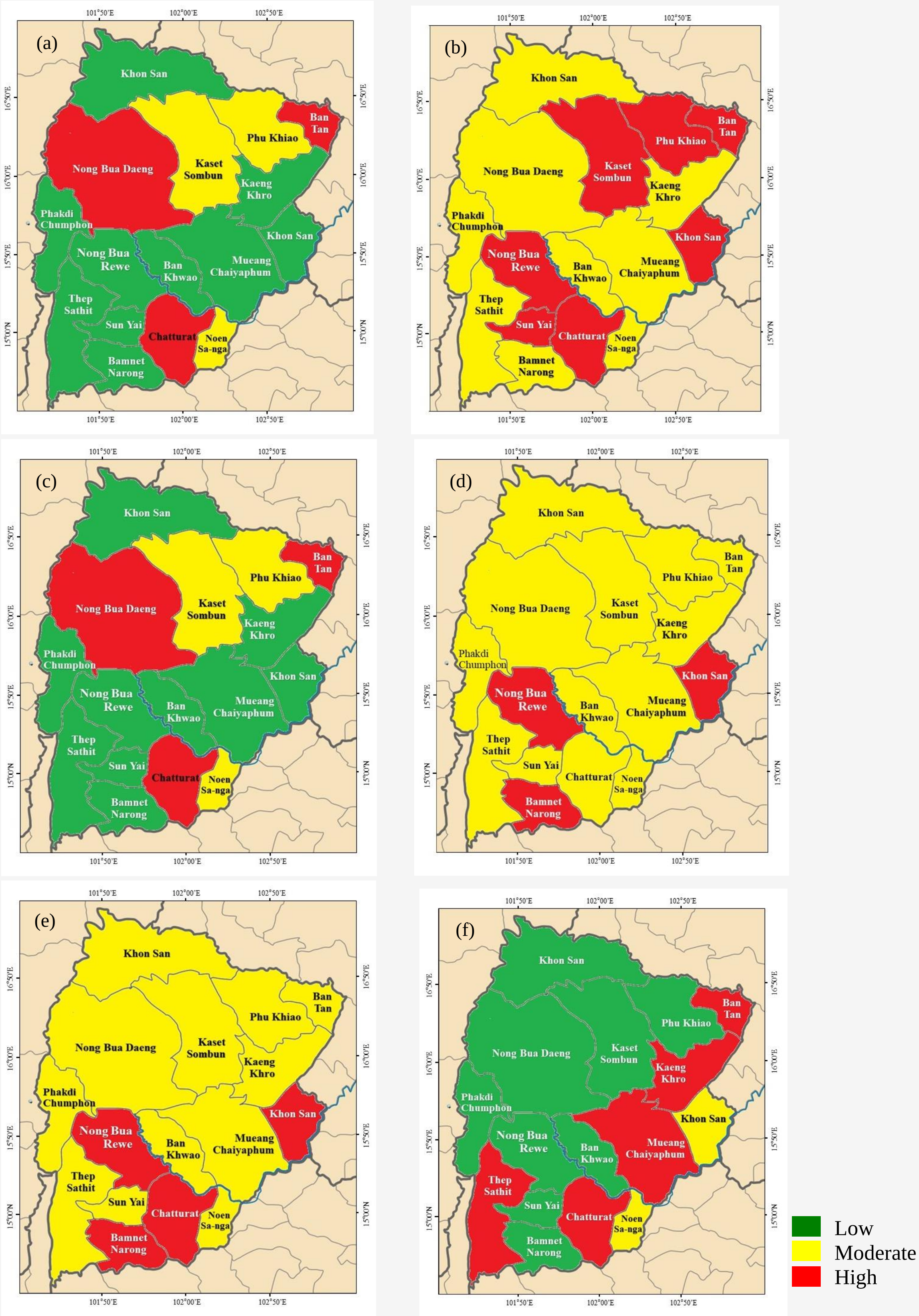

Figure 3: DHF influencing factors (a) house index in 2023 (b) recurrent DHF from 2020-2022 (c) five-year median of DHF morbidity rates from 2019 to 2022 (d) container index (e) population movement in 2023 (f) population density in 2023

This study utilised a questionnaire focused on preventing and controlling DHF based on guidelines from the Department of Disease Control at the Communicable Disease Control Center in Chaiyaphum Province. The questionnaire consisted of three sections:

Part 1: A general information questionnaire is presented as a checklist.

Part 2: A questionnaire assessing DHF prevention and control behaviours using a 5-level rating scale based on the Likert method [12]. The behaviour levels were classified as follows:

- High level (average score of 3.67-5.00)
- Moderate level (average score of 2.34-3.66)
- Low level (average score of 1.00-2.33)

Part 3: An opinion questionnaire regarding factors that influence DHF control behaviours, also using a 5-level rating scale based on the Likert method [12]. The opinion levels were categorised as follows:

- High level (average score of 3.67-5.00)
- Medium level (average score of 2.34-3.66)
- Low level (average score of 1.00-2.33)

3.2.1 Quality of the instrument

The literature review revealed that the study employed a questionnaire that had undergone thorough quality checks. This questionnaire demonstrated acceptable levels of quality and reliability, as confirmed by construct validity and reliability assessments. The Cronbach alpha coefficient was calculated to be 0.78, and the Item Objective Congruence (IOC) value was 0.80, confirming the instrument's reliability and suitability for use in the study.

3.2.2 Data collection

The process starts by identifying a sample group and then distributing questionnaires for individual completion. After that, the collected forms undergo thorough checks for completeness and accuracy before moving on to data analysis.

3.2.3 Data analysis and statistics

The analysis examined general information, behaviours, and opinions related to various factors. Descriptive statistics, including numbers, percentages, means, standard deviations, medians, minimums, and maximums, were employed to gain a comprehensive understanding of the dataset.

3.3 Phase 3: Development of a DHF Control Model Using Geographic Information Systems (GIS) in Combination with Linebot Technology

3.3.1 The study progressed through the following steps

Step 1: Conduct a focus group to analyse the issues and control models related to dengue hemorrhagic fever (DHF) in Chaiyaphum Province. The sample group will consist of 23 DHF control operators from provincial, district, and sub-district levels, selected through purposive sampling. Data will be collected through unstructured focus group discussions, and the results will be analysed using content analysis.

Step 2: Develop a DHF control model in Chaiyaphum Province using geographic information systems and Linebot technology 3-3-1, as detailed in Table 1. This involves analysing and designing the system and comprehensively testing it for practical usability.

Step 3: Establish the DHF model using GIS and Linebot technology.

3.3.2 Tools

Tools used include Line Official Account (LOA) and Looker Studio.

3.3.3 Data analysis and statistics

Data analysis of problems and patterns of DHF control using content analysis.

3.4 Phase 4: Assess the DHF Control Model in Chaiyaphum Province using Geographic Information Systems in Conjunction with Linebot Technology

3.4.1 The study steps were as follows:

Step 1: Implement the developed DHF control model in high-risk districts by randomly selecting one district.

Step 2: Evaluate the model's effectiveness using a three-dimensional evaluation form that includes the following criteria:

- DHF morbidity rate
- *Aedes* larvae index
- System efficiency

The evaluation of system efficiency will focus on four components:

- Accuracy and completeness of operations, by Measure 3-3-1.
- Timeliness in reporting patients, from the doctor’s diagnosis to acknowledgement, within three hours.
- Speed of initial disease control, implemented within three hours.
- Internal fogging was conducted one day after receiving the report.

Table 1: Disease control model in the case of finding a DHF patient according to measures 3-3-1

Day	Operation
Day 0 Date the patient was found. (Starting from the day the patient was found)	Report the disease within 3 hours as follows. - Hospital: Notify the Subdistrict Health Promoting Hospital or local public health service center of a diagnosed DHF patient in the area within 3 hours. Subdistrict Health Promoting Hospital Action: Conduct mosquito vector control, including spraying chemicals (using spray cans) and eliminating standing water sources within the patient's home within 3 hours of receiving the report of a patient in the community. Note. In cases where reports are received outside official hours, mosquito vector control measures can be taken the next day.
Day 1	Control mosquito vectors within a 100-meter radius from the patient's home and places suspected of being the source of the disease, such as workplaces and schools, within 1 day after receiving notification of a patient in the community. Various sectors should proceed as follows. - Local Government Agencies: Spray chemicals to eliminate adult mosquitoes. Village Health Volunteers, Homeowners, and Citizens: Eliminate *Aedes* mosquito breeding grounds. Subdistrict Health Promoting Hospital Action: Conduct community gatherings to clarify the situation, provide health education about self-protection, and highlight symptoms to watch out for. Also, establish preventive measures within the community. Note. If mosquito vector control operations cannot be completed within 1 day, the operation can be repeated on the 2nd day.
Day 7	Control mosquito vectors within a 100-meter radius from the patient's home and points suspected of being the source of the disease, such as workplaces and schools. Various sectors should proceed as follows. - Local Government Agencies: Spray chemicals to eliminate adult mosquitoes. Village Health Volunteers, Homeowners, and Citizens: Eliminate *Aedes* mosquito breeding grounds. Note. Target Household Index (HI) and Container Index (CI) in the patient's home and within a 100-meter radius = 0.
Day 14	Proceed as follows. -Village Health Volunteers, Homeowners, and Citizens: Conduct surveys and eliminate *Aedes* mosquito larvae in villages where the disease is occurring. Subdistrict-wide Action: In subdistricts where many villages are found to have patients, conduct surveys and mosquito larvae elimination throughout the entire subdistrict. Note. The Household Index (HI) target in villages where < 5 patients are found.
Day 21	Village health volunteers, homeowners, and citizens should survey and eliminate *Aedes* mosquito larvae in villages where the disease occurs. The targets are as follows. - Target: Household Index (HI) in villages where patients are found < 5. Target: Container Index (CI) in medical facilities and schools in the village = 0. Target: CI in religious places, hotels, and factories in the village < 5.
Day 28	Proceed as follows. - Maintain measures to survey and eliminate Aedes mosquito larvae in the community every 7 days by involving the community and maintain measures to spray additional chemicals every 7 days if there are still continuous patients. The Provincial Public Health Office evaluates the *Aedes* mosquito larvae index in areas where the outbreak has continued for more than 28 days.

3.4.2 Tools

The tool used assessed DHF control based on the 3-3-1 measure.

3.4.3 Data analysis and statistics

We use descriptive statistics, including mean and standard deviation, to comprehensively summarise.

3.5 Human Research Ethics

This research study obtained approval from the Human Research Ethics Committee at Mahasarakham University, with the approval number 255-258/2566.

4. Results and Discussions

The results of the development and study of the DHF control model in Chaiyaphum Province using geographic information systems combined with Linebot technology can be summarised in four parts according to the objectives.

4.1 Analysis Results of Areas at Risk for DHF using Geographic Information Systems

A literature review and analysis conducted by local disease control practitioners identified six factors that influence the occurrence of DHF in Chaiyaphum province. These factors were:

- House Index (HI)
- Recurrent DHF
- DHF Morbidity Rates
- Container Index (CI)
- Population Movement
- Population Density

The study evaluated and assigned appropriateness scores and weights to various factors influencing the occurrence of DHF. Each factor's weight was assessed, and the factors were categorised according to predefined criteria. Finally, a risk map for DHF was created using six associated factors. The Container Index (CI), or the Percentage of Containers with Aedes Larvae, is a crucial metric for preventing and controlling DHF. It indicates the risk level of an *Aedes* mosquito outbreak since these mosquitoes are known vectors for dengue. The CI measures the presence of *Aedes* larvae in water-holding containers within the surveyed area, representing the percentage of containers that contain *Aedes* larvae. A high CI value implies a greater risk of DHF outbreaks, highlighting the need for mosquito population control in that area to mitigate the risk.

Table 2: Pairwise comparison of DHF outbreak dimensions

Dimensions	House Index (HI)	Recurrent DHF	DHF Morbidity Rates	Container Index (CI)	Population Movement	Population Density	Weights
House index (HI)	1	3	5	7	7	9	0.442
Recurrent DHF	1/3	1	3	5	7	9	0.260
DHF morbidity rates	1/5	1/3	1	3	5	7	0.146
Container index (CI)	1/7	1/5	1/3	1	3	5	0.081
Population movement	1/7	1/7	1/5	1/3	1	3	0.046
Population density	1/9	1/9	1/7	1/5	1/3	1	0.025
λ max = 6.501; CI = 0.100; CR = 0.081							

Table 3: Classification and weighting of factors

Factors	Domain	Suitable Level	Score Values	Average Score	Weight
1. House Index (HI)	< 1	Low	1		
	1 – 10	Moderate	2	6.5	0.442
	> 10 and up	High	3		
2. Recurrent DHF from 2020 - 2022	No recurrent	Low	1		
	1-year recurrent	Moderate	2	5.4	0.260
	2-years recurrent	High	3		
3. Morbidity rate from 2018-2022	< 22.22 per 100,000 population	Low	1		
	22.22-42.01 per 100,000 population	Moderate	2	5.3	0.146
	> 42.01 per 100,000 population	High	3		
4. Container Index (CI)	< 1	Low	1		
	1 - 5	Moderate	2	6.0	0.081
	> 5	High	3		
5. Population movement	Areas characterized by low population migration. The areas experience	Low	1		
	moderate labor migration and benefits from convenient transportation.	Moderate	2	4.5	0.046
	Areas exhibiting high population migration due to numerous tourist attractions, labor activities, economic trade, Transportation and from these areas were convenient.	High	3		
6. Population density [people/sq.km.]	< 96.81	Low	1		
	96.81 – 137.51	Moderate	2	5.2	0.025
	> 137.51	High	3		

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Population movement significantly influenced the occurrence of DHF in various ways, particularly in regions where *Aedes* mosquitoes, the vectors of DHF, are prevalent. Several factors related to population movement affected the incidence of DHF in this analysis. Notably, the area was characterised by a high population migration due to its popularity as a tourist destination. This resulted in the considerable labour movement, economic trade, and transportation activities facilitated by the area's convenient transport options.

Creating a map illustrating the factors associated with waterlogged containers and population movement involved several vital techniques, primarily data collection. Surveys were conducted to analyse waterlogged containers containing mosquito larvae, and GIS tools were utilised to gather and map the data. In assessing population movement, expert opinions were considered alongside data concerning regions with high migration rates attributed to various tourist attractions, labour opportunities, economic trade, and accessible transportation. Subsequently, spatial analysis was performed using ArcGIS to overlay maps of the identified risk factors. This analysis utilised the Analytical Hierarchy Process (AHP) to evaluate areas at risk for DHF.

This technique analyses multiple risk factors, assigning a weight value to each factor to evaluate areas at risk for DHF. This assessment is based on a risk map that includes six factors, as illustrated in Figure 3. Using multi-criteria analysis and GIS tools, high-risk areas were identified in Chatturat District, Nongbuadang District and Bantan Districr. Three districts were categorised as moderate-risk areas, including Kesatsombun District, Phukhiao District and Nernsanga District. Furthermore, ten districts were classified as low-risk: Mueang Chaiyaphum District, Ban Kwao District, Khon San District, Bumnetnarong District, Nongbuarawei District, Tepsatit District, Kaeng Khro District, Konsan District, Pukdeechumphon District and Subyai District. The areas at risk for DHF in Chaiyaphum Province are depicted in Figure 4, as detailed in Table 4.

4.2 Study Results on Factors Influencing DHF Prevention and Control in Chaiyaphum Province

The study's results indicated that the overall prevention and control behaviour regarding DHF among people in Chaiyaphum Province was rated high, with an average score of 4.47 (SD = 0.54). When examining specific behaviours, the three highest-scoring practices were sleeping under a mosquito net or in a room equipped with window screens (mean = 4.78, SD = 0.60), ensuring containers are covered to prevent Aedes mosquitoes from laying eggs (mean = 4.73, SD = 0.60), and strictly following prevention measures when there were DHF patients in the community to avoid bites from Aedes mosquitoes (mean = 4.70, SD = 0.60). The behaviour with the lowest score involved using an electric mosquito swatter to prevent Aedes mosquito bites, with a mean score of 3.73 (SD = 1.23).

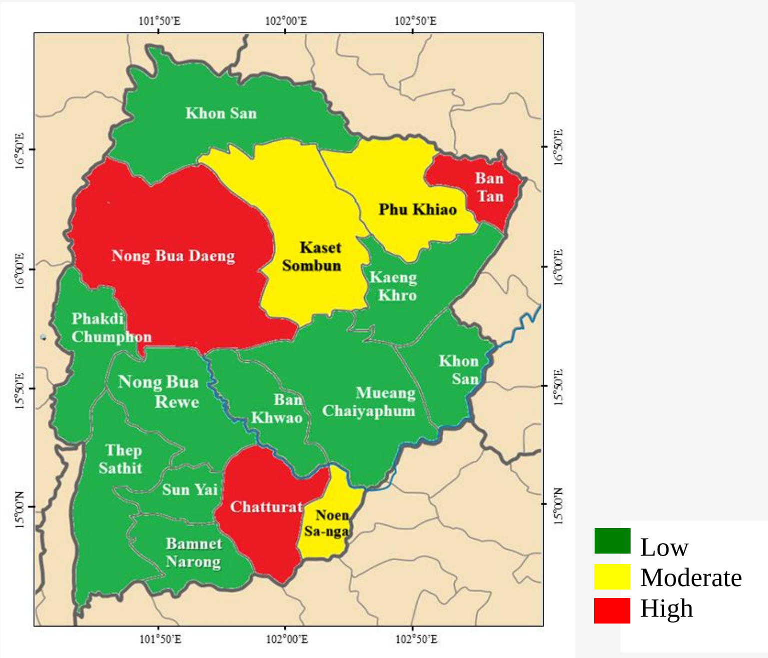

Figure 4: DHF risk map of Chaiyaphum province, Thailand

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Table 4: Risk levels for DHF outbreak in Chaiyaphum Province, classified by district

No.	Districts	Risk Levels for DHF Outbreak
1	Muangchaiyaphum	Low
2	Bankao	Low
3	Konsawan	Low
4	Kesatsombun	Moderate
5	Nongbuadang	High
6	Chatturat	High
7	Bumnetnarong	Low
8	Nongbuarawei	Low
9	Tepsatit	Low
10	Phukhiao	Moderate
11	Bantan	High
12	Kaeng Khro	Low
13	Konsan	Low
14	Pukdeechumphon	Low
15	Nernsanga	Moderate
16	Subyai	Low

Table 5: Number and percentage of DHF prevention and control behaviours among people in Chaiyaphum Province. Classified by level (n = 417)

Behavior level	Number	Percentage (%)
Hight level	395	94.72
Medium level	21	5.04
Low level	1	0.24
Overall, the behavior level was high, with a mean of 4.47 and a standard deviation of 0.54.		

Table 6: Means and standard deviations of opinions on factors affecting DHF prevention and control behaviour among people in Chaiyaphum Province, classified by aspect (n = 417)

No.	Aspects	Mean	SD	Level
1	Awareness of DHF occurrence.	4.19	0.48	High
2	Sufficiency of resources for prevention and control of DHF.	4.07	0.51	High
3	Receiving advice on prevention and control of DHF from public health personnel.	4.18	0.45	High
4	Receiving advice on prevention and control of DHF from public health volunteers.	4.15	0.45	High
5	Receiving information about DHF.	3.98	0.40	High

In evaluating behavior levels, most participants displayed high levels of DHF prevention and control behaviour, accounting for 94.70%. A smaller percentage, 5.04%, showed a medium level of behaviour, while only 0.24% exhibited a low level, as shown in Table 5. In a study examining the factors influencing the prevention and control of DHF among residents of Chaiyaphum Province, the results were categorised by various aspects. The aspect with the highest mean score relating to its impact on disease incidence was awareness of DHF occurrences, with a mean score of 4.19 (S.D. = 0.48). This was closely followed by receiving advice on DHF prevention and control from public health personnel, with a mean score of 4.18 (S.D. = 0.45). The aspect with the most negligible impact was the reception of information about DHF, scoring a mean of 3.98 (S.D. = 0.40), as detailed in Table 6.

4.3 Results of Developing the DHF Prevention and Control Model using Geographic Information Systems Combined with Linebot Technology

The study results, gathered from discussions with stakeholder groups, highlighted issues in implementing DHF control measures, mainly measures 3-3-1. The findings indicated that disease control efforts could be more efficient and timelier. In response, a model for DHF control was developed that integrates Geographic Information Systems (GIS) with Linebot technology.

We designed and implemented a Linebot named DHF-Solve through the Line Official Account (LOA), incorporating both a chatbot and the Line Messaging API alongside GIS.

Following its development, the Linebot now includes six menus within the LOA: 1) DHF Situation Real-time, 2) DHF Reporting System, 3) DHF Control System, 3.3) Measures, 4) Aedes Mosquito Larvae Survey System, 5) GIS Disease Occurrence and Successful Disease Control, and 6) Knowledge Think Tank. The platform for managing DHF aims to prevent and control the disease in real time. Chatbot AI commands assist officials by promptly managing disease control issues and offering detailed information on the current DHF situation. This includes a reporting system, a notification system, worksite images, a dashboard, disease control activities, GIS location coordinates, and a knowledge bank. This comprehensive system supports decision-making, enabling officials to quickly address problems and effectively control the disease using the DHF control model, which integrates GIS technology with Linebot capabilities, as illustrated in Figure 5.

4.4 Results of the DHF prevention and Control Model using Geographic Information Systems Combined with Linebot Technology

After implementing the developed model in the target area for eight consecutive weeks, covering two generations of the outbreak, the results showed that 45 reported DHF were in the target area. Notably, eight cases were reported during the first week of implementing the DHF control model using the DHF-Solve Linebot (Week 37). This number fluctuated over the following weeks, with 12 cases in week two, followed by 4, 7, 4, 4, 4, and 2 cases in the last week. It was clear that the number of patients continued to decline. In the second generation of the outbreak, which comprised the previous four weeks, there were fewer patients compared to the first generation in the initial four weeks, as illustrated in Figure 6.

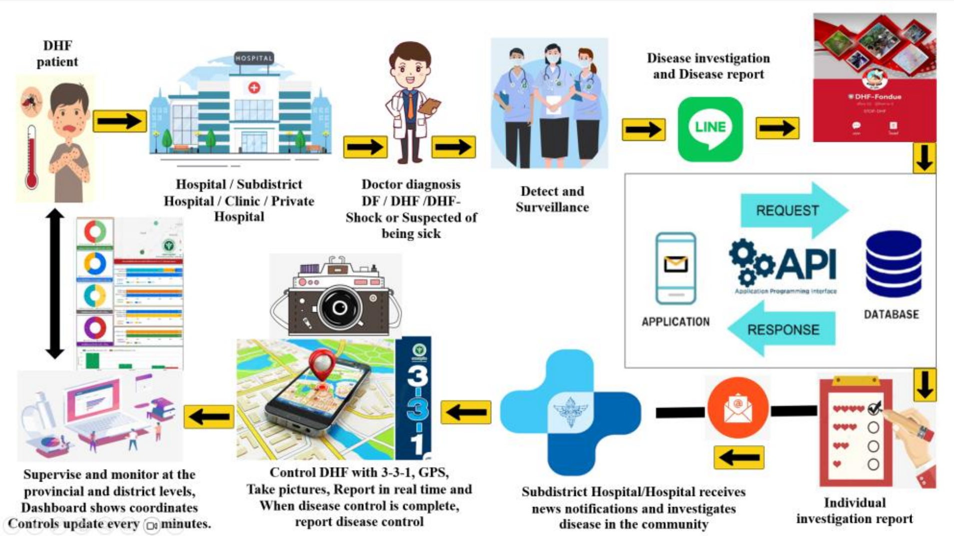

Figure 5: DHF prevention and control process using GIS combined with Linebot technology

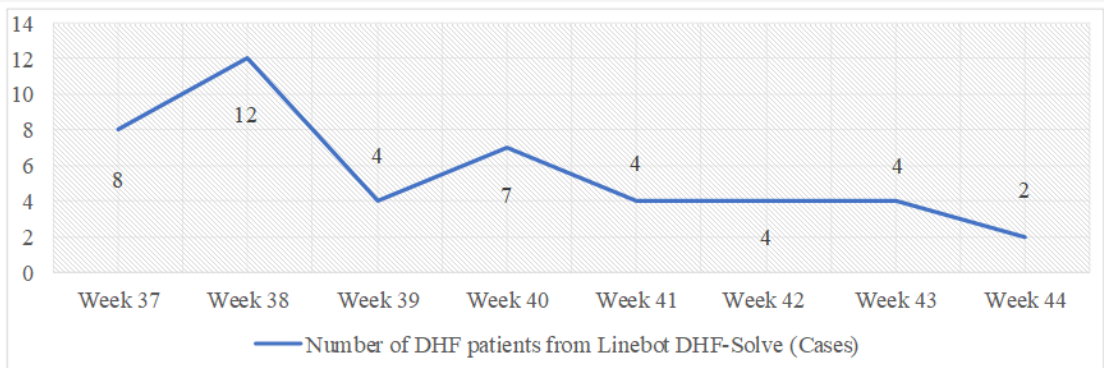

Figure 6: Number of DHF patients in the target area, weekly classification

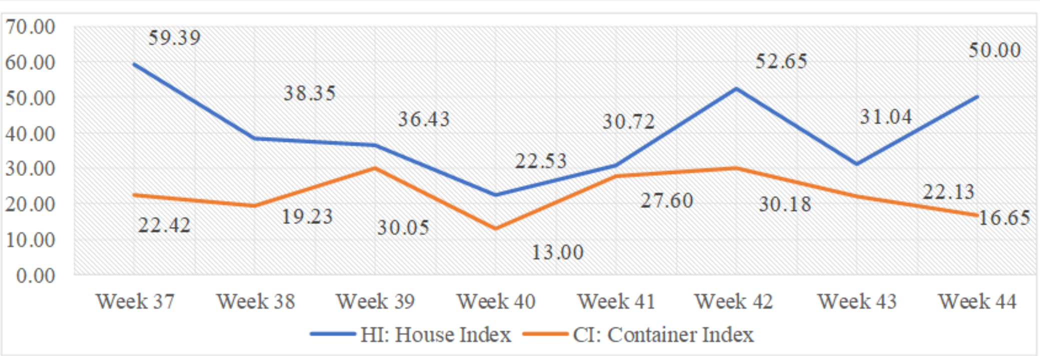

Figure 7: Index of *Aedes* mosquito larvae in the target area, weekly classification

Table 7: Number and percentage of DHF prevention and control evaluation results according to 3-3-1 measures using GIS combined with Linebot technology, classified by component

No.	Component	Evaluation Results Number (Percent)		
		Completely	Done, but not completely	Not implemented
1	Accuracy and completeness of operations according to measures 3-3-1.	19 (42.22)	22 (48.89)	4 (8.89)
2	Timeliness patient reporting, aiming to acknowledge diagnoses from doctors within 3 hours.	39 (86.67)	0 (0.00)	6 (13.33)
3	Speed of initial disease control within the next 3 hours.	39 (86.67)	2 (4.44)	4 (8.89)
4	Quality of disease control within 1 day after receiving the report.	6 (13.33)	26 (57.78)	13 (28.89)

During the eight-week implementation of the model in the target area, we examined the index values of Aedes mosquito larvae. The results showed that the mean House Index (HI) was 40.14 (ranging from 0 to 83.33), while the mean Container Index (CI) was 22.66 (ranging from 0 to 66.67). The highest HI value was recorded in Week 37 at 59.39, followed by Week 42 with an HI of 52.65. In contrast, the lowest HI value occurred in Week 40 at 22.53. For the Container Index, the highest CI value was also observed in Week 42 at 30.18, followed by Week 41 at 27.60, while the lowest CI value was noted in Week 40 at 13.00. Overall, it was evident that most weekly mosquito larvae index values fell below the average HI and CI, as illustrated in Figure 7.

Table 7 demonstrates the effectiveness of the DHF prevention and control model implemented through the DHF-Solve Linebot. The study's findings revealed that Component 2, which focuses on the timeliness of reporting, was the best-performing component. An impressive 86.67% of participants completed the process from the doctor's diagnosis to acknowledgement within three hours. Component 3, which assesses the speed of initial disease control within the next three hours, also achieved an 86.67% completion rate. Component 4, which evaluates the quality of disease control within one day after receiving the report, had a completion rate of 57.78%. In contrast, the least successful component was Component 1, which measures the accuracy and completeness of operations according to the 3-3-1 standards, with only 48.89% completion. While the disease was managed effectively, it was not completely controlled.

5. Discussion

The results can be summarised and discussed as funding the study and development of models for preventing and controlling DHF using GIS combined with Linebot technology. Analysing areas at risk for DHF using Geographic Information Systems (GIS) identified six critical factors based on a literature review and spatial analysis. These factors are as follows:

- The prevalence index of Aedes mosquito larvae
- Areas with recurrent outbreaks of DHF
- The median DHF morbidity rate over the past five years
- The types of waterlogged containers
- Population movement
- Population density

A spatial analysis of each factor revealed that the prevalence index of *Aedes* mosquito larvae and the type of water container have the most significant

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impact on the occurrence of DHF, particularly in districts classified as high-risk areas. The prevalence of *Aedes* mosquito larvae is a significant factor contributing to the occurrence of DHF, particularly in areas with repeated outbreaks [13][14][15][16] and [17]. Additionally, another factor contributing to the incidence of DHF in moderate to high-risk areas is population movement, which plays a crucial role in the occurrence of DHF, especially in districts with high population density and convenient transportation [18]. The factor of house clustering in areas surrounding locations with a high density of DHF patients and a large number of houses also contributes to the outbreak of DHF [19] and [20].

Prevention and control behaviours regarding DHF among residents of Chaiyaphum Province were found to be predominantly high, with a score of 94.70%. When analysing specific behaviours, the most highly regarded practice was sleeping under a mosquito net or in a room fitted with a screened net. This approach effectively prevents Aedes mosquitoes from biting, making it a practical and efficient individual-level behaviour. The average score regarding awareness regarding DHF's prevention and control was 4.19, indicating a high level of understanding among the residents that Aedes mosquitoes are carriers of DHF. This awareness prompts proactive actions, such as removing breeding grounds and protecting oneself from mosquito bites. The 5P1K measures are guidelines for individual-level preventive actions set by the Department of Disease Control, which impact the level of DHF prevention and control behaviors at both the individual and community levels by making changes [21]. Additionally, self-efficacy plays a crucial role in effectively preventing DHF [22].

Developing an official DHF control model using GIS and Linebot technology resulted in the creation of a Line controller named DHF-Solve. This tool is designed to manage and address DHF control issues through the Line Official Account. It features a chatbot and a Line Messaging API integrated with GIS, functioning as a real-time management platform for the prevention and control of DHF. The AI-powered chatbot provides six comprehensive menus that assist officials in promptly addressing disease control challenges and displaying detailed information. The use of a chatbot can raise public awareness about the symptoms, effects, and prevention of the DHF [23]. Additionally, the use of a chatbot to detect mosquito breeding grounds by utilizing Street View imagery and object recognition technology helps display the detailed locations of dengue fever vector breeding areas [24].

The efficiency of the DHF control model, which integrates geographic information systems with Linebot technology, was demonstrated through the use of the DHF-Solve Linebot for managing and resolving DHF issues. Key factors contributing to its effectiveness were timeliness and speed. Patients can be reported within three hours, from the doctor's diagnosis to the acknowledgement. Initial disease control measures can then be initiated within three hours, achieving an efficiency rate of 86.67%. The quality of disease control is completed within one day of receiving the report, reaching a completion rate of 57.78%.

An analysis of patient numbers over eight consecutive weeks, covering two outbreak generations, revealed a continuous decline in cases. In the second generation of the outbreak (the last four weeks), the number of patients was lower than during the first generation (the initial four weeks). The incidence of DHF in the epidemic area of Chaiyaphum Province in 2020 exceeded the established control standards [25]. The DHF surveillance system and the 3-3-1 measures tracked through an application on Google Drive can effectively control dengue fever. This method allows quick and easy access to information from anywhere at any time [26]. Additionally, the 7-1-7 principles aim to make the world safer from dengue fever by focusing on the detection, notification, and effective response to outbreaks. Every suspected outbreak should be investigated within seven days of occurrence, reported to public health authorities, followed by an investigation and response initiated within one day, with an adequate response achieved within seven days [27].

The DHF prevention and control model that utilises a Linebot, in conjunction with the developed GIS, effectively addresses the issue of DHF. This model aids real-time situation management and enables efficient control of dengue fever by following the 3-3-1 measures. It has been crucial in reducing both the incidence and impact of DHF. Therefore, this technology-based DHF prevention and control model should be expanded and implemented to respond to emergency breaks.

6. Conclusion

This study developed and evaluated a model for preventing and controlling DHF combining GIS (Geographic Information System) with Linebot technology. The model proved effective for real-time management and prompt responses to DHF outbreaks. Through spatial analysis, six key factors contributing to the risk of DHF were identified.

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Among these, the prevalence of *Aedes* mosquito larvae and the types of water containers were found to be the most significant contributors in high-risk areas.

Furthermore, the public's behaviour in preventing DHF, particularly the widespread use of mosquito nets, has proven to be an effective and practical way to reduce exposure to Aedes mosquitoes. High levels of awareness about DHF transmission have led to active community involvement in prevention efforts. Integrating Geographic Information Systems (GIS) with Linebot technology through the DHF-Solve Linebot platform has created a responsive and efficient management system for controlling DHF. This model enables health officials to respond within critical timeframes, allowing for rapid reporting and the initiation of disease control measures within hours of a DHF case being reported. As a result, there has been a noticeable decrease in cases over consecutive weeks. While the model proved highly effective in the studied context, it had limitations, including the requirement for reliable internet connectivity and users' digital literacy, which may have hindered its scalability in rural or underserved areas. Future research could focus on refining the model for broader use, exploring adaptations for other vector-borne diseases, and addressing logistical challenges. This study contributed to the existing body of knowledge by demonstrating a practical application of GIS and Linebot technology in epidemic control, laying the groundwork for future advancements in DHF prevention and integrating public health technologies.

The implications of this research were significant, as it addressed immediate concerns related to the DHF outbreak in Chaiyaphum Province and provided a scalable framework for other regions facing similar challenges. While the study offered valuable insights, it is essential to recognise the need for ongoing evaluation and adaptation of the model in diverse contexts. Future research could investigate the long-term sustainability of technology-driven approaches in disease control, focusing on user engagement, integration with existing health systems, and the impact on public health outcomes. By emphasising the relevance of this study, the findings made a substantial contribution to the existing body of knowledge on disease management. They highlighted the potential for innovative solutions in tackling public health crises.

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