THE ANALYSIS OF URBAN HEALTH WITH INTEGRATING CROWDSOURCING DATA

BY

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ABSTRACT

Dengue is a vector born disease transmitted by Aedes aegypti mosquito. It has seen an increase in the number of cases in Southeast Asia and Malaysia. The burden of dengue fever outbreaks is causing the loss of lives and unnecessary waste of resources to the authorities. There have been numerous research work studying the variables involved in the life-cycle of the dengue spread. Variables mainly related to the vector elements such as being an “Urban Disease”, weather patterns (temperature and rain), moon phases and land use. In this context, the easy access to internet technology through smartphone's and lowest cost of devices worldwide opens the way to new possibilities for data collection through volunteered geographic information. The aim of this study is to develop an urban health system to generate an index based on factors influencing the dengue outbreaks and study the interest by the citizens to be involved and transmitting data using smartphones using an App. The data could in a later stage be integrated into the developed system. The developed index was generated by combining spatial and temporal factors consisting of land use, temperature, rainfall, moon phases. The app would transmit the data comprising of the existence of mosquito larvae, rubbish, known dengue cases in the neighborhood, the vector bites pattern including the location and the date. This study was restricted geographically to the areas of Selangor state in Malaysia and the federal territories of Kuala Lumpur and Putrajaya for using data for the years of 2014. The findings show that, after generating the dengue index for the years of 2014 and 2015, it was observed from the time series that the generated dengue index reflected the fluctuation in the number of cases 52 days in average before the occurrence of the actual number of cases. Finally, the results also show that the number of cases of dengue increased during the new moon phase every lunar month and the cases and sites increased during raining seasons with little rain and high temperatures while they would decrease during raining seasons with lower temperatures. Crowdsourcing data from volunteers were received from users within Malaysia and other countries as well, however, the data was out of the temporal frame with the dengue data used in this research. In conclusion, this research two forewarning cycles that have been identified on upcoming dengue outbreaks; a short cycle coinciding with the moon phases while a longer cycle coinciding with the weather, land use variables. Finally, data obtained from crowdsourcing in this study shows that even if there was no advertising about the developed app, there was an interest drawn in Malaysia and outside the country to contribute voluntarily with information. This data could be integrated with the index in the future to assist relevant authorities to pinpoint spatially the locations to intervene ahead of probable dengue outbreaks.

خلاصة البحث

إن حمى الضنك هي مرض يولد بواسطة ناقل ينتقل عن طريق البعوضة الزاعجة. وقد شهدت زيادة في عدد الحالات المصابة في جنوب شرق آسيا وماليزيا. يتسبب عبء تفشي حمى الضنك في فقدان الأرواح وإهدار الموارد بشكل غير ضروري للسلطات. كان هناك العديد من الأعمال البحثية التي تدرس المتغيرات المشاركة في دورة حياة انتشار حمى الضنك. ترتبط المتغيرات بشكل أساسي بعناصر المتجهات مثل "المرض الحضري"، وأنماط الطقس (درجة الحرارة والمطر)، ومراحل القمر واستخدام الأرض. في هذا السياق، فإن الوصول السهل إلى تكنولوجيا الإنترنت من خلال الهواتف الذكية وأقل تكلفة للأجهزة في جميع أنحاء العالم يفتح الطريق أمام إمكانيات جديدة لجمع البيانات من خلال المعلومات الجغرافية التطوعية. تهدف هذه الدراسة إلى تطوير نظام صحي حضري لإنشاء فهرس يعتمد على العوامل التي تؤثر على تفشي حمى الضنك ودراسة اهتمام المواطنين بالمشاركة ونقل البيانات باستخدام الهواتف الذكية باستخدام التطبيق حيث يمكن دمج البيانات في مرحلة لاحقة في النظام المطور. تم إنشاء المؤشر المطور من خلال الجمع بين العوامل المكانية والزمانية التي تتكون من استخدام الأرض ودرجة الحرارة وهطول الأمطار ومراحل القمر. وسيقوم التطبيق بنقل البيانات التي تتضمن وجود يرقات البعوض والقمامة وحالات الضنك المعروفة في الحي ونمط لدغات المتجهات بما في ذلك الموقع والتاريخ. اقتصرت هذه الدراسة جغرافيا على مناطق ولاية سيلانجور في ماليزيا والأقاليم الاتحادية في كوالا لمبور وبوتراجايا لاستخدام البيانات لسنوات 2014. وتبين النتائج أنه بعد توليد مؤشر حمى الضنك لسنتي 2014 و 2015 ، وقد لوحظ من السلاسل الزمنية أن مؤشر حمى الضنك المولَّد يعكس التقلب في عدد الحالات من 52 يومًا في المتوسط قبل حدوث العدد الفعلي للحالات. أخيرًا، أظهرت النتائج أيضًا أن عدد حالات حمى الضنك يزداد خلال طور القمر الجديد كل شهر قمري، وتزايدت الحالات والمواقع خلال مواسم الأمطار مع هطول أمطار قليلة ودرجات حرارة عالية، بينما ستنخفض خلال مواسم المطر التي تنخفض فيها درجات الحرارة. تم تلقي بيانات التعهيد الجماعي من المتطوعين من المستخدمين داخل ماليزيا وبلدان أخرى أيضًا، ومع ذلك كانت البيانات خارج الإطار الزمني مع بيانات حمى الضنك المستخدمة في هذا البحث. في الختام، بحث هذا في دورتين تحذيريتين تم تحديدهما في حالات تفشي حمى الضنك القادمة؛ دورة قصيرة تتزامن مع مراحل القمر بينما دورة أطول تتزامن مع الطقس ومتغيرات استخدام الأرض. أخيرًا، تُظهر البيانات التي تم الحصول عليها من التعهيد الجماعي في هذه الدراسة أنه حتى إذا لم يكن هناك إعلان عن التطبيق المطوَّر، فقد كان هناك اهتمام في ماليزيا وخارج البلاد للمساهمة طوعًا بالمعلومات. يمكن دمج هذه البيانات مع الفهرس في المستقبل لمساعدة السلطات المختصة على تحديد الأماكن المكانية للتدخل قبل تفشي محتمل لحمى الضنك

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APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion. It conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment)

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DECLARATION

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TABLE OF CONTENTS

Abstract i
Abstract in Arabic ii
Approval Page iii
Declaration iv
Copyright Page v
Acknowledgements vi
List of Abbreviations ix
List of Tables x
List of Figures xi

CHAPTER ONE: INTRODUCTION 1
1.1 Background 1
1.2 Dengue Outbreak 2
1.3 Crowdsourcing in Urban Health 4
1.4 Problem Statements 6
1.5 Research Questions 7
1.6 Aim and Objectives 7
1.7 Research Scope and Limitation 8
1.7.1 Research Scope 8
1.7.2 Research Limitations 8
1.8 Research Significance and Contribution 9
1.9 Study Area 9
1.10 Structure of the Thesis 12
1.11 Conclusion 15

CHAPTER TWO: LITERATURE REVIEW 16
2.1 Introduction 16
2.1.1 Dengue Symptom 16
2.1.2 Dengue in History 17
2.1.3 Geographical Extents of Dengue 18
2.1.4 Life Cycle of Aedes aegypti 19
2.1.5 Factors Affecting the Dengue Vector 21
2.2 Urban Health and Dengue 25
2.2.1 Theoretical of Urban Health 25
2.2.2 Contribution of Urban Health on Dengue in Southeast Asia 26
2.3 Crowdsourcing System 27
2.3.1 Theoretical of Crowdsourcing 27
2.3.2 The Importance/Benefits of Crowdsourcing 27
2.3.3 Crowdsourcing in Urban Health 28
2.4 Dengue Index 29
2.5 Conclusion 32

CHAPTER THREE: RESEARCH METHODOLOGY 33
3.1 Introduction.. 33
3.2 Research Methodology 34
3.3 Data Collection 37
3.3.1 Dengue Data 38
3.3.2 Moon Phase Data... 41
3.3.3 Rainfall and Temperature Data 43
3.3.4 Land Use Data 45
3.3.5 Crowdsourcing Data 45
3.4 Processing the Data.. 46
3.4.1 Geocoding the Dengue Data.. 48
3.4.2 Moon Phases Data Processing... 48
3.4.3 Processing Rainfall and Temperature Data 49
3.5 System Development 50
3.5.1 Flowchart of the System Development 50
3.5.2 Gathering the Data for the System Development.......................... 52
3.5.3 Components of the System.. 52
3.5.4 Development and Integration of the System 53
3.5.5 Crowdsourcing App 55
3.5.6 Computing the Index 58
3.5.7 Displaying the Index 58
3.6 Conclusion of Chapter 3 59

CHAPTER FOUR: RESULTS AND DISCUSSION... 61
4.1 Introduction.. 61
4.2 Analysis and Findings.. 61
4.2.1 Processing the Data 61
4.2.2 Dengue Index 64
4.3 Results.. 67
4.3.1 Land Use.. 67
4.3.2 Temperature... 74
4.3.3 Rainfall 78
4.3.4 Moon Phases.. 83
4.3.5 Crowdsourcing Data... 91
4.3.6 Computing the Dengue Index... 99
4.4 Conclusion of this Chapter 103

CHAPTER FIVE: RECOMMENDATION AND CONCLUSION 104
5.1 Introduction.. 104
5.2 Recommendations for Future Research... 104
5.3 Summary of Results Achieved Based on the Objectives...................... 106
5.3.1 Research Objective 1... 109
5.3.2 Research Objective 2... 110
5.3.3 Research Objective 3... 110
5.3.4 Research Objective 4... 111
5.4 Conclusion 113

BIBLIOGRAPHY 116
APPENDIX.. 121

LIST OF ABBREVIATIONS

API	Application Program Interface
Bi	Breteau Index
CDC	Centers for Disease Control (and Prevention) – The United States of America
Ci	Container Index
CMC	Colombo Municipal Council
COSMIC	Centre of Social Media Innovations for Communities
CSV (file)	Comma Separated Values (file)
DENV	Dengue Virus
DF	Dengue Fever
DHF	Dengue Haemorrhagic Fever
DVSS	Dengue Virus Surveillance System
EDA	Exploratory Data Analysis
FME	Feature Manipulation Engine
GIS	Geographic Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
Hi	House Index
ISNTD	International Society for Neglected Tropical Diseases
MACRES	Malaysian Centre for Remote Sensing
MCMC	Malaysia Communication and Multimedia Commission
MOH	Ministry of Health (Malaysia)
OS	Operating System
PAHO	Pan American Health Organization
PBT	Pihak Berkuasa Tempatan (translated as local authority)
PDF	Portable Document File
RDBMS	Relational Database Management System
RS	Remote Sensing
VGI	Volunteered Information System
WHO	World Health Organization
WWII	World War II

LIST OF TABLES

Table 2.1	Breteau Classification levels and action to be taken	31
Table 3.1	Required Data for the research	37
Table 3.2	Sample Weather Data for Selangor	43
Table 4.1	Built Up Area Classification in the Study Area	68
Table 4.2	X-Waba Crowdsourcing Data by Continent	97
Table 4.3	X-Waba Crowdsourcing Dengue Presence Data (Malaysia)	97
Table 4.4	X-Waba Crowdsourcing Larvae Presence Data (Malaysia)	97
Table 4.5	X-Waba Crowdsourcing Rubbish Presence Data (Malaysia)	98
Table 4.6	X-Waba Crowdsourcing Number of Bites Presence Data (Malaysia)	98
Table 5.1	Research Questions and Research Objectives Achieved in this research	106

LIST OF FIGURES

Figure 1.1 Smartphone Penetration in Malaysia by State. Source: MCMC 2014 5

Figure 1.2 Location map of Selangor State and the Federal Territories of Kuala Lumpur and Putrajaya in Peninsular Malaysia 11

Figure 1.3 Malaysia Population by State (Malaysian Statistics Department) 12

Figure 1.4 Structure of the Thesis 14

Figure 3.1 Flow Chart of Research Activities 34

Figure 3.2 Screenshot Sample Dengue Data by State. 39

Figure 3.3 Screenshot Dengue Data Sample by Address 40

Figure 3.4 Moon Phase Data Source: Time and Date Website (Years 2014 and 2015) 42

Figure 3.5 Standardizing the Data 42

Figure 3.6 Data Processing Chart 47

Figure 3.7 Moon Phases Example for Kuala Lumpur 49

Figure 3.8 Flowchart of the System Development 51

Figure 3.9 Components of the System 53

Figure 3.10 X-Waba App 55

Figure 3.11 X-Waba Interface on Web 56

Figure 3.12 X-Waba Interface on Android Phones 57

Figure 4.1 FME Workspace for Downloading Weather Data. 62

Figure 4.2 Calculation of Dengue Index 66

Figure 4.3 Map of Existing Land Use Repartition in Study Area 70

Figure 4.4 Map Dengue Cases Spread in Study Area 71

Figure 4.5 Map of Dengue Concentration in Study Area 72

Figure 4.6 Map of Dengue Cases Observed in Industrial Land Use Type in Study Area 73

Figure 4.7 Correlation Chart Normalized Temperature - Normalized Dengue Sites year 2014, Study area 74

Figure 4.8 Correlation Chart Normalized Temperatures - Normalized Dengue Cases year 2014, Study area 75

Figure 4.9 Correlation Chart Normalized Temperatures - Normalized Dengue Sites year 2015, Study area 76

Figure 4.10 Correlation Chart Normalized Temperature - Normalized Dengue Sites year 2015, Study area 77

Figure 4.11 Correlation Chart Normalized Precipitation - Normalized Dengue Sites year 2014, Study Area 79

Figure 4.12 Correlation Chart Normalized Precipitation - Normalized Dengue Cases Year 2014, Study area 80

Figure 4.13 Correlation Chart Normalized Precipitation - Normalized Dengue Sites year 2015, Study Area 81

Figure 4.14 Correlation Chart Normalized Precipitation - Normalized Dengue Cases year 2015, Study Area 82

Figure 4.15 Dengue Cases Correlation Weekly Sum of Cases - Moon Phase - 2014 Data 84

Figure 4.16 Dengue Cases Correlation Weekly Sum of Cases - Moon Phase - 2015 Data 85

Figure 4.17 Dengue Cases Correlation Weekly Site Counts - Moon Phase Selangor – 2014 Data 85

Figure 4.18 Dengue Cases Correlation Weekly Site Counts - Moon Phase Selangor – 2015 Data 86

Figure 4.19 Dengue Cases Correlation Weekly Mean - Moon Phase - 2014 Data 86

Figure 4.20 Dengue Cases Correlation Weekly Mean - Moon Phase - 2015 Data 87

Figure 4.21 Dengue Cases Correlation Weekly Standard Deviation - Moon Phase - 2014 Data 87

Figure 4.22 Dengue Cases Correlation Weekly Standard Deviation - Moon Phase - 2015 Data 88

Figure 4.23 Dengue Cases Correlation Standard Deviation - Moon Phase - 2014/2015 Data 90

Figure 4.24 Map of Crowdsourcing Data from Malaysia 93

Figure 4.25 Map of Crowdsourcing Data in Klang Valley Study Area 94

Figure 4.26 Map of Crowdsourcing Data from Asia, Africa and Europe 95

Figure 4.27 Map of Crowdsourcing Data from Asia, Africa and Europe 96

Figure 4.28 Correlation of Dengue Index Number of Outbreak Sites - 2014 Data 100

Figure 4.29 Correlation of Dengue Index Number of Outbreak Sites - 2015 Data 100

Figure 4.30 Amplitude, Period, Phase Shift and Vertical 101

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Dengue is one of the most alarming urban health related diseases Malaysia has been facing since the first outbreak in 1962 even though many dengue outbreaks have been documented since the 1950s in the region (Chew, 2016). Ongoing urban developments in Malaysia in particular and the world as a whole, taking into consideration the alarming dengue outbreaks in the past years with the highest recorded in 1996 (L. P. Wong, 2016); this research on current and historical data is an attempt to predict where outbreaks will occur by studying existing cases and probable expansions of the outbreaks by developing a system to generate an index based on the well-known factors contributing in dengue outbreaks and crowdsourcing for displaying the data using Geographic Information System (GIS).

Dengue is the result of the effect of a growing urban environment and the high concentration of the population in the cities (Cheong et al, 2014). Putrajaya, the new administrative capital of Malaysia with its modern urban planning is no exception to the outbreaks (Mulligan, 2012). Urban health studies the effects that these urban environments have on the health of a population. Acevedo-Garcia, D. (2001) in their report titled "Why Urban Health Matters" by the World Health Organization (WHO), it is stated that cities growth tend to promote unhealthy lifestyles, such as “convenient” diets, sedentary behavior, smoking, and the consumption of alcoholic substances (WHO, 2010) especially in marginalized populations (Holveck, 2007). Other effects such as the availability in these environments of man-made containers, transportation of recycled tires and other goods are responsible for the rapid growth of the dengue epidemic globally from two (2) countries in the fifties (The Philippines and Thailand), to nine (9) countries in 1970 and reaching about 100 countries in 2014 (WHO, 2015). Several factors are causing this disease, in this research a system will be developed in order to make use of the well-known factors in an attempt to help reduce the dengue outbreaks and the transmitting entity from spreading and developing further using crowdsourcing.

Subsequently, a "Dengue Index" mechanism will be established in order to be used by the relevant authorities to take necessary action. By this research, a "Dengue Index" will be generated based on known factors to predetermine short-term prediction of dengue outbreak. The index will help local authorities to pinpoint the most probable dengue locations to use their resources in a systematic, timely and efficient manner.

1.2 DENGUE OUTBREAK

Dengue is a viral infection transmitted by Aedes mosquitoes female bite (WHO 2012). Until today, there is no treatment for dengue fever. Incubation takes 3-14 days after the insect bite and has flu-like symptoms (Murray, 2013). Severe dengue is a flu-like vector-borne disease transmitted by the female mosquito (Aedes aegypti) bite from human or carriers to other humans. The burden of dengue is even if the number of cases is underreported according to the World Health Organization is mainly concentrated in South-East Asia. Dengue has four distinct serotypes: DEN1-, DEN-2, DEN-3, DEN-4. Recovery from one provides immunity, however, cross-immunity against the others is minimal (WHO 2015). In the same report WHO reported that the disease repartition globally has increased dramatically. There is no real evidence on the numbers used by

WHO, uncertainties in countries with high populations such as China, Brazil makes it difficult to have realistic figures (Bhatt, 2013).

According to WHO; more than 70% of the worldwide repartition is concentrated in South East Asia and Western Pacific although the severity of the disease has increased in recent years in terms of dengue cases and number of countries. Although vaccines are being tested, the flu-like disease cannot be treated. Dengue can be lethal if not treated on time (Bhatt, 2013).

Aedes cannot be mentioned without introducing its common name "mosquito" and the term " vector". Vector-borne diseases are diseases transmitted from human to human or animals to humans by insects such as mosquitoes, ticks, aquatic snails, tsetse flies, sandflies. Half of the world population is affected by vector transmitted disease. Mosquitoes are the most efficient transmitting disease vectors (WHO 2015). Mosquitoes are the origin of 9 vector-borne diseases. There are three main species of mosquitoes that transmit the diseases according to WHO report:

i) **Aedes**: Dengue fever, Rift Valley fever, Yellow fever, Chikungunya. ii). **Anopheles**: Malaria, Culex, Japanese encephalitis. iii). **Lymphatic** filariasis: West Nile fever (WHO 2014). The first dengue outbreak in Malaysia was recorded in 1962 with 41 cases and 5 deaths, followed by an increasing number of outbreaks in the seventies with thousands of cases and tens of deaths (Mudin, 2015) with an alarming all-time record of more than 100,000 cases and 900 deaths. According to this research, it was reported that the age group affected by the disease was the group between 15 and 49 years old with no indication of ethnicity differentiation (Mudin, 2015).

Since 1990, the Malaysian government has put in place a surveillance system at the hospitals and institute of medical research called “Dengue Virus Surveillance

System" (DVSS) (Mudin, 2015). According to The Star Malaysian daily newspaper, the state of Johor (neighboring Singapore) had 10,660 dengue cases for the first 9 months of 2015 where 32 deaths were reported. This is a sharp increase of 163% compared to the same period last year (The Star, 2015). The state of Selangor remains highest with the number of cases reaching fifty-six percent (56%) of the cases. These cases are contributed by Klang Valley 49% and 7% from the federal territories of Kuala Lumpur-Putrajaya during the period of 2000 to 2014 (Mudin, 2015). Taking into account that there is no existing vaccine or cure for dengue (WHO 2015), World Health Organization (WHO) has published a list of preventive actions in order to control the transmission of the dengue virus (WHO 2015) which are:

i. Preventing mosquitoes from accessing egg-laying environments.

ii. Disposing of solid waste properly.

iii. Covering and disposing of domestic water storage containers.

iv. Applying proper insecticides.

v. Improving community participation in “Dengue Prevention”.

vi. Using mosquito repellents and mosquito nets.

vii. Active monitoring of vectors.

1.3 Crowdsourcing in Urban Health

Some study found that a social media system enabling the prevention of dengue in and proposed a predictive surveillance system to forewarn the relevant authorities (Lwin, 2014). The mechanism of this system enables the data to be sent to servers using civic engagement. Using the crowdsourcing platform, it will enable citizens to relay data through an intuitive user interface. Existing research work was done in the state of

Johor (Salawu, 2013) suggesting the use of a mashup web map to display and allowing manual Volunteered Geographic Information (VGI). Knowing the number of mobile phone users in Malaysia would be a determinant factor in vector surveillance through crowdsourcing. According to Malaysian Communications And Multimedia Commission (MCMC), as of 31st March 2014, there was a total number of 43,248,000 mobile phone subscribers throughout the country, with penetration of 144.20 per 100 inhabitants (MCMC, 2015). The same study reveals that as per the survey date, about close to two-third (63.3%) of the mobile phone users access the Internet through their mobile phones (MCMC, 2015). Below is the mobile phone users distribution by state in Malaysia extracted from the 31st March 2014 MCMC report (MCMC, 2015).

Figure 1.1 shows clearly that the highest number of users of smartphones in Malaysia is located in Selangor, Johor and Kuala Lumpur.

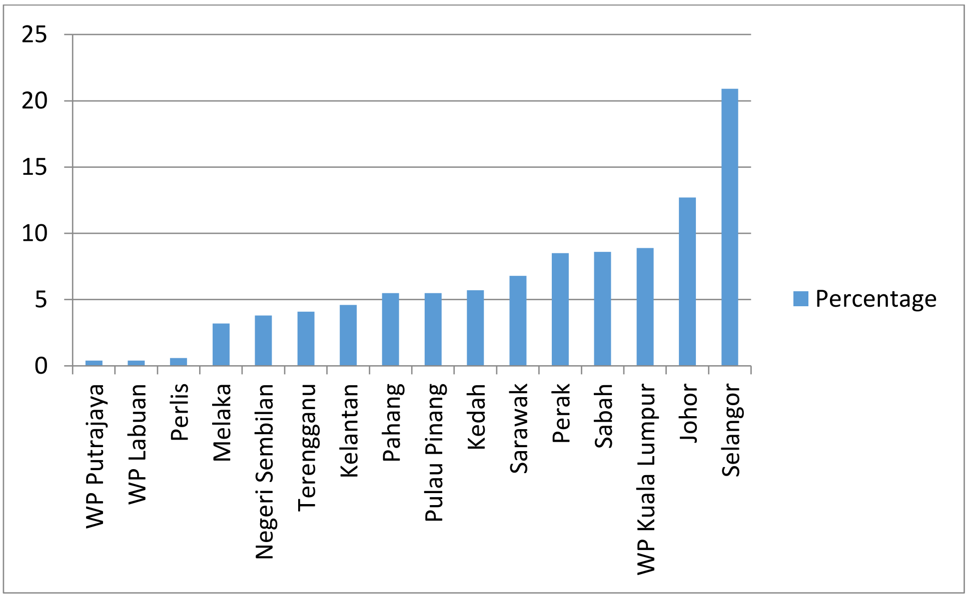

Figure 1.1 Smartphone Penetration in Malaysia by State. Source: MCMC 2014

1.4 PROBLEM STATEMENTS

In Malaysia, dengue outbreaks and dengue cases are still present, the local authorities are still struggling to pinpoint the areas of higher dengue risk. In addition, there is no way for the communities to be involved in the fight nor to be alerted with the emergence of outbreaks. Thus, in this research, the problems for the study are:

- Dengue outbreaks are on the rise on a yearly basis in Malaysia and the rest of the world. All data collected by the relevant health authorities are post dengue outbreak and the information is disseminated through slow channels.
- Disseminating the information and persuading the citizens to be involved even at a smaller scale would be a challenge. Gathering real-time data from several parties would is time-consuming and requires tremendous efforts to follow up and maintain digital data acquisition.
- Local authorities cannot pinpoint locations prone to dengue outbreaks as there is no pre-dengue-outbreak alarm system to alert the population about the probable risks ahead.
- There is no app for the citizens of Malaysia to volunteer and be involved in relaying systematically the existence of dengue vector proliferation to the relevant authorities.
- There is no accurate way to measure dengue through an index.

1.5 RESEARCH QUESTIONS

The following are the research questions:

a. How do spatial and temporal factors system help to predict a dengue outbreak in an urban health context?

b. How does a crowdsourcing system developed in this study support in reducing the yearly growth of dengue cases in Malaysia?

c. How can we quantify a dengue outbreak and measure the severity of a dengue outbreak in Malaysia through an index?

d. Would developing a mobile phone app encourage citizens to participate voluntarily in flagging dengue known factors and make dengue information disseminate faster?

1.6 AIM AND OBJECTIVES

This research aim to develop a system on urban health to generate a dengue index based on using known spatiotemporal factors contributing positively in the vector's lifecycle and crowdsourcing. The process would allow the relevant authorities to identify areas with high dengue outbreak probability. In this context, the main objectives are:

1. To analyze historical dengue outbreak data for the years of 2014 and 2015.
2. To develop a crowdsourcing system and analyzing the interest by the citizens in responding voluntarily.
3. To develop a system to extract data of the vector supporting factor to generate a dengue index.
4. To recommend the potential of crowdsourcing technology in handling urban health issues.

1.7 RESEARCH SCOPE AND LIMITATION

1.7.1 RESEARCH SCOPE

The research scope would include:

1. Database timeframe for the research will be from the year 2014 to 2015 due to the data limitation.
2. The development of this system based on the analysis of land use, temperature, rainfall, moon phases and data from crowdsourcing.
3. Analyzing crowdsourcing data from the app (X-Waba) that has been developed to support the calculation of dengue index.
4. Using temporal factors: temperature, rainfall, moon phase and the spatial factor: land use to forecast dengue outbreaks.

1.7.2 RESEARCH LIMITATIONS

Three limitations have been identified in this study which are as follow:

1. Data Availability: This research would not be possible without the dengue outbreak data provided in detail and in the continuous timeline required. Complete data is only available for the years of 2014 and 2015 due to data restrictions by the government policies.

2. Time Constraint: The research timeframe for this study is two years.

The time constraints for this research work is mainly for the data collection and conversion into a seamless GIS database.

3. Crowdsourcing data availability:

i. Crowdsourcing data will not be available if the app is not used by the citizens or the level of participation is low.
ii. The data collected by the app would be from the date the app starts to be used until present which is outside of timeframe of the data made available by the ministry of health in Malaysia.

1.8 RESEARCH SIGNIFICANCE AND CONTRIBUTION

This research will allow to predict dengue outbreaks and reduce the cases significantly. Our contribution would be to use GIS tools to predict dengue outbreaks rather than analyzing new outbreak data. The developed system will generate a dengue index based on a set of variables influencing the life cycle of the vector. The index will be generated on a daily basis to alert citizens through the volunteered geographic information provided an existing surrounding data affecting the lifecycle and the behavior of the Aedes mosquitoes. The Dengue Index will be displayed as a heat map representing the probability of contracting dengue in a certain location of the study area. Once the system is developed, it could be easily replicated in the rest of the states in Malaysia and even in other countries suffering from the heavy dengue burden.

1.9 STUDY AREA

The location of the research will be concentrated in the state of Selangor (Figure 1.2) and its federal territories which are Kuala Lumpur and Putrajaya in Malaysia. This choice was made taking in consideration that the statistics show that the state of Selangor and its federal territories have the highest number of dengue cases in the year of 2014 (Mudin, 2015) it has the highest rate of smartphone penetration in the country (MCMC, 2015). The state of Selangor is located on the west coast of Peninsular Malaysia. it contains spatially the federal territories of Kuala Lumpur and Putrajaya. Selangor also contains two cities, Shah Alam and Petaling Jaya. Thus, the state is the most populated in the country with a total of more than 6.1 million population excluding Kuala Lumpur and Putrajaya which is more than 20% of the overall population in Malaysia (Figure 1.3). Selangor is located in Latitude 3.519863° and longitude 101.538116°, it is the largest state by area in West Malaysia with a total number of nine districts which are namely Gombak, Hulu Langat, Hulu Selangor, Klang, Kuala Langat, Kuala Selangor, Petaling, Sabak Bernam and Sepang. The study area has been selected for the following criteria:

1. Mostly dense in the country in terms of population.
2. It has the highest smartphone penetration in the country.
3. The state of Selangor with the federal territories of Kuala Lumpur and Putrajaya have recorded the highest cases of dengue fever (DF) in the country for the years of 2014 and 2015.