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Surveillance System Architecture for Mitigating Contagious Disease with the Adaptive Area-based Risk Model

Graduate School of Media and Governance

Keio University

Wahjoe Tjatur Sesulihatien

ABSTRACT

This dissertation addresses the architecture of the surveillance system for managing the dengue spreading. It is built to answer the challenge of spreading of contagious disease, such as: (1) dynamic changing of the spreading of disease in a network, (2) realistic action to suppress the disease, (3) unobservable phenomena of transmission, and (4) complexity in the pattern of contact of human movement.

The system consists of three model: (1) The Location-Contraction Risk Model, (2) The Adaptive Area-based Risk Model (ADRESS), and (3) The Ecological Context-Dependent Strategy.

The Location-Contraction Risk Model is the spatial risk model based on the weighting of the the contagious area. The method for calculating the weight is the weight of evidence. The contagious area represents level of the disease transmission in the area as an impact of engagement between host(human) and vector(mosquito). The model transforms the unobservable phenomena of disease transmission into sensible attribute of the disease transmission. This model has simulated using a set of data Surabaya, Indonesia in 2012, the accuracy is 87%.

The Adaptive Area-based Risk Model is the algorithm of spreading of disease. The uniqueness of the algorithm is that the algorithm utilizes the agent who has "state-space temporary behavior" to simulate the propagation of disease. By this behavior, the spreading of disease is depending on the pattern of dynamic movement of human and the environment of disease. It simplifies the complexity in the pattern of contact among the agent. This model consists of: (1) the state-space model of routine movement cycle, (2) the algorithm of spreading, (3) the prediction model of infection area by graph relation, and (4) the model to calculate risk of area. The method is applied to simulate routine movement of people in Kecamatan Tandes, Surabaya. Compare with the real data, accuracy of the method is 76%.

The Ecological Context Dependent Strategy is the semantic strategy to determine the real action to combat the disease. This model performs a semantic action by projecting the data of abiotic environment of mosquito to the stage of mosquito life by using Mathematical Model of Meaning. It is applied to a set of monthly data of Surabaya from January 1984 to December 2014. The average result is 77%.

The dissertation also presents the combination between The Spatial-Contracting Risk model and The Ecological Context Dependent Strategy. It is implemented to perform the common strategy for 3 cities of 3 countries: Surabaya of Indonesia, Kuala Lumpur of Malaysia, and Bangkok of Thailand. It is investigated during ASEAN Dengue Day 2012. The result shows that accuracy of the system is 82.3 %.

Keyword: *dengue spreading, adaptive area risk, location-contraction, semantic strategy.*

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CHAPTER 1

Introduction

1.1 Background

The spreading of Contagious spreading of disease is a critical issue in the world. In this dissertation, contagious diseases are defined as infectious and transmissible diseases caused by direct or indirect contact [36]. The spreading is strongly influenced by the the global environmental changing and the increasing mobility of human [20]. The Spreading of disease reflects the propagation of virus in the network as an impact of accumulation of disease transmission. A disease transmission depends on the relation among a disease determinant factors. Disease determinant factor is a factor (such as environmental or a disease agent) that affects the frequency of disease occurrence. Relations among disease determinant factors are shown as the transmission chain of disease as illustrated in Figure 1.1.

In order to suppress the spreading, relations between disease determinant factors need be controlled, for example, by managing human-environmental relation, or environment-vector relation. The method to manage relations among determinant factors becomes the uniqueness of every surveillance system.

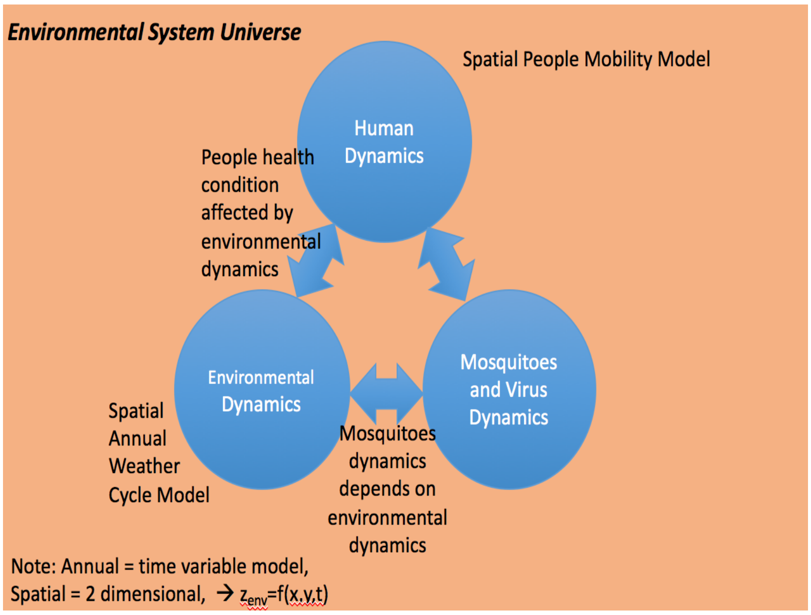


Figure 1.1 The transmission chain of disease

This dissertation discusses the architecture of surveillance of spreading of disease. Dengue fever is chosen with a reason that among contagious disease, WHO declared dengue fever as the fastest spread disease in the world. It attacked 125 countries, with a 50 million people are injured every year [97].

1.2 Challenges of Research in Spreading of Disease

In the absence of vaccine, eradicating the communicable disease relies on the surveillance system to manage them in many ways. The potential incidence of the communicable disease is a complex phenomenon [9], because it may have performed by several variables in the pathogen transmission context [30], dynamic-environmental context [74], and action-intervenes context [87]. There are four challenges in creating the surveillance system, as explained on the following pages.

1. Select a sensible predictor of spreading of disease

In most surveillance systems, the prediction is at the heart of the system. Therefore, determining the accurate predictor is the most important. There are many predictors discussed in dengue spreading research, however, not all of them are observable. Table 1.1 shows several predictors in the spreading of disease. Table 1.1 shows several predictors associated with the incidence of dengue. The predictors reflect phenomena related directly or indirectly with the incidence of dengue. Finding in the fifth column of Table 1.1 represent the phenomena measured in accordance with the indicator. For example, weather predictor represents when there is an abundance of mosquito.

Table 1.1 The predictors in surveillance system of dengue

Predictor reflects the phenomena related directly or indirectly with the incidence of dengue. The term "sensible" refers to the data that can be collected by the sensor. Column on finding represents the phenomena measured in accordance with the indicator. For example, weather predictor represents when there is an abundance of mosquito.

	Predictor	Sensible	Area of Study	Finding
Fellipe, 2012	Weather	Yes	Surabaya, Indonesia	Role of weather in an abundance of mosquito
Schmidt 2011	Population density	Yes	92 rural area in Vietnam	Activity of human related dengue
Cheong, 2014	Land use	Yes	Malaysia	Suitable place for mosquito's life
Otero, 2008	Number of larvae	No	Boenos Aires, Argentina	Mosquito dispersal
Adam, 2011	Immunity	No	Bangkok, Thailand	Cross-protective immunity
Barera, 2011	Population density of vector	No	San Juan City, Puerto Rico	Prevalence adult mosquito in dengue

In Table 1.1, the term “sensible” refers to the data that cannot be collect by a sensor. If the predictor data could not be represented in the sensor data, it is difficult to realize a real-time prediction. The challenge is how to transform the insensible predictor to the sensible predictor.

2. <u>Complexity in the pattern of contact of human movement</u>

The spreading of disease symbolizes propagation of virus in a network through the movement of both local vector and global vector. It involves the phenomena of connection, transmission, and propagation process. Previously, the spreading of disease is considered as a spatial diffusion phenomenon that only depends on the behavior of vector. Due to the mobility of human, disease spreads rapidly in the long distance. Several kinds of research in dengue had explored many aspects regarding with type of contact in a social network. Table 1.2 shows various types of contact in a social network.

Table 1.2 Various type of social contacts in a spreading of disease. It shows the role of social contact in spreading of disease. The finding represents the relation between social contact and model of the spreading of disease.

	Area of Study	Type of contact	Finding
Reiner, 2014	Iquitos, Peru	Social structure	Social proximity determines the pattern of fine-scale network transmission
Stodart, 2012	Iquitos , Peru	Neighborhood social interaction	Neighborhood social pattern triggers the disease transmission
Prokopec, 2013	North Queensland, Australia	Social pattern dependent	Social pattern influences the scale of transmission
Padnamabha, 2015	Columbia City	External social relationship	External social relationship generates the frequent viral

Table 1.2 shows the role of social contact in spreading of disease The finding represents the relation between social contact and model of spreading disease. Different type of communal contact influence the scale of spreading. Therefore, different social contact is the problem that need to be resolved in modern spreading of disease analysis.

3. The real action for suppressing the disease.

Communicable disease is closely connected to the dynamic factor such as demographic, environmental or lifestyle. Therefore, the action for combating the disease may take an account of the dynamic situation. Many types of research are carried out based on an association between historical evidence of these factors and the occurrence of disease to establish the action. Table 1.3 shows the application of action for suppressing the disease.

Table 1.3 The action to suppress the disease

Application of action-method regarding to dynamic situation in dengue spreading. The method utilizes the association between historical and the incidence of dengue

	Area of Study	Methodology	Finding
Parker 2014	Barbados, Brazil, Thailand	Signal processing	Length of epidemic as a feature of control
Estallo, 2014	Cordoba city, Argentina	Spatio-temporal cluster	Imported case as a trigger of control
Hwang, 2016	Iloilo City, Phillipine	Web-base and Neural Network	Tracking-recorded case for control

Due to the rapid changes in the factors, the new historical evidence predictive models have been considered with this dynamic situation.

4. **Dynamic changing of the spreading of disease in a network**

Every communicable disease has distinctive aspects that lead to different approaches for modeling. An important point to fulfill the requirement to implement the surveillance system is how to deal with the complexity of the real condition [22]. The way to simplify the problem determines whether the approach is realistic or not realistic to be implemented [89] [50]. Table 1.4 shows some approaches in spreading of disease in a network.

Table 1.4. The Approaches in spreading of disease in a network.
An example of several study to simplify the network of spreading and their implementation.

	Area of Study	**Methodology**	**Finding**
Saba, 2014	Bahia, Brazil	Time varying network-correlation	Timeline graph-correlation among case as method of control
Stolerman, 2015	Rio de Janeiro, Brazil	Meta population	Epidemic threshold for homogenous and mildly heterogeneous
Rodriguez	Central Valley, Costa Rica	Multi-scale Analysis Network	Combination macro level and micro level scale to identify significant event

1.3 Objective of the Research

In this dissertation, the integration system that involves the important variable in spreading of disease is built. It is consists of: the weather as a temporal variable, human movement that reflects the spatio-temporal spreading in a network network, and the contagious area that represents the disease transmission. Objective of the research is to design the architecture of a surveillance system based on Sensing-Processing-Actuation with the features:

- Sensible predictor: contagious area
- Environment-dependent of external force
- Time-varying near- future risk prediction
- Ecological context –dependent strategy for suppressing the disease.

Motivation to build the surveillance system is tantamount to realize quick and effective action for combatting spreading of disease. The swift action particularly aimed at preventing another area from the next spreading by near-future prediction. Effective-operational action means deliberating the disease with minimum damage to the environment. It is established by temporal semantic action.

The dissertation presents the architecture of surveillance system with several approaches:

1. Calculating the probability of disease transmission phenomena by site associated risk in Location-Contraction Risk model. It represents the site where disease host (human) engages with disease vector (mosquito). Associated site reflects a point of interest in both host and vector. Compare with the existing predictor (in Table 1.1). Contraction Risk is a new predictor that represents comprehensively probability of disease penetration and it is a sensible predictor. Therefore, it is useful for real time prediction.
2. Performing a new algorithm of spreading of disease in a network which is called the Adaptive Area-based Risk Model. This algorithm reduces dependency on scale or social-contact (in Table 1.2). The model eliminates the scale-dependency using origin-destination for obtaining the risk. While dependency in social-contact is accommodated by making a control area (grid).
3. Proposing the risk of disease propagation by Risk of Area provided by the Adaptive Area-based Risk Model. This evaluation is summing individual

risks of the visitor in a certain area. The new evaluation method simplifies the complexity in risk caused by individual contact (in Table 1.4). The risk by individual contact is difficult to be measured in the actual condition.

5. Constructing the Context-dependent Strategy module for action to control spreading of disease by the similarity method. Compare with another method (in Table 1.3, the benefit for applying similarity is that it gives a space for outlier data, such as disaster: flood or typhoon in this case.
6. Implying the modularity of modules by incorporating the Location-Contraction model with Context-dependent Strategy to apprise the risk of an area of common resources of three cities: Surabaya, Kuala Lumpur, and Bangkok.
6. Applying the idea to extract natural history features in dengue fever into the disease of coral. In the application, fusion of water sensor, weather sensor, and the light sensor are utilized to obtain the feature of natural history, i.e. survival time, symptom, latent-time, and monitoring-time. As a confirmation, the image captured by a camera is utilized.

The framework of the proposed surveillance system is shown in Figure 1.2.

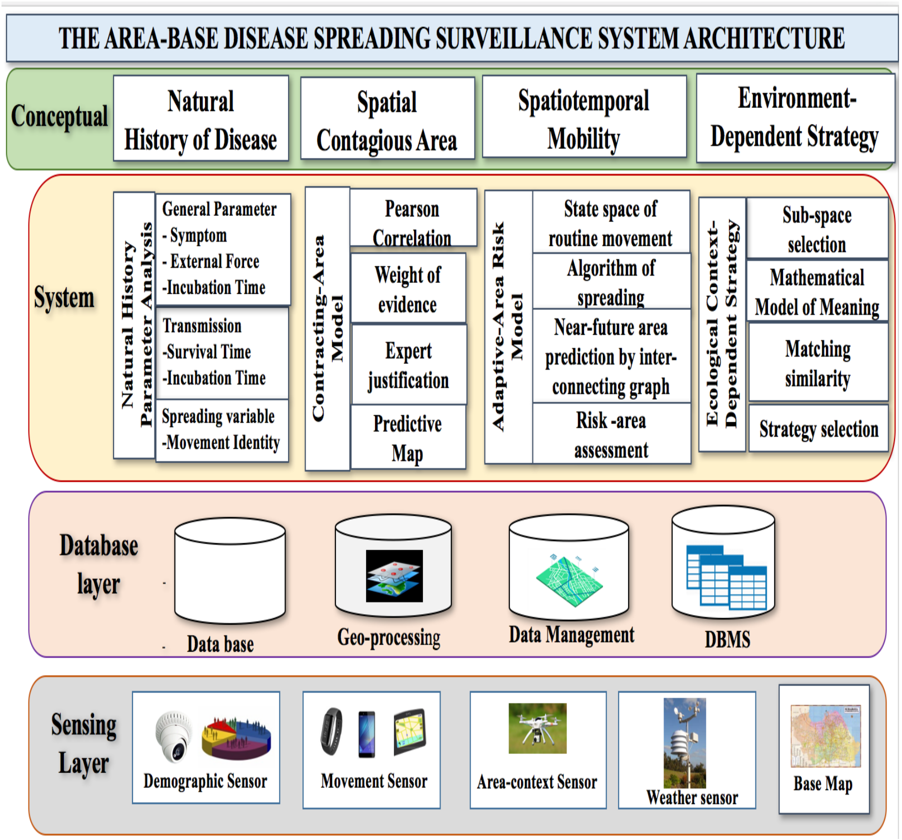


Figure 1.2 The Conceptual framework of the proposed system

The proposed system integrates three models: The Location-Contracting model, the Adaptive Area-based Risk Model and The Ecological Context-dependent Strategy model.

The Location-Contraction Risk is a method for weighing the spatial human-mosquito engagement. The spatial probability to get the disease is calculated by the relation between the evidence of disease and the attribute of the meeting place. The Bayesian weighing of evidence is utilized to calculate the longitudinal weight of every grid area.

The main part of the proposed system is an algorithm of the spreading of disease in a network named as the Adaptive Area-based Risk Model (ADRESS). The model provides the dynamic layer. This model consists of: (1) state-space model of routine movement cycle, (2) algorithm of the local-global scenario of spreading, (3) prediction of the next infection area by the graph of human moving, and (4) determination of the vulnerability value of a suspected area. ADRESS integrates agent-based model to simulate the mechanism of disease propagation, Compartment model for disease transmission, and spatial analysis for appraising the attribute. In this research, the Agent-based model is used to perform the simulation of routine people's movement. Every human acts as an agent. An agent has no personal behavior in the context of disease immunity, but has different "temporary behavior". Temporary behavior causes an individual risk that represents the probability disease transmission corresponding to the location-contraction. The value of the probability is obtained by Location-Contraction module. The personal risk behaviors of an agent are gathered when an agent stays in the area in a certain time. When the agent leaves that area, it brings this transient behavior to the next state. Since the immunity of every agent is unchanged, population of the agent is "well-mixed". Therefore, the interaction among agents is assumed as homogenous, and the personal risk depends only on their mobility. Thus, the personal risk of an agent follows the transmission in the Compartment model. A disease risk as a consequence of agent movement is evaluated as a cumulative personal risk of the agent in a certain area and a certain time.

Context Dependent Strategy is a semantic strategy and it leads to an action as a response to prediction in the proposed system in term of semantic strategy. The terminology is mined from WHO for dengue fever. The basic method of the system is measuring the parallel pattern between the data and the disease stage by using Mathematical Model of Meaning (MMM) [Kiyoki, 1994]. This model consists of (a) subspace selection and (b) context-similarity calculation. Through this system, the effective, specific and realistic strategy are carried out. In this dissertation, Mathematical Model of Meaning is applied to obtain semantic similarity by projecting data of the weather to strategy-space. The strategy-space is designated from an ecological context.

1.4 Contribution

In this research, the new system to realize a near-future spreading prediction of communicable disease is realized. Since the research is an integration of several disciplinary fields, the contribution of the research also covers the following fields: Geographic Information System (GIS), Public Health, Agent-based Model, and Modelling System.

1. Geographic Information System

This research introduces the new appraisal system by overlaying virtual dynamic layers in static layers. Currently, the appraisal of definition context - in this case, it is risk context - is determined by weighting some overlaid attributes. The risk is constant as long as the attribute is constant. By ADRESS algorithm, two additional features are composed: the dynamic layers of movement and the engagement between static and dynamic layer. It enhances the appraisal of a constant attribute.

2. Public Health

In communicable disease, one key for success to combat again the disease is public participation. The proposed surveillance system involves public participations in (1) predicting the risk of the spreading of disease, and (2) action policies in real combatting. People, as an agent, participate in predicting the risk of disease by giving the information of their location. The Origin-Destination information is important to perform the Risk of Area. The proposed system enhances the action policies by providing different action-strategy for different weather situation. It will be advantageous comparing with the existing policies – e.g. chemical spray treatment is planned based on a prediction, and the action is understandable because every action has standard and guidance.

3. Agent-based Model

In an Agent-based model, every agent has static behavior. In this research, the dynamic behavior is presented. ADRESS algorithm integrates an interaction among agents in the Agent-based model for a transmission approach and the Compartment model to perform pathogen transmission in a network. By this method, the attribute of an agent is assembled from the environment spatiotemporally, and the behavior is dynamic. It enables the system to be more dynamic.

4. Modelling System

In this system, a semantic control based on context-dependent is presented. By the context dependency, a strategy of control is performed more specific and precise. The action from as a result of the model is more realistic.

1.5 Roadmap of the Dissertation

Roadmap of the dissertation is organized as follows.

Chapter 1. Introduction

Chapter 1 illustrates the overview of the proposed research. It covers the background, the motivation, a brief explanation of the system and the contribution of the research.

Chapter 2. The Location-Contraction Risk Model

Chapter 2 describes how to perform the Spatial-Contracting Risk of disease. It starts from the statistical analysis to obtain the relation between some spatial attributes and the incidence of dengue. Then, the weighting process, namely Weight of Evidence, is applied. Surabaya city is selected as a target place of analysis.

Chapter 3. The Adaptive Area-based Risk Model

Chapter 3 discusses an algorithm of spreading disease. It is an algorithm called the the Adaptive Area-based Risk Model (ADRESS), which is created by a mathematic model. It also describes the application in a small area in Surabaya and the evaluation of ADRESS performance.

Chapter 4. The Ecological Context-Dependent Strategy

This chapter explains the action-strategy in dengue fever based on a context-dependent. In this chapter, the ecological context is discussed. The semantic strategy is chosen from WHO strategy for dengue fever. Basically, there are two processes in a context-dependent strategy in this research: the attribute selection and pattern matching.

Chapter 5. Vector-Control Strategy Collaboration for Surabaya, Kuala Lumpur, and Bangkok

This chapter describes an extended implementation of semantic control for dengue fever based on context-dependent strategy. In this chapter, the prototype of interoperable strategy among neighborhood countries; that is Indonesia, Malaysia and Thailand, is built.

Chapter 6. Conclusion

This chapter reviews the work and future of the research.

CHAPTER 2

The Location-Contraction Risk Model

This chapter discusses the contagious area as a predictor of dengue spreading and how to calculate the weight of contagious area regarding the spreading of disease.

2.1 Preliminary Study: Literature Study and Statistical Analysis

Previous studies had investigated the effect of population density in communicable disease-contracting. Theoretically, in the high population density, possible to get the disease is higher. This has been shown in some studies made in areas like Kuala Lumpur [38], Jeddah [3], Barbados, Brazil, and Thailand [26]. In reality, individuals vary widely in the frequency, distance, and nature of their movements [94]. Research in Vietnam reported that cases of dengue occurred in low-to-moderate population densities [103], while in Peru [91], there is no significant association between population density and cases of dengue.

The preliminary study leads to find another factor that more significant in communicable disease, in this case, is dengue fever. For this purpose, the statistical analysis is conducted to classify the area study. The Pearson correlation is chosen to analyze the relation between population density and an incidence of dengue. The result is shown in Figure 2.1.

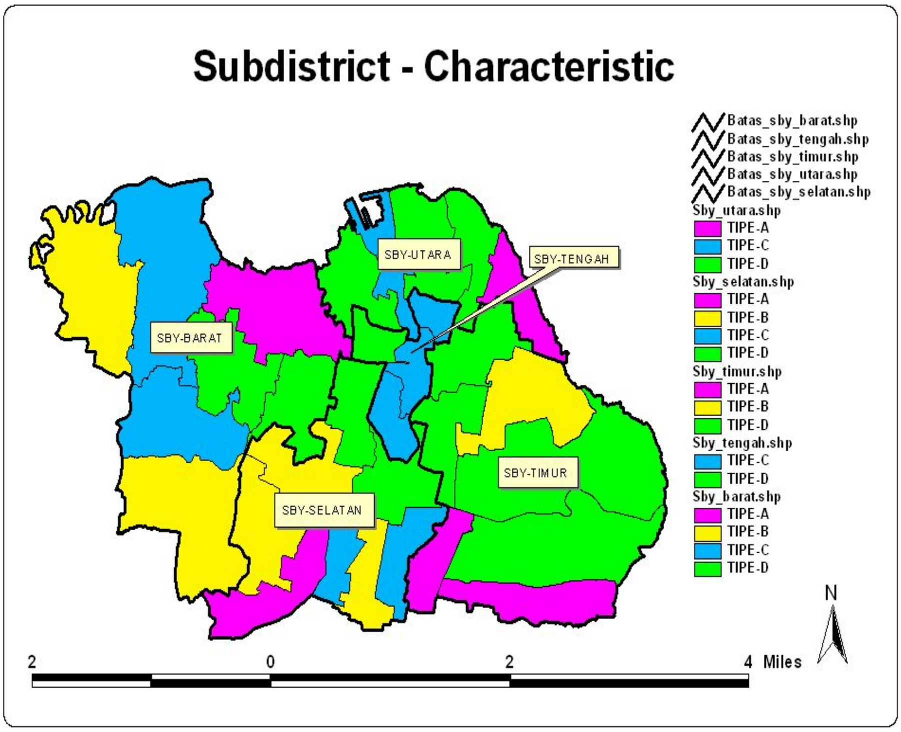


Figure 2.1 Classification of Sub-district of Surabaya.
The area is classified by relation between population density and an incidence of case.

The result shows four combinations of relations: Type A is an area with low density and lower case (L, L), Type B is an area with low density/ and high case (L, H), Type C is an area with high density and low case (H, L), Type D is an area with high density and high cases (H, H). The analysis shows that in some case population density has a correlation with the number of case, while in the other case there is no correlation between population density and number of the case. From the result, it is clear that considering diversity in a piece of the picture for drawing the city is better than assume that every city has only one characteristic. Therefore, the new predictor which is better than population density should be addressed.

2.2 The Location- Contraction Risk Model

Location-contraction is the point of interest for engagement between female mosquito and human. Female mosquito searches human to feed the blood for surviving the mosquito's egg. This is the differences between the contagious area approach and land use approach in dengue spreading. In land use approach, land use reflects the existence of mosquito [107] [63]. Location-contracting integrates the involvement of human movement and the existence of mosquito.

In this chapter, a novel analysis of contagious place risk-ranking that explicitly represents dynamic engagement between human and mosquito is proposed. Basically, weighting of multi contagious place types is calculated. The model identifies ranking of contagious places layers and population density, and then compare both to determine which one is better to represent human movement. Design system is shown in Figure 2.2.

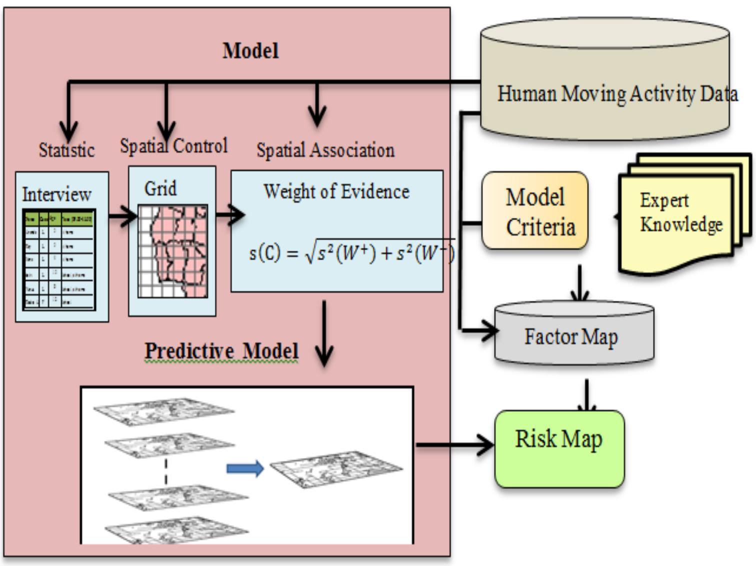


Figure 2.2 The system design of the Location-Contraction Risk model
The objective is to examine the relative impact of transmission as an effect of contact among people by calculating a weight of multi contagious place types. The output is ranking of contagious places.

Then, all variables are mapped and controlled in a small area of the grid. The weight of evidence method [12] is applied to extract value from the spatial-association. Indeed, spatial-association analysis, completing spatial distribution analysis because its results are quantitative [53]. The results of these analyses are associated with expert opinions for building the prediction models. The results of prediction are integrated into evidenced-map layers for producing a perspective map. The output is ranking of risk for every area.

2.2.1 Data Preparation

Area of study is divided into a small control area namely grid. In this case, 1 km2 grid area is selected because it is a common standard size for control of the population in the world.

Datasets were interpolated by statistical equation [Gregory,2002]:

$$D = \frac{\sum_{i=1}^{n} D_i x A_i}{n} \qquad \text{……………………… (2.1)}$$

Where D is the population density in a specific grid that performed by i district, A_i is percentage of area districts in grid area (1 km2) and n is a grid area number.

2.2.2 The Risk Map

In this research, the goal is to determine the vulnerability-ranking of a contagious-place performed by risk map by following steps:

(1) Assembling an inventory of contagious place,

(2) Sorting an inventory out into a modelling set and validation set,

(3) Calculating a weight of each controlling factor by using the modelling a set of spreading

(5) Generate multiclass-evidences by the cumulative weighting,

(6) Establishing a posterior probability map,

(7) Validating the model using the validation set of the inventory

The first through third step includes collecting data (contagious place, dengue case, population density), digitizing the data, layering it in separate maps, and assembly suspected contagious place with dengue case.

The fourth step is utilizing WOE as the spatial association analysis of a given region by weighting inside and outside of the given region [12]. The weighting yields are (1) W^+ is weighted within the region (DP), and (2) W^- is weights outside the region (DN) and T = DP+ DA; T is the total study area.

Weight positive and negative is written as:

$$W^+ = ln\left(\frac{P(B_i|s)}{P(B_i^+)}\right) \quad \text{………………………… (2.2)}$$

$$W^- = ln\left(\frac{P(B_i|s)}{P(B_i^-)}\right) \quad \text{………………………… (2.3)}$$

W+ >0 implies positive spatial association; and W−> 0 implies negative spatial association; while W+= W−= 0 implies no spatial association.

The differences between W+ and W− indicate contrast relation in both spatial association parameters.

Contrast is denoted as

$$C = W_i^+ - W_i^- \quad \text{………………………………… (2.4)}$$

If C >, 0 spatial association is positive, conversely C < 0, while C = 0 means no spatial association. The maximum of C can determine the optimum cutoff weight from features.

The uncertainty of the weights and contrast is denoted as:

$$s(C) = \sqrt{s^2(W^+) + s^2(W^-)} \quad \text{……………………….. (2.5)}$$

The uncertainty of the weights and contrast would be large if the number of resources sought points is small in the study area. It generates the meaningless or unreal result. For solving this problem, the standardized measure of C (stud (C) is usually calculated to show the significance of the spatial association [Bonham,1994]

$$stud(C) = \frac{C}{s(C)} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots (2.6)$$

The weight of every cell is determined by comparing stud of several classes. For this purpose, expert opinion is needed to determine close rankings between contagious places and dengue cases [17].

The fifth step is generating multiclass evidence as the results of several layers. Each evidence-map layer converting three criteria: cut off distance, weight, and inter-layers scores to factor map. In the multi-class index overlay model, the classes on each i evidential map layer input resulting different scores by Index Overlay equation [24]:

$$S = \frac{\sum_i^n w_i \, S_{ij}}{\sum_i^n w_i} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.7)$$

where : w_i is the weight of the i-th map,

S is index overlay system

S_{ij} denotes the index overlay for every class: value is 1 for presence or 0 for absence of the binary condition.

The output score ranges from 0 (implying extremely safe) to 1 (implying high vulnerability). The result is a risk map showing regions from low to high risk.

The remaining procedure is the validation method. In this case, the risk map of prospective map based on contagious map and risk map based on population density will be compared with the risk map based on dengue case.

2.3.1 The Result

2.3.1 The Area of Study

Dengue case data of the year 2012, includes the address of the victim, was issued by municipal health departments in Surabaya, Indonesia. There were 1088 total cases reported from January to December 2012. These cases were scattered across 166 Kelurahan (smallest administrative district) as showed in Figure 2.3.

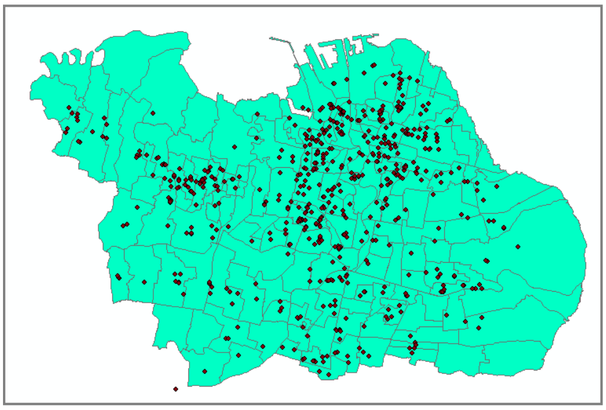


Figure 2.3 Map of dengue incidence in Surabaya,2012.
The black point indicates location of reported-case of dengue

To assign the contagious place, the interview takes place among some infected people. The interview is explicitly intended to gather information about the feasibility of contagious place. Some interview data are shown in Table 2.1. Based on data from an interview, the contagious places are selected from several attributes in land use features in Surabaya [73].

Table 2.1 The example of data from interview
Interview is conducted among victim of dengue about the contagious area

Name	Gender	Age	Place (09.00-16.00)
Ananda	L	3	at home
Betri	L	13	school, at home
Reskia A.	P	12	School
Umayah	P	35	home, market
Hesty Wulandari	P	11	school, at home
Ana Ikawati	P	27	at home, market
Rofianti	P	32	Market
Dwi Indah	P	24	at home
Karina	P	20	Warehouse
Moh. Ardiansyah	L	6	school, at home
Ryan	L	19	Office

Based on data from an interview, the contagious places are selected from several attribute in land use features in Surabaya [73]. Figure 2.4 shows the allocation of several classes of contagious area.

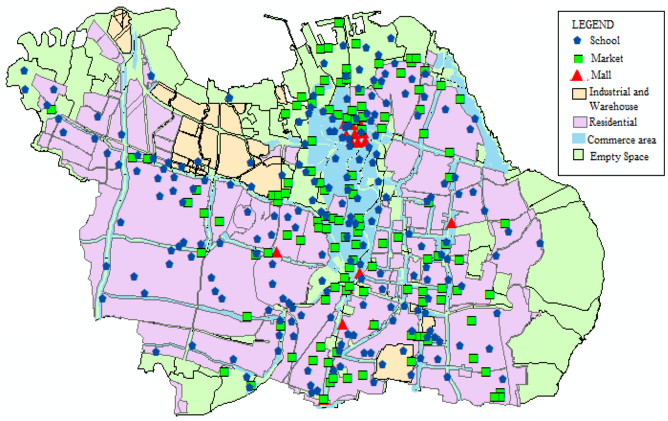


Figure 2.4 The map of contagious area in Surabaya 2012.
The point indicates a contagious area in Surabaya. The size of the point area is available in Table 2.2.

Figure 2.4 shows the allocation of several classes of contagious area. Estimation of potential risk areas for dengue case occurrences is determined based on transmission among vector and host. In particular, it was focused on the correlation between several suspected contagious place types: point, line and polygon in Table 2.2.

Table 2.2 The Suspected contagious area

Layer of Place	Type	Conversion
Education Facilities	Point	1 point = 300 m2 [Kemdiknas 2009]
Industrial and Warehouse	Polygon	
Traditional Market and Supermarket	Point	1 point = max 60 m2 [Kemperindag,2007]
Commerce and business	Line	
Residential	Polygon	
Mall	Point	1 point = 500 m2 [Kemperindag,2007]

The suspected contagious-place is selected based on interviews and correlation with dengue cases by using the Pearson Correlation method

[Wahyu,2013]. Each datum is geo-processed. The result is shown in Figure 2.5.

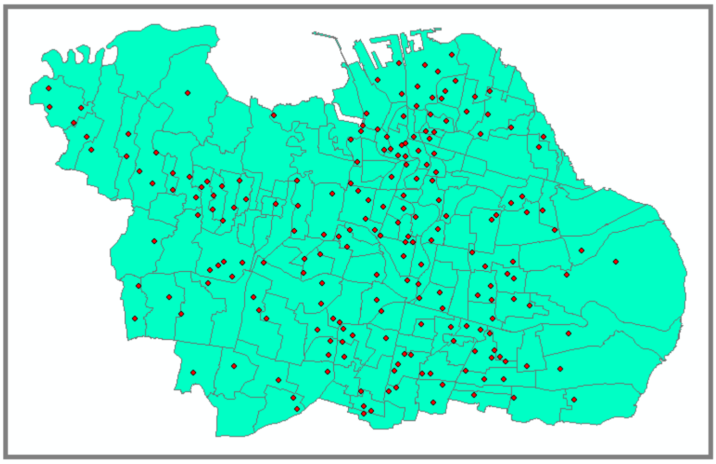


Figure 2.5 (a) Prevalence of the education Facilities

The point indicates the location of the education facility in Surabaya,2012. The size of education facility is available in Table 2.2.

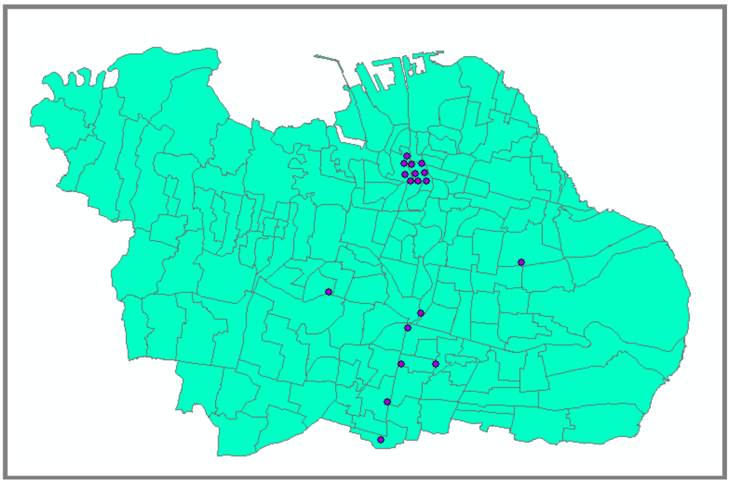


Figure 2.5 (b) Prevalence of mall

The point indicates the location of the mall in Surabaya,2012. The size of the mall is available in Table 2.2. The contagious area of the mall is calculated with the assumption the mall only has 1 floor.

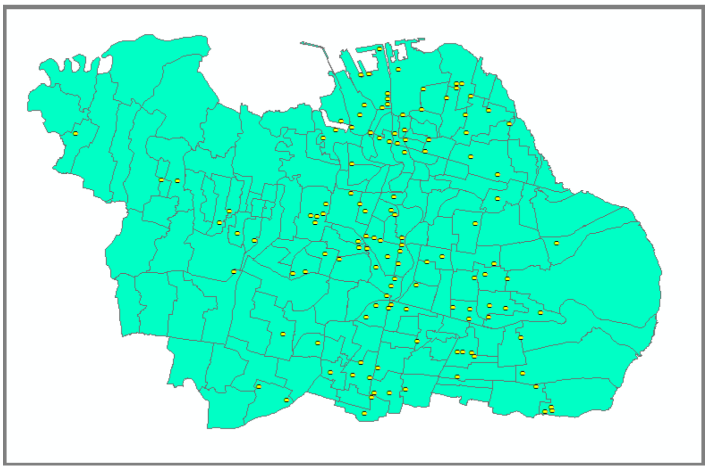


Figure 2.5 (c). Prevalence of traditional market and supermarket
The point indicates the location of the traditional market and supermarket in Surabaya,2012. The size of the market is available in Table 2.2.

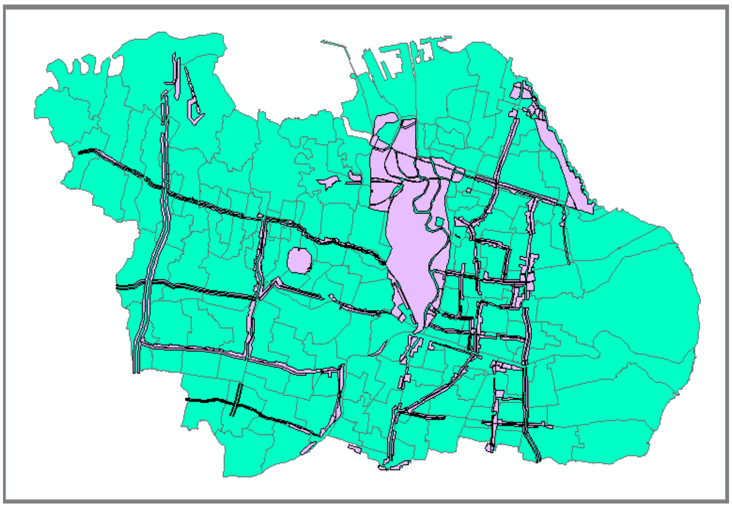


Figure 2.5 (d) Prevalence of commerce and business.
The purple color indicates the region of commerce and business area in Surabaya,2012.

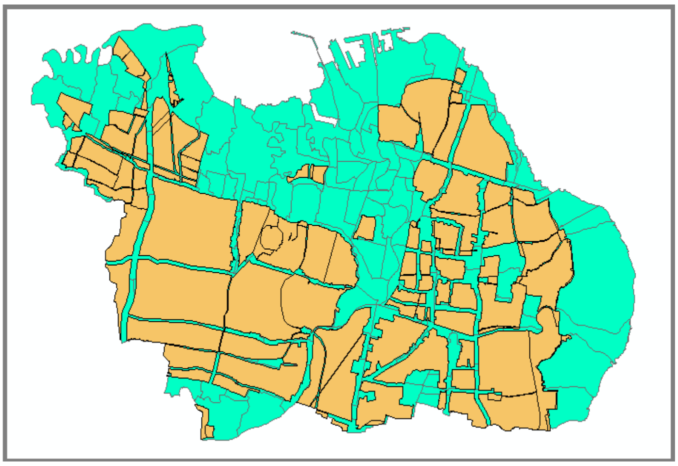


Figure 2.5 (e) Prevalence of residential.
The brown color indicates the region of residential area in Surabaya,2012.

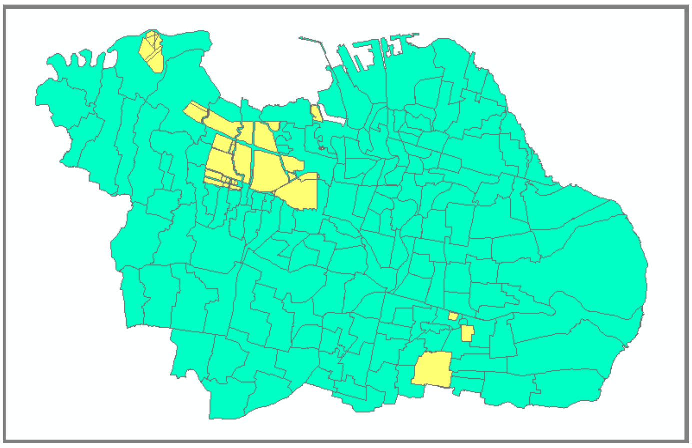


Figure 2.5 (f) Prevalence of industrial and warehouse
The yellow color indicates the region of the industrial area and warehouse area in Surabaya,2012.

Figure 2.5. Prevalence of contagious area

2.3.2 Determining the Control Area

The Control area indicates the certain size where all contagious areas are weighted. In this research, 1km x 1 km area is applied in Surabaya map. The result is shown in Figure 2.6

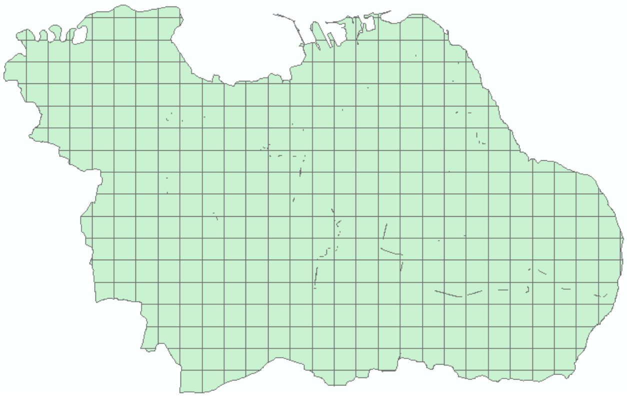


Figure 2.6 The grid of Surabaya map
Size of grid area 1km x 1km

The area study, Surabaya, covers 333 km^2. It consists of 392 grids. In this research, 328 grid areas are chosen to represent the Surabaya area. Another grid is too small to be analyzed. The database of area after the grid process is shown in Figure 2.7.

FID	Shape *	F	J	T	J	T	J	T	J	T	Jo	T	T	Layer	KELURAHAN	Layer_1	Layer_12	LAYER_L	ID	KETERA
1111	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1112	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1113	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1114	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1115	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1116	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1117	Polygon ZM	1	8	1	1	1	4	1	0	1	0	1	1	Batas Kelurahan	Darmo	Perdagangan	Perumahan		0	
1118	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1119	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1120	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1121	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1122	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1123	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1124	Polygon ZM	1	3	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Kupang Krajan	Perdagangan			0	
1125	Polygon ZM	1	9	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Jemur Wonosari	Perdagangan	Perumahan		0	
1126	Polygon ZM	1	9	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Jemur Wonosari	Perdagangan	Perumahan		0	
1127	Polygon ZM	1	9	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Jemur Wonosari	Perdagangan	Perumahan		0	
1128	Polygon ZM	1	9	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Jemur Wonosari	Perdagangan	Perumahan		0	
1129	Polygon ZM	1	9	1	4	1	1	1	0	1	0	1	1	Batas Kelurahan	Jemur Wonosari	Perdagangan	Perumahan		0	
1130	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1131	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1132	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1133	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1134	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1135	Polygon ZM	1	4	1	4	1	2	1	4	1	0	1	1	Batas Kelurahan	Krembangan Selata	Perdagangan	Perumahan		9	Mall
1136	Polygon ZM	1	1	1	1	1	0	1	0	1	0	1	1	Batas Kelurahan	Bendul Merisi	Perdagangan	Perumahan		0	
1137	Polygon ZM	1	1	1	1	1	0	1	0	1	0	1	1	Batas Kelurahan	Bendul Merisi	Perdagangan	Perumahan		0	
1138	Polygon ZM	1	1	1	1	1	0	1	0	1	0	1	1	Batas Kelurahan	Bendul Merisi	Perdagangan	Perumahan		0	

Figure 2.7 The database relation of the contagious area after grid process

2.3.3 The Risk Map

The Weight of Evidence (WOE) method is implemented to assess the vulnerability distribution of dengue. In this calculation, the probability of occurrence is applied for evaluating the overall weight. Figure 2.8(a) - 2.8(f) shows the prevalence of some contagious-places that are suspected as dengue transmission places. A high value in a particular grid cell indicates suitable conditions for transmission; or in this case probability for DF case-occurrences.

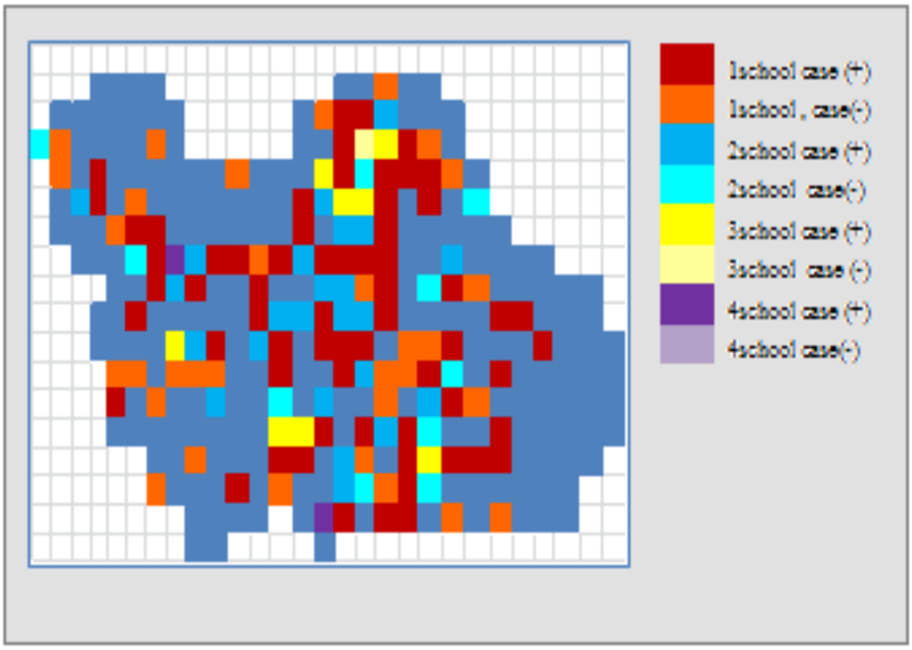


Figure 2.8 (a) Prevalence of school in grid school
Different color indicates different class. For example, class 1school in the area indicates 1 school is existing in the grid. The light color points out the area without dengue case, while the darker one is area with dengue case.

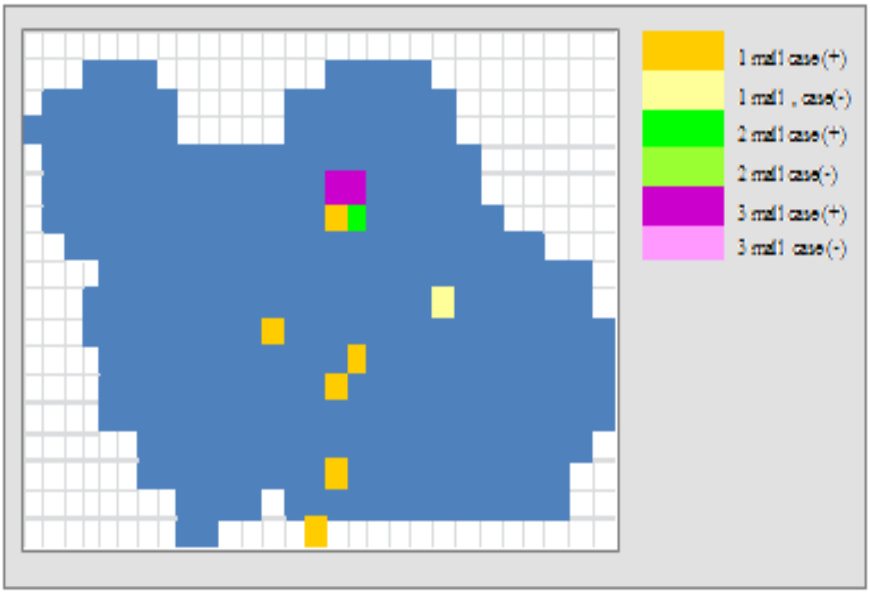


Figure 2.8 (b) Prevalence of mall
Different color indicates different class. For example, class 1 mall in the area indicates 1 school is existing in the grid. The light color points out the area without dengue case, while the darker one is area with dengue case.

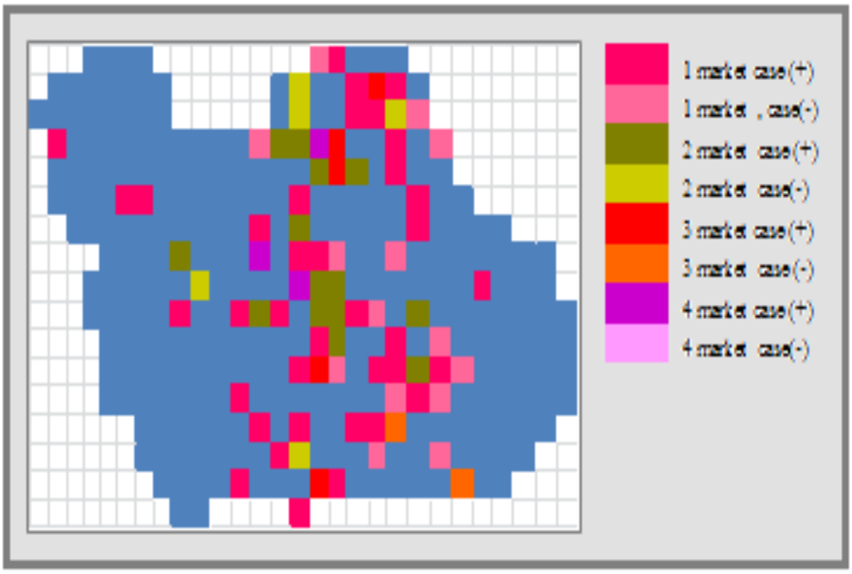


Figure 2.8 (c) Prevalence of traditional market and supermarket
Different color indicates different class, for example class of 1 market in the area. The light color points out the area without dengue case.

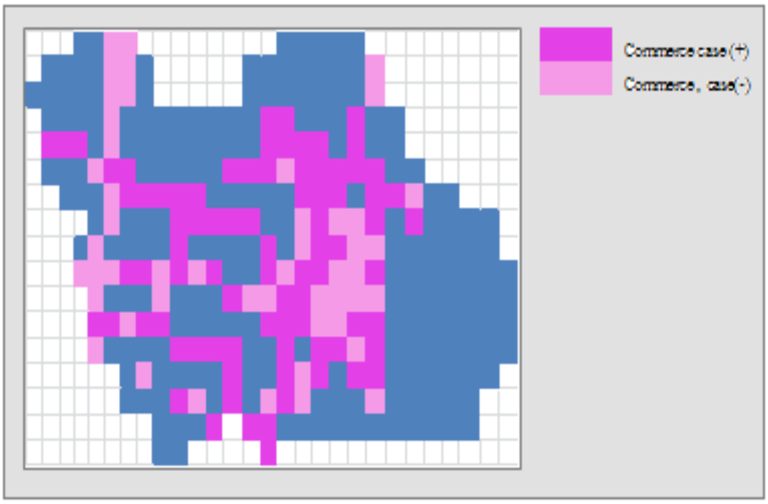


Figure 2.8 (d) Prevalence of commerce and business area
The light color points out the area without dengue case, while the dark one is area with dengue case.

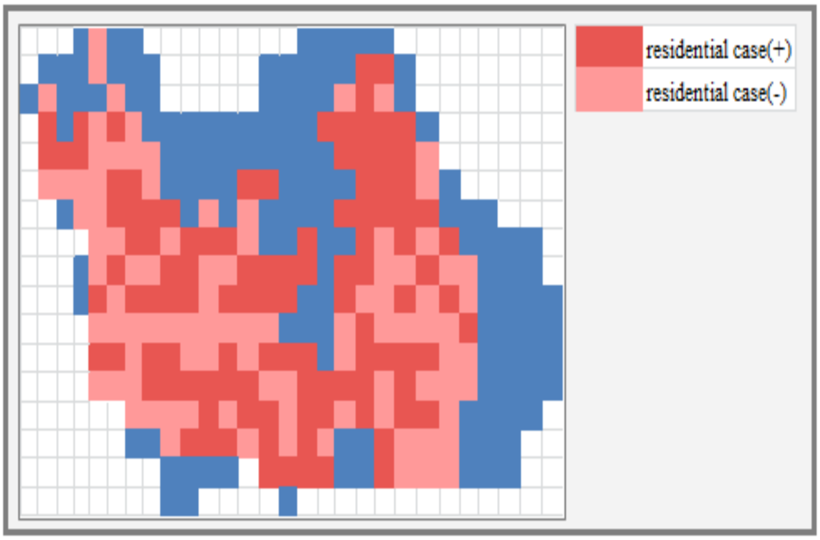


Figure 2.8 (e) Prevalence of residential
Different color indicates different class. The light color points out the area without dengue case, while the darker one is area with dengue case.

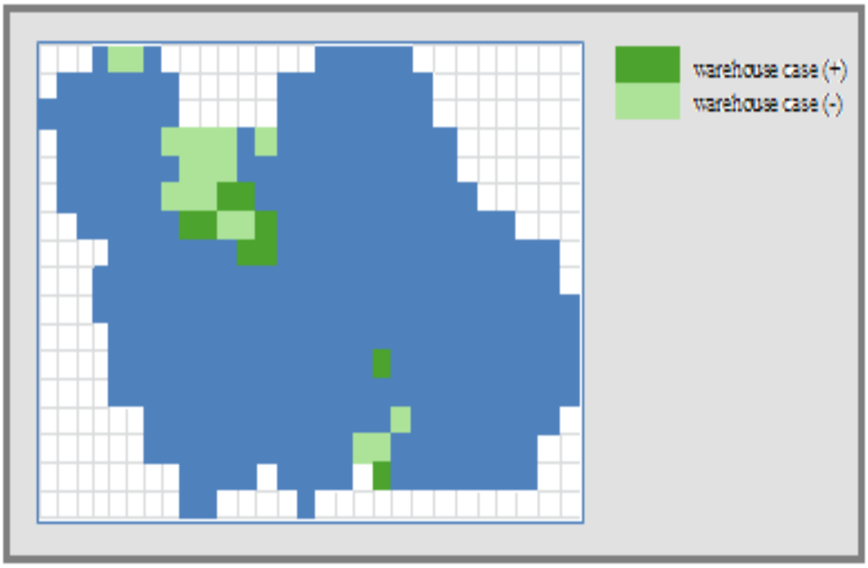


Figure 2.8 (d) Prevalence of industrial and warehouse
The light color points out the area without dengue case, while the dark one is area with dengue case.

Figure 2.8 Prevalence of the contagious area after grid process

A high value in a particular grid cell indicates suitable conditions for transmission; or in this case probability for DF case-occurrences. Figure 2.8 shows the presence or absence of evidence variable (called a class) in dengue case. The area in question is shown on the map in blue. Presence of evidence is shown in dark color and absence in bright color. Presence means in a given cell there is a class (school. Market, etc.) with dengue case, while absence means there is class without dengue case.

A weight is calculated for each class of the variable, separately. Variations of weighting interpret the importance of classes on dengue spread proneness. The result is shown in Table 2.3.

Table 2.3 Variation of the weights of evidence

Variable	Class	W+	W-	C	stud(c)
School	1	-0.7755908	-1.5004867	0.724895879	22.471772
	2	-1.7989797	-2.6318888	0.832909123	8.3290912
	3	-2.8550324	-4.9344739	2.079441542	2.0794415
	4	-3.8358616	-4.9344739	1.098612289	1.0986123
Industry and Warehouse		-1.0986123	-0.4054651	- 0.693147181	12.476649
Traditional market and Supermarket	1	-0.7731899	-1.7917595	1.018569581	13.241405
	2	-1.7176515	-2.5649494	0.84729786	5.0837872
	3	-2.9704145	-3.6635616	0.693147181	1.3862944
	4	-3.2580965	-4.3567088	1.098612289	1.0986123
Mall	1	-0.5877867	-2.1972246	1.609437912	1.6094379
	2	-1.0986123	-2.1972246	0.693147181	0.6931472
	3	-1.5040774	-2.1972246	0.693147181	0.6931472
Business and Commerce		-0.4563567	-1.0039963	0.547639597	26.286701
Residential		-0.3884868	-1.133459	0.744972248	70.027391

In Table 2.3, class indicates the number of contagious area, contrast indicates a range of data: bigger contrast means better range, while stud indicates spatial significances of data linearly.

The next step is calculating multi-class weights. In this case, expert opinion plays an important part in judging the importance among variables, such as determining the hierarchy of importance for every class, and determining comparison over the entire range of variables. In this study, expert justification is represented by the comparison significance of data. The result is shown in Table 2.4.

Table 2.4 The weight of every contagious area

Variable	Contrast	Stud	weight
Residential	0.744972248	70.02739135	0.4792671
Business and Commerce	0.547639597	26.28670065	0.179906
School	0.724895879	22.47177225	0.1537967
Trad market and Supermarket	1.018569581	13.24140455	0.0906241
Mall	1.609437912	1.609437912	0.011015

Then, the weight of every cell is calculated by equation 2.7, and visualized in area-risk map.

2.4 Discussion

The objective of this research is to present prevailing vulnerabilities of dengue fever in Surabaya, Indonesia by using a composite vulnerability index. The index is based on a set of underlying human movement indicators. The result is a predictive map of contagious places as a proposed method. In contrast, with proposed map is the density map. Population data is perceived as secondary data from each Kelurahan in Surabaya City [www.surabaya.go.id]. Both will be compared with real dengue-case map as validation as shown in Figure 2.9 (a) -2.9 (c).

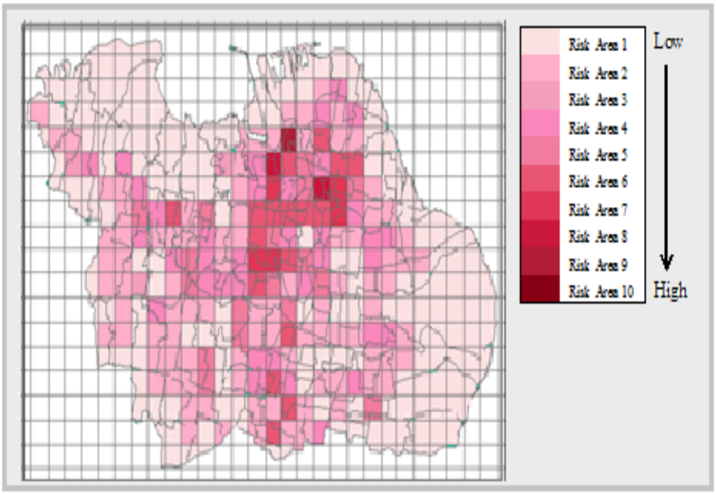


Figure 2.9 (a) The risk map of the proposed method

This map represents vulnerability of Surabaya,2012, with a contagious area as a variable. Vulnerability is reflected at Risk Area in the range 1-10. Risk Area1 represents save area. While Risk Area 10 is a very dangerous area.

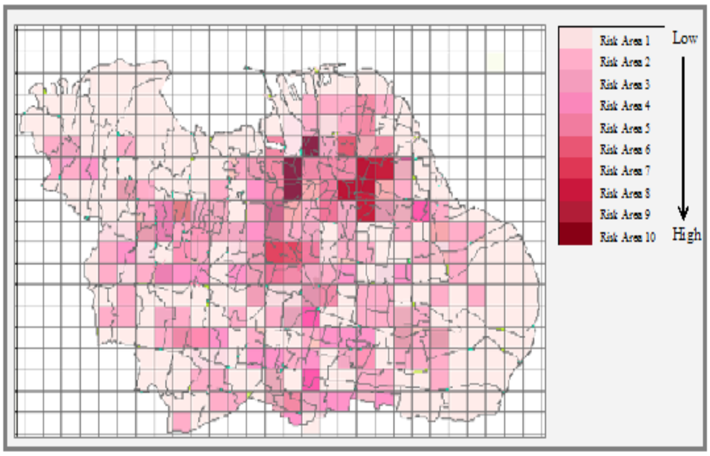


Figure 2.9 (b) The risk map of dengue case

This map represents the real map of dengue case reported in Surabaya,2012. Vulnerability is reflected at Risk Area in the range 1-10. Risk Area1 represents save area. While Risk Area 10 is a very dangerous area.

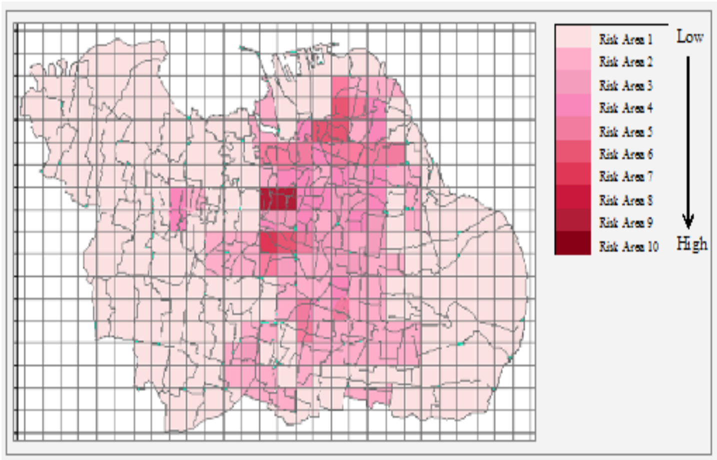


Figure 2.9 (c) The risk map of population density

This map represents vulnerability of Surabaya,2012, with a population density as a variable. Vulnerability is reflected at Risk Area in the range 1-10. Risk Area1 represents save area. While Risk Area 10 is a very dangerous area.

Figure 2.9 The risk map

The areas being studied were divided into 328 cells. This number that denotes 328 km^2 total area of study. For predictive map, result of WEO is categorized by 10 risk areas based on the result of the equation (2.7). The smallest population density is 9 and the highest is 2748. While the smallest case is 0 and the highest is 13 in every cell. Total case is 1088. Every cell in both the proposed map and population density map is compared with the existing control-map. Error in this case represents the level of variation exists compared to the real value. The total error of each map is calculated by :

$$error = \sum_{R=1}^{10} \frac{(Xpredictor(R) - Xreal(R)) * N(predictor)}{M}$$

$$Total\ error = \frac{1}{R} * error \qquad \text{………………. (2.8)}$$

Where : R denotes level of risk = 10.
M denotes number of grid = 328.

The result is shown in Table 2.5.

Table 2.5 The result of evaluation

Comparison accuracy between the proposed method and the existing method (ex) to the real condition

The existing predictor				The Proposed predictor		
Population Density (PD)				Contagious Area (CA)		
No	(X1-X)	N(PD)	Error	(X2-X)	N(CA)	Error
1	0	119	0	0	172	0
2	1	98	0.2987805	1	88	0.268293
3	2	44	0.2682927	2	16	0.097561
4	3	21	0.1920732	3	19	0.17378
5	4	19	0.2317073	4	14	0.170732
6	5	13	0.1981707	5	10	0.152439
7	6	12	0.2195122	6	9	0.164634
8	7	2	0.0426829	7	0	0
9	8	0	0	8	0	0
10	9	0	0	9	0	0
Total error			0.145122	Total error		0.122744

By statistical analysis, it is clear that the error of the contagious area map is smaller than the population density map. It implies that the risk areas can be predicted without relying on information about the population density. The risk areas are built by developing a map that shows the place of contact in the study area. All paper states on the contribution of public facilities (such as a business area, school, cemetery, etc.) in the existence of dengue besides population density, even though the level of their influence in risk is not mentioned clearly.

This result also designates that, in case of communicable disease, the social dynamic is more critical than distance. As an impact, spatial association methods, such as Mooran's index, should consider about long distance association. It also revises the classical outbreak method such as LISA (Local indicators of spatial association). Thus, an index of vulnerability should be added in global and local spatial analysis [61]. In this study, this index of vulnerability is a dangerous level of public meeting-places.

The new approach provides useful information to health authorities, and could assist in focusing and implementing prevention and control. Recently in Indonesia, dengue control is performed randomly based on population density. Nowadays, it is not effective. Because people move dynamically. Therefore, human moving gives the opportunity to transmit dengue outside their area. Monitoring a number of public facilities is easier and more effective than monitoring a number of people in a certain area. It is also handy for city planning with regards to public health, evacuation when outbreak comes, such as planning in hospital placement and managing disease control system based on dynamic city model.

To evaluate effectiveness of contagious area as a new predictor, it is also compared with another method. Table 2.6 shows a comparison of several predictors.

Table 2.6 Comparison among several predictors

	Yien Ling Hii, 2012	Wiwik Winahyu, 2012	Muhammad Sarfraz ,2012	Paulo Missier, 2016	The Proposed method
Predictor	Weather	Weather	Brateu Index	Social media data (Twitter)	Contagious area
Physical Phenomena	Weather-history data association	Weather-history data association	Vector density-land use relation	Dengue topic-dependent	Human-vector engagement
Methodology	Poisson multi variate regression	Poisson INAR	Spatial Regression	Supervised classification	Weight of evidence
Area of Study	Singapore	Surabaya, Indonesia	Phtsanulok, Thailand	Rio de Janeiro, Brazil	Surabaya, Indonesia
Set of Data	520 weekly weather data	120 monthly weather data	92 village data	1000 set of data	328 grid-area
Accuracy	82%	76%	67%	80%	88%
Advantage	Easy to get a data	Easy to get a data climate change	Easy to get data	Quick &Dynamic	Close to reality
Disadvantage	Uncertain due to climate change	Uncertain due to climate change	Data untrusted	Data untrusted	Difficult to measure 3D area

In spite of the benefits of our calculated risk map, there are certain limitations in its predictive capabilities. In this study, human is the only factor that attracts mosquitoes to come, and each individual equally attracts mosquitoes to come. In fact, some people have a different possibility to come into contact with mosquitos. It is alleged as an uncertain factor in risk maps [32]. Therefore, this model is more suitable for an urban area rather than a rural area.

Regarding accuracy, there are two things that possible to increase the accuracy. First, add more contagious area. And then, consider about 3D size of the area. The area of this study is a 2D area (or one floor). While some building like mall or school may cover more than one floor. Therefore, for the future, it is important in order to add the preparation method to convert 2D to 3D location-contracting or to redefine the contagious area.

CHAPTER 3

The Adaptive Area-based Risk Model

This chapter discusses the proposed algorithm of spreading of disease in the network, namely the Adaptive Area-based Risk (ADRESS) Model. This chapter explains how to build the model from physical phenomena, integrates different types of data, and expands the model in the network.

3.1 Phenomena of Dengue Spreading in Network

3.1.1 The Natural History of Dengue

The natural history of a disease is defined as time-series of disease progression in the absence of medical intervention. It starts from the first time human is infected by a virus, until the virus or human die. For every disease and every individual, natural history is different. Figure 3.1 shows a time line of prognosis of dengue disease. The important features are incubation time and clinical phase. Incubation time determines how long the agents keep the risk to get the disease when they stay together with the victim. The clinical phase determines the cycle of spreading. The disease will be transmitted during the survival time of an agent1. This time becomes the incubation time of an agent 2.

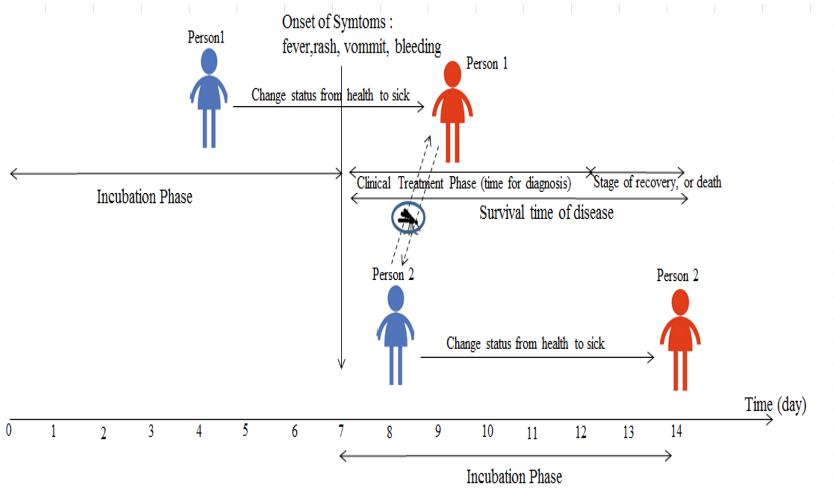


Figure 3.1 Timeline of prognosis in dengue natural history

3.1.2 Phenomena of Disease Transmission

Disease transmission reflects the diffusion of the disease from person to person by mosquitoes as a local vector. This phenomenon is illustrated in Figure 3.2.

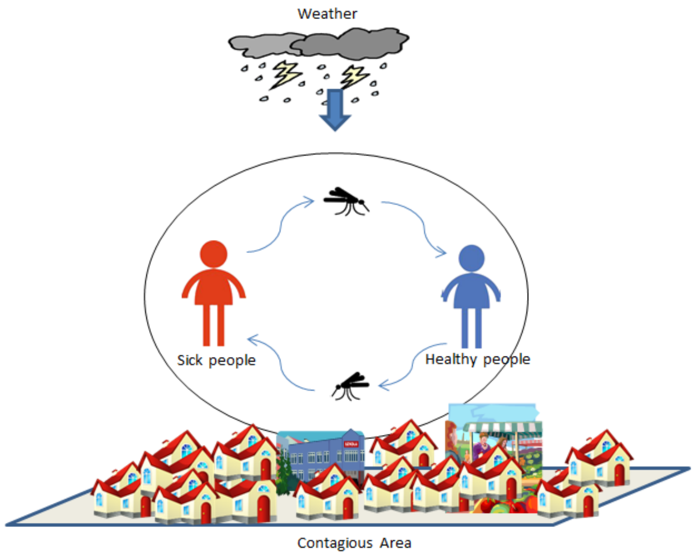


Figure 3.2 The Disease transmission process

In this research, transmission of dengue occurs when sick people, healthy people, mosquito stay in the same area. In this research, contagious area and weather are variable of spreading. The contagious area reflects engagement between human and mosquito. Weather represents the number of mosquitoes, where it relates to a risk of disease transmission.

3.2 Related Work

Previous study of communicable disease, particularly dengue fever. Focused on strategy based on "static situation". The static means connection between host (human) and vector (mosquito) occurs under the assumption that people never moving across the border areas. By this point of view, some strategy is established. Some published strategies are prediction based on history of dengue occurrences [1] [26] [34] [65], an association among spatial attribute [36] [3][8], a statistic approach of significant variable [50] [66] [60] [67], a modelling in vector (mosquito) behavior [2] [55] [76], a relation between geographical distribution [80][61] and analysis in population density to dengue case [102][4][58].Modelling based on static condition bring on a variety of conclusions, and sometimes bring contrast result on. The consequence is not suitable to be applied due to the increasing number of traveler. If number of people who travel out of area increases, the "static situation" could not keep anymore.

Afterward research, then, was focused on "dynamic situation'. Dynamic means people, with their attributes. Moving across their border area. During a traveling time, they possibly interact with an infected person. The disease is transmitted via mosquito's bite. Modelling of spreading is investigated from different interaction process. For instance, by social structure [75][scaling range of contact [54][94]. All models were built by agent base model. Later, the agent base model is expanded the network to analyze the interplay between network and epidemiology [25]. This model is appropriate to understand phenomena of transmission, but, since it developed by hypothesis information, level of readiness is relatively low [8]. The difficulty is caused by a unique pattern of personal contact among agent every day.

To build a realistic model, contact among agent should be transformed to the dynamic contact in the contagious area. There are several models in risk diseases in the network, but not in spatial heterogeneity, such as based on knowledge [68], social network information [35] and social contact [103]. In contrast, some models based on spatial heterogeneity and individual in spreading [57] [94].

3.3 The Adaptive Area-based Risk Model

The proposed method is the Adaptive Area-based Risk Model. A feature of this model is adaptive, data-driven, and based on human movement. This model deals with spatial heterogeneity and works in the network. It consists of (1) state-space model of routine movement cycle (2) the algorithm of spreading (3) prediction of the next infection area by the graph relation of human movement, and (4) model of suspected area's vulnerability. Since it is data-driven, this model is flexible in changing the pattern. Figure 3.3 shows in the system design of the proposed method.

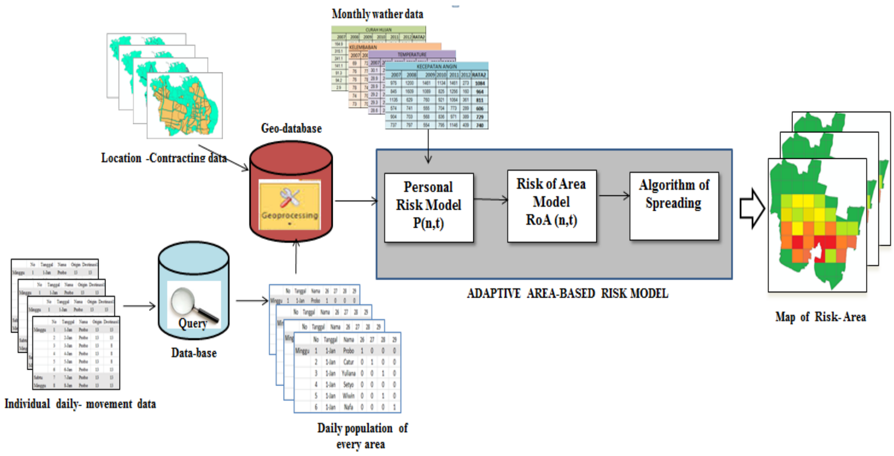


Figure 3.3 The data flow of ADRESS.

Agent reflects the movement of people. The compartment model is applied to evaluate the risk of the area. Table 3.1 shows the feature of the agent.

Table 3.1 Characteristic of the agent

Definition	**Transmission of the disease is reflected as Individual Risk of an agent (human).**
Rule	• Agent has no individual behavior in immunity-context. Therefore, every agent has the same probability to get the disease • Agent get the "temporary behavior" when he/she enter the area. The behavior is Risk value of every area where an agent visit
Task	The main task of an agent is move from Origin (O) to Destination. Every agent has different O and D, depend on the data base of movement
Evaluation	The individual Risk (P(n,t) is evaluation for every agent [Stoddart,2009]

Flowchart of the simulation is illustrated in Figure 3.4.

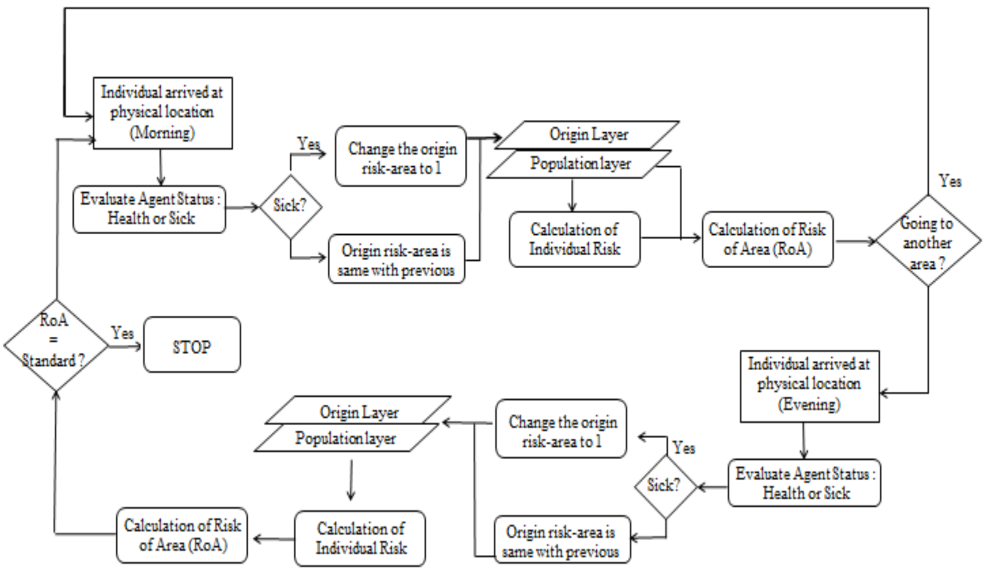


Figure 3.4. The flowchart of movement of the agent

3.3.1 The Dengue Contraction Risk

Dengue Location-Contraction Risk model [99] is the model to measure the effect of the contagious area in spreading of disease. The contagious area is the place where people and mosquito meet. A risk value of every contagious area is L(t).

3.3.2 The Seasonal Risk

Seasonal Risk is a model to measure the influence of the season in the spreading of disease. Characteristic of a seasonal factor is temporal and continuous. In this research, a seasonal factor is a dynamic weather which symbolizing the number of mosquitoes [100]. The essential features in weather are rainfall, humidity, and temperature. The risk is written as:

$$Risk_w = \exp\,(0.045485 + 0.00550564\,T_{t-2} + 0.00265723_H\,H_{t-2} + 0.000846R_{t-2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.2)$$

where T is temperature
H is humidity
R is rainfall

3.3.3 The Risk of Area (RoA)

Risk of Area reflects accumulation of individual disease risk when they visit the area. Accumulation happened as a consequence of human movement. The movement in this study is assumed over routine movement from origin (home) to destination (school, office, etc.) in the morning and from destination to origin in the evening return to home. The population of every area is very different in the morning and in the evening. Every individual who is entering the destination area brings Individual risk, T, as attribute.

This model is constructed from dynamic of the population. People visit the area *n* at time *(t)*, and spend their time in the destination at interval time Δt, then return to their home area *m* at time *(t+1)*. Then number of people in area in *n* during time Δt is written as :

$$X_n(t+1) - X_n(t) = X_n(\Delta t) \qquad \ldots \ldots (3.3)$$

We define Xn(t) as a number of individuals from the area *n*, P_n represent an individual risk when they enter an area m. We can write relation between input and output as follows:

$$X_m(t+1) = P_n X1_m(\mathrm{t}) \qquad \ldots \ldots (3.4)$$

Where : X1 denotes population in day 1,
n is the identify number of area where individual leaving for,
m is the identify number of area where individual coming from,
note that if m=n , individual stay at this area.

Risk of area is divided by two states: Risk Area in the morning and Risk Area in the Evening. RoA in the morning is denoted by $H2M$ and written as
While H2E represent resistance of area in the evening, it is written as:

$$H2M = \sum_1^m P2M_n X1_m(t) \qquad \ldots \ldots (3.5)$$

$$H2E(t) = \sum_1^m P2E_n X1_m(t) \qquad \ldots \ldots (3.6)$$

Total Risk for every area is:

$$Tot_{H2M} = H2M + Risk_W \qquad \ldots \ldots (3.7)$$

3.3.4 The Algorithm of Spreading

The cyclical flow of moving people that relate with disease transmission is illustrated in Figure 3.5. This figure shows an example of graph that captures the interaction between area in the network. The graph symbolizes spatio-temporal projection of human movement, which provides location occupancy by time of day, implying person-mosquito-person contacts.

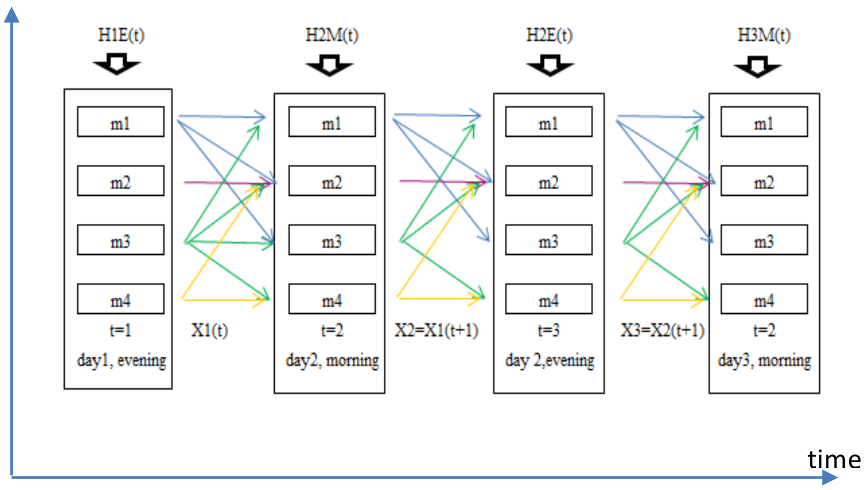


Figure 3.5 The Dynamic movement
This figure expresses flow of daily-routine movement of person

The algorithm of spreading is run under assumption that system is isolated; during spreading process there is no migration in the system.

.

The Algorithm of Spreading

1. Initialization: - weather factor: W(t-1)

 - Dengue-contracting risk value $\vec{L} = (L_1(t), L_2(t), L_3(t), \ldots L_n(t))$

- Initial origin-destination vector $\vec{M}(t) = (M_1(t), M_2(t), \ldots M_n(t))$

2. Calculate $P_n(t)$

3. Calculate Risk Area H1M(t), H2M(t), H2E(t) standard include the weather factor.

4. Input : Infected people $\overrightarrow{MI_n}(t+1)$

 If Infected people = $\overrightarrow{MI_n}(t+1) = \big(M_1(t+1), \ldots M_n(t+1)\big)$

 then $L_n(t+1) = 1$

 else $L_n(t+1) = L_n$

5. Repeat step 3 for t= t+1

6. Calculate $DH1M_m = H1M_m(t+1) - H1M_m(t)$

$DH2E_m = H2E_m(t+1) - H2E_m(t)$

$DH2M_m = H2M_m(t+1) - H2M_m(t)$

7. Check : if $DH1M_m = 0$, $DH2E_m = 0$, $DH2M_m = 0$

   then stop

   else select from vector $\vec{M}(t)$ to get $AI_n(t+1)$

   $AI_n(t+1)$are Area Infected with specification

   $DH1M_m \neq 0$, $DH2E_m \neq 0$, $DH2M_m \neq 0$

8. Select next suspected area from vector $\overrightarrow{MI_n}(t+1)$ by inputting $AI_n(t+1)$
9. Update standard H1M(t), H2M(t), H2E(t) with H1M(t+1), H2M(t+1), H2E(t+1)
10. Repeat process for t = t+n with condition :

    H1M(t-2)= H1M(t), H2M(t-2)= H2M(t), H2E(t-2)= H2E(t)

The example bellow shows how to implement the algorithm of spreading. The step by step code is written in MATLAB software.

The Data

-Data of human movement

1-12 indicates area identity number (for example area no 1)

Coefficient
Location-Contracting Area

Destination

Origin

	L	1	2	3	4	5	6	7	8	9	10	11	12
1	0.1	12	0	0	0	1	1	0	1	0	0	1	0
2	0.4	0	14	0	1	0	0	0	1	0	0	1	0
3	0.2	0	0	13	0	1	1	1	0	0	0	1	4
4	0.4	1	1	1	3	1	1	0	0	0	1	1	0
5	0.3	0	0	1	0	8	0	0	1	0	0	1	1
6	0.2	0	1	0	1	0	3	1	1	0	0	0	1
7	0.4	0	1	0	0	0	0	5	1	0	0	1	1
8	0.4	0	1	0	0	0	0	0	3	0	0	1	1
9	0.4	0	0	1	1	1	1	0	1	7	0	0	1
10	0.3	0	1	0	1	0	0	1	0	0	6	0	1
11	0.3	1	1	0	1	1	1	0	1	0	1	14	1
12	0.5	1	1	0	1	0	1	1	1	1	1	0	5

- Data of weather

	Temperature (C)	Hummidity (%)	Rainfall (mm)	Number of victim
Januari	28.2	79	312.1	90
Februari	28.5	79	212.5	105
Maret	28.3	78	311.4	173
April	29.5	74	43.7	131

1. **Initialization: weather factor: W(t-1)**

```
% Initialization:  weather data
for m=1:4
    for n=1:4
        D_W(m,n)=data_weather(m,n);% Data vektor
        D_Wt(n,m)=D_W(m,n);
    end
end
```

```
D_W =  Data of Weather

   28.2000   79.0000  312.1000   90.0000
   28.5000   79.0000  212.5000  105.0000
   28.3000   78.0000  311.4000  173.0000
   29.5000   74.0000   43.7000  131.0000
```

```
% Weather weighting.
%For example: weather factor in March
m=3;
Weat=exp(0.045485+0.0550564*D_W(m-2,m-2)+0.0265723*D_W(m-2,m-1)+0.000846*D_W(m-2,m));
D=D_W(m-1,m+1);
W=Weat/D;
```

```
W =  Weather factor

    0.5003
```

1. Initialization:

Dengue-contracting risk value $\vec{L} = (L_1(t), L_2(t), L_3(t), \ldots L_n(t))$

```
% Initialization:  Location-Contraction Area
for m=1:12
    for n=1:1
        K(m,n)=data_mov(m,n);% Data vektor
        K_t(n,m)=K(m,n);
    end
end
```

K = Constant of Location-Contraction Area

0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

1. Initialization: human movement data

```
%Initialisasi human movement data
for m=1:12
 for n=1:12
   Dmov(m,n)=data_mov(m,n+1);% Data vektor
   Dmovtran(n,m)=Dmov(m,n);
 end
end
```

Dmov =

Destination

Origin

12	0	0	0	1	1	0	1	0	0	1	0
0	14	0	1	0	0	0	1	0	0	1	0
0	0	13	0	1	1	1	0	0	0	1	4
1	1	1	3	1	1	0	0	0	1	1	0
0	0	1	0	8	0	0	1	0	0	1	1
0	1	0	1	0	3	1	1	0	0	0	1
0	1	0	0	0	0	5	1	0	0	1	1
0	1	0	0	0	0	0	3	0	0	1	1
0	0	1	1	1	1	0	1	7	0	0	1
0	1	0	1	0	0	1	0	0	6	0	1
1	1	0	1	1	1	0	1	0	1	14	1
1	1	0	1	0	1	1	1	1	1	0	5

2. Calculate Individual Risk P(n,t)

```
%Individual Risk
vtime=8;% length of stay of every people in the
area
for m=1:12
    Tot(m)=0;
    for n=1:12
        Tot(m)=Tot(m)+Dmovtran(m,n);
    end
end
for m=1:12
    for n=1:12
        Totmat(m,n)=Tot(m);
        Totmat_tran(n,m)=Totmat(m,n);
    end
end

for m=1:12
    for n=1:12
        hj1(m,n)=(Totmat_tran(m,n)*vtime)/(24*7);
        P(m,n)=((K(m,n)/hj1(m,n))^2)*(1/hj1(m,n));
    end
end
```

P = Individual Risk for every Origin-Destination area

0.0274	0.0100	0.0226	0.1270	0.0422	0.1270	0.1270	0.0696	0.1809	0.1270	0.0100	0.0226
0.4390	0.1600	0.3618	2.0326	0.6744	2.0326	2.0326	1.1133	2.8941	2.0326	0.1600	0.3618
0.1098	0.0400	0.0904	0.5081	0.1686	0.5081	0.5081	0.2783	0.7235	0.5081	0.0400	0.0904
0.4390	0.1600	0.3618	2.0326	0.6744	2.0326	2.0326	1.1133	2.8941	2.0326	0.1600	0.3618
0.2470	0.0900	0.2035	1.1433	0.3794	1.1433	1.1433	0.6262	1.6279	1.1433	0.0900	0.2035
0.1098	0.0400	0.0904	0.5081	0.1686	0.5081	0.5081	0.2783	0.7235	0.5081	0.0400	0.0904
0.4390	0.1600	0.3618	2.0326	0.6744	2.0326	2.0326	1.1133	2.8941	2.0326	0.1600	0.3618
0.4390	0.1600	0.3618	2.0326	0.6744	2.0326	2.0326	1.1133	2.8941	2.0326	0.1600	0.3618
0.4390	0.1600	0.3618	2.0326	0.6744	2.0326	2.0326	1.1133	2.8941	2.0326	0.1600	0.3618
0.2470	0.0900	0.2035	1.1433	0.3794	1.1433	1.1433	0.6262	1.6279	1.1433	0.0900	0.2035
0.2470	0.0900	0.2035	1.1433	0.3794	1.1433	1.1433	0.6262	1.6279	1.1433	0.0900	0.2035
0.6860	0.2500	0.5652	3.1759	1.0538	3.1759	3.1759	1.7395	4.5220	3.1759	0.2500	0.5652

4. Input : Infected people $\overrightarrow{MI_n}(t+1)$

If Infected people = $\overrightarrow{MI_n}(t+1) = \left(M_1(t+1), \ldots M_n(t+1)\right)$

then $L_n(t+1) = 1$

else $L_n(t+1) = L_n$

```
% for example  area number 1 is infected
number=input ('infected area number=  ')
for m=1:12
    for n=1:12
        IP(number,n)=Dmov(number,n);% Data vektor
        if IP(number,n)> 0
            K(number,n)=1
        else
            K(number,n)=K(number,n)
        end
    end
end
```

K = Constant of Location Contraction area with infected people

1.0000	0.1000	0.1000	0.1000	1.0000	1.0000	0.1000	1.0000	0.1000	0.10
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.40
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.20
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.40
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.30
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.20
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.40
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.40
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.40
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.30
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.30
0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.50

The red rectangular shows the area that connect with the infected area

5. Repeat step 2-4 for t= t+1

```
%Total Risk of human movement and weather before
infected people is
%inputted
scale =max(H2M)/max(H2MI);
Nor_H2M=((H2M-0)/(max(H2M)-0))*scale;
% Total Risk
Tot_H2M = Nor_H2M+W;

%Total Risk of human movement and weather after
infected people is inputted
% Data normalization
Nor_H2MI=((H2MI-0)/(max(H2MI)-0));
% Total Risk
Tot_H2MI = Nor_H2MI+W;
```

```
infected area number=  1

H2M = Risk of area by human movement without infected people

   1.7013    3.1900    2.1027   16.1337    4.9740   10.5441   15.4985   10.0194   24.7804   13.2119    2.0400    4.9742

H2MI = Total Risk of area without infected people

  34.3000    3.1900    2.1027   16.1337    9.1472   23.1207   15.4985   16.9078   24.7804   13.2119    3.0300    4.9742

Tot_H2M = Risk of area by human movement with infected people

   0.5499    0.5933    0.5616    0.9706    0.6453    0.8077    0.9521    0.7924    1.2227    0.8854    0.5597    0.6453

Tot_H2MI = Total Risk of area by human movement and weather with infected people

   1.5003    0.5933    0.5616    0.9706    0.7669    1.1743    0.9521    0.9932    1.2227    0.8854    0.5886    0.6453
```

The red rectangular shows the area that connect with the infected area

6. Checking condition

Check :

if $DH1M_m = 0,\ DH2E_m = 0\ ,\ DH2M_m = 0$

then stop

else select from vector $\vec{M}(t)$ to get $AI_n(t+1)$

$AI_n(t+1)$are Area Infected with specification

$DH1M_m \neq 0,\ DH2E_m \neq 0,\ DH2M_m \neq 0$

Select next suspected area from vector $\overrightarrow{MI_n}(t+1)$by inputting $AI_n(t+1)$
Update standard H1M(t), H2M(t), H2E(t) with H1M(t+1), H2M(t+1), H2E(t+1)

```
% Checking condition

deltot=Tot_H2MI-Tot_H2M;
if deltot==0
  fprintf('The  spreading of disease is over.lets having
fun\n');
  else
      K = K % Location-contraction coefficient with
infected people become the new standard for simulation
      H2M=H2MI;
  end
```

If there is no infected people

```
The disease spreading is over..lets having fun
```

If the area has an infected people

deltot = The differences between risk of area before and after he infected people is reported

0.9504	0	0	0	0.1217	0.3667	0	0.2008	0	0	0.0289	0.0000

K =

1.0000	0.1000	0.1000	0.1000	1.0000	1.0000	0.1000	1.0000	0.1000	0.1000	1.0000	0.1000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

H2M = The new standard of risk of area

34.3000	3.1900	2.1027	16.1337	9.1472	23.1207	15.4985	16.9078	24.7804	13.2119	3.0300	4.9742

H2MI = Risk of area after infected people is reported

34.3000	3.1900	2.1027	16.1337	9.1472	23.1207	15.4985	16.9078	24.7804	13.2119	3.0300	4.9742

3.4 Simulation and Analysis

3.4.1 The Area of Study

Simulation was conducted by real data year 2012 of Kecamatan Tandes, Surabaya. Kecamatan Tandes covers 9.3 km2 areas, consist of 4 kelurahan with population density 8,447 population/km2. Compare with another kecamatan in Surabaya, population density in Tandes is relatively low, and the GDP is relatively high [87]. However, from 2010-2012, number of dengue victim is high. Figure 3.6 shows the map of the study area: kecamatan Tandes.

Figure 3.6 The Area of Study: Manukan district, Surabaya

The study area is 14 km2, consist of 24 grids. The numbers of participants are 734 people from 167 houses in 4 districts. In this research, the respondent should, mainly, stay in this area for 24 hours during the simulation. Therefore, most of them are retired people, house wife, student, owner of a private business or a worker who stay close to their office. Data infected people are collected by the Ministry of Health in Surabaya.

The interview was conducted to gather the information about the place where people usually visit in between 09.00 to 18.00. In that place, people are assumed spend 2-8 hours of the morning, in week day and weekend. Every person acts as an agent. He/she is allowed to visit mainly the area of study. From the interview, most of them have a same movement pattern during the week day, and weekend. From the questionnaire, we performed a matrix of data as showed in table 3.2

Table 3.2 The Example of data from interview

It shows the daily active-place of people. Number in Origin or Destination indicates the number of grid.

				PAGI					SORE	
	No	Tanggal	Nama	Origin	Destinasi1	Lama_tinggal1	Destinasi2	Lama_tinggal2	Origin	Lama_tinggal
Minggu	1	1-Jan	Wildan	32	32	4	32	4	32	14
	2	2-Jan	Wildan	32	33	5	32	3	32	14
	3	3-Jan	Wildan	32	33	5	32	3	32	14
	4	4-Jan	Wildan	32	33	5	32	3	32	14
	5	5-Jan	Wildan	32	33	5	32	3	32	14
	6	6-Jan	Wildan	32	33	5	32	3	32	14

The next step is querying the data to perform daily movement data. Then the data are transformed into a matrix for calculating process of Individual risk and Risk of Area. The result is given in Table 3.3.

Table 3.3 The example of matrix data of Origin-Destination

The horizontal column characterizes a destination identification area (D) while vertical ones are origin identification area(O).

	L	929	930	931	932	933	934	935	936	881
929	0.1	12	0	0	0	1	1	0	1	0
930	0.4	0	14	0	1	0	0	0	1	0
931	0.2	0	0	13	0	1	1	1	0	0
932	0.4	1	1	1	3	1	1	0	0	0
933	0.3	0	0	1	0	8	0	0	1	0
934	0.2	0	1	0	1	0	3	1	1	0
935	0.4	0	1	0	0	0	0	5	1	0
936	0.4	0	1	0	0	0	0	0	3	0

The horizontal column characterizes the the destination (D), while vertical ones is the origin (O). L is the risk value of contagious area. Value of matrix cell represents the number of people from origin to destination. For example, in origin 929 and destination 931, number of people from O 929 to D 933 is 1. Value 0 denotes this area has no connection to graph.

3.4.2 The Result of Simulation

First simulation was tantamount to analyze dynamic ROA. The standard and Infected (number of infected people and the grid they live in). The result is presented in table 3.4.

Table 3 4 The example of risk value of every area

A standard is a risk area value without infected people, "Infected" is a risk area value after inputting infected people. H1M is First day Morning, H1E is first day evening, H2M is second day morning.

		929	930	931	932	933	883	884	885
Standard	H1M	0.101464	0.71707	0.295258	0.347892	0.275495	0.458267	1.092002	0.868781
	H1E	0.379529	0.856874	1.221979	0.315956	0.799294	0.645102	1.063877	1.213752
	H2M	0.213283	1.50836	0.691693	0.732801	0.578781	0.975227	2.52558	2.328631
Infected	H1M	0.101464	0.71707	0.295258	0.347892	0.275495	0.458267	1.02768	0.974335
	H1E	0.379529	0.856874	1.220053	0.315956	0.798813	0.644621	1.105597	1.355521
	H2M	0.212802	1.507878	0.691693	0.73232	0.578781	0.975227	2.316119	2.620562
	Delta	-0.00048	-0.00048	0	-0.00048	0	0	-0.20946	0.291931

The standard is RoA without infected people. Infected represents value of RoA with infected people. Delta is the differences between Standard and Infected. If delta is negative, the ROA is high; if zero, there is no connection in network and if positive the ROA is low.

The next step is predicting the next spreading area. Refers to recovery time; 7-10 days, the simulation for one week was run. After one week, prediction of this week becomes the standard of the next week. If the result of prediction is greater than the standard, ROA is bigger, vice versa. The result is shown in Table 3.5

Table 3.5 The example of prediction result

3th week Jan	Standard	4.151654	10.03729	0.691693	5.247511	0.578781	5.128349	8.9803
	Prediction	4.622457	12.16942	3.269104	6.576678	6.30832	6.224342	10.62766
4th week Jan	Standard	4.622457	12.16942	3.269104	6.576678	6.30832	6.224342	10.62766
	Prediction	5.093259	14.30155	4.464127	7.905846	7.009185	7.320334	12.27502

The first simulation is dynamic spreading without seasonal factor. The weekly simulation in one month, January 2011 is conducted. The result is mapped in Figure 3.7.

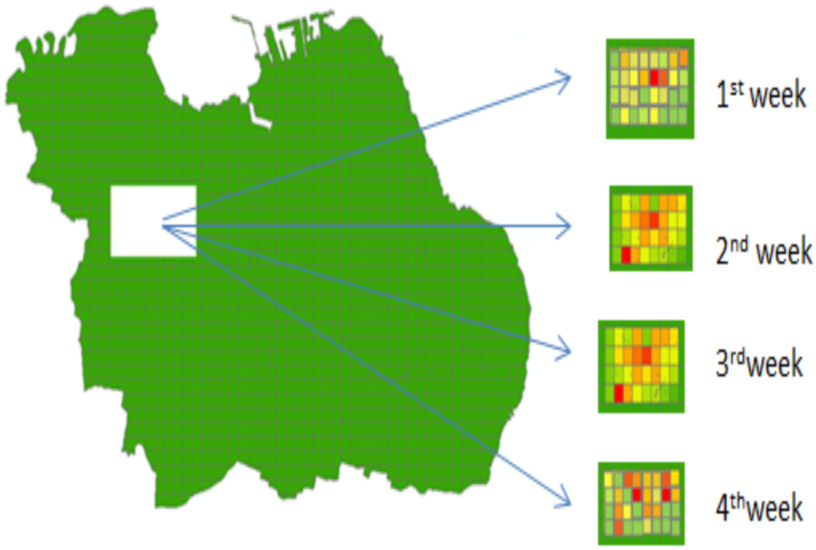


Figure 3.7 The risk of area without seasonal risk
Result of risk-area prediction in the same weather condition. Risk is an impact of human movement. The different pattern shows variation of human movement, especially at the week end (Saturday and Sunday)

In this simulation, there are several patterns of spreading of disease. The area where the most contagious area is residential, and the pattern of human movement is house to house movement [91], the disease is possible to return as cyclical. While, in the area where most of people do not move out, for example nonworking people or retired people, the risk is small. Therefore, transformation of disease is influenced by social structure [75]. Also, the probability of local spreading is bigger than global spreading. For this type, it is easy to localize the disease.

The second simulation is dynamic spreading with seasonal risk. Monthly simulation, from January 2011 to June 2011, was conducted. The purpose of the simulation is to compare the seasonal situation of the same human movement pattern. The result is mapped in Figure 3.8.

Figure 3.8 The risk of area with a seasonal risk
Result of prediction with involving seasonal factor. It describes the risk in both weather and human movement. The weather increases level of risk for every area temporally. The human movement increases number of infected area.

Dynamic seasonal risk adds the number of the infected people, but the pattern of spreading is not change. Variation of RoA value is important to decide mathematical model of the controller. In our study, the controller is policy in chemical treatment, self-protection and promote awareness in hygiene.

3.4.3 Performance of the System

To evaluate ADRESS, the simulation result was compared with real data. The error is defined as differences between the highest risk areas in the simulation with the real data of dengue case location (represented by location of victim).

In this research, there are three possibilities:

1. Location of the highest risk area = location of dengue case, error = 0
2. Location of the highest risk area different from location of dengue case, but it is still in the graph connection, error = ranking of dengue case area- ranking of highest simulation.
3. Location of the highest risk are different from location of dengue case and it is not in the graph connection, error =1.

The way to determine the error is illustrated in Figure 3.9.

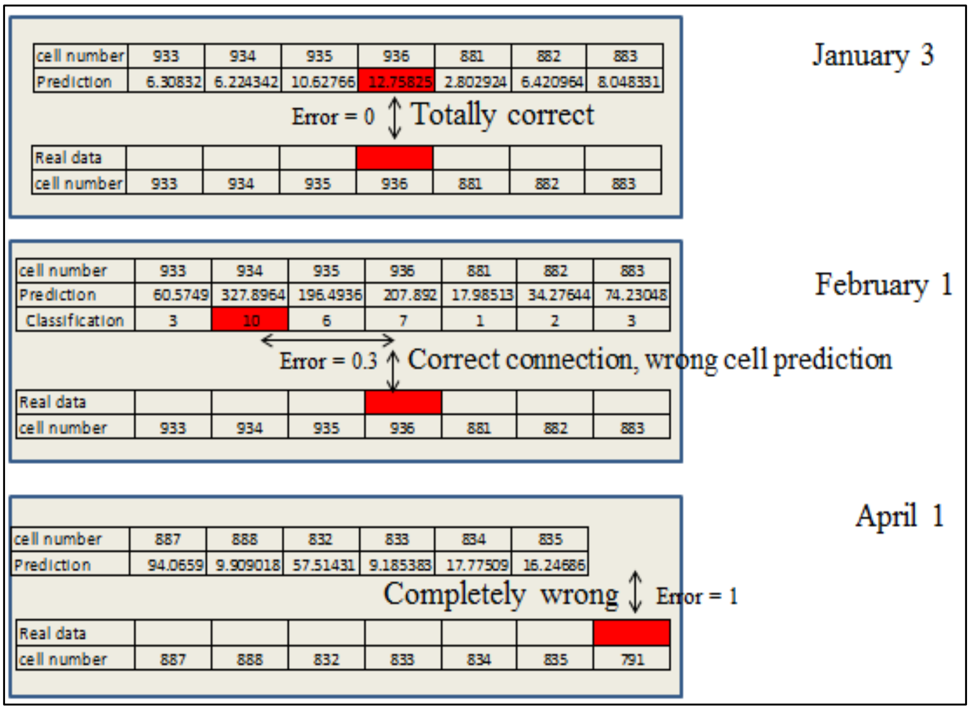


Figure 3.9 The evaluation method

The rule to evaluate the error of spreading in ADRESS simulation

From the definition above, the error of 24 weeks' simulation is calculated. The result is shown in Figure 3.10

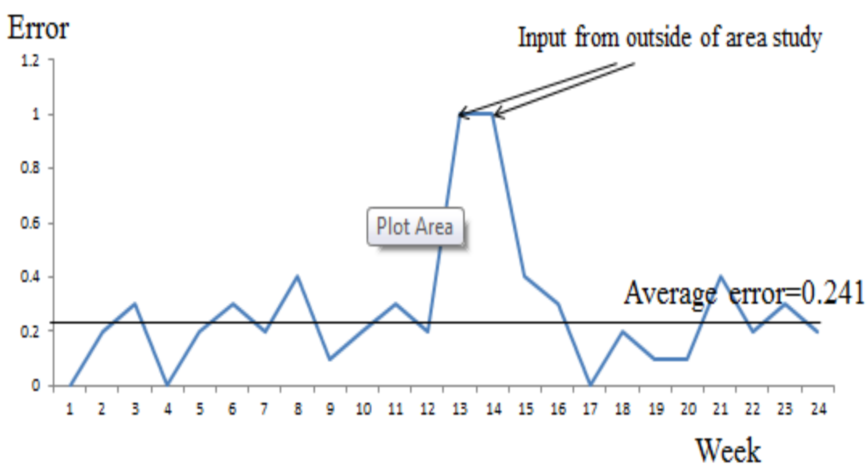


Figure 3.10 Error of the simulation

The performance of the system is observed by measuring error for every event during 24 weeks' simulation. The average error is 0.24.

To evaluate the effectivity of the proposed method, it is compared with the existing method. The existing method applied in several countries included Surabaya is House index. House index represents the percentage of vector-covered area. The data are collected month

$$House\ index = \frac{Number\ of\ house\ infested\ by\ mosquito}{Number\ of\ house} \quad \text{............(3.7)}$$

Table 3.6 Comparison between ADRESS and House Index

	The Error of House Index	The error of Proposed Method
January	0.14	0.11
February	0.2	0.275
March	0.35	0.115
April	0.52	0.675
May	0.45	0.1
June	0.21	0.17
Total error	0.321	0.241

The result claimed that the system is adaptive to input from outside, but totally performance still low. This system is suitable for predicting the near future spreading because it is adaptive to the situation. Therefore, it is good for quick action in order to manage the next spreading. On contrast, the performance is low because in this system, it is difficult to identify the boundary of "close world". Some aspect is uncontrollable, for example the impulsive event like a funeral ceremony or wedding ceremony. At that event, it is sometimes difficult to manage and evaluate the human movement. As an impact, the prediction is entirely wrong.

CHAPTER 4

The Ecological Context-Dependent Strategy

This chapter explains an action to combat against dengue fever based on context-dependent strategy. In this chapter, the ecological context is chosen. The semantic strategy is selected from WHO strategy for dengue fever. Basically, there are two processes in context-dependent strategy in this research: the attribute selection and the pattern matching.

4.1 Related Work

Dengue fever is illnesses caused by pathogens and parasites in human populations. The parasite, namely vector, needs a suitable environment for their existence. Therefore, novel strategies for prevention and control of vector-borne diseases are emphasizing "Integrated Vector Management" – as an approach that reinforces linkages between health and environment [96]. Hence, it is obvious that the prediction based on the environment plays a significant role [43].

There are several methods in environmental-base prediction: spatial analysis with remote sensing [1], event history [26], statistical method [99], spatial analysis [8], and temporal analysis [66]. Also, predictor variables are introduced: weather [72] [35] and specific locality [18]. All methods discuss the relation between environmental data and dengue cases directly without including a stage of the mosquito's life. In fact, the occurrence of dengue is caused by a different combination of stages in mosquito's life cycle and disease transmission by mosquito [59]. The stage of a mosquito varies, depend on a different environmental condition. Thus, every dengue case is associated with altered dominant stage under singular circumstances. Therefore, it is clear that selecting the dominant stage for the unique situation plays an important role in dengue prevention. Consequently, the precise analysis must deal with the concept of context (situational)-dependency.

In this research, we present the new system to calculate and select the stage of the mosquito, based on context-dependency. This system is based on the similarity pattern between environmental data with the mosquito's stage as a predictor by using Mathematical Model of Meaning (MMM) [102]. Through this system, several advantages will be obtained by the following aspects:

(1) Improving prediction method by introducing the context-dependent ecological parameter that represent important reproductive and survive stage of a creature.

(2) Determining a suitable strategy for prevention through matching prediction between the stage performed by environmental data and the impact of dynamic changing of it in life of the creatures. In this case, we can realize the different strategy for different situation

(3) Reducing damage of the environment and health, because current dengue prevention mostly utilizes the same chemical treatment for a different case.

4.2. Methodology

System design of the proposed method is illustrated in Figure 4.1.

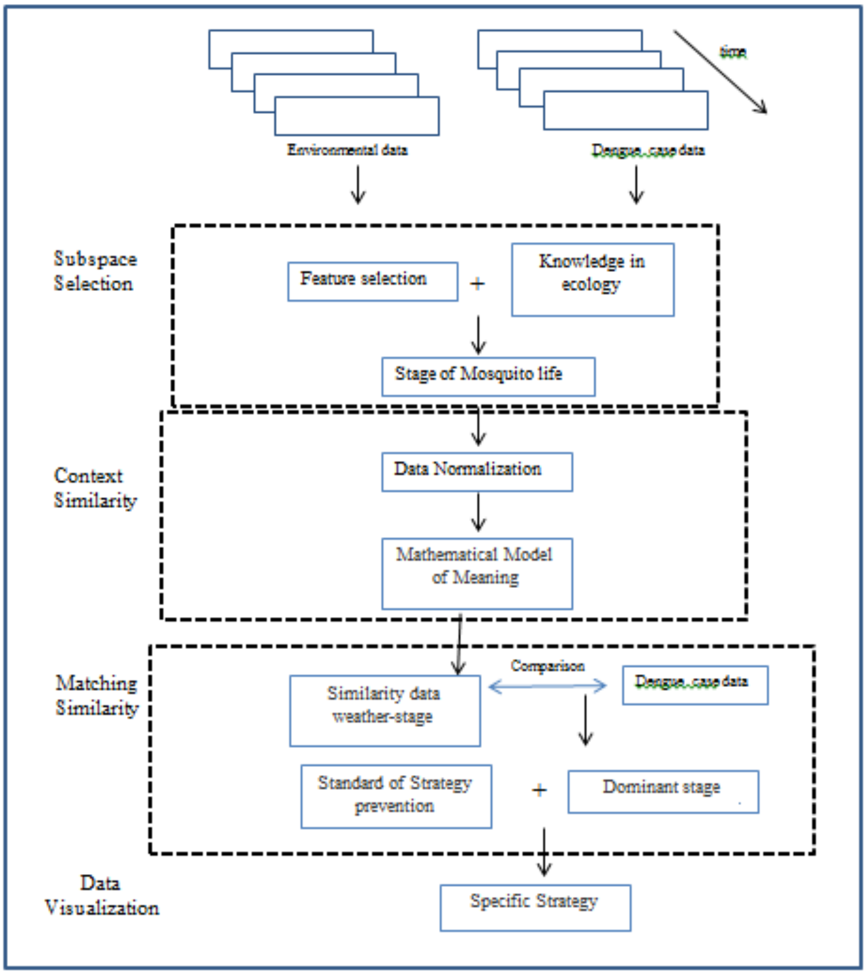


Figure 4.1 The system design of ecological-based strategy.

4.2.1 The Subspace Selection

First of all, the abiotic features are selected. Abiotic is all of the non-living things in an ecosystem such as temperature, pH, CO2, rainfall, etc. In this case, the chosen features are weather data: temperature, rainfall, humidity, CO2, wind speed, and percentages of sunshine duration. Weather significantly influences dengue incidence and that such relationships are highly nonlinear [35]. While, the longitudinal study demonstrates that the population dynamics of mosquito relate with dengue incidence [61].

The next step is creating subspace for prediction and tracking their time evolution (prognostic). The subspaces are performed from some individual or mix of the abiotic component. To create the subspace. Terminology from ecological niche model for the fundamental life of mosquito [76]. This model based on a dynamic energy budget where energy for life is represented as the heat exchange. Therefore, fundamental life is performed based on an abiotic feature in environmental data. In this case is the weather.

In a case of dengue fever as a vector-borne disease, there are several stages of mosquitos that correlate with dengue case. This stage and definition are shown in Table 4.1.

Table 4.1 The Ecological context in dengue
(Definition of stage in mosquito life as a representation of abiotic feature)

stage	Definition
Gonothropic development	initiation and complete growth in larval and pupal stages.
Methamorphose	the process of transformation from an immature form to an adult
Sporogonic development	Reproduction by multiple fission of a spore or zygote
Activity level	level activity of mosquito to get food
Oviposition choice	process of choosing place for laying eggs.
Gonothropic cycle	cycle of taking a blood meal and laying a batch of eggs,
Resting	behaviour resting of mosquito
Development rate	rate of growth in adult mosquito
Flight path	path of flight mosquito in order to find human

Since the context of mosquito life in this research is based on a dynamic energy budget where energy for life is represented as a heat exchange, the stage is chosen based on the abiotic feature that supports energy for mosquito life. The stage, as a subspace, is strongly influenced by some feature in weather as a part of abiotic. Table 4.2 shows subspace and the combination feature that performs it.

Table 4.2 The Relation between context and the feature

stage	Rainfall	Humidity	Temp	Wind	CO2	Sunshine
	(mm)	(%)	C	(m/sec)	(ppm)	(%)
Gonothropic development		X	X			
Methamorphose	X	X	X			
Sporogonic development	X	X				
Activity level		X			X	X
Oviposition choice	X					
Gonothropic cycle			X			
Resting						X
Development rate	X		X			
Flight path				X	X	

4.2.2 Measuring the Similarity

The next process as the main process is measuring the similarity between the data and the subspace. In this study, MMM is utilized. In this section, the outline of our semantic associative search method founded on the Mathematical Model of Meaning (MMM) is briefly reviewed. This model has been submitted in [Y Kiyoki,1994] in detail. In this case, MMM was applied to calculate the similarity of weather data set with subspace that represent an ecological context by following steps:

1) Create a data matrix (B) of weather data set.

Data matrix (B) can be seen in the following matrix.

$$
\begin{pmatrix}
B & T & H & R & W & S \\
b_1 & T_1 & H_1 & R_1 & W_1 & S_1 \\
b_2 & T_2 & H_2 & R_2 & W_2 & S_2 \\
..b_3 & T_3 & H_3 & R_3 & W_3 & S_3 \\
. & . & . & . & . & . \\
b_m & T_m & H_m & R_m & W_m & S_m
\end{pmatrix}
$$

Where T denotes temperature
H denotes humidity
R denotes rainfall
W denotes wind speed
S denotes Sunshine duration
$\bar{B} denotes \{b_1\ b_2\ b_3\ \ldots..b_n\}$

A set of invariant subspaces as the projections semantic space is performed by the standard of a suitable environment for every subspace. The datum is determined by statistical analysis of mosquito in Indonesia. Referring to Table 4.2, we performed matrix for the standard as shown in Table 4.3.

Table 4.3 A set of orthogonal semantic subspace

Stage	Rainfall (mm)	Humidity (%)	Temperature (C)	Wind (Knot)	Sunshine (%)
Gonithropic Development (GD	0	80	24	0	0
Methamorphose (M)	302	80	24	0	0
Sporogonic Development (S)	302	80	0	0	0
Activity Level (AL)	0	80	0	0	64
Oviposition Chioce	302	0	0	0	0
Gonothropic Cycle (GC)	0	0	24	0	0
Resting	0	0	0	0	64
Development Rate (DR)	302	0	24	0	0
Flight Path (FP)	0	0	0	3.85	0

2. Find the similarity pattern by using MMM.

All data were projected to all stages and calculate the distance between the data and stage. Similarity can be expressed by the nearest distance in the following equation

$$min(b\_i\ (k) \in B)\ \ ||P(S(i)(b - \overline{b_{\iota}(k)}||,1 < i < m \qquad \ldots\ldots \quad (4.1)$$

If the calculation result value of the stage close to 1, the meaning is, the data has high similarity with this stage. A negative value indicates inversely proportional while a positive value indicates proportional.

4.3 The Prediction Matching

The purpose of prediction matching is to identify semantic equivalence between projection data and prediction data. Therefore, series of prediction data, x(t), should be shifted to x(t+1). This data, x(t), will be decomposed by the suitable delay to get pattern using Hilbert Transform. Hilbert transform is defined as:

$$H[x(t)] = x(t) * \frac{1}{\pi t}$$

$$= \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{g(\sigma)}{t - \infty} dt$$

$$= -\frac{1}{\pi} \int_{-\infty}^{\infty} \frac{g(\sigma)}{t} dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4.2)$$

Hilbert transform produces a phase shift for the positive frequency components of the input x(t), without changing an amplitude. The signal resulted from Hilbert transform is a prediction signal.

4.4 The Experiment

4.4.1 Experimental Set up

In this study, input data are set to real weather data from The Surabaya Municipal City from January 2007 to December 2012. This data is monthly-accumulated data from the weather station as showed in Table 4.4.

Table 4.4 The example of abiotic feature data

Year	Month	Rainfall	Humidity	Temperature	Wind	Sunshine
		(mm)	(%)	(C)	(Knot)	(%)
2010	Januari	303.2	78	28.5	1.13	52
	Februari	402.8	78	29.2	1.85	64
	Maret	216.2	77	29.4	3.91	59
	April	320.5	80	29.3	2.94	58

Then, data was normalized to transform the data in a specific range corresponding to a different data set. The validation data are series of dengue incident from January 2007 to December 2012. This indicator (X(t)) is extracted by using Hilbert transform to transform x(t) to x(t+1). Thus, X(t) becomes validation data. The result is given in Figure 4.2.

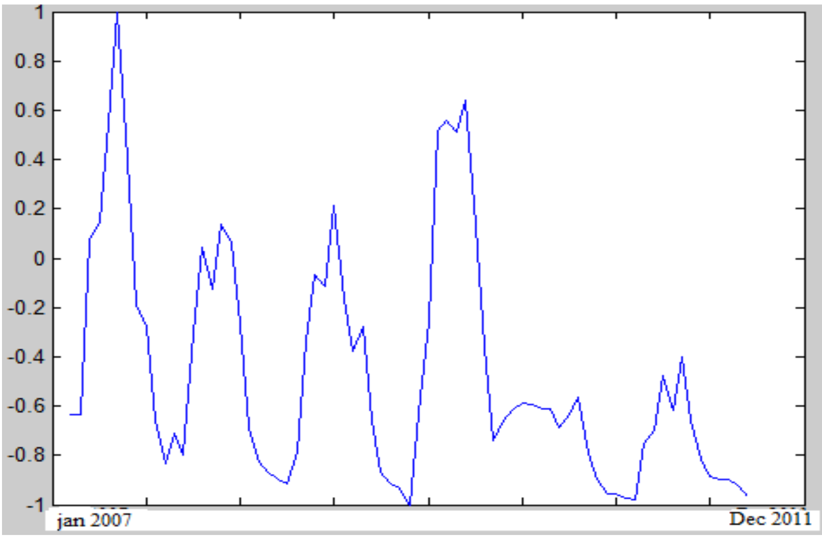


Figure 4.2 The result of Hilbert Transform of dengue case

4.4.2 Analysis of Similarity

The purpose of this similarity is to identify the subspace which is fit with prediction data X(t). For this purpose, MMM was implemented as semantic computation. Table 4.5 shows an example result of the similarity calculation for the different stage during four months in 2007.

Table 4.5 The Result of similarity

stage	Month (2007)			
	January	February	March	April
Gonothropic development	0.438744	0.381558	0.7655	0.7952
Methamorphose	0.186873	0.489764	0.4456	0.6463
pupa development	0.709365	0.754687	0.276	0.6797
Activity level	0.655098	0.162612	0.119	0.4984
Oviposition choice	0.959744	0.340386	0.5853	0.2238
Gonothropic cycle	0.751267	0.255095	0.506	0.6991
Resting	0.890903	0.959291	0.5472	0.1386
Development rate	0.149294	0.257508	0.8407	0.2543
Flight path	0.814285	0.243525	0.9293	0.35

The similarity of the pattern is evaluated by calculating differences of data to the average differences between every stage with dengue case. In this case, the weather data were compared with next two-month dengue case data. This is happened because prognosis of the disease is two months.

4.4.3 Analysis of Prediction Matching

In order to predict the succeeding situation, we compared the existence of dengue with the dominant stage. For example, a number of the victim in January 2008 was compared with the similarity of all stages in November 2007. The stage that has the lowest differences is the dominant stage. Table 6 shows 3 dominant stages associated with the month which lowest victim and highest victim. We chose 3rd ranking for highest (denoted by X) and 3rd for the lowest (denoted by O). The result is given in Table 4.6.

Table 4.6. The Result of prediction matching
(X denote the highest, and o denotes the lowest)

Year	Ranking	GD	M	S	AL	OC	GC	R	DR	FP
2007	1		X				O			
	2			X	O					
	3	O						X		
2008	1		X				O			
	2			X	O					
	3	O						X		
2009	1		X					O		
	2			X			O			
	3							X		
2010	1			X	O					
	2		X							O
	3					X	O			
2011	1	X						O		
	2					O	X			
	3	X					O			
2012	1	X					O			
	2			X		O				
	3							O	X	

From Table 4.6, it is clear that the stages that relate to feature rainfall play an important role in the wet season, where a number of victims are high. On the other hand, stages that relate to the sunshine and the wind are important in the dry season. Something interesting that features temperature and humidity always includes both dry and wet season. That is for this reason that dengue fever becomes endemic in tropical countries, and now dengue spreading in subtropical countries because these countries become warmer due to global warming.

Also, there is patterned in 2007-2009, while in 2010-2012 there is no pattern. When it is confirmed with the situation, the fact said that in 2010 and 2011 Surabaya is stricken by several disasters as an aftermath of extremely dry and wet, such as flood and typhoon. The result is given in Table 4.7.

Table 4.7 The Example of anomaly in similarity

Stage	Flood 2010	Typhoon 2010
	Nov	Feb
Gonothropic development	-0.69	-0.68
Methamorphose	-0.65	0.63
Sporogonic development	-0.57	0.64
Activity level	-0.89	-0.89
Oviposition choice	-0.67	0.64
Gonothropic cycle	-0.88	-0.88
Resting	-0.99	-0.986
Development rate	-0.66	0.62
Flight path	-0.72	-0.71

In a case of flood, all stages have no similarity, it means there is no information what happens in ecological of mosquito. While in typhoon some stage has some value in similarity, there is no dominant stage. There is not any information about the situation in mosquito life.

4.5 The Application

The purpose of this research is to determine the suitable strategy for combatting dengue occurrence. Table 4.8 shows the standard strategy for every stage built upon guidance from WHO [96].

Table 4. 8 The Relation between stage and strategy

stage	Strategy of control
Gonothropic development	insecticide for larvae
Methamorphose	interrupting aquatic stage
Sporogonic development	reppelent
Activity level	individual protection
Oviposition choice	vegetation control
Gonothropic cycle	chemical spray
Resting	eliminating habitat
Development rate	outdoor control (electric)
Flight path	mechanical barrier

Since this data is on a timeline, in one sequence there are several subspaces involved. Duration of every sequence is two months. For example, from July 1, 2011, to August 31, 2011, is one sequence. During two months, almost all stages of mosquito's life cycle occurs. But, some stages are dominant while others are not, is dependent on the environmental condition. This variation is important in order to govern comprehensive prevention. Comprehensive prevention means a combination of some strategy based on dominant stage. Due to limited training data. We performed 70 variations of strategy based on situational-dependent. The situation is reflected in the name of the month, for example, "January 2007" to "October 2012", etc.

In this study, the performance of retrieval result is measured by the ambiguities of the query result. Ambiguities mean, in one query there are several alternate or several ranking. In our case, no ambiguities are good, because it reflects sharp prediction. We choose 3 ranking of ambiguities. For every ranking, the error was computed.

To evaluate the performance of the retrieval result, 290 sets of weather situation database from January 1984 to December 2014 are applied. All tested data are mapped in 70 semantic spaces and discuss the result. An example of query result data is shown in table 4.9.

Table 4.9 The Example of evaluation in semantic searching

Season	Tested data	Similarity	error (%)
Wet	"February 2006"	"January 2007"	17
		"January"2008"	
		"January 2009"	
Transition	"June 1989"	" March 2009"	36
		"May 2008"	
		"June 2011"	
Dry	"Sept 1990"	" October 2011"	23
		"november 2007"	
		" December 2012"	

The experiment result shows that this system can realize a new context for environmental data, but the result is not so accurate. There are some ambiguities in the result, especially in a transition season from wet to dry. In the peak of the wet season or dry season, this system is running well. This ambiguity is probably caused by lack of predictor number (stage) and should be improved by following:

- Extracting another abiotic context, for example, landscape, nutrition, etc.
- Adding the new specific strategy in extreme condition, for example, strategy after the disaster or unusual extreme season.

Table 4.10 shows the comparison between the proposed method with several existing methods.

Table 4.10 Comparison with the existing method

	Castro, 2010	Tapya-Covyer, 2012	Sarfraz, 2014	Dasgupta A, 2014	Proposed Method
Area of study	Havana Cuba	Guerrero, Mexico	Bangkok Thailand	Kolkata, India	Surabaya, Indonesia
Methodology	Cluster randomized control	Clean Backyard campaign	Semantic in object-based satellite	Audiovisual education	Mathematical Model of Meaning
Output	Community-base strategy	Real action	Image-based strategy	Knowledge-based individual prevention	Community-base strategy
Context	Vector-control	Vector-control	Dengue incidence	Prevalence	Ecological-context
Target	Public Knowledge	Public behavior	Area-awareness	Individual Awareness	Area-awareness
Accuracy	74 %	54 %	77 %	68%	77%

In this research, an ecological context-dependent analysis for predicting the situation and determine suitable prevention is to be submitted.

This new system is important for:

- Implementing specific strategy in specific situations such in order to manage the effect to the environment and health,
- Develop new prediction system by the meta-level knowledge base.

However, this system should be improved to increase the accuracy of prediction by adding more features in an ecological context or another context related to the creature life cycle.

In the future, the challenge in semantic strategy is integrating many heterogeneous databases, such as the image of the landscape, to develop innovative sensing in communicable disease, especially in dengue fever. For the implementation, an integration sensor by drone and weather sensor will be built.

CHAPTER 5

The Vector-Control Collaborative Strategy for Surabaya, Kuala Lumpur, Bangkok

This chapter describes the integration of Location-Contraction Risk Model with Semantic Strategy Model to combat against dengue fever. It is implemented for the collaborative strategy among the city of three neighboring countries: Surabaya (Indonesia), Kuala Lumpur (Malaysia), and Bangkok (Thailand). The semantic strategy is selected from WHO strategy for dengue fever. Basically, there are two processes in this research: the attribute selection and pattern matching.

5.1 Related Work

Dengue fever is a painful, debilitating mosquito-borne disease brought about by one of four closely related dengue viruses [94]. The process of dengue spreading in the world depends on two vehicles (known as a vector): Aedes Aegepty mosquito as a local vector and human as a global vector. Mosquito transmits dengue from an infected person to a healthy person in its flying range (around 40 m). The dengue virus can spread in another country because the infected people fly away to another country. Since the mosquito is available almost in every country, the local transmission is taking place in another country.

Given such a fact, WHO published an inclusive strategy for controlling the dengue. This strategy is highlighted in dengue transcends international borders [31]. Therefore, the collaboration among countries, especially among neighboring countries is imperative [33]. There are several kinds of research collaboration is conducted from different point of view: global travel [100], world risk map [21], or practical work to reduce mosquito susceptibility [40]. However, all collaborations are temporary and sporadic. The result shows that the collaboration has no substantial impact on long-term surveillance. To overcome, we need to find the long-term collaboration strategy for surveillance [27]. The keys of success in long-term surveillance collaboration are monitoring and evaluation [94]. Therefore, the collaborative strategy for monitoring and evaluation is important. In the health care domain, interoperability architecture in the data management [e.g.16], the platform [e.g.92], and the data interpretation [e.g. 42] are known well. However, strategy and implementation of policy are rarely to be discussed [104].

This study deals with the awareness strategic among neighboring countries. The model consists of (1) determining a ranking of importance of the global attribute by weighting, and (2) mapping the data to suitable action subspace in the vector-control context by measuring the similarity. As the study area, Surabaya (Indonesia), Kuala Lumpur (Malaysia) and Bangkok (Thailand) are selected.

5.2 The Research Approach

One of interoperability challenges in neighborhoods-countries collaboration is the way to express an action to combat the dengue in the same measurement system. WHO have the global guidance, and every country translates it in their local governance, differently. In this study, we developed the common-risk strategy to provide the system for disseminating the information. Our approach is projecting the dengue-related data to the "suitable action" by similarity. The suitable action is broken down from the objective of WHO strategy for South-East Asia [WHO, 2011].

5.2.1 Preliminary Data Observation

In this research, the area of study is Surabaya (Indonesia), Kuala Lumpur (Malaysia) and Bangkok (Thailand). Description of the area studies at a glance is written as follows:

- Surabaya [73], the second big city in Indonesia. It is famous as a commercial and business city since it is a port city on the Indonesian island of Java. With the area of 350 km2, the population density is 8500/km2. Surabaya consists of 31 districts. Seasons in Surabaya are the rainy season (October - March) and dry season (March-October).
- Kuala Lumpur [45] is the cultural, financial and economic center of Malaysia. It has an area of 243 km2 while the population density is 6,891/km2. Kuala Lumpur is divided into 11 districts and. It has rainy season (October - March) and dry season (March-October).
- Bangkok [11] is the capital of Thailand where business and tourism growing rapidly. It encompasses area 1,568 km2 with population density 5300/km2. Bangkok comprises 50 districts. It has hot season (March -June, rainy season (July-October), and cool season (November – February).

Due to the differences in vision, every city interprete the global guidance of WHO into different governance. The differences in governance brought to the differences in research approach. Table 5.1 shows governance in preventing dengue and the research approaches of every city.

Table 5.1 The governance and the research of dengue in three cities

Indonesia	Empowering the people to prevent dengue [PPPL,2015]	Spatial-transmission of vector-borne(e.g. [47]) Spatiotemporal dengue-event history (e.g. [83]) Weather prediction (e.g.[99]) Event-based monitoring (e.g. [64])
Malaysia	Vector-borne surveillance [MOH,2015]	Community-Wealth based forecasting (e.g. [18]) Spatial Vector-borne Dimension (e.g. [8]) Community-based surveillance (e.g. [80]) Vector-breeding site classification (e.g. [69])
Thailand	Case-based Risk assessment [BOE,2015]	Community-based assessment (e.g. [19]) Event-history risk prediction (e.g. [65] Demographic transition Analysis (e.g. [30]) Case-sustainable factor (e.g. [44])

5.2.2 Architecture of the System

The architecture of the system is shown in Figure 5.1.

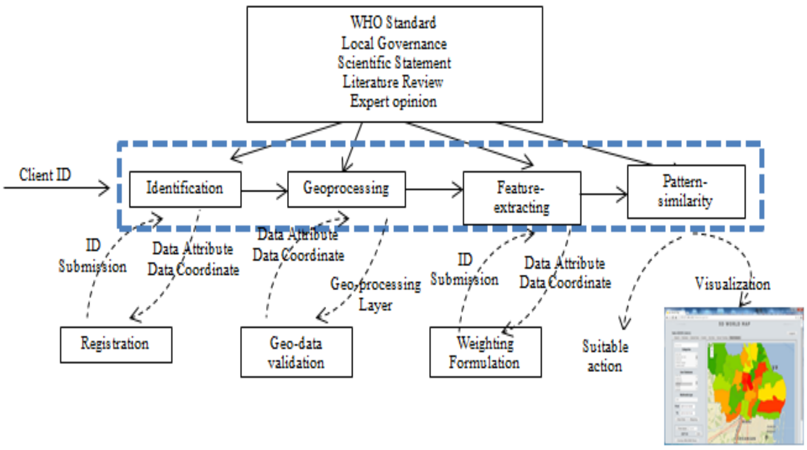


Figure 5.1 The architecture of the collaborative strategy. The thin dash represents business rule and the blue thick one represent operational agent.

All process that relate with the operational agent (identification, etc.) refers to a semantic strategy (WHO standard, etc.) from different resources. The agent translated the process into a module (registration) as a representative of business service. The business rule is illustrated as thin-dash between the operational agent and the module. The result is suggestion and visualization. In our research, we utilized 5D World Map [81] as a platform for visualization.

5.2.3 The Attribute Selection

The attribute selection indicates the process to select a global attribute. WOE (Weight of Evidence) is utilized as the spatial association analysis between a given feature and a real case of dengue. The weighting result are (1) W+ is weights of the attribute which has evidence (in this case: infected people) (DP), and (2) W− is weights of the attribute which has no evidence (DN) and T = DP+ DA; T is a total study area. Weight positive and negative is written as:

$$W^{+} = ln\left(\frac{P(B_i|S)}{P(B_i^{+})}\right) \quad \text{……………………… (5.2)}$$

$$W^{-} = ln\left(\frac{P(B_i|S)}{P(B_i^{-})}\right)$$

W+>0 implies a positive association; and W−> 0 implies a negative association; while W+= W−= 0 implies no association. The differences between W+ and W− indicates the contrast relation in both spatial association parameters, it is written as:

$$C = W_i^{+} - W_i^{-} \quad \text{……………………… (5.3)}$$

If C > 0 association is positive, C < 0 is negative, if C = 0 is no spatial association. Each cell's weighting is determined by comparing stud of several classes.

$$stud(C) = \frac{C}{s(C)} \quad \text{…………………………… (5.4)}$$

The outcome of WOE is ranking of local system attribute s that reflecting the most significant attribute s in the local system. To characterize the global system, we calculated average of every attribute from 3 cities, and then make a ranking of them.

$$y_m = \frac{\sum_{n=1}^{k} x_{(n,m)}}{k} \qquad \text{.............................. (5.5)}$$

Where : y_m denotes the global attribute m
$x_{(n,m)}$ denotes the local attribute m of the city n
k denotes number of city

5.2.4 The Spatial Matching

The purpose of pattern matching is projecting a set of local data matrix to the projection semantic space: in this case is the action standard. Note that only a data matrix of global attribute is chosen. In this study, we concentrated on vector-control context [WHO,2011]: environmental management, chemical control, biological control, and non-insecticidal control, as a subspace. Table 5.2 shows the definition of every action.

Table 5.2 Definition of the action control of Dengue from WHO

Action	Definition
Environmental management (EM)	Modification or manipulation of environmental factor
Chemical Control (CC)	Removing adult mosquitoes by chemical spray
Non Insecticidal Control (NC)	Prevention from mosquito by personal action that is not including chemical spray
Biological Control (BC)	Introductionof organisms that prey upon dengue mosquitoes in order to reduce the size of the vector propagation.

Every action is strongly influenced by some attributes. Table 5.3 shows the subspace that performs it.

Table 5.3 The relation between the subspace and the attribute

Action-Strategy	Feature									
	House (H)	Rainfall (R)	Commerce area (CA)	House Index(HI)	Population Density(PD)	Temperature (T)	Traditional Market (TMA	Garden (G)	Primary school (PS	Bussiness Area(BA)
Environmental Management (EM)	X	X		X	X	X		X		
Chemical Control (CC)	X	X	X	X				X	X	X
Biological Control (BC)		X				X	X	X		
Non-insecticidal Control (NC)	X	X		X	X	X	X	X		

The next process is measuring similarity between the data and all subspaces. We utilized vector similarity to calculate the similarity from a data set with subspace that reflects vector-control context by following step:

- Create set of data matrix of global attribute s for every sub city. The data should be normalized in between -1 to 1.
- A set of invariant subspaces as the projections semantic space is performed by a composition of data standard.
- Find the similarity pattern by similarity in MMM [Kiyoki]. All data are projected to all subspace, distance between data and subspace are calculated. Similarity is expressed by the nearest distance as the following equation :

$$min(b\_i\ (k) \in B)\ \ ||P(S(i)(b - \overline{b_{\iota}(k)}||, 1 < i < m \quad \ldots\ldots\ldots \quad (5.6)$$

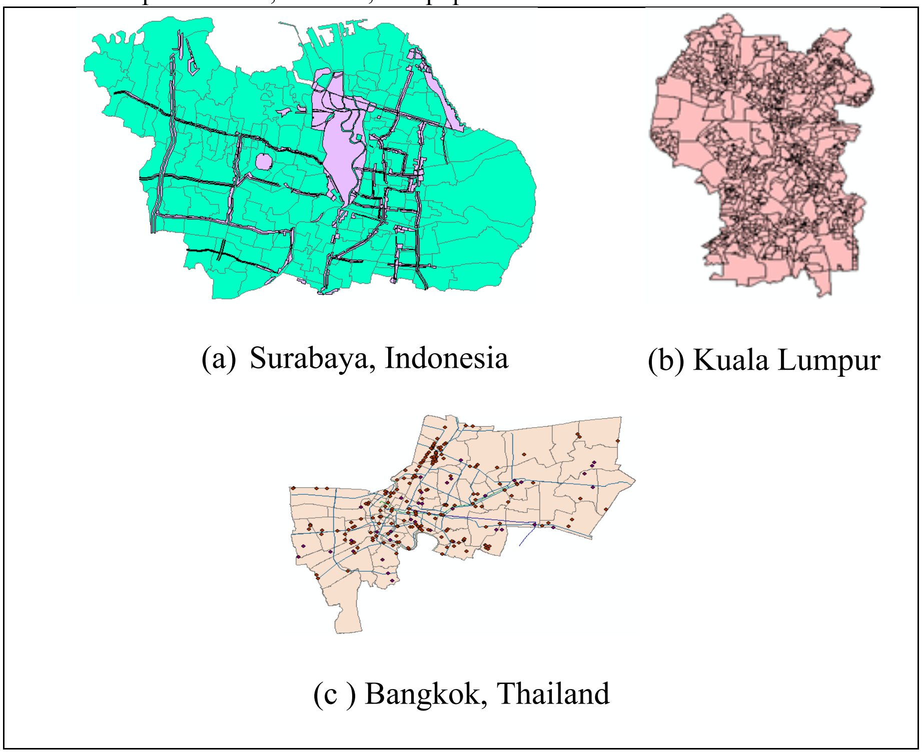
5.3 The Application

The prototype, as an application, is built to realize common-risk policy for practical action. It provides the system for sharing the information with the empirical data of 3 cities: Surabaya, Kuala Lumpur and Bangkok

5.3.1 The Data

The secondary data is provided by the government of Surabaya, Kuala Lumpur and Bangkok. Also, we gathered data of victim in the district from those cities. Figure 5.2 shows the example of data (scale 1:500000).

Figure 5.2 The spatial data: Surabaya, Kuala Lumpur, and Bangkok
The spatial data represent basic natural resources data for every city, for example land use, weather, and population.



5.3.2 The attribute

Literature review of 53 papers concerning the awareness strategy in Indonesia, Malaysia, and Thailand was conducted. It consists of: 31 research papers, 10 collaboration-work papers and 12 official papers from the government. From the literature study, the global attribute and local attribute is chosen. The global attribute represents the attribute which has similarity in: the type of data, the measurement, and the definition; for every city in this study. The local data represent the attribute that is specific in: type of data, measurement, and definition; for every city in this study. Table 5.4 shows the global and local features in our study. Table 5.4 indicates the global attribute and the local attribute.

Table 5.4 The attributes: global attribute and local attribute

The global attribute represents the attribute which has similarity in: the type of data, the measurement, and the definition; for every city in this study. The local data represent the attribute that is specific in: type of data, measurement, and definition; for every city in this study.

The Global attribute of Surabaya, Kuala Lumpur and Bangkok		The Local attribute		
		Surabaya	**Kuala Lumpur**	**Bangkok**
Rumah /Teres/Housing area	Rainfall	Apartment	Cemetery	Canal Station
Commerce area	Temperature	Ruko	Apartment	Condominium
Business area	Population density	Humidity	Religion facility	Public Facilities
Traditional market	House Index	Industrial area	Hospital	Youth Facility
Supermarket	Primary school	River	Banglow house	River
Mall	Secondary school			
Garden	High school			
Apartment	University			
Open area	Solid waste			

5.4 The Result

5 .4.1 The Attribute Selection

The attribute selection is the process to determine the weight of both the global and local attribute. The equation (5.2) - (5.5) is applied to get the weight. The weight performs the subspace standard of every strategy. WHO does not mention specifically about the data but the guidance said that we can refer to the standard from the countries in the same region [105] [104] [62] [5]. Table 5.5 shows standard of every subspace. Every subspace represents one strategy to combat the dengue spreading.

Table 5.5 The subspace standard of every strategy

Action	House[43]	Rainfall [44]	Commerce area [45]	House Index[41]	Population density[43]	Temperature [44]	Solid Waste [41]	Garden / City-Forrest[43]	Primary school [45]	Bussiness area[45]
EM	0.392	0.84	0	0.87	0.8	0.58	0.613253	0.063	0.46	0
CC	0.392	0.84	0.19	0.87	0	0	0.417534	0.063	0.79	0.19
BC	0	0.84	0	0	0	0	0.51832	0.063	0	0
NC	0.392	0.84	0	0.87	0.8	0.58	0.41754	0.063	0	0

5.4.2 The Spatial Matching

In this research, the degree of similarity indicates the spatial matching between a data of district/sub district with the strategy. Table 5.6 shows the example of data.

Table 5.6 The example of data

Name of District	House	Rainfall	Commerce area	House Index	Population density	Temperature	Solid Waste	Garden	Primary school	Bussiness area
Tegalsari, Surabaya	0.7196078	0.6196078	0.147541	0.7081967	0.917647059	-0.8666667	0.637284	-0.535294118	0.4117647	0.239215686
Cheras, Kuala Lump	0.6885246	0.7568627	0.1901639	0.7081967	0.890196078	-0.7081967	0.3514374	-0.275409836	0.2131148	0.498039216
Prawet, Bangkok	0.6980392	0.8803922	0.2754098	0.7176471	0.787843137	-0.8803922	0.4235343	0.28627451	0.3941176	0.666666667

To get the similarity, a set of matrix data is projected to the semantic strategy. The strategy is Environmental Management, Chemical Control, Biological Control, and Non-Insecticidal Control.

The system is evaluated based on accuracy and degree of implementation. To measure the accuracy of a system, the scenario is transcribed as follow:

(1) The proposed strategy is simulated according to scenario of Dengue Day 2012

(2) The effectivity of the strategy is evaluated by comparing with the real data one month after the Dengue Day 2012.

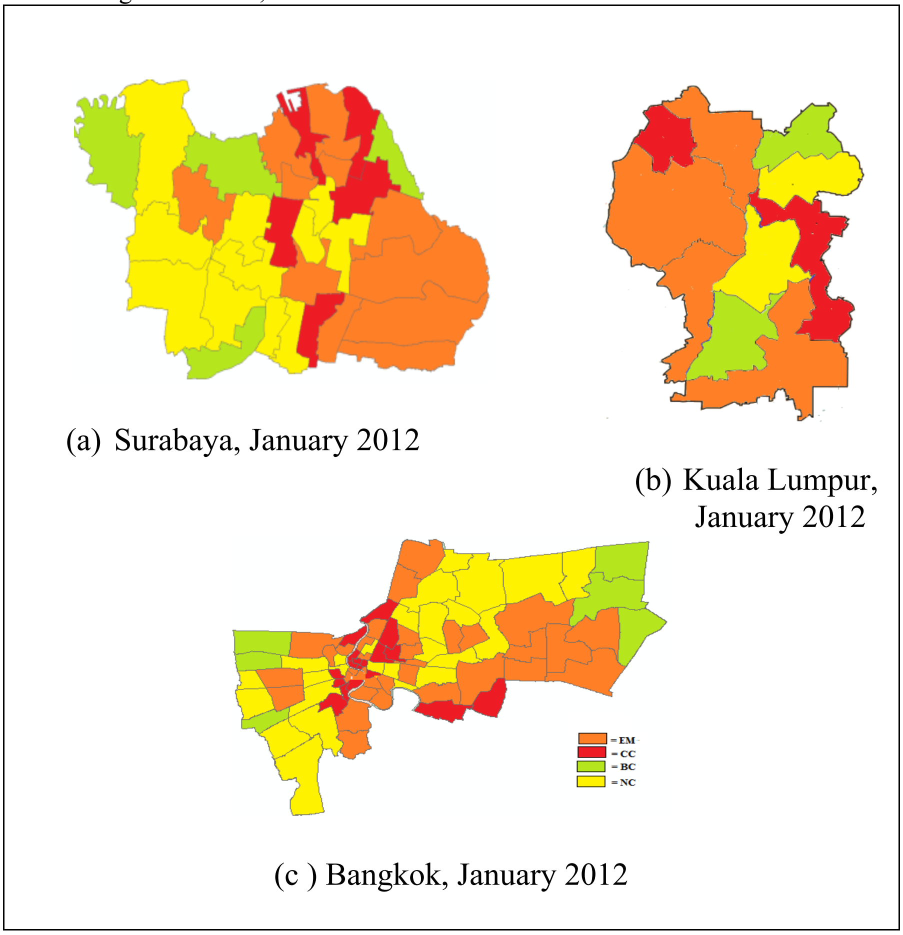
(3) For every district:

- if the real action is same with the proposed strategy, and number of case increase in the next month, the score is 0,
- else, the score =1

Action in all district is calculated and compared with the real action in January 2012-April 2012. The result is similarity of the data with the action from WHO. Figure 5.3 shows one example of action in every district.

Figure 5.3The Result of similarity in action

The actions: EM is Environmental Management, CC is Chemical Control, BC is Biological Control, and NC is Non insecticidal Control



Here is fact of Dengue Day activity in 3 cities during " Dengue Day ASEAN 2012":

(1) Surabaya: Campaign "Awas DB" the actions are Environmental Management and self- protecting using chemical spray and chemical lotion.

(2) Kuala Lumpur: Campaign "Jom Ganyang Aedes", the action is environmental management.

(3) Bangkok: Campaign "Big Cleaning Day" the action is environmental management.

The result of similarity is compared with the real action in January 2012-April 2012. The result is shown in Table 5.7.

Table 5.7 Result of accuracy

City	Surabaya	Kuala Lumpur	Bangkok	Average
Accuracy (%)	79	86	82	82.3

From Table 5.7, it is clear that in the point of view of accuracy, the performance of the system is quite good. However, to increase the accuracy, several parameters should be considered. Recently, we faced difficulties to get standard data for action. For example, the standard of using the chemical spray in Surabaya is different with Kuala Lumpur. Also, preference to choose the decision of action is depending on the authority holder, it affects to the differences in strategy for the same situation. Another problem is the size of the district is varying; it brings about difficulties to compare the success of action in every area. The next research deals with how to analyze the area in a grid, involving knowledge of the beholder, and establish a standard of awareness in every country.

5.5 Conclusion

The new system is proposed for collaboration in combat dengue spreading among 3 big cities in neighboring countries: Surabaya (Indonesia), Kuala Lumpur (Malaysia) and Bangkok (Thailand). The proposed system is an interoperability system in policy regarding on vector control. It explores similarity in attribute s and implement the real data among the 3 cities to build the conventional strategy. The result shows that this strategy is possible to be the best candidate system in an active practice in the future.

However, in order to convey the prototype to the actual implementation, it is needed to collaborate with the health authority in this country. There are many aspects should be considered regarding with technical implementation. The next future work is dealing with preparation in the real implementation of the small scope.

CHAPTER 6

Conclusion

This dissertation has addressed the problem in spreading of disease, the new disaster that killed more than 120 million people. Among the diseases, dengue fever is the fastest spreading all over the world. Dengue has spreads in 128 countries with more than 3 million victims. Because, on the one hand, increasing human mobility and climate change are increasing, the number of infected people and country of spreading are also dramatically increasing. On the other hand, the capability of managing the disease is limited due to the complex phenomena of spreading itself, i.e.: (1) Dynamic situation, (2) Realistic application, (3) Immeasurable variables of the spreading, and (4) Complexity in spreading.

Regarding the spreading of disease, this dissertation presented the new direction to combat the spreading of disease through three fundamental factors: 1) involving public participation in the system, (2) utilizing the sensible variable, and (3) performing action strategy that covers dynamic situation.

In this research, there are several new aspects, such as:

(1) Transforming the natural history of disease into time-state of spreading of disease.

(2) Changing the way to analyze the disease transmission, from the previous method: host-vector connection, to the weighting of meeting places. The Host-vector connection is unobservable, the meeting place is observable.

(3) The output of an existing prediction method is the number of the infected people; it is non spatial. The output this research is the number of infected areas; it is spatial. Using the new method, the government can monitor the spreading of disease easily by identifying the location of spreading.

(4) Increasing the feasibility to apply as the surveillance system in the real condition. The result of simulation by the real data shows that performance of the method in this research is better than the existing method.

(5) Performing the surveillance system which has high modularity. The two models in this research: the Location-Contraction Risk Model and Ecological Context-Dependent Strategy, have integrated to be applied as the vector control collaboration strategy in the real data of Surabaya, Kuala Lumpur and Bangkok. It means modularity of the models is high.

6.1 Future Work

The principal contribution of this research is tantamount to manage the spreading of disease with consider about the environmental and impact in public health. This dissertation is the starting point for future research.

6.1.1 Future Work of the Surveillance System

There are three points to address n the future work. First, a further exploration of the factor in disease spreading. Because of the dynamic changing in human activity, human health-behavior and environmental, pattern of disease probably might probably change as well. The challenge of the future research is to find the new sensible predictor and involving the human behavior in modelling of spreading.

Second, applying the integrated system in the actual condition online. The current version of the algorithm of spreading only covers the routine mobility. Meanwhile, in the future, the pattern of mobility is might be more random than routine. The system should be enhanced to be more adaptable in change.

Third, possibility to expand the geographic research plants to the similar spatial characteristic. It already started by collaboration with researchers in Kuala Lumpur and Bangkok to realize travel warning in three cities, by performing the common-risk assessment in dengue spreading.

6.1.2 Future of the Research

In this research, the surveillance system that involving public participation is started. It is part of community-based resilience to prevent the disaster. The research opposite to the current situation, where government or organization in charge of disaster managing the disaster by using top-down. The experience shows, top down management dealing with catastrophe is not effective, since they put the victim as an object. In the future, any feature that relates to public need in disaster will be explored more deeply, and put in the system. Future of the research will be about green technology in disaster management based on community needs.

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3. Wahjoe Tjatur Sesulihatien[1], Shiori Sasaki, Yasushi Kiyoki, Azis Safie, Subagyo Yotopranoto, Petchporn Chawakitchareon, Virach Sornlertlamvanich,, Aran Hansuebei, *Building the Prototype of Vector-Control Strategy Interoperability in Dengue Fever: Case Surabaya, Kuala Lumpur, Bangkok,* INFORMATION MODELLING AND KNOWLEGDE BASES Vol XXVIII, IOS Press (will be published in January 2017, accepted 13 pages).

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APPENDIX

Fusion Sensing for Analyzing the Natural History of Coral Disease

During my study, I got the opportunity to visit Thailand for internship. Under support of GESL, I conducted the research in coral conservation with the researchers from Chulalongkorn University, Thailand. This research is conducted in Sichang Marine Science Research and Training Station, Sichang Island, Thailand. This appendix describes the the result of my internship. We extracted the feature of the natural history of the coral disease by using fusion sensing data.

Introduction

The coral reef plays an important role in supporting marine life. The fact shows that the existence of coral is highly depending on their environmental. This research deals with the feature extraction of the healthiness of coral based on relation between the data from water sensor and image analysis. The result is expected to be guidance for daily monitoring in coral reef.

The Objective

The objective of this research is to analyze the behavior of the coral under specific circumstances. The Goniophora coral species is investigated in laboratory experiment under circumstance different water salinity. In the experiment, we investigate the activity of coral due to changing of water salinity , from 10 ppm (represent worst pollution) to 30 ppm (suitable environment As a confirmation data, the image data is utilized.

Methodology

We applied image processing to analyze the activity of Goniophora. Activity of coral is the important visible parameter that could be captured by image. We chose entropy of image and coverage object area of Goniophora to reflect the level of healthiness.

The scenario of image data captured is written based on the event detection: for daily monitoring, the image is captured from the beginning of light presence (in this case is 09.00), the maximum light intensity (in this case is 13.00) and the end of light intensity presence (17.00). Figure 1. shows the example of image data.

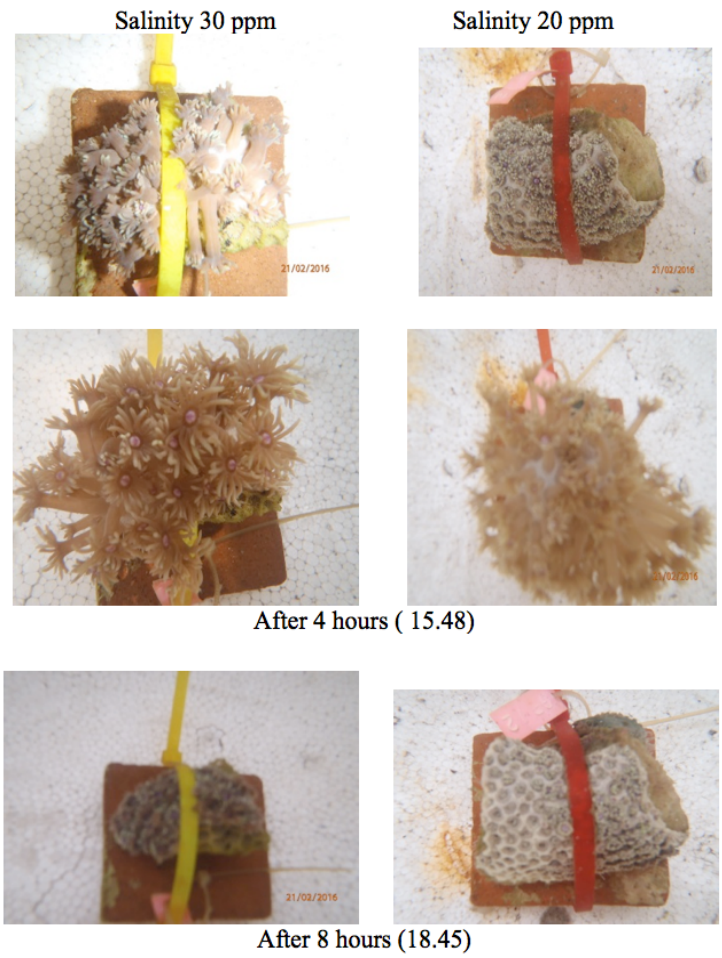

Figure 1. The image data of Goniophora in salinity 20 ppm and 30 ppm

Result and Discussion

The image was processed by image enhancement and image analysis to get the feature that reflecting the healthiness of Goniophora. The example result of image analysis is shown in Figure 2.

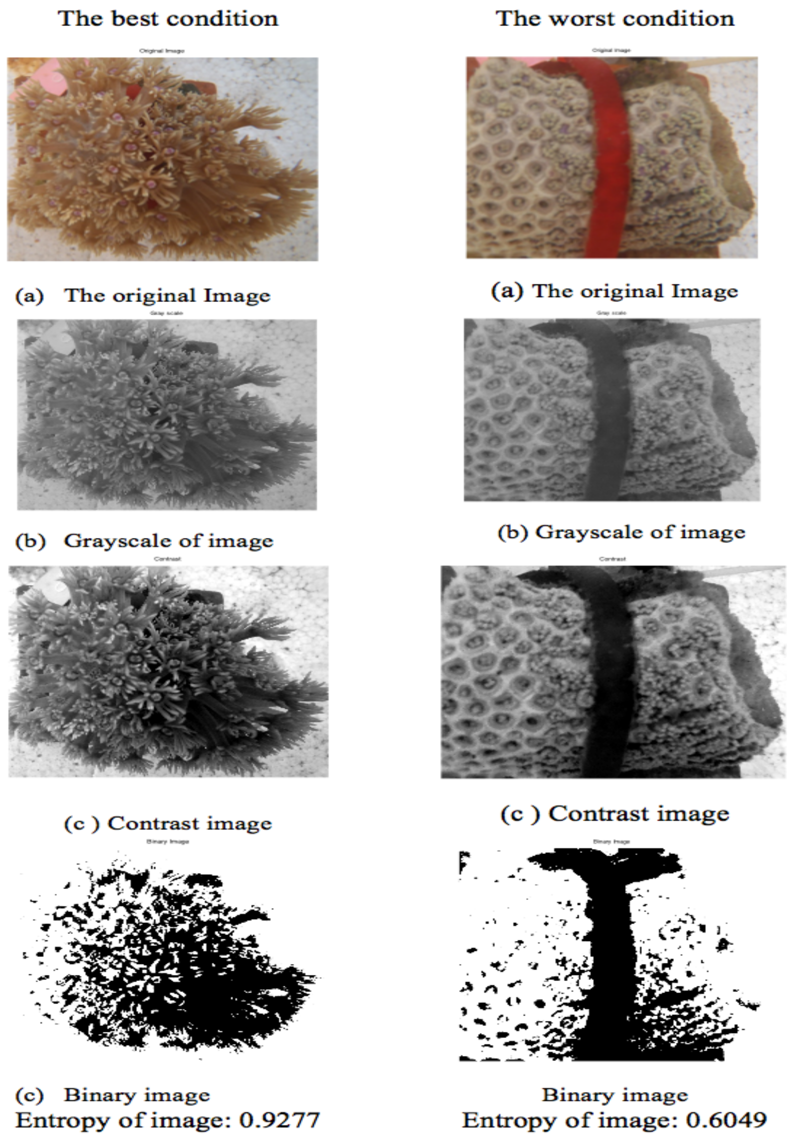

Figure 2. The result of image processing of the coral

Figure 2 shows the result of image analysis of health coral and death coral. Entropy image is a statistical measure of randomness that figure out the texture character of the image. In this research, the healthiness is indicated by entropy of image coverage area of Goniophora. The entropy of health coral and death coral is different. The figure indicates different texture of image of the sick coral and the healthy coral. Coral reefs are home of of thousands of tiny animals so called coral polyps; they are anemones and jellyfish. Polyps can live as an individual or live in group as a colony. If the polyp lives in suitable environment, they can catch their food: zooplankton, actively. Healthy coral is recognized from number of the polyp they have. The healthy coral have more polyps compare with the sick one. When the environment is not suitable for the polyp, they will die or move to another coral reef. It is recognized in texture of the image.

Another health indicator is tentacle. Tentacle acts as an arm to catch a prey during feeding. The tentacles out from its body, extending and wave in the water flow where they encounter small fish, zooplankton, bacterioplankton, or other food particles. In the healthy coral, the tentacle is active to wave everywhere, while in contrast, the tentacle of sick coral no longer moves. The differences are reflected in the coverage area of tentacle image.

The objective of coral monitoring is to detect the damage of coral. Thus, the feature of monitoring should relate to how long the coral will survive when the environment changing, and how to detect damage of coral as early as possible. In this research, we inspected the degradation of coral by their important event by laboratories experiment. The first inspection is detecting the early damage. We analyzed the first-four-hours of coral image and determine the damage. By expert justification, we determine the percentage of damage in the first-four-hours. The result is shown in Figure 3.

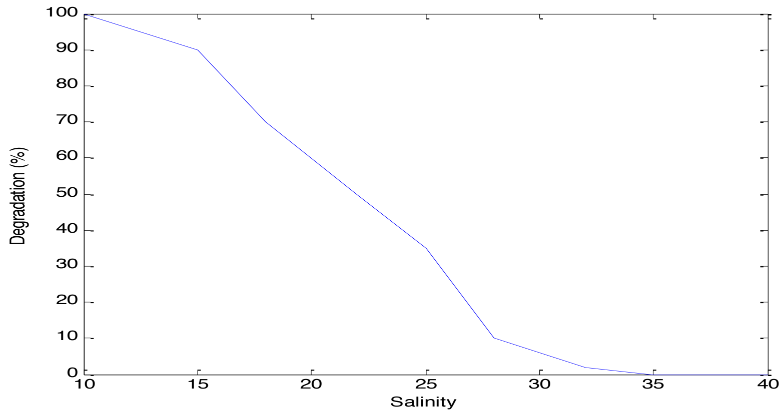

Figure 3. Degradation in first-four-hours of coral under different salinity

From figure 3, it is clear that the damage of the coral is inversely proportional to salinity concentration. The low salinity is usually found in the ocean shore line where the river and ocean meet, or where many people live in. The river or the people flow of the fresh water that decreasing the salinity of ocean water around it. The graph in figure 3 shows that degradation is decline sharply in salinity up to 28 ppm. While, in 28 ppm or above, the degradation is relatively small. The result shows that the ability to adapt in pollute water is tolerated until 28 ppm. The result is important for building early warning system in coral conservation. When the salinity decreases sharply, the coral should be moved in the better area.

As a first step in automated monitoring, this research has many limitations especially in image analysis. The difficulty in this research is inconsistency of image captured setting. It leads to ambiguity result of both texture and coverage area of object. In this research we success to analyze the extreme condition, but we failed to analyze in detail.

Conclusion

In this research, we investigated the important feature of the healthiness of coral through laboratories experiment. We observed the environmental signal data to acquire event of monitoring and the image data to evaluate the healthiness. The result shows that there are important event in health detection and the image data can express the healthiness by texture and coverage area. Moreover, experimental study shows that level of coral health degradation is appraised in the early investigation. This finding is important as a guideline for daily monitoring of coral healthiness. However, this research has limitation in image analysis. We need more feature to increase the accuracy of the system. In the next research, we will focus on the image-captured setting and explore more about the visible feature of healthiness.