# QUANTITATIVE FORECASTING TREND OF DENGUE FEVER AND DENGUE HAEMORRHAGIC FEVER CASES IN PENINSULAR MALAYSIA

by

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**Dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Science (MEDICAL STATISTICS)**

UNIVERSITI SAINS MALAYSIA

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2006

# ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere appreciation to my supervisors, Dr. Lin Naing @ Mohd Ayub Sadiq and to my co-supervisor, Dr. Than Winn for their knowledge, teaching, experiences and their precious time to continue giving me valuable advice, guidance, encouragement, recommendation and constant support throughout my research.

My acknowledgment also goes to the Vector Borne Diseases Section and Institute of Medical Research (IMR) in Ministry of Health, Malaysia for their permission and support in conducting this study. Special thanks also to my co-researcher Dr. Junaidden B. Mohd. Zain (Ketua Penolong Pengarah, Vektor, Jabatan Kesihatan Negeri Kelantan) and Rohaini Binti Hasim (Penolong Pegawai Rekod Perubatan, Cawangan Penyakit Bawaan Vektor, Putrajaya) who had provided the DF data that I needed and for their kind generosity in helping me through out the study.

I would like to thank Malaysian Meteorological Service, Malaysia, in providing the climatic data and other information for my research. I would also like to thank Assoc. Prof. Dr. Syed Hatim Noor (Course Coordinator of MSc. Medical Statistics) and all lecturers, who had taught me, during the first year of the course in Universiti Sains Malaysia (USM).

I am also grateful to my colleagues and friends for their encouragement, support, help, love and kindness throughout my study in USM to ensure that this dissertation became a reality.

Finally, I would specially also want to thank my family, particularly to my parents and my sister, for their love, support, kindness, encouragement, motivation and help from the beginning until the end of my study to make this dissertation from a dream to reality.

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# LIST OF SYMBOLS

| | |
|---|---|
| α | alfa |
| β | beta |
| γ | gamma |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| DF | Dengue Fever |
| DHF | Dengue Haemorrhagic Fever |
| WHO | World Health Organization |
| IMR | Institute for Medical Research |
| MOH | Ministry of Health |
| ES | Exponential Smoothing |
| HLES | Holt's Linear Exponential Smoothing |
| WLSES | Winters' Linear and Seasonal Exponential Smoothing |
| DECO | Decomposition for Time-series Forecasting |
| ARIMA | *A*utoregression *I*ntegration *M*oving Average |
| MAE | Mean Absolute Error |
| MAPE | Mean Absolute Percentage Error |
| PE | Percentage Error |
| MSE | Mean Square Error |
| SSE | Sum of Squared Error |
| SD | Standard Deviation |
| SDA | Spectral Density Analysis |
| K. Lumpur | Kuala Lumpur |
| N. Sembilan | Negeri Sembilan |
| i.e. | *id* est/that is |
| e.g. | for example |
| etc. | et cetera |
| Fig / Figs | Figure / Figures |

| | |
|---|---|
| mm | Millimeter |
| km | Kilometer |
| °C | Degree Celsius |
| NS | Not Significant |
| *et al.* | *Et alii* |

## LIST OF APPENDICES

**RAMALAN KUANTITATIF TREND BAGI KES DEMAM DENGGI DAN DEMAM DENGGI BERDARAH DI SEMENANJUNG MALAYSIA**

## ABSTRAK

**Pendahuluan:** Ramalan kes Demam Denggi (DD) (termasuk demam denggi berdarah, DDB) adalah penting dalam meningkatkan kecekapan pengawalan demam denggi dengan mengenal pasti masa, tempat dan populasi berisiko tinggi.

**Tujuan:** Kajian in dijalankan untuk menghuraikan wabak, musim, trend-kitar corak DD, mengenal pasti model ramalan terbaik, menguji keupayaan ramalan faktor hujan dan suhu, dan akhirnya meramalkan kes DD bulanan bagi dua tahun yang berikutnya (2005 - 2006) di 11 negeri dan Wilayah Persekutuan K. Lumpur di Semenjung Malaysia.

**Kaedah:** Kajian ramalan secara kuantitatif telah dijalankan dengan menggunakan kes DD bulanan (termasuk DDB) yang dilapor dan hujan dan suhu sepanjang lapan tahun, dari tahun 1997 hingga 2004. Data kes ini telah diperolehi dari Cawangan Penyakit Bawaan Vektor, Kementerian Kesihatan Malaysia. Manakala data hujan and suhu bulanan diperolehi dari Perkhidmatan Kajicuaca Malaysia. Corak DD dihuraikan dengan menggunakan kaedah dekomposisi. Model ramalan terbaik daripada enam model seri masa telah dikenal pasti. Ramalan hujan dan suhu telah diuji dengan menggunakan model regresi mudah dan model ARIMA campuran. Akhirnya, model siri masa yang terbaik digunakan untuk meramalkan kes DD untuk dua tahun yang berikutnya (2005-2006).

**Keputusan:** Kajian menunjukkan semua negeri di Semenanjung Malaysia pernah menghadapi penyebaran wabak DD, terutama pada tahun 1998 dan 2002. Variasi musim ditemui berlaku di semua negeri kecuali Selangor, Melaka, Perak dan Kedah. Terdapat peningkatan kes Denggi di tujuh buah negeri daripada keseluruhan 12 buat tempat kajian. Kaedah dekomposisi adalah model ramalan yang terbaik bagi semua negeri di Semenanjung Malaysia kecuali Perak (WLSES) dan Terengganu (ARIMA dengan musim). Walau bagaimanapun, faktor iklim seperti hujan dan suhu didapati bukan sumber ramalan yang tepat untuk DD. Dengan menggunakan takat ukuran (min + 2 sisihan piawai), negeri seperti Melaka, Kedah, Pulau Pinang, Perlis dan Terengganu diramalkan akan menghadapi sekurang-kurangnya satu bulan wabak di antara tahun 2005 hingga 2006.

**Kesimpulan:** Kajian in berjaya menentukan model ramalan terbaik, mengira ramalan bagi setiap negeri di Semenanjung Malaysia untuk dua tahun yang berikutnya. Ini dapat membantu pihak kesihatan dalam menjalankan aktiviti mengawal dan mencegah penyakit DD dengan mengatur strategi yang sesuai.

Kata Kunci: Dekomposisi, DD, Hujan, Musim, Ramalan, Seri masa, Suhu, Trend-kitar, Wabak

## QUANTITATIVE FORECASTING TREND OF DENGUE FEVER AND DENGUE HAEMORRHAGIC FEVER CASES IN PENINSULAR MALAYSIA


### ABSTRACT

**Introduction:** Forecasting dengue fever (DF) cases (including dengue haemorrhagic fever, DHF) is important in improving the effectiveness of control measures by early identification of period with higher DF cases, areas and populations at risk.

**Objective:** This study was carried out to describe epidemic, seasonal and trend-cycle of DF patterns, to determine the best time series forecasting model, to test the predictability of rainfall and temperature and finally, to forecast the monthly DF cases in the next two years (2005-2006) in Peninsular Malaysia which includes 11 states and Federal Territory of Kuala Lumpur.

**Methods:** A quantitative forecasting study was conducted using reported monthly DF cases (including DHF), rainfall and temperature during eight years, from 1997 to 2004. The DF data were obtained from the Vector Borne Diseases Section, Ministry of Health Malaysia and rainfall and temperature data was obtained from Malaysian Meteorological Service, Malaysia. The patterns of DF were described using decomposition time series method. The best time series forecasting model was identified among six time series models. The predictability of rainfall and temperature was tested using linear regression model and ARIMA mixed model. Finally, the best model was used to forecast the DF cases in the next two years (2005-2006).

**Results:** During eight years, all states in Peninsular Malaysia faced epidemic outbreak, especially in 1998 and 2002. Seasonal variation was found in all states of Peninsular Malaysia except Selangor, Malacca, Perak and Kedah. Increasing trend of DF cases was observed in seven out of twelve study areas. Decomposition method was identified as the best forecasting model for all states except Perak and Terengganu where Winter's and ARIMA with seasonal components model were the best respectively. However, rainfall and temperature were not found to be good predictors for DF. With a cut point (i.e. mean+2SD) for epidemic, several states such as Malacca, Kedah, Penang, Perlis, and Terengganu were forecasted to have at least one month of epidemic during 2005 to 2006.

**Conclusion:** The study successfully identified the best forecasting model, and calculate forecasts for the next two years for each state in Peninsular Malaysia, which could help the health management in carrying out the activities of DF prevention and control by making the appropriate choice of strategy.

Keywords: Decomposition, DF, Epidemic, Forecasting, Rainfall, Seasonal, Temperature, Time series, Trend-cycle

# CHAPTER ONE
# INTRODUCTION

## 1.1 Background Information

Dengue fever (DF) is an acute febrile illness of two to five days duration characterized by two or more of the manifestations including headaches, retro-orbital pain, myalgia, rash, GI disturbances and anorexia (WHO, 2004). Dengue haemorrhagic fever (DHF) frequently presenting with four major clinical manifestations: high fever, haemorrhagic phenomena, often with hepatomegaly and signs of circulatory failure in severe cases (WHO, 1997). Dengue viruses belong to the genus *Flavivirus*, family *Flaviviridae* and include four serotypes (designated DEN-1, DEN-2, DEN-3 and DEN-4) which can be distinguished by serological methods. These same viruses are responsible for DHF and it can be transmitted to man by the bite of infective mosquitoes, mainly *Aedes aegypti*, the most efficient mosquito vector for *arboviruses* (WHO, 2004, WHO, 1997).

Dengue Fever has been identified clinically for more than 200 years and was first described in northern Australia at the end of the past century (Pinheiro and Corber, 1997). The main appearance of DHF epidemic was reported in Philippines in 1953, which rapidly spread to Thailand, Vietnam, Indonesia and to other Asian and Pacific countries (WHO, 1997). Dengue research began early in the 20$^{th}$ century where the clinical and laboratory features of dengue were established in a series of well-designed human volunteer studies (Halstead, 2000). Substantial research capability is very important to solve the long-term problem of dengue control.

Throughout the year 1960s and 1970s, DF had progressively increasing global concern as a public health problem. Generally, it established seasonal and cyclical epidemic patterns with a large outbreaks occurring at two to three year interval. However, DHF cases are virtually seen every year and major epidemic occurring at three to five years intervals in country where it is endemic. In many endemic countries, DF and DHF are primarily diseases of children and they represent the largest susceptible individuals within the population at risk. DHF is now a significant public health problem in most of the countries in the tropical areas of the South-East Asia and Western Pacific Regions including Malaysia. In at least eight tropical Asian countries, the disease is among the ten leading causes of hospitalization and death in children (WHO, 1997). In Peninsular Malaysia, the numbers of death from the past eight years (1997-2004) were shown in table 1.1.

Table 1.1 Total number of death from clinically diagnosed cases in the states of Peninsular Malaysia

| States | Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| K. Lumpur | 3 | 0 | 0 | 0 | 3 | 2 | 8 | 21 |
| Selangor | 13 | 9 | 4 | 3 | 8 | 15 | 21 | 37 |
| N. Sembilan | 0 | 3 | 2 | 7 | 4 | 4 | 4 | 1 |
| Johor | 14 | 24 | 10 | 16 | 11 | 16 | 11 | 5 |
| Malacca | 2 | 0 | 0 | 0 | 1 | 0 | 3 | 5 |
| Perak | 0 | 5 | 0 | 1 | 4 | 10 | 6 | 9 |
| Kedah | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 4 |
| Penang | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 1 |
| Perlis | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Kelantan | 3 | 9 | 2 | 0 | 3 | 1 | 7 | 7 |
| Terengganu | 3 | 5 | 0 | 0 | 1 | 2 | 2 | 3 |
| Pahang | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |

*Sources: Vector Borne Diseases Section, Ministry of Health, Malaysia, 2005*

Dengue epidemic in Malaysia Peninsular was first reported in Singapore in 1901 (More, 1904) and first described by Skae (1902) following an outbreak in Penang in 1902. It is now one of the major public health problems in Malaysia. DF and DHF infection was made a notifiable disease in 1971. It is requiring all the medical practitioners to report any case of confirmed or suspected DF or DHF to the nearest health office. Dengue fever was the predominant type in Malaysia with the DF/DHF ratio of 16.28:1 in 2000 based on the notified clinically diagnosed cases. DEN-3 was the predominant serotype throughout 1992 to 1995 and was replaced by DEN-1 and DEN-2 in the next four years from 1996 to 1999. After 2000, DEN-3 and DEN-2 has re-emerged with an increasing number of these serotypes (Teng and Singh, 2001).

Among many other factors, transmission of dengue viruses is influenced by climate. In some regions, the cyclical pattern of increased transmission is coinciding with the rainy season and the interactions between rainfall and temperature are important determinants of dengue transmission. Moreover, rainfall and temperature may affect patterns of mosquito feeding, reproduction and the population density of vector mosquitoes, thus influencing transmission rates (WHO, 1997).

An Institute of Medical Research (IMR) model shows that high rainfall is required for dengue transmission. Temperature changes will increase the availability of suitable breeding habitats for the vectors including dengue fever (UNFCCC, 2000). In some circumstances, closed association between mosquito vector and human population is essential to cause the transmission (Liehne, 1988). Besides, DF is a problem of urbanization with city developing inwardly. In Malaysia, The most affected states are Federal Territory, Selangor and Johor.

There is an increasing trend of this disease and possibility of the occurrence of a dengue epidemic is very high in endemic countries. Thus, the pattern of the disease needs to be studied and appropriate control activities, allocation of the health resources and facilities can be implemented by the health planners or policy makers of the country. Studies on the number of series on DF cases can be done by using statistical analysis especially time series models to identify the peak season and forecast the occurrence of DF.

However, forecasting is not a fortune-teller. It is considered as a technical, primarily statistical, the field its major concern was providing predictions about the future event, help in planning, decision making and managing issues (Wheelwright and Makridakis, 1985). There is an increasing of need in forecasting as health management attempts to decrease its dependence on chance and becomes more scientific in dealing with its environment.

**Background of study area**

Malaysia is situated in Southeast Asia with an area of 329.733 $km^2$ which comprises peninsular Malaysia and states of Sabah and Sarawak on the island of Borneo (FAO, 1999). In Malaysia Census 2000, population was estimated at around 23.27 million where 83 percent live in the Peninsular, eight percent in Sabah and nine percent in Sarawak (Department of Statistics Malaysia, 2001). The study area which is Peninsular Malaysia is lying between latitudes 1.5°N and 7°N and longitudes 99.5°E and 104°E and covers 13.16 million hectares. It comprises 11 states and federal territory Kuala Lumpur (Malaysia, 2005).

The proportion of urban population had increased to 62% in Census 2000 from 50.7% in 1991. States with high proportions of urban population were Kuala Lumpur (100%), Selangor (87.6%) and Penang (80.1%). Conversely, Kelantan (34.2%), Perlis (34.3%) and Kedah (39.3%) which had lower urbanization levels (Department of Statistics Malaysia, 2001).

Malaysia has two main seasons, the Northeast Monsoon (November to March) and the Southwest Monsoon (May to September) (MMS, 2005). The period between these two monsoons is marked by heavy rainfall. The climate is warm and humid throughout the year but cooler temperature in the hill resorts. The average temperature throughout the year is very stable which is 26°C and the mean annual rainfall is 3000 mm (FAO, 1999).

## 1.2 Problem Statement

The global burden of dengue fever and dengue haemorrhagic fever continues to be major health problem and has grown dramatically in recent decades. It is classified as an emerging or re-emerging infectious disease (TDR, 2002). Dengue viruses infect nearly 100 million human beings each year (Halstead, 2000) and about 40% of the world population (2.5 billion people) are globally at risk (WHO, 2004). This disease is living in 110 countries spread over all tropical areas of Africa, Southeast Asia, South America, the Western Pacific and Eastern Mediterranean (Halstead, 2000).

The major disease burden is found in South-East Asia and the Western Pacific regions of WHO with increased reporting of DF/DHF (TDR, 2002). Globally, the number of cases increased more than four fold between 1970 to 1995 (TDR, 2002) and 1.2 million cases of DF and DHF were reported to WHO in 1998 including 3,442 deaths (WHO, 2004). According to WHO, it was estimated that over 50 million infections with about 400,000 cases of DHF recorded annually which is a leading cause of childhood mortality in several Asian countries (WHO, 2004).

Dengue fever has been a public health problem in Malaysia showing an increasing trend from 27.5 cases/100,000 populations in 1990 to a high of 123.4 cases/100,000 populations in 1998. However, based on clinically diagnosed cases, this number had declined to 31.99 cases/ 100,000 populations in the year 2000 (Teng and Singh, 2001).

The case-fatality rate reported in 2000 was 9.9% for DHF alone and 0.63% for DF and DHF (Teng and Singh, 2001). Incidence (per 100,000 populations) of DF and DHF which has been reported in the book of Health Facts 2002 by the Ministry of Health Malaysia were 63.17 and 7.99 respectively in 2002. However, mortality rate (per 100,000 populations) was low with 0.27 for DF and 0.28 for DHF (MOH, 2004). Although, it rarely kills, dengue fever causes a severe flu-like illness that can lead to hospitalization.

In addition, occurrence of DF outbreak also linked to other factor which is the density of mosquito vectors, especially *Aedes aegypti*. In some endemic area with high densities population and low immunity, house indices (the percentage of houses infested with larvae or pupae) as low as 2% are enough for the dengue epidemic transmission. Furthermore, DF/DHF hospitalization rates increase during rainy season and decrease several months after the cessation of the rains. Eventually, it ensures a constant supply of susceptible individuals and numerous vectors breeding (WHO, 1997).

There are no much studies on the economic impact of DF and DHF have been conducted. However, it is well known that intensive care is required for severely ill patients especially for DHF. This includes intravenous fluids, blood or plasma transfusion and medicines. Moreover, children most frequently suffered from DHF and parents can miss work. As a result, there are both direct and indirect costs for each dengue patient (WHO, 1997). A study by Shepard, *et al.* (2003) on DF/DHF in 10 countries of Asia including Malaysia revealed that health burden of dengue was estimated as 0.42

DALYs per 1000 population. According to an unpublished data (2002; unpublished data WHO; MOH, Malaysia), annual spending cost per 1000 population was US$240 in Malaysia (Shepard *et al.*, 2003). However the exact cost of each epidemic is difficult to calculate, but it is clear that DF and DHF represent a significant economic burden to the societies affected.

Malaysia is a tropical country and experiences frequent rainfall and hot weather which is an ideal place for the *Aedes* mosquito to breed. Thus, the information of the rainfall and temperature might be able to determine the outbreak of the disease. Moreover, there is no vaccine or specific medicine currently available for the treatment. The option is to have a proper and early treatment to relieve the symptoms and prevent complication or death (WHO, 2002).

Nevertheless, the major factors which are responsible for emergence of epidemic DF are associated with demographic and societal changes, unplanned and uncontrolled urbanization, lack of effective mosquito control, the increase of air travel and lack of resources especially trained specialists (Gubler, 1998). Thus, early detection of DF cases and confirmatory laboratory reports could help in placing control measures early. It is clear that emphasis must be on disease prevention if the trend of emergent disease is to be reversed. Therefore, efforts of control the disease should be intensified before the transmission season and at the time of the epidemic (WHO, 2004).

Under the Eighth Malaysia Plan (2001-2005), Malaysia had set several objectives and programme to reduce the morbidity and mortality caused by DF/DHF. The ministry of Health is in the process of developing a comprehensive national computerized communicable disease control information system (CDCIS) and it covers the early warning system of the disease (Teng and Singh, 2001). Thus, there is a need to forecast and develop any system of early warning to understanding the factors involved in the outbreak of DF and DHF disease.

A nationwide study has been carried out to determine the risk factors of dengue fever (IMR, 2005). The research activities have provided vital information to the health authorities in maintaining relevant control and preventive measures. However, the control activities toward DF will be more effective if the accurate time (year or month) when disease will happen in each state can be determined by using the appropriate statistical analysis. Thus, more effective management in controlling disease outbreak can be proactively implemented by allocating the resources where disease will become epidemic.

Forecasting is needed to determine when the outbreak or event of disease will occur or arise, so that appropriate actions can be taken. The knowledge of forecasting the disease is very important to provide an effective and efficient management and administrative planning for the country. There are varieties of forecasting methods (e.g. Decomposition, ARIMA, Census II) which can be used and thus appropriate decision making activities regarding the outbreak of DF and DHF can be done.

## 1.3 Justification on the Study

The benefits from the result of the study would be provision of an essential information to the country especially Ministry of Health, Malaysia. Generally health planner has some idea regarding the pattern of the DF occurrence in Malaysia. However, knowing the pattern more accurately by using the statistical method will help them in planning to control the disease more effectively.

Besides, the difference of the pattern of occurrence of DF (if exists) among states can be known. Thus, the resources can be allocated to the states where the disease is forecasted to be occurred and therefore, the prevention and control can be done more effectively. The resources can be in terms of financial allocation and man power especially the health workers. In addition, the focus of preventive measures can be applied on priority in the high risk states and it helps saving time and money.

Especially knowing the possibility of epidemic or next spike of DF cases in advance, it will help the state's health planners to have effective control activities by proper resource allocation including the preparation in hospitals. In addition, hospital management may find the solutions (e.g. preparing extra beds) in order to handle the problem of over crowding in the hospital due to the increasing number of infected patients during the peak season of the DF disease.

This study may offer some useful information regarding the relationship between the climatic variable which are temperature and rainfall and the dengue cases. It is important to know the relationship of the climatic factor towards the occurrence of DF since in many endemic countries it shows the positive relationship. Thus, it will provide additional information to those who are involved in the DF prevention.

If the proper prevention and control actions can be taken according to the knowledge of the forecasting, then the lost of future life years due to premature mortality and disability during the period can be reduced to the minimal level. Consequently, it will reduce the substantial costs for hospitalization, loss of potential learning and earning capacities which have a great impact on national development.

There is an important need for reliable forecast of the epidemic events or the DF cases in a particular month or state. Since the historical data of number of DF cases is available in Ministry of Health Malaysia, it should be used properly for forecasting analysis. The information which can be gained from the analysis result is valuable for the country in DF prevention, disease surveillance system and outbreak preparedness.

# CHAPTER TWO
# OBJECTIVES

## 2.1 General Objective

To provide the useful information for public health planners and decision makers in terms of patterns of occurrence of DF and DHF disease in Malaysia, which will be useful for early and effective management, prevention and control

## 2.2 Specific Objectives

1. To describe the epidemic, seasonal, trend, and cyclical pattern of DF cases in each state in Peninsular Malaysia during the past eight years (from January 1997 to December 2004)

2. To identify time series model which reasonably fits the past eight years data of monthly DF cases in each state

3. To evaluate the predictability of temperature and rainfall for the monthly DF cases

4. To forecast the monthly DF cases for the next two years (from January 2005 to December 2006) by using the most appropriate quantitative forecasting model

5. To predict the epidemic occurrence of DF cases in the next two years

## 2.3 Research Hypotheses

1. There are systematic patterns including epidemic, seasonal, trend and cyclical in the occurrence of DF/DHF.

2. Temperature and rainfall are significant predictors for the occurrence of DF/DHF in each state of Peninsular Malaysia.

## 2.4 Operational Definitions

1. Dengue Fever (DF)

   A disease caused by *arboviruses* and transmitted to humans principally by the mosquito (*Aedes aegypti*) (John *et al.*, 1995).

2. Dengue Haemorrhagic Fever (DHF)

   Characterized by a breakdown of the blood-clotting mechanism with internal bleeding (John *et al.*, 1995).

3. Monthly DF cases

   Total number of cases of DF and DHF (reported to Vector Borne Diseases Section, Ministry of Health, Malaysia in a particular month) during a particular month in a particular state.

4. Endemic

   The constant presence of a disease or infectious agent within a given geographic area or population group; or may also refer to the usual prevalence of a given disease within such area or group (John *et al.*, 1995).

5. Dengue Epidemic

It was defined as an important rise in the number of cases in the area where dengue is endemic. It may also refer to either the detection of the first cases in an area free of any dengue virus circulation (Hayes *et al.*, 1996). In this study, it was defined as the average number of DF cases plus two SD as usual applied by local health officer. However, the choice of one SD can identify early most of the epidemic and thus more proactive control activities (Dr. Junaidden B. Mohd. Zain, personal communication, January 3, 2006).

6. Stationary Pattern

It exists when the data values fluctuate around a constant mean; also called horizontal pattern (Makridakis *et al.*, 1998).

7. Seasonal Pattern

It exists when a series fluctuates according to some seasonal factor (e.g. the quarter of the year, the month, or day of the week) (Makridakis *et al.*, 1998).

8. Cyclical Pattern

It exists when the data exhibit rises and falls that are not of a fixed period, usually longer than one year (Makridakis *et al.*, 1998).

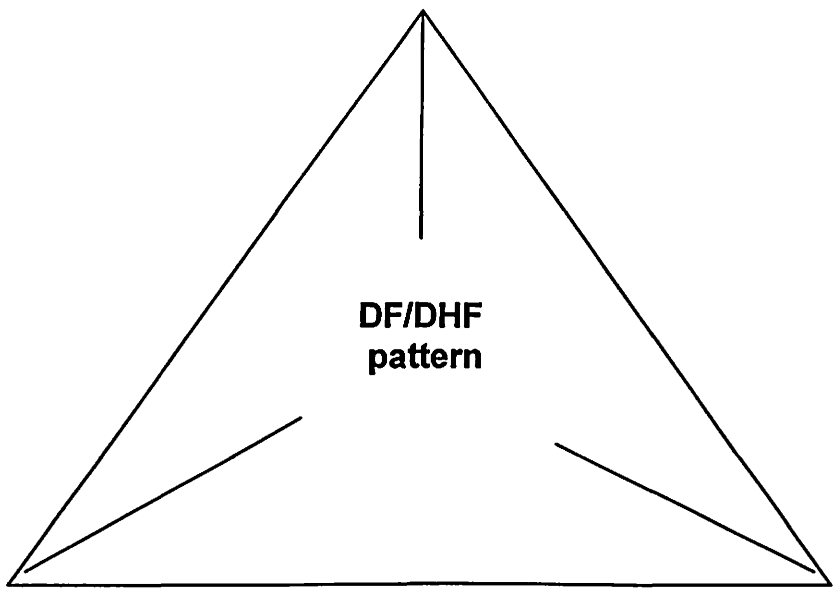
9. Trend Pattern

It exists when there is a general increase or decrease in the value of the variable over time (Makridakis *et al.*, 1998).

## 2.5 Conceptual Framework

Epidemiological triangle:
(PHAC, 2001, WHO, 1997)

**Host**-human, mosquitoes[1], non-human primates
Change in immunity status, travelers, and migrant




**Agent** –virus serotype DEN-1 DEN-2, DEN-3, DEN-4
Vector – infective female *Aedes* Mosquitoes[1]
Changes in:
Pathogenesis- sudden onset of fever 3-5 days; intense headache, myalgia, arthralgia, retroorbital pain, anorexia and rash; for DHF, abnormal vascularpermeability hypovolemia and abnormal clotting mechanisme[2]
Virulence- fatality 40-50%
Infectious dose- not known

**Environment** – rainfall, temperature, wind, unclean place, rapid growth cities led to overcrowd, urban decay, increase in non-biodegradable plastic packaging, increased jet air for travel[3] peridomestic fresh water[4], artificial Containers[5], less public awareness

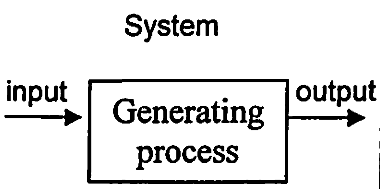
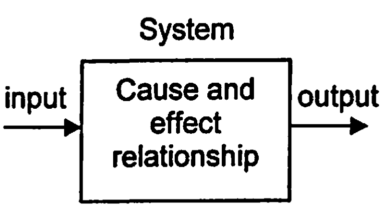
[1] *Aedes albopictus, Aedes aegypti*
[2] *a more severe manifestation on second exposure*
[3] *helping people infected with dengue viruses to more easily from place to place*
[4] *for vector Aedes aegypti*
[5] *example: old tires, flowerpots, water storage containers*

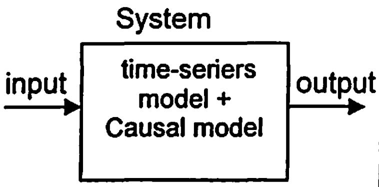
## 2.6 Theoretical/ Conceptual Models Applied in Forecasting

Quantitative forecasting can be applied with existing three conditions (Makridakis *et al.*, 1998):

1. Past information of DF monthly reported cases is available.
2. This information can be quantified in the form of numerical data.
3. It can be assumed that some aspects of the past pattern will continue into the future.

There are three major types of model – time-series, causal and mixed relationship:

| | |
|---|---|
| (a) Time series<br><br>Figure 2.1 Time series relationship | It treats the system as a black box and makes no attempt to discover the factors affecting its behavior. For example,<br>$DF_{t+1} = f(DF_t, DF_{t-1}, DF_{t-2}, DF_{t-3}, \ldots, \text{error})$, (2.1)<br>where $t$ is the present period. The main reasons are it is extremely difficult to measure the relationships assumed to govern its behavior and main concern may be only to predict what will happen and not to know why it happens. |
| (b) Causal or explanatory<br><br>Figure 2.2 Explanatory or causal relationship | It assumes that the variable to be forecasted exhibits an explanatory relationship with one or more independent variables. For example,<br>$DF = f(\text{rainfall, temperature, human immune, vector}, \ldots, \text{error})$. (2.2) |

| | |
|---|---|
| | The purpose is to discover the form of the relationship and use it to forecast future values of the forecast variable. Any change in inputs will affect the output of the system in a predictable way. |
| (c) Mixed Model<br><br>Figure 2.3 Mixed Relationship | This model will combine an explanatory model with an ARIMA model. The example model will be:<br>$DF_t = f(\text{rainfall}_t, \text{temperature}_t, \text{human immune}_t, \text{vector}_t, \ldots, N_t)$ (2.3)<br>where $t$ is the present period and $N_t$ is modeled as an ARIMA process. This method will combine the ARIMA models to handle the autocorrelations[1] with the regression models to describe the explanatory relationship and called as regression with ARIMA errors.<br><br>[1] *term used to describe the correlation between values of the same time series at different time periods or time lags.* |

# CHAPTER THREE
# LITERATURE REVIEW

Research on dengue epidemic has been done in several Asian countries which infested with dengue vectors. Most of the research is based on the DF incidence, DF cases and the possible meteorological factors in a country. Generally, researchers' interests were identifying the DF pattern and the association with climatic factors. In this chapter, several articles and journals related to the quantitative forecasting of DF and the factors involved in the occurrence of DF were presented.

## 3.1 Climatic factors and DF

Knowledge about the relationship between climatic and environmental factors is good to be discovered for prevention. Spatial factors which affecting DF/DHF epidemic had been analyzed by exploring the potential of remotely sensed data and GIS (Geographic information systems) technology in Sukhothai, Thailand. This study revealed that rainfall, temperature and humidity had significant high correlation with DF/DHF incidence if applied only in rainy season and these factors could be related to forecasted dengue cases (Kanchana and Nitin, 2005).

Focks and colleagues (1995) reported that rainfall and temperature had directly influenced vector reproduction and mortality rates. As a result, it controlled the vector mosquito population distribution. However, temperature did not enable the prediction of an epidemic outbreak in an endemic area but it allows the definition of areas and periods at risk for dengue virus transmission (Focks *et al.*, 1995, Jetten and Focks, 1997). A study done in Thailand, which indicated that the variability of DHF incidence was less explained by independent climatic factors ($R^2$ = 0.2% ~ 3.6%) (Thammapalo *et al.*, 2005). However, they indirectly affected epidemiological significant factors such as the blood feeding frequency of vectors (Hay *et al.*, 2000). These effects often resulted in predictable annual cycling, or seasonality in mosquito-borne diseases (Focks *et al.*, 1995).

Generally, the incidence of DHF was peak during the hot and rainy seasons and this phenomenon is repeated every year (Barbazan *et al.*, 2002). A study revealed that the dengue occurred when average temperature rose above normal which was found in 1998 during the El-nino period in Sukhothai Province, Thailand (Kanchana and Nitin, 2005).

However, outbreak occurred when temperature decreased during the post monsoon period in New Delhi, India (Chakravarti and Kumaria, 2005). The same study showed that outbreak coincided with the post monsoon period of subnormal rainfall with a low cumulative rainfall of 30.3 mm. However in Myanmar, a study revealed that a higher number of cases were reported in the monsoon period which marked as heavy rainfall (Cho-Min-Naing *et al.*, 2002). Conversely in Malaysia, Foo, *et al.* (1985) had reported that larvae would be washed away during heavy rain and have an immediate negative impact on the *Aedes* index.

A recent study done in Thailand revealed that an increase in temperature was associated with an increased of DHF incidence in nine provinces out of 73 provinces. In another seven provinces, it showed that an increase in rainfall was associated with a decrease in DHF incidence (Thammapalo *et al.*, 2005). Therefore, the review shows that occurrence of DF with the climatic factors are inconsistent in different geographical areas.

According to Kanchana, *et al.* (2005) there is a time lag of about one month that leads to DF cases occurring (during 7-45 days). The development of larvae stages to adult is about seven to 12 days and the lifespan for female mosquito is about eight to 15 days (Gubler and Kuno, 1997). Besides, the development of the virus in the mosquito is about 8-10 days. Approximately two to seven days for the virus to be found in serum or plasma, in circulating blood cells of an infected person (WHO, 1997). Therefore DF cases at the current month (e.g. August) depend on those factors at previous month (e.g. July). Additionally, rainfall lagged three months was found to have a significant impact on the number of dengue cases in a study done in Selangor ten years ago (Foo *et al.*, 1985). Thus, rainfall lagged up to three months and temperature lagged up to one month is possible predictor for DF cases.

Furthermore, Thammapalo, *et al.* (2005) had cited several references showing laboratory evidence which indicated that temperature affects the development of larval, decreased the size of mosquitoes, increased their fly-range, biting rates, survival time, replicated the dengue virus and raised the dengue cases. In addition, it reported that *Aedes albopictus* was outdoor breeder and *Aedes aegypti* was indoor breeder, thus, DF was less likely affected by the rainfall (Thammapalo *et al.*, 2005). During the last century, *Aedes aegypti* had been the primary epidemic vector of dengue viruses in urban areas in Asia (Halstead, 1992).

Previous studies had illustrated that changes of local rainfall and temperature would give a different magnitude of DF/DHF in different countries or places. Thus it will be appropriate if we can find out the association between climatic factors and DF cases in each state in Malaysia rather than depending on our limited general knowledge of their pattern.

## 3.2 Environment and Demographic Factors

Several surveys had been conducted to determine the suitable environmental of habitat for larval to survive. Since the mosquitoes are extremely sensitive to climate (Hay *et al.*, 2000), thus changes in environment have been suggested as a contributing factor to DF incidence. In addition, transmission of DF is associated with the susceptible environmental factors which can provide better condition for larval survival.

A study exploring the risk factors of DF in Palau, Western Pacific revealed that the 10 most larvae positive habitats were tires, cisterns, water barrels, cans and bottles, animal drinking pans, buckets, plastic containers, cooking pots, flower pots and taro (Ashford *et al.*, 2003). Generally, source of water with unintentionally collected rainwater produced more larvae and pupae compared to intentionally collected rainwater or well water (Strickman and Kittayapong, 2003). This indicated that population of larval depend on the quantity of containers with high nutrition stored by residents.

Several researchers reported that land use or land cover types and climate have significant relationship with dengue infection. A study done in Thailand reported that built-up areas had highest risk zones and agricultural areas had moderate risk while forest areas had no influence on DF/DHF epidemic (Kanchana and Nitin, 2005). It suggests that urban areas are still high risk zone of DF infectious. However, prevention programme should not restrict to urban areas only because it can be seen in rural areas as well (WHO, 2001).

### 3.3 Time Series Analysis on DF and Climatic Factors

Studies have shown that time series analysis is a very useful tool to forecast the disease like DF which shows regular seasonal, trend or cyclical pattern. Estimation of incidence or number of cases of DF in the future can be done by using appropriate forecasting method. It is essential to know what will happen in the near future regarding the disease. Thus, appropriate control activities of the disease can be implemented.

Forecasting of DF is proposed as a warning of epidemic outbreak enabling an early launch of control activities. When applying the data retrospectively during the study period and then, identify the epidemic outbreaks, control activities can thus be improved through early management and prevention of the supplementary cases which occur during epidemics (Hay *et al.*, 2000).

A description and forecasting of DHF epidemics study conducted in Thailand, found that from 1958 to 1995 the trend of the average annual DHF incidence in the whole country was positive (Barbazan *et al.*, 2002). Another study conducted in Myanmar forecasting the DF/DHF incidence, ARIMA time-series analysis was carried out (Cho-Min-Naing *et al.*, 2002). The study revealed an upward DF/DHF trend with cyclical pattern and seasonal variation.

Fluctuations of DF incidence followed two main patterns which were cyclic and non-cyclic in Thailand and in most of the countries where DHF is endemic (Chareonsook *et al.,* 1999). Climate variables like rainfall and temperature were cyclical in nature. The association between these factors and DHF incidence would be strongly confounded by other determinants which were also cyclical (Thammapalo *et al.*, 2005) such as viral transmission (Ferguson *et al.*, 1999).

The study done by Thammapalo, *et al.* (2005) which demonstrated the effects of climatic factors on DHF incidence by using time-series model and found that the variability of the DHF incidence was mostly explained by trend and cyclic change rather than climatic factors. The study also concluded that climatic factors are redundant and should not be included in the forecasting model.