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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต

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DEVELOPMENT OF A WEB-BASED SPATIAL DECISION SUPPORT SYSTEM FOR THE RISK ASSESSMENT OF ROAD ACCIDENT

Sippakarn Kassawat

A Thesis Submitted in Partial Fulfillment of Requirements for the Degree of Doctor of Philosophy in Geoinformatics

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DEVELOPMENT OF A WEB-BASED SPATIAL DECISION SUPPORT SYSTEM FOR THE RISK ASSESSMENT OF ROAD ACCIDENT

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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วัตถุประสงค์หลักของการศึกษานี้คือพัฒนาระบบสารสนเทศบนเครือข่ายเพื่อประยุกต์การประเมินความเสี่ยงการเกิดอุบัติเหตุบนถนนด้วยการบูรณาการการตัดสินใจโดยผู้เชี่ยวชาญแบบต้นไม้ (DEX approach) ร่วมกับการวิเคราะห์การถดถอยแบบปัวซอง (Poisson regression) และค่าเฉลี่ยถ่วงน้ำหนักของการจัดลำดับ (OWA) ระบบสามารถรองรับการปรับเปลี่ยนปัจจัยที่แตกต่างกันซึ่งส่งผลต่อการเกิดอุบัติเหตุและจำลองสถานการณ์ที่หลากหลายของสภาพสิ่งแวดล้อม วัตถุประสงค์ของการศึกษานี้คือ (1) เพื่อระบุจำนวนปัจจัยที่เกี่ยวข้องด้วยวิธีการวิเคราะห์ปัจจัย (Factor analysis) (2) เพื่อสร้างอัตราความเสี่ยงจากปัจจัยสิ่งแวดล้อมด้วยวิธี DEX-MADM ตามความต้องการของผู้ใช้แต่ละคน (3) สร้างแบบจำลองการประเมินความเสี่ยงของการเกิดอุบัติเหตุบนท้องถนนโดยใช้สมการถดถอยแบบปัวซอง และค่าเฉลี่ยถ่วงน้ำหนักของการจัดลำดับ (4) เพื่อพัฒนาระบบผ่านทางระบบเครือข่ายโดยอนุญาตให้มีปฏิสัมพันธ์กับที่ต้องการเลือกรูปแบบและการเปลี่ยนแปลงของคุณลักษณะด้านสิ่งแวดล้อม

ระบบสามารถแสดงข้อมูลที่เป็นประโยชน์ให้กับสาธารณะโดยระบบนี้ได้รับการพัฒนาให้อยู่บนของระบบเว็บเพื่อสนับสนุนการตัดสินใจ เชิงพื้นที่ (WSDSS) ซึ่งรองรับการเปลี่ยนแปลงของปัจจัยที่แตกต่างกันซึ่งมีผลต่อการเกิดอุบัติเหตุ ระบบนี้เอื้อให้สามารถปรับปรุงข้อมูลและกฎในฐานข้อมูล ผู้ใช้สามารถมีปฏิสัมพันธ์กับระบบในการปรับเปลี่ยนสถานการณ์สภาพสิ่งแวดล้อมได้และจะแสดงผลบนแผนที่ของ Google Map

ผลที่ได้รับจากการศึกษาระบุว่าความเสี่ยงของการเกิดอุบัติเหตุจะแตกต่างกันตามข้อมูลเรขาคณิตถนน ปริมาณการจราจร สภาพอากาศ และเวลาของแต่ละช่วงถนน ผลจากแบบจำลองแสดงให้เห็นว่าความเสี่ยงการเกิดอุบัติเหตุจะมีแนวโน้มสูงขึ้นเมื่ออยู่ในพื้นที่ชุมชนของจังหวัดนครราชสีมาที่มีการจราจรคับคั่งและมีจำนวนทางเชื่อมต่อเป็นจำนวนมาก ผลการตรวจสอบ Root Mean Square Error ในสถานการณ์เดียวกัน พบว่าผลจากแบบจำลองการถดถอยปัวซองมีความแม่นยำมากกว่าผลจากแบบจำลองค่าเฉลี่ยถ่วงน้ำหนักของการจัดลำดับ ในทุกทางหลวงที่ศึกษา

ซึ่งนำไปสู่การแสดงศักยภาพความเสี่ยงการเกิดอุบัติเหตุบนส่วนของถนนที่เพียงพอสำหรับการวางแผนและการบริหารจัดการเพื่อลดอุบัติเหตุได้

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา____________________

ปีการศึกษา 2558 ลายมือชื่ออาจารย์ที่ปรึกษา____________________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม____________________

SIPPAKARN KASSAWAT : DEVELOPMENT OF A WEB-BASED SPATIAL DECISION SUPPORT SYSTEM FOR THE RISK ASSESSMENT OF ROAD ACCIDENT. THESIS ADVISOR : ASST. PROF. SUNYA SARAPIROME, Ph.D. 157 PP.

DEVELOPMENT OF A WEB-BASED SPATIAL DECISION SUPPORT SYSTEM FOR THE RISK ASSESSMENT OF ROAD ACCIDENT

The main objective of this work is to develop a web-based system applying to risk assessment of road accident using integration of MADM decision tree (DEX approach), Poisson regression, and OWA models. It supports the changes of different factors affecting the road accident and shows the simulation of changing circumstances in various environmental conditions. The specific objectives of the study are as follows: (1) to identify a number of influencing factors using factor analysis; (2)to establish the rating of environmental factors using the DEX-MADA approach based on the situations varied according to the requirement of individual users; (3) to model the risk assessment of road accidents using the Poisson regression and OWA models; (4) to develop as a web-based system allowable for interaction of users' requirements on model selection and variation of environmental attributes.

The system can provide useful information to the public. It has been developed in form of the Web-based Spatial Decision Support System (WSDSS), which supports the changes of different factors affecting the accident. The system allows database and rule base to be updatable. It also allows user interaction in form of varying environment scenarios and result observation on Google Map.

The study results present that the risk of accidents will vary according to the data on road geometry, ADT, weather, and time of each segment. The model indicates that the road segments with high risk of accidents are in the community areas of Nakhon Ratchasima, where there is the traffic congestion and there are a number of connections to various blocks. The validation RMSE result on the same scenario found that Poisson regression model has more accuracy than OWA model in every studied highways. This leads to the conclusion that the identification of highly accidental potential of road segments is adequate for planning and management in road accident reduction.

School of Remote Sensing

Academic Year 2015

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Sippakarn Kassawat

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LIST OF ABBREVIATIONS

APMs	=	Accident Prediction Models
OWA	=	Ordered Weighted Averaging
WSDSS	=	Web Spatial Decision Support System
MADM	=	Multi Attribute Decision Making
DEX	=	Decision Expert
ADT	=	Average Daily Traffic
DOH	=	Department of Highways
GLM	=	Generalized Linear Modeling
SDSS	=	Spatial Decision Support System
DSS	=	Decision Support System
EFA	=	Exploratory Factor Analysis
CFA	=	Confirmatory Factor Analysis
GIS	=	Geographic Information System
MCA	=	Multicriteria Analysis
DBMS	=	Database Management System
MBMS	=	Model Base Management System
GUI	=	Graphical User Interface
MHOs	=	Medical Health Officers
SAS/OR	=	Statistics and Operations Research
SOWA	=	Spatial Ordered Weighted Averaging

LIST OF ABBREVIATIONS (Continued)

HPHS	=	Highest Potential Hot Spots
TCSP	=	Transportation, Community, and System Preservation
DMS	=	Decision Making System
SVM	=	Support Vector Machine
ANN	=	Artificial Neural Network
CFS	=	Correlation-Based Feature Selection
RBF	=	Radial Basis Function
LBS	=	Location Based Services
PW	=	Pavement Width
SW	=	Shoulder Width
DS	=	Design Speed
HC	=	Degree of Horizontal Curve
VG	=	Percentage of Vertical Grade
NSD	=	Non Sight Distance
RC	=	Number of Road Connection
IN	=	Number of Intersection
EFA	=	Exploratory Factor Analysis
PHP	=	Personal Home Page
HTML	=	Hypertext Markup Language
XML	=	Extensible Markup Language
Ajax	=	Asynchronous JavaScript and XML

LIST OF ABBREVIATIONS (Continued)

DOM	=	Document Object Model
DFD	=	Data Flow Diagrams
API	=	Application Programming Interface
KML	=	Keyhole Markup Language
JSON	=	JavaScript Object Notation
CSS	=	Cascading Style Sheets
JSP	=	JavaServer Pages
SQL	=	Structured Query Language
RMSE	=	Root Mean Square Error

CHAPTER I

INTRODUCTION

1.1 Background problem and significance of the study

In both developed and developing countries, traffic accidents have been known as one of the main causes of human and economic losses. This is a problem with great concern in developing countries because it is relatively serious and there are limited resources available to develop possible countermeasures for reducing this ever-growing problem (Berhanu, 2004). According to UN ESCAP report in 2004, the road accidents were an increasing worldwide problem. There were around one million deaths and over twenty-three million injuries per year, and around 85% of these fatalities were happened in developing countries. This has been a particularly urgent problem in developing countries because, although the Asia - Pacific region currently only has around 16% of the worlds motorized vehicle fleet, this region already contributes 44% of global road deaths (Ross and Melhuish, 2005). It was widely known that road accident had been a major problem in Thailand for years. According to Royal Thai Police report in 2010, 71,000 of road crashes occurred and took around 10,000 lives and cost the economy a loss of more than 232,000 million baht. In 1998, supported by the World Bank loan assistance, a comprehensive road safety master plan was developed by the Ministry of Transportation. This report clearly identified that the lack of knowledge with regard to road accidents was one of the major restrictions for road safety improvement in Thailand. The causes of accident need to be quantified in terms of its causal factors which could depend on geometric factors, traffic, weather, human behavior and the interactions among different factors. Nevertheless, it was substantially difficult and complex to understand human factors and their interactions with other factors that led to accidents. A possible solution to this problem was the development of accident prediction model based on the attributes that affect the accidents and could be quantified (Thailand Accident Research Center [TARC], 2009).

Accident prediction models (APMs) have been applied to various purposes; most frequently to estimate the expected accident frequencies from a number of roadway entities (highways, intersections, interstates, etc) and also to identify geometric, environmental and operational factors that are related to the occurrence of accidents. It is important to examine the nature of relationships between roadway, environmental and operational factors and, accidents, on the one hand, to understand the causal mechanisms involved in accidents and, on the other hand, to better predict their occurrence. APMs were path of inquiry often used to gain these insights (Reurings et al., 2006).

The literature reviews, involving the analysis of road accidents, have been executed and found that there were diverse ways and models used to analyze the work. Poisson regression model was the original one used as worldwide and it was acceptable because the number of accidents occurred were not continuous and cannot be removed. Also, it was a simple method to understand and gave the highest accuracy for forecasting (Greibe, 2003).

The Ordered weighted averaging (OWA) was another approach and offered to predict the analysis of accidents, which was among many possible techniques for ranking various criteria, ranging from simple scalar to complex models based on fuzzy logic (Bell, Schuurman, and Hayes, 2007). The OWA weights the analysis of accidents, and there are differences in each segment of road which may cause some values of the probability of accidents close to fact even more. The road safety condition can be assessed and existing hazardous locations can be identified using the accident prediction model. With different models based on the accident severity, the maintenance area can be prioritized and used as an effective maintenance strategy tool with the identified hazardous locations along the road section. Furthermore, the model can be implemented as a proactive tool for the future design of safer road features, too. Safety impact of various road design features can be figured out by the road planners and designers.

In the thesis, a system has been developed in a form of the Web-based Spatial Decision Support System (WSDSS), which supports the changes of different factors affecting the road accident and shows the simulation of changing circumstances in the commercial area. This may help in making decisions of improvement or additional safety measures to decrease the road accidents. The preparation of the system has already been developed.

1.2 Research objectives

The main objective of this work is to develop a web-based system applying to road accident assessment using integration of MADM decision tree (DEX approach) and Poisson regression and OWA models. It supports the changes of different factors affecting the road accident and shows the simulation of changing circumstances in various environmental conditions. The specific objectives of the study are as follows:

1. To identify a number of influencing factors using factor analysis.
2. To establish the rating of environmental factors using the DEX-MADM approach based on the situations varied according to the requirement of individual users.
3. To model the risk assessment of road accidents using the Poisson regression and OWA models.
4. To develop as a web-based system allowable for interaction of users' requirements on model selection and variation of environmental attributes.

1.3 Scope and limitation of the study

The scope and limitation of a research study is summarized below.

1) The risk assessment of accidents on the road is analyzed using 2 models - Poisson regression and OWA models.
2) The main factors for evaluating the risk of accidents on the road cover 4 groups of data:

   Road accident data,

   Road geometry data,

   Average Daily Traffic (ADT), and

   Environment condition.
3) The results of the risk assessment of accidents on the roads of the two models are compared in term of accuracy and application performance.
4) Accessing, analyzing, and displaying spatial data are processed through WSDSS developed, which allow users to interactively modify and select factors such as climate, period of time, and road conditions.

5) Study highways are located in Nakhon Ratchasima province and chosen from the ones having maximum accident recorded (Table 1.1) by the Department of Highways (DOH). They are: highway no. 2, 224, and 304.

6) The human behavior and their interaction with other factors are substantially difficult and complicated to identify. Therefore, they are not included as a factor in the analysis of the research.

7) Limitation of the data used in this study:

- Parts of input data of highway 2 are not updated or missing. Therefore, only parts with complete data are taken into account for the study.

- The ADT data are available only by a survey of the Department of Highways during time period of 7.00 a.m. - 7.00 p.m. It means that the results from the models are relied on the effective time of the day.

1.4 Study highways

Nakhon Ratchasima, or "Khorat," is the largest province in the northeastern (Isan) Thailand and locate on the western end of the Khorat Plateau, separated from the Chao Phraya Plain by the Phetchabun and Dong Phaya Yen mountain ranges.

Nakhon Ratchasima acts as a gateway to other provinces in the Northeastern part of Thailand. It is 259 kilometers away from Bangkok and has an area of around 20,494 square kilometers. In 2011, Department of Provincial Administration reported that Nakhon Ratchasima province had a population of 2,582,089 that making it the second largest province in term of population, and the largest in area.

According to the four year accident data (2007-2010) extracted from the road accident database developed by the DOH, on the average of 258 traffic accidents in Nakhon Ratchasima occurred along highways were presented in Table 1.1 and Table 1.2 (selected important highways).

Table 1.1 Traffic accidents in Nakhon Ratchasima occurred along highways during 2007 - 2010.

Highway No.	2007	2008	2009	2010	Total (Highways)	Percentage of occurrences
2	173	132	118	131	554	53.73
224	32	36	38	10	116	11.25
304	35	11	16	42	104	10.09
24	15	9	9	9	42	4.07
201	8	2	8	10	28	2.72
202	6	5	5	6	22	2.38
205	5	2	4	4	15	1.45
207	10	2	1	2	15	1.45
226	6	3	2	4	15	1.45
206	9	1	3	0	13	1.26
Total (Year)	299	203	204	218	924	89.87

Source: The road accident database developed by the DOH, 2007-2010.

Table 1.1 revealed, that highway No. 2 had the highest percentage of accident occurrences (54%), followed by highway No. 224 (11%), and highway No. 304 (10%).

Table 1.2 Injuries and fatality of traffic accidents in Nakhon Ratchasima during 2007 - 2010.

Highway No.	2007		2008		2009		2010		Total (Highways)	
	Inj.	Fa.	Inj.	Fa.	Inj.	Fa.	Inj.	Fa.	Inj.	Fa.
2	205	28	190	15	133	32	177	32	705	107
224	42	14	46	3	68	6	8	2	164	24
304	88	7	15	0	28	3	43	5	174	15
24	25	6	8	1	23	1	7	0	63	8
201	11	6	5	0	4	1	11	2	31	9
202	0	0	5	0	0	0	0	0	5	0
205	8	2	1	0	11	4	2	2	22	8
207	14	3	0	0	0	0	2	0	16	3
226	3	3	1	0	2	8	2	1	8	12
206	5	5	0	0	0	0	0	0	5	5
Total (Year)	401	74	271	19	269	55	252	44	1193	191

(Inj: Injuries, Fa: Fatality)

Source: The road accident database developed by the DOH, 2007-2010.

In addition, Table 1.2 showed the severity of accidents by the number of injuries and deaths in each route. It was evident that highways No. 2, 224, and 304 had highest number of injuries and deaths, respectively, which corresponded to the number of traffic accidents on highways.

According to the vast majority of accidents along the highways No. 2, 224, and 304, they were selected as study highways. The network of these highways in the province is shown in Figure 1.1.

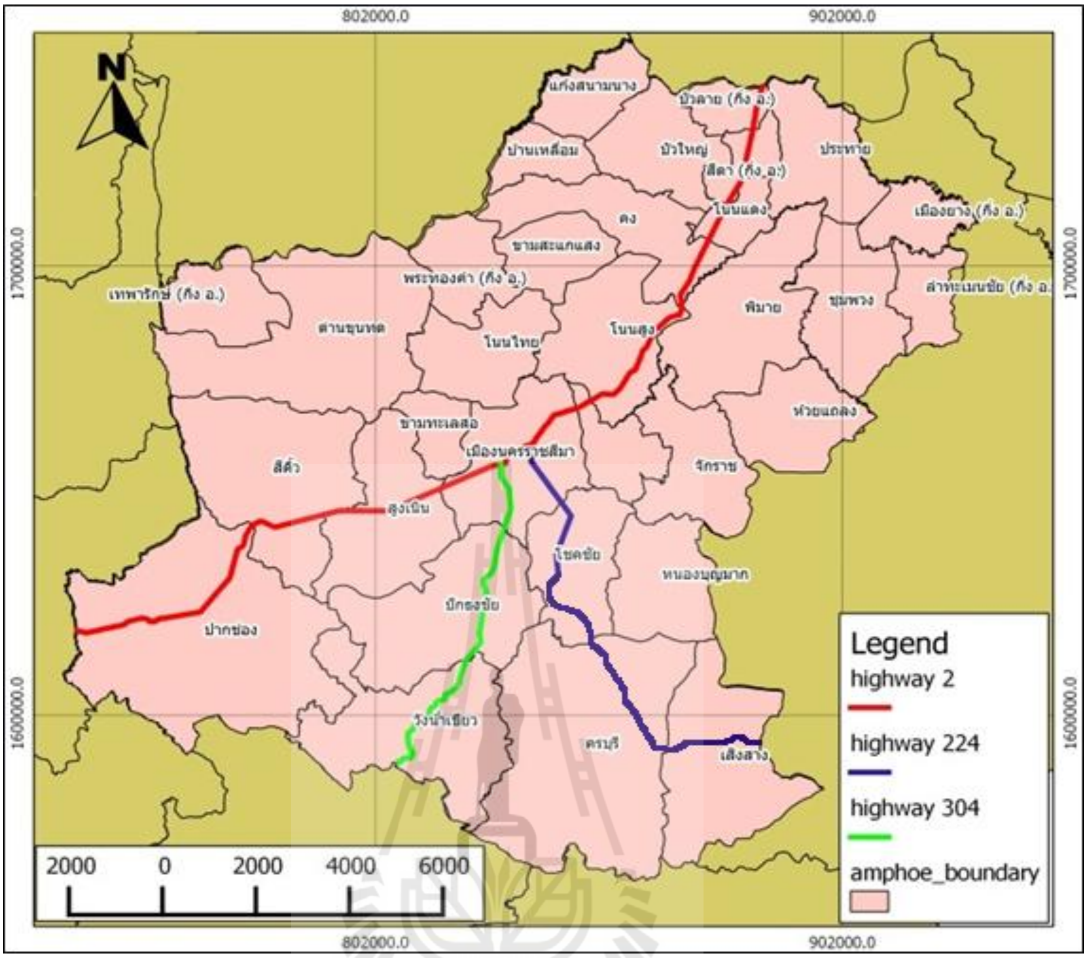

Figure 1.1 Highway network in the study area.

Highway No. 2, commonly known as Mittraphap Road, is a major arterial highway heading towards Northeastern part of Thailand with a total of 548 kilometers in length at present. It is the main route that connects 9 districts in Nakhon Ratchasima including Mueang Nakhon Ratchasima district. This route also connects Nakhon Ratchasima to Saraburi and Khon Kaen provinces. The total length of this highway passing through the province is 216.4 kilometers.

Highway No. 224, commonly known as Ratchasima - Chok Chai Road is a highway heading from Mueang Nakhon Ratchasima to Chok Chai Khornburi and

Soengsang districts. The line of focus is starting from station 0+000 to station 108+100 in Nakhon Ratchasima. The total length in this study is 108.1 kilometers.

Highway No. 304, commonly known as Kabin Buri - Pak Thong Chai is a major arterial highway heading from Khorat towards Eastern of Thailand with a total of 132 kilometers in length. It is the main route that connects 3 districts in Nakhon Ratchasima including Mueang district. This route also connects Nakhon Ratchasima to Prachin Buri and Chachoengsao provinces. The line of focus is starting from station 54+600 to station 132+500 in Nakhon Ratchasima. The total length in this study is 77.9 kilometers.

1.5 Synthesis for the research approach

The result of the literature review is concluded and used as a guide to establish the new approach for this research. The approach is focused on establishing ratings of environmental factors using the DEX-MADM so as to be further used in Poisson regression and OWA models implementing for risk assessment of road accidents, including developing a web-based system for the same purpose which allows users to interact with the system by means of model selection and variation of environmental attributes.

The conclusion from the review and the research approach can be discussed below.

1) The review revealed that the spatial analysis and modeling for risk assessment of road accident can be obtained by incorporating information on accident data, ADT, road geometry, land use, and environment condition which are further conveyed to employ in this research.

2) This study involves environment factors in the risk assessment, which has almost never been found in any previous studies. How to score the environment factors before input to the risk assessment model makes this involvement hardly to be possible. Therefore, this study applies DEX-MADA to aggregating environment factors to achieve final scores as input for risk assessment model.

3) A considerable effort has been devoted to developing understanding factors that contribute to road accidents and statistical models have also been chosen to predict accident frequencies under given traffic, road geometric and environmental factors. The generalized linear modeling (GLM) approach with the assumption of Poisson distributed error has been the choice among most of these models. Early researches in accident modeling established the adequacy of this modeling approach to estimate expected accident frequencies on highway segments. The models mentioned come under the category of fixed parameter models, where the model parameters are assumed to be the same for any individual observation in the population. In other words, the magnitude of influence of given explanatory variable on outcome is the same for any individual observation. In the case of accident prediction models, this means that the contribution of given explanatory variable on accidents is the same on any highway segment.

4) A new approach and contribute to road accidents risk assessment modeling suggests that it would be more challenge and appropriate to model accident frequencies with the OWA. One of the major characteristics of the OWA is that it allows decision-makers to change the form of attribute (criterion) combinations from a minimum-type (logical AND) combination through all intermediate types to a maximum-type (logical OR) combination. The OWA operators provide a new

technique for directly aggregating uncertain information with uncertain weights via the OWA mechanism in soft decision making and data mining, where these uncertain objects are modeled by fuzzy sets.

5) The study developed a web-based SDSS which is a new category of DSS. It has emerged which uses a spatial representation for displaying spatial data and supporting spatial modeling. The web-based SDSS includes a web-based geographic information system as a problem solver and facilitates geographic data retrieval, display, and analysis. Moreover, the system allows to adjust the values/scores/weights of basic factors and to select a given model so that resulting road accident risk assessments can be properly evaluated and chosen to implement.

CHAPTER II

LITERATURE REVIEW

Essential information, relevant theories, and previous research studies are reviewed in this chapter with emphasis on the 7 main topics of interest: 1) theories and related concepts of accident, 2) factor analysis, 3) multi-attribute decision making using decision expert approach, 4) Poisson regression model and maximum likelihood estimation, 5) OWA, 6) spatial decision support system, 7) web-based spatial decision support system.

2.1 Theories and related concepts of accident

Bureau of Highway Safety, DOH (2014) defined that traffic accident is an accident occurred on national highways resulting in death or injury and damaged property. Deery (1999) defined traffic risk perceptions as subjective interpretations of the risks involved in various traffic situations. The occurrence of accident can be contributed by six major sets of explanatory variables, i.e., transportation system, socio-economic condition, external environmental factors, data collection, randomness, and the countermeasures interventions. Some of these factors can be described by the accident prediction model that can identify the relationship between the independent variables causing the accidents and the dependent variables which are the number of accidents or their severity. This model is used to identify the black spot and to evaluate the effects of alternative design as countermeasures taken before and after studies (TARC, 2009). Understanding of the accident prediction model is rich in information, references, theories and literature as listed and described.

2.1.1 Theories of accident causation

Accidents are defined as an unplanned occurrence that results in injuries, fatalities, loss of production or damage to property and assets. Preventing accidents is extremely difficult in the absence of an understanding of the causes of accidents. Many attempts have been made to develop a prediction theory of accident causation; however, none has been universally accepted. Researchers from different fields of sciences and engineering have been trying to develop a theory of accident causation that will help identify, isolate and ultimately remove the factors that contribute to or cause accidents. The causes of accident are often described by using Domino theory.

Heinrich's Domino Theory

Heinrich's Domino theory states that accidents are caused by a chain of sequential events, like a line of dominoes falling over. When one of the dominoes falls, it triggers the next one, and the next…but removing a key factor (e.g. an unsafe condition or an unsafe act) prevents the start of the chain reaction. Heinrich posits five metaphorical dominoes labeled with accident causes, including Social Environment and Ancestry, Fault of Person, Unsafe Act or Mechanical or Physical Hazard (unsafe condition), Accident, and Injury. He defines each of these "dominoes" explicitly, and gives advice on minimizing or eliminating their presence in the sequence (The Rapid Results College [RRC], 2011).

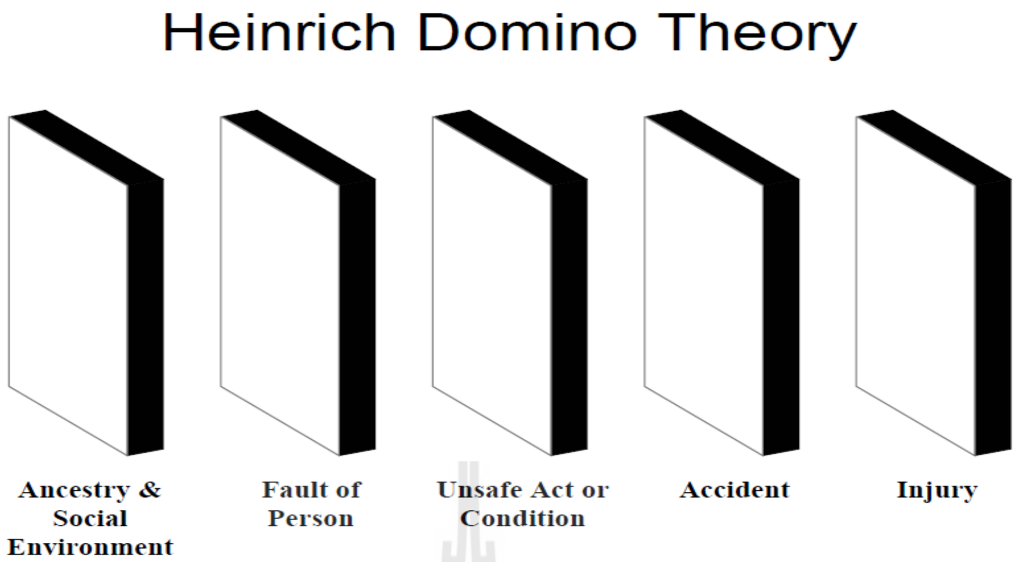

Figure 2.1 Heinrich domino theory.

Source: RRC (2011)

Five stages of accident causation is identified by Domino' Heinrich theory. Firstly, the social environment and ancestry encompass anything that may lead to produce undesirable traits in people. More precisely, this includes the nature and nurture aspects of someone's background.

Secondly, faults of a person refer to personal characteristics that possibly lead to accidents. For example, having a bad temper may result in spontaneous outbursts and disregard for safety. Likewise, general recklessness can be one of the manifestations of poor character, too. Ignorance, e.g. not knowing safety regulations or standard operating procedures, is also a good example.

Thirdly, an unsafe act or condition is often the beginning of a specific incident. This stage is closer to the accident in terms of temporal proximity, unlike the first two stages that affect the probability of accidents occurring. This can include a specific act that is unsafe, e.g. starting a machine without proper warning, or failing to perform appropriate preventative actions, e.g. using guardrails or other safety measures. Most importantly, this stage entails acts (or failures to act) that occasionally cause accidents.

Fourthly, it is the accident itself and only little explanation is needed. It is when something that is undesirable and not intended occurs. Finally, injury is the unfortunate outcome of some accidents. Whether an injury occurs during an accident is often a matter of chance and not always the outcome. The relationships between stages in terms of causality are highlighted by this relationship. An accident occurring is not a sufficient cause for an injury, but it is a necessary one. Likewise, the undesirable characteristics in stage two do not always occur in poor environments, but could not occur without such environments.

From this necessary causality, the most important policy implication is to remove one of the dominos (though try for more than one just to be safe); produce a healthy subculture through positive accident prevention training and seminars, attempt to weed out people with undesirable characteristics (or otherwise address said traits), and, if all else fails, have a procedure in place for dealing with accidents to minimize injury and loss (Haddow and Bullock, 2006).

One viewpoint in accident research is to identify factors that contribute to a specific accident and to elucidate its occurrence. In-depth accident analysis tries to apply causality to certain factors that led to the accident. The major components most often mentioned in literature and traffic accident research studies include: Human (H), Environment (E), and Vehicle (V). The Environment is most often only referring to the physical environment where the accident takes place, including everything referred to as the road and infrastructure. The sociological environment is also sometimes included or added (Haddon, 1972).

2.1.2 Variables effecting traffic accident

The literature reviews study evaluating accident databases and providing percentages of contributing factors prevalence shows that within the most important factors given by those studies, not a lot of sociological factors are either collected at all, or not presented.

(1) Traffic

(a) ADT: The traffic flow and traffic volume influence the risk of an accident. The higher is traffic volume the larger ratio between the number of accidents and the length of road section. This relationship is constant and approved by many countries (Pakalnis and Gužys, 2003). The annual average daily traffic showed a positive association with crashes (Kim, Lu, Xia, and Gerstein, 2006).

(b) Overtaking: The overtaking accidents are comparatively rare, even though they are quite common and typically fairly serious. They accounted for 7.9% of fatal road accidents in Nottinghamshire England (Clark et al., 1998).

(c) Speed: The speed dispersion between vehicles is also associated with the crash risk; especially for vehicles moving much faster than the other traffic around a higher crash-rate can be found (Aarts and Van, 2006).

(2) Road geometry

(a) Type of road: Motorways have much lower accident rates than other roads (Peek-Asa and Zwerling, 2003).

(b) Number of lanes: The compared of a higher crash incidence rate for 3 lanes, 2 lanes for accidents on inter urban motorways less than 400 vehicles/h of traffic flows (Martin, 2002).

(c) Junctions: This finding is also confirmed by a literature review on access points. The number of driveways per segment (as a measure of land-use) shows a positive association with the highway crash rate for multiple vehicle accidents also finds a positive association between the number of driveways and crashes (Kang, Washington, and Oh, 2006). The number of intersections shows a negative correlation with the highway crash rate for multiple and single vehicle accidents (Ivan, Wang, and Bernardo, 2000).

(d) Grade: A literature review indicates the following all studies concluded that accident frequency increases with gradient on downgrades. Some studies concluded that the same is true for upgrades (Hauer, 2001).

(e) Curves: The average crash rate to be 3 times higher on curves compared to tangents (Lyles and Taylor, 2006). This finding is confirmed by literature review from database evaluations in literature the road geometry (bends/curves) is among the most frequent risk factors attributed to accidents (Hauer, 2001).

(f) Shoulder: This is a positive correlation between shoulder width and the highway crash rate for single vehicle accidents (Ivan et al., 2000).

(g) Median width: The median width of the driveway showed a negative association with crashes (Kang, Washington, and Oh, 2006).

(h) Road width: Already general tendencies for increasing the lane width leading to a decrease in accident rate were discussed (Hauer, 2001).

(i) Ramps: These ramps show an effect of ramps on the crash risk on freeways (Abdel-Aty, Pande, Uddin, Dilmore, and Pemmanaboina, 2005).

(3) Road and environment condition

(a) Road Surface: The surface type is seldom analyzed as risk factor. However, the evenness has an influence on speed after global surfacing the accident rate increases. The risk of accidents on wet surfaces increases when the friction level of the road decreases (Carl-Gustaf and Henrik, 2001).

(b) Light conditions: Light conditions mainly depend on the time of the day and street lighting. However, the time of day is also associated with traffic flow, and thus a crash risk is also related to the type of road. The highway crash rate for multiple vehicle accidents was found to be positively associated with daytime between 6:00 a.m. and 19:00 p.m., whereas the highway crash rate for single vehicle accidents was higher for night-time between 19:00 p.m. and 6:00 a.m. (Ivan et al., 2000) . For crashes of all types, night-time crash risk is only slightly higher overall than daytime risk (Williams, 2003).

(c) Weather conditions: An increased risk for having a motor vehicle accident under adverse weather conditions was compared to not driving under adverse weather conditions in a case control study (Ivan et al., 2000). There is a higher relative risk for urban crashes during rainfall, especially the longer the dry period was before the rainfall (Keay and Simmonds, 2006). This was also shown for precipitation and fatal accidents (Eisenberg, 2004).

(d) Obstacles: On the trip level especially permanent obstacles are of interest. These refer to immobile objects and vehicles that are regarded as temporary immobile while parked. Mobile objects like vehicles, pedestrians, and animals are relevant on the driving task level. Visual obstacles were found to bear a population attributable risk proportion of 20% for child pedestrian accidents (Stevenson, 1997). A curb parking density of more than 10% compared to less than 5% shows an elevated risk for child pedestrian accidents (Roberts, Norton, Jackson, Dunn, and Hassall, 1995).

(e) Festive season: Accident statistic during long holiday showed that 5% of fatal accident took place during festive season in Malaysia (Mustafa, 2006).

(4) Vehicle type

Six classes of vehicles were found to be most commonly involved in work-related road traffic accidents. These were: company cars; vans/pickups, lorries, buses, taxis (including Hackney carriages and minicabs), and emergency vehicles. These top six vehicle categories covered over 88% of the sample as a whole (Clarke and Hagge, 2004). Comparison of crash statistics across various crash and vehicle types reveals several notable examples of over representation or under representation of particular vehicle types in particular crash types/roles. Collisions with different vehicle types often result in under ride/override due to geometric mismatching, and thus increases the risk for occupant compartment intrusion and thereby injury risk (Stigson, Ydenius, and Kullgren, 2006).

(5) Land use

Automobile-oriented land use patterns tend to increase per capita automobile travel, which tend to increase traffic crashes and causalities. The secondary retail and high density residential land use types are associated with all child pedestrian casualties (Dissanayake, Aryaija, and Wedagama, 2009). In addition, educational sites, junction density, primary retail and low density residential land use types are also associated with child casualties at different time periods of the day and week.

Accident and pollution exposure risks that often develop in lower-income countries as informal commercial and residential districts develop along highways. They recommends a combination traffic speed control, access management and better land use planning to reduce these risks (Litman and Fitzroy, 2016). Road geometric, road surface condition, land-use, traffic volume and driver's characteristic was the influence factors affected the number of accidents (Soemitro and Bahat, 2005).

(6) Demographic

(a) Age: Higher risks for young drivers were 16 to 17 year old drivers (yod), respectively (Williams, 2003). A 3 times higher crash rate for 16 to 20 yod compared to more than 25 yod, compared to 25 yod, and older finds an increased risk for younger than 25 yod (Hijar, Carrillo, Flores, Anaya, and Lopez, 2000; Zador, 1991).

(b) Gender: It is widely accepted that male drivers, especially of young age, have a higher risk for crashes (Al-Balbissi, 2003). A higher risk at fault crash for male's people already had at least one crash (Chandraratna, Stamatiadis, and Stromberg, 2006).

(c) Alcohol/Drug use: Enough evidence for an increased risk for crashes exists when being under the influence of alcohol. In addition an interaction between alcohol and being of young age due to physiological tolerance characteristics is known. Alcohol intake was found to bear an increased risk for motor vehicle accidents (Hijar et al., 2000; Movig et al., 2004).

(d) Residence: Experience of the area (site and also weather and road conditions) and of the traffic rules and their informal laws shows an influence on safe driving, when compared with foreign drivers. There was an increased risk for causing a collision for foreign drivers (OR between 1.2 and 2.1, depending on nationality) in

Spain (Lardelli Claret et al., 2002). The accident rate of foreign drivers is higher than for domestic drivers in Finland (Leviäkangs, 1998). The Independent factors can be concluded and displayed in Table 2.1

Table 2.1 Summary of variable effecting traffic accident.

Independent factors	Accidental causatives	Direction
ADT	The ADT showed a positive association with crashes (Kang et al., 2006). The ADT showed a higher risk for pedestrian accidents (Lee and Abdel-Aty, 2005)	+
	This is finds an increased risk for accidents at junctions at higher speed limits (Mountain, Maher, and Fawaz, 1998).	+
No overtaking	The overtaking accidents are comparatively rare, even though they are quite common and typically fairly serious. (Clark et al., 1998).	-
Number of lanes	The compared of a higher crash incidence rate for 3 lanes, 2 lanes for accidents on inter urban motorways less than 400 vehicles/h of traffic flows (Martin, 2002).	-
Pavement width	Already general tendencies for increasing the lane width leading to a decrease in accident rate were discussed (Hauer, 2000).	-
Degree of horizontal curve	The average crash rate to be 3 times higher on curves compared to tangents (Lyles and Taylor, 2006)	
Shoulder width	Several studies point to the fact that shoulder width is more beneficial to safety at higher traffic volumes than at lower ones (Hauer, 2000).	-

Table 2.1 Summary of variable effecting traffic accident (Continued).

Independent factors	Accidental causatives	Direction
Number of intersection	The complexity of junctions and the method of junction control seem to show an association with the crash rate (Kenneth, 1993).	+
Percentage of vertical grade	All studies concluded that accident frequency increases with gradient on downgrades. Some studies concluded that the same is true for upgrades (Hauer, 2000).	+
Day light (time)	For crashes of all types, night-time crash risk is only slightly higher overall than daytime risk (Williams, 2003).	-
Season (festive)	Accident statistic during long holiday showed that 5% of fatal accident took place during festive season in Malaysia (Mustafa, 2006).	+
Road condition	There is a higher relative risk for urban crashes during rainfall (Keay and Simmonds, 2006).	+
Weather	An increased risk for having a motor vehicle accident under adverse weather conditions was compared to not driving under adverse weather conditions in a case control study (Hijar et al., 2000)	+
Vehicle type	These were: company cars; vans/pickups, lorries, buses, taxis, and emergency vehicles. These top six vehicle categories covered over 88% of the sample as a whole (Clarke and Hagge, 2004).	+
Land use	Automobile-oriented land use patterns tend to increase per capita automobile travel. The secondary retail and high density residential land use types are associated with all child pedestrian casualties (Dissanayake et al., 2009).	+

Table 2.1 Summary of variable effecting traffic accident (Continued).

Independent factors	Accidental causatives	Direction
Age	Higher risks for young drivers were 16 to 17 year old drivers (yod) (Williams, 2003). Compared to 25 yod, and older finds an increased risk for younger than 25 yod (Hijar et al., 2000).	+
Gender	An elevated accident rate is found for males (Al-Balbissi, 2003). A higher risk at fault crash for male's people already had at least one crash (Chandraratna et al., 2006).	+
Alcohol/ Drug use	Alcohol intake was found to bear an increased risk for motor vehicle accidents (Hijar et al., 2000). In a prospective case control study an increased risk for motor vehicle accidents with the use of alcohol (Movig et al., 2004).	+
Residence	Experience of the area (site and also weather and road conditions) and of the traffics rules and their informal laws show an influence on safe driving, when compared with foreign drivers. There was an increased risk for causing a collision for foreign drivers in Spain (Lardelli Claret et al., 2002).	+

2.2 Factor analysis

Factor analysis is a statistical method used to describe variability among observed variables in terms of a potentially lower number of unobserved variables of this study. Factor analysis is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables (Tryfos, 2001).

There are basically two types of factor analysis: exploratory and confirmatory.

- Exploratory factor analysis (EFA) attempts to discover the nature of the constructs influencing a set of responses.
- Confirmatory factor analysis (CFA) tests whether a specified set of constructs is influencing responses in a predicted way.

Both types of factor analyses are based on the Common Factor Model, illustrated in Figure 2.2. This model proposes that each observed response (measure 1 through measure 5) is influenced partially by underlying common factors (factor 1 and factor 2) and partially by underlying unique factors (E1 through E5). The strength of the link between each factor and each measure varies, such that a given factor influences some measures more than others.

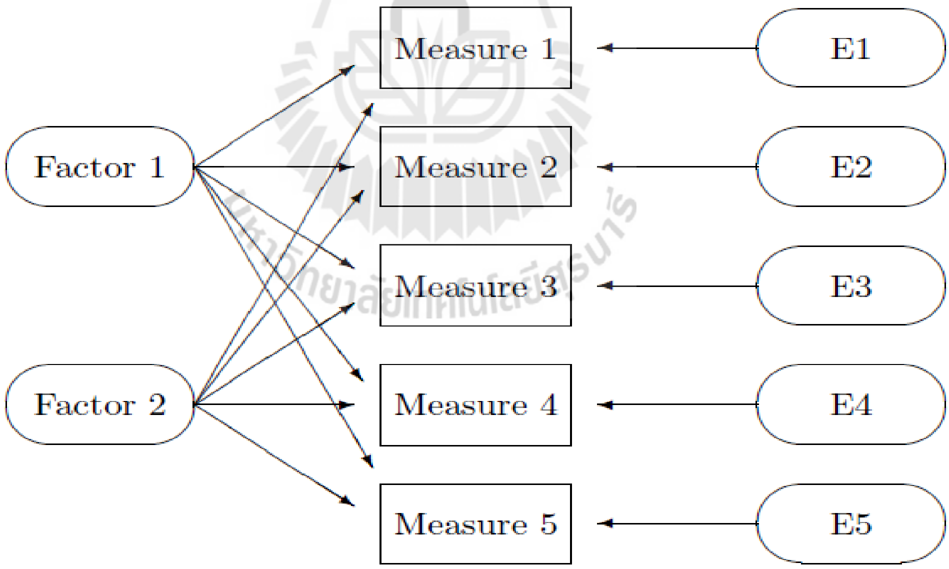

Figure 2.2 The Common Factor Model.

Source: Tryfos (2001)

They are performed by examining the pattern of correlations (or covariance) between the observed and measures. The same factors likely influence the measures that are highly correlated (either positively or negatively), whereas those that are relatively uncorrelated are likely influenced by different factors (DeCoster, 1998). It has been suggested that these grades are functions of two underlying factors, F1 and F2, tentatively and rather loosely described as quantitative ability and verbal ability, respectively. It is assumed that each Y variable is linearly related to the two factors, as below:

$$\begin{aligned} Y1 &= \beta_{10} + \beta_{11}F1 + \beta_{12}F2 + e1, \\ Y2 &= \beta_{20} + \beta_{21}F1 + \beta_{22}F2 + e2, \text{ and} \\ Y3 &= \beta_{30} + \beta_{31}F1 + \beta_{32}F2 + e3. \end{aligned} \tag{2.1}$$

The error terms, e1, e2, and e3, serve to indicate that the hypothesized relationships are not exact. In the special vocabulary of factor analysis, the parameters β_{ij} are referred to as loadings. For example, β_{12} is called the loading of variable Y1 on factor F2 (Tryfos, 2001).

2.3 Multi-attribute decision making (MADM) using decision expert (DEX) approach

The MADM method is one of the decision-making support methods which is based on a selected list of criteria, parameters, variables or factors, which we usually monitor in the decision making process (Bohanec and Rajkovic, 1999). The multi-attribute decision making theory provides a formal base for the establishment of a model and the key criterion is the interconnectedness of assessments based on the individual parameters that produces an integrated assessment (Arh and Blazic, 2007). A decision tree is a potential method for studying traffic accident severity and an advantage of this method is that decision rules can be extracted from its structure. In addition, we can use these decision rules to identify safety problems and establish certain performance measures (Abellan, Lopez and Ona, 2013).

The development of an expert system shell for multi-attribute decision support DEX (Bohanec and Rajkovic, 1990) has been the contribution to these fields which is designed as an interactive expert system shell that offers tools for building and verifying a knowledge base, evaluating options and explaining the results. The structure of the knowledge base and evaluation procedures nearly comply with the multi-attribute decision making paradigm and this therefore makes the system specialized for decision support (Pipan, Arh, and Blazic, 2008).

As for the knowledge representation in DEX, the methodology of hierarchical decision models is composed of attributes X_i and utility functions F (Figure 2.3). Attributes are variables that represent decision sub-problems. It has been developed and extensively used relating to multi-attribute decision support. The structure of the knowledge base and evaluation procedure almost comply with the multi-attribute decision making paradigm. A particular knowledge base of DEX includes (1) a tree of attributes and (2) utility functions (Bohanec and Rajkovic, 1999; Bohanec, 2011):

1) A tree of attributes is the structure of a given decision problem. We can create these attributes according to their interdependence, i.e. a higher-level attribute depends on its descendants (sons) in the tree. The leaves of the tree, as basic attributes, depend solely on the option characteristics. The tree's internal nodes

are called aggregate attributes and their values are defined according to the basis of utility functions. The most important aggregate attribute is the root of the tree. The purpose of this tree is to represent the overall utility of options.

2) Utility functions define the process of aggregation of lower-level attributes into the corresponding higher-level fathers. For each aggregate attribute Y, the decision maker should define a utility function *F* that maps values of sons of X into values of X.

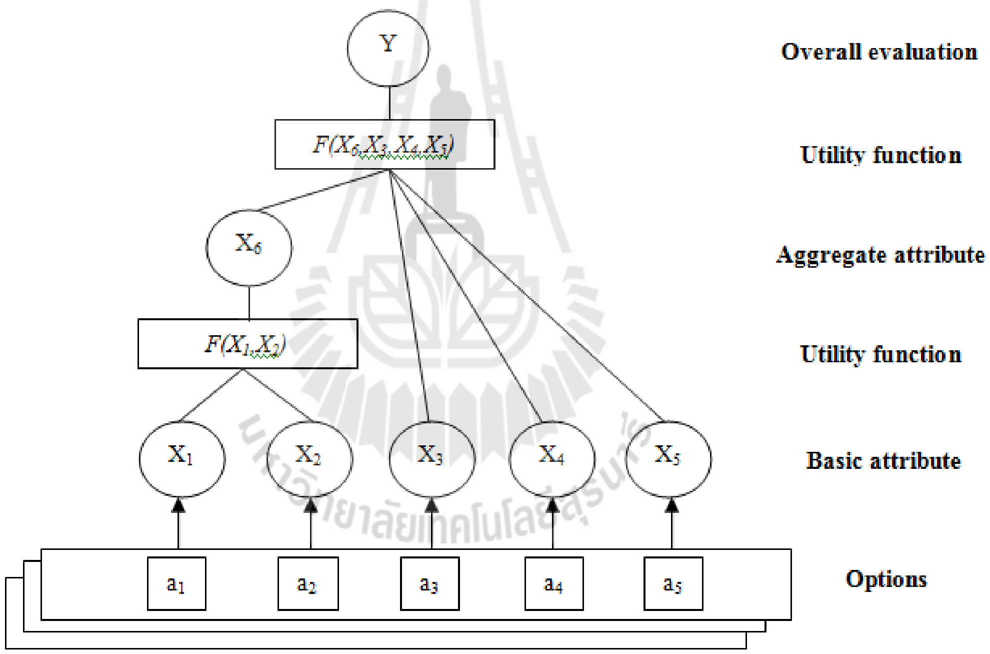

Figure 2.3 Components of a hierarchical decision model (Bohanec, 2011).

A hierarchy is represented by a directed cyclic graph, but in practice it is usually simplified to a tree. Figure 2.3 shows an abstract model that consists of five basic attributes X_1 to X_5, and two aggregate attributes, X_6 and Y. For each aggregate attribute there is a corresponding utility function *F* that determines the dependency of that attribute with respect to its immediate descendants in the hierarchy.

A utility function maps all the combination of the lower-level basic attributes into the values of Y. The mapping is represented in a table, where each row gives the value of *F* for one combination of the lower-level basic attributes. Row are also called decision rules, because each row can be interpreted as an if-then rule of the form:

If X_1 = $value_1$ and X_2 = $value_2$ and … and X_n = $value_n$ then Y = value1

Options are represented by values a_i of basic attributes. The evaluation of options is performed by an aggregation that is carried out from bottom to the top of hierarchy according to its structure and defined utility functions. The overall evaluation of an option is finally represented by the value of one or more root attributes (Y in Figure 2.3).

2.4 Poisson regression model and maximum likelihood estimation

poisson regression model

Poisson models deal with discrete data so that they have most of desirable characteristics to describe vehicle collisions of positive number and random attribution. Nevertheless, these models may produce wrong coefficients and wrong standard errors if data has excessive variance, and it has been problem to apply this model because variables that elucidate the number of accidents were categorized data (Kim et al., 2005).

Fundamentally, accident follows a Bernoulli trial with unequal probability of independent events that is also known as Poisson trial. A binomial trial is an experiment with two possible outcome, success or failure. The probability of success is the same in each of the trial and each of the trial is independent of other trials. If P is the probability of success, binomial distribution is given as:

$$\mathrm{P}(\mathrm{Y}=\mathrm{y})=\binom{\mathrm{N}}{\mathrm{y}}\mathrm{P}^{n}(1-\mathrm{P})^{\mathrm{N}-\mathrm{y}}, \tag{2.2}$$

where $n = 0, 1, 2 \ldots \mathrm{N}$,

N = no. of trial,

y = no. of accidents.

For typical accident cases, the number of trial *N* is very large and the probability of occurrence of accident, for example, success is very low and it is not the same in each of the trial. Let the expected number of accident occurrence be λ, then the $P = \lambda/N$ in with N number of trial.

Then as $N \rightarrow \infty$, Poisson distribution is given as:

$$\cong \frac{\lambda^{y}}{y!}e^{-\lambda} . \tag{2.3}$$

The mean and variance of Poisson distribution are:

$$E(y) = \lambda, \text{ and} \tag{2.4}$$

$$VAR(y) = \lambda. \tag{2.5}$$

Maximum likelihood estimation

Maximum likelihood estimation was used to estimate for parameters given data of this study. Maximum likelihood estimation is a way that finds the most likely value for the parameter based on the data set collected. A handful of estimation methods existed before maximum likelihood, for example, least squares, method of moments, and Bayesian estimation. This review will discuss the development of maximum likelihood estimation, the mathematical theory and application of the method, including its relationship to other methods of estimation. A basic knowledge of statistics, probability theory, and calculus is assumed (Evans, 2008).

The principle of maximum likelihood estimation originally developed by R.A. Fisher in the 1920s, states that the desired probability distribution is the one that makes the observed data "most likely" which means that one must seek the value of the parameter vector that maximizes the likelihood function $L(\lambda|\mathrm{y})$. The resulting parameter vector, which is sought by searching the multi-dimensional parameter space, is called the MLE estimate (Myung, 2003).

From Poisson distribution to model the data:

$$y_i \sim_{iid} \text{Poisson}\ (\lambda),$$

where λ is the mean of the Poisson distribution,

$$L(\lambda|\mathrm{y}) = \prod_{i=1}^{n} \frac{\lambda^{yi} e^{-\lambda}}{yi!}. \qquad (2.6)$$

To make the math easier, it will take the log-likelihood.

$$\sum_{i-1}^{n}(y_i \ln \lambda) - n\,\lambda. \tag{2.7}$$

A doubly semi-parametric zero-inflated in Poisson model to fit data of this type, which assumes two partially linear link functions in both the mean of the Poisson component and the probability of zero. Xuming, Hongqi X, and Ning-Zhong (2010) study a sieve maximum likelihood estimator for both the regression parameters and the nonparametric functions. They state, under routine conditions, that the estimators are strongly consistent. Moreover, the parameter estimators are asymptotically normal and first order efficient, whereas the non-parametric components achieve the optimal convergence rates. Simulation studies suggest that the extra flexibility inherent from the doubly semi-parametric model is gained with little loss in statistical efficiency.

2.5 Ordered weighted averaging

OWA operator that was initially introduced by Yager (1988) has attracted much interest among researchers. Since then several applications of the OWA operators are reported in different areas, for example decision making, expert systems, neural networks, group decision making, and fuzzy systems and control. Many more applications of OWA are recently reported in various criteria decision making and preference ranking (Malczewski, 2006). Synthesizing judgments is an important part of various criteria decision making methods. The typical situation concerns individuals which form quantitative judgments with regard to a measure. These classical operators are offered in order to obtain a consensus of these judgments: arithmetic means, geometric means, root power means, quasi arithmetic means, fuzzy integrals and among them the OWA aggregators (Makropoulos and Butler, 2006). The traditional OWA operator models an aggregation process in which a sequence A of n scalar values are ordered decreasingly and then weighted based on their ordered position by means of a weighting vector.

W = (w_i), such that $w_i \in [0; 1]$, and $\sum_i^n w_i = 1$. In particular, if c_i represents the i th largest value in A,

$$\mathrm{OWA}(A) = \sum_{i=0}^{n} w_i c_i, \qquad (2.8)$$

The OWA's main strength is its abilities, since it enables us to model a whole range of aggregation strategies. Moreover, the reordering of the arguments introduces an element of non-linearity into an otherwise linear process (Cornelis, 2010). The tradeoff measure specifies the degree of compensation or substitutability between criteria. It indicates the compensation of low values on one criterion by high values on another criterion (Jiang and Eastman, 2000). They use two parameters, ANDness, ORness, and TRADEOFF, to characterize the nature of an OWA operation:

$$\text{ANDness} = (1|(n-1))\sum((n-i)\text{Worder } i), \qquad (2.9)$$

$$\text{ORness} = 1\text{-ANDness}, \tag{2.10}$$

$$\text{TRADEOFF} = 1\text{-}\sqrt{\frac{\sum(\text{Worder i}-1/\text{n})^2}{\text{n}-1}}, \tag{2.11}$$

where n is the total number of factors, i is the order of factors, and Worder i is the weight for the factor of the i order.

A geographic information system (GIS) is used for constructing the index. It employs a GIS-based OWA, and multicriteria analysis (MCA) as techniques to validate deprivation indices that are constructed using more qualitative data sources. Both OWA and traditional MCA are well-known and used methodologies in spatial analysis.

2.6 Spatial decision support system (SDSS)

A SDSS approach is a combination of DSS and GIS. It is an interactive computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial decision problem (Malczewski, 1999).

An advantage of the SDSS is the seamless integration of the model portion of the DSS with the graphical representation of the GIS, thereby aiding decision makers with semi-structured or unstructured spatial problems. Crossland, Wynne, and Perkins (1995) determined that SDSS, through visualization, and enabled decision makers to complete their tasks quicker, more efficiently, and with greater understanding of the problem.

It is also a system that provides a framework for integrating analytical modeling capabilities, database management systems, graphical display capabilities, tabular reporting capabilities, including decision makers' expert knowledge.

Based on its characteristics, the SDSS is normally made up of five modules (Baloye, Adesina, and Kufoniyi, 2010).

(1) Database management system (DBMS) containing the functions of manipulation of the geographical database, that is, the module that stores the spatial data that will be used for the analysis.

(2) Model base management system (MBMS) containing the functions for model use and management. That is, the module that stores various models relevant to the application at hand and the parameters required to build such model.

(3) Dialogue generation and management system which manages the interface between the user and the rest of the components of the system.

(4) A report generator.

(5) Graphical User Interface (GUI), wherein the parameter for the models and queries are entered.

2.7 Web-based spatial decision support system (WSDSS)

Despite highly appealing, the SDSS based on traditional GIS requires sophisticated hardware and capital intensive resources, and these restrictions hindered their adoption. With the development of the internet, WSDSS has been developed, adding Internet interface programs to the computational models and geographic databases of the SDSS, in order to give geographic information and decision support through the Web (Rozakis, 2010).

The WSDSS includes a web-based geographic information system as a problem solver and facilitates geographic data retrieval, display, and analysis. It combines several different components including user interfaces, Internet interface programs, computational models and geographic databases. There are two ways to set up a WSDSS: a) server-side processing, and b) client-side processing. The server-side approach uses a thin client and most of the processing, including spatial data access and manipulation is performed on the server side. The resulting information and image objects are then sent to the client to be rendered. The client-side processing approach uses a thick client in which GIS functionality is preloaded on the client machine and only the geographic data is accessed from one or more servers. The server-side WSDSS requires only a browser installed on the client machine to carryout SDSS tasks. But, every user action requires communication between the client and the server (Sugumaran and Ramanathan, 2005). The structure and components of WSDSS can be displayed in Figure 2.4.

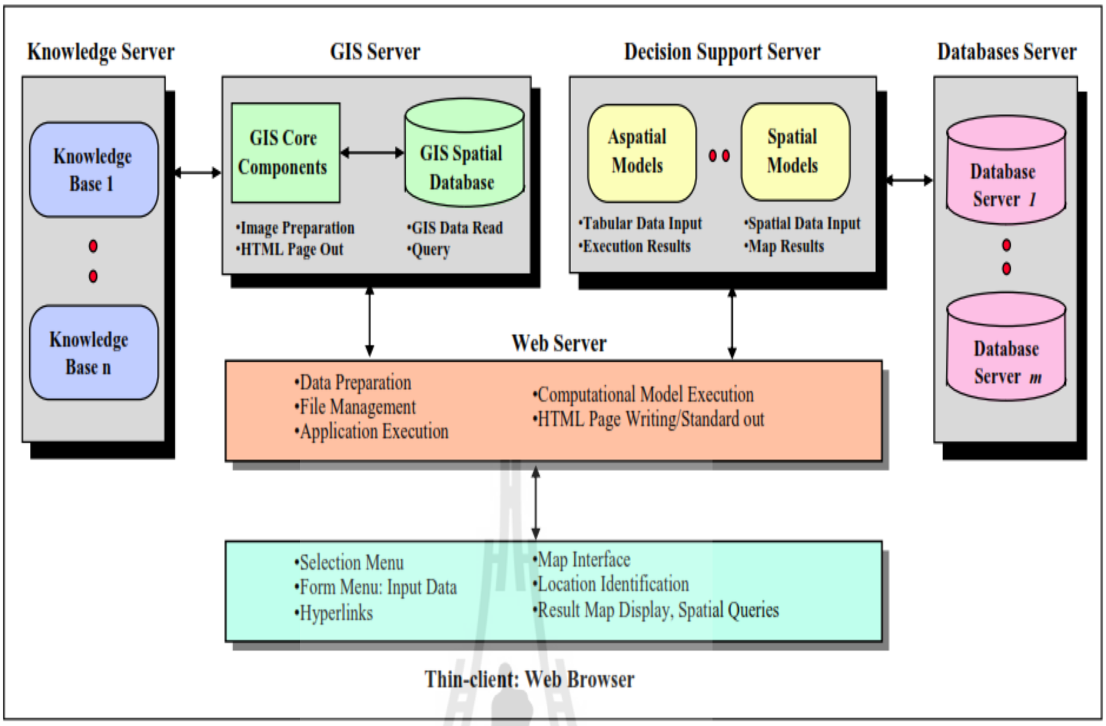

Figure 2.4 Schematic representation of the WSDSS components.

Source: Sugumaran and Ramanathan (2005).

2.8 Previous studies

The studies of spatial analysis for road accident risk assessment have involved many researches, and this was a model of the concept and can be used as a guide for this study.

2.8.1 Accident prediction model

To have better understanding of the accident prediction model, the previous studies will be described here as below:

Eisenberg (2004) developed an accident prediction model using negative binomial regression. The study was based on accident data for California. The accident frequencies were predicted in terms of fatality, injury and Property damage only on the basis of month and day with the inclusion of weather variables e.g. the amount of precipitation and snowfall. Increase in magnitude of these variables was found to be decreasing the monthly frequencies of accident while following the reverse trend in the prediction of daily frequencies of accident with the same variables.

Jones and Jorgensen (2003) introduced the potential of a recently developed form of regression models, known as multi-level models, for quantifying the various influences on casualty outcomes. The application of multi-level models is illustrated by the analysis of the predictors of outcome amongst over 16,000 fatally and seriously injured casualties involved in accidents between 1985 and 1996 in Norway. Risk of fatality was found to be associated with casualty age and sex, including the type of vehicles involved, the characteristics of the impact, the attributes of the road section on which it took place, the time of day, and whether alcohol was suspected. After accounting for these factors, the multilevel analysis revealed that 16% of unexplained variation in casualty outcomes was between accidents, whilst 1% was associated with the area of Norway in which each incident occurred. The benefits of using multilevel models to analyze accident data are discussed together with the restrictions of traditional regression modeling approaches.

Dinu and Veeraragavan (2011) had an assumption of Poisson or negative binomial error structure, which has been widely employed in road accident modeling. A number of explanatory variables related to traffic, road geometry, and environment that contribute to accident occurrence have been identified and accident prediction models have been offered. The accident prediction models reported in literature largely employ the fixed parameter modeling approach, where the magnitude of influence of an explanatory variable is considered to be fixed for any observation in the population. Similar models have been proposed for Indian highways too, which include additional variables representing traffic composition. The mixed traffic on Indian highways comes with a lot of variability within, ranging from difference in vehicle types to variability in driver behavior. This could result in variability in the effect of explanatory variables on accidents across locations. Random parameter models, which can capture some of such variability, are expected to be more appropriate for the Indian circumstances. The present study is an attempt to employ random parameter modeling for accident prediction on two-lane undivided rural highways in India. Three years of accident history, from nearly 200 km of highway segments, are used to calibrate and validate the models. The results of the analysis suggest that the model coefficients for traffic volume, proportion of cars, motorized two-wheelers and trucks in traffic, and driveway density and horizontal and vertical curvatures are randomly distributed across locations.

Caliendo, Guida, and Parisi (2007) developed the crash prediction model for the multilane roads in Italy express the relationship between the geometric infrastructure, traffic flow and environmental factors using five years historical data. Generalized linear models, i.e. Poisson regression, Negative Binomial and Negative Multinomial regression, were used for curves and tangents for all crashes and severe crashes. The variables included were length, ADT, curvature, sight distance, side friction coefficient, longitudinal slope and presence of junction. It was found that the variables, e.g., length, curvature and ADT are only the significantly influential factor for accident prediction model at curve sections. Likewise, length, ADT and junctions are the significant factor for the accident prediction at tangent section. The likelihood ratio goodness of fit was used to assess the model. Negative multinomial regression model has the greatest total and systematic variation elucidated and then followed by negative binomial and Poisson regression model.

Greibe (2003) used generalized linear model in the accident prediction model of urban area in Italy. Poisson regression model was formulated to estimate the expected number of accidents in intersection and road section for motorways in Italy. In this study, data (e.g. speed limit, ADT, road width, number of lane, speed reducing measures, cyclist facilities, central island, parking facilities, bus stop and land use) were collected from 142 km section of road. All variables were included in the analysis, but after that the insignificant variables were removed. The results revealed that the accident limit significantly affects the accident occurrence in the road section. The speed limit of 60 km/hr can cause more accident than the 50 km/hr. while 70 km/h. has the least effect. The finding concludes that the high speed roads tend to have few vulnerable road users. Likewise, the accident with lane width ranging from 5.0 to 7.5 m has relatively larger number of accident occurrence. The ADT variable also has a significant effect in which the accident frequencies are related to the ADT raised to power of 0.8. Other variables (e.g., parking, land use, and number of minor side roads) also have an influential impact to accidents that result in higher number of accidents with increase in each magnitude. The ADT, a four continuous variable, was the most significant factor followed by the land use and the minor number of side roads.

A survey of British Columbia's Medical Health Officers (MHOs) was used to populate the MCA-based index. Seven variables were selected and weighted based on the survey results. OWA variable weights assign both local and global weights to the index variables using a sliding scale, producing a range of variable scenarios. The local weights also give leverage for controlling the level of uncertainty in the MHO response scores. This is distinct from traditional deprivation indices in that the weighting is simultaneously dictated by the original respondent scores and the value of the variables in the dataset (Bell, Schuurman, and Hayes, 2007). The optimization procedures in SAS/OR software with application to the OWA operators of decision-making (Emrouznejad, 2008).

The OWA was originally has gained much interest among researchers, hence many applications in the areas of decision making, expert systems, data mining, approximate reasoning, fuzzy system and control have been proposed. To facilitate the use of OWA operator by SAS users, a code was implemented. An example is given to illustrate the features of the proposed macro (Yager, 1988). The road safety performance of countries is conducted by combining seven main risk indicators into one index using a particular weighting and aggregation method. Weights can be determined with respect to the assumed significance of the indicator, whereas aggregation operators can be used to stress better performances differently from worse performances irrespective of the indicator’s meaning. In this research, both expert weights and ordered weighted averaging operators are explored, evaluated and integrated resulting in a ranking of countries based on a road safety index (Hermans, Brijs, and Wet, 2009).

The decomposition analysis aggregation approach to multi-criteria spatial decision-making and proposes a novel aggregation method applicable to problems of the object-location or suitability for application type, concentrating on methodological rather than software development aspects. The choice of methodology used for this aggregation is very important as different aggregating techniques may yield different results to the (same) original problem. The method presented here, which is in effect an extension of the OWA method into a spatial decision-making technique, is termed spatial ordered weighted averaging (SOWA). The main advantage of the method offered is the incorporation of spatially variable attitude to risk into the decision-making process. The mathematical background of the method and an example of its application in urban water management are presented and discussed. The authors suggest that the method could be useful as an analytical and decision-making tool for the incorporation of spatially variable risk perception in GIS-based decision support systems (Makropoulos and Butler, 2006).

2.8.2 Accident prediction model in GIS

Early researches that have studied the predictive analysis of accidents have conducted on the GIS system as described below.

Gundogdu (2010) developed methods to obtain maps to determine traffic Hot Spots in Konya, Turkey, by applying linear analysis supported by GIS. Hot Spot analysis is known method but the study differs from former researches at the point of determining of risky zones, classification and illustration of them on the maps with the different accident parameters. The purpose is not to contribute another Hot Spot analysis using a number of statistical methods, but to determine the Highest Potential Hot Spots (HPHS), which are inter-sectional clusters, and to use different parameters, e.g. number of accidents, fatalities and injured, and accidents with only financial loss. Additionally, apart from classical illustrational techniques, HPHS on roads divided into 1 km segments are shown by their grading based on their numerical values. Hence, thematic illustration distinguishes them from others. The main intention of this study is to emphasize the importance of using criteria, other than total accident number, to illustrate intersection Hot Spots and to constitute a model of accident severity and variety. It is anticipated that the results obtained from highway accidents data will guide improvement of the route segments.

Erdogan, Yilmaz, Baybura, and Gullu (2008) developed a system transforming these textual data to tabular form and then this tabular data were georeferenced onto the highways. Then, the hot spots in the highways in Afyonkarahisar administrative border were explored and determined with two different methods of Kernel Density analysis and repeatability analysis. Subsequently, accident conditions at these hot spots were examined. We realized that the hot spots determined with two methods reflect really problematic places, e.g., cross roads, junction points, etc. Many of previous studies introduced GIS only as a visualization tool for accident locations. The significance of this study was to use GIS as a management system for accident analysis and determination of hot spots in Turkey with statistical analysis methods.

Wang, Quddus, and Ison (2009) explored the effect of traffic congestion on the frequency of road accidents using a spatial analysis approach, whereas controlling for other relevant factors that may affect road accidents. The M25 London orbital motorway, divided into 70 segments, was chosen to conduct this study and relevant data on road accidents, traffic and road characteristics were collected. A robust technique has been developed to map M25 accidents onto its segments. Since existing studies have often used a proxy to measure the level of congestion, this study has employed a precise congestion measurement. A series of Poisson based non-spatial (e.g., Poisson-lognormal and Poisson-gamma) and spatial (Poisson-lognormal with conditional autoregressive priors) models have been used to account for the effects of both heterogeneity and spatial correlation.

Jantakat, Sarapirome, Ongsomwang, and Littidej (2010) ranked road sections in terms of risk together with ranked weights of factors considered to cause accident for each section are highly effectual information for road safety implementing planning. To achieve this goal, thirty six road sections from five highways in Nakhon Ratchasima, Thailand with varying slopes, surface widths, and a number of connection routes, initially selected from 166 sections by using three-year accident data, are ranked into order from the highest risk to the lowest risk using OWA decision rule. OWA is a multi-criteria evaluation procedure using combination operators. Apart from risk ranking of road sections, the result reveals that slope is considered to be the highest rank among risk factors for sixteen sections

2.8.3 SDSS for risk assessment of road accident

Frank, Jean-Claude, and Rajan (2000) presented a working and easy to use hazmat (hazardous materials and dangerous goods) routing SDSS that overcomes three significant challenges, i.e. handling a realistic network, offering sophisticated route generating heuristics and functioning on a desktop personal computer. Although many parts of this work can individually be found in previous work, they have never been combined into one single working system before. A successful SDSS necessitates the development of custom software. Decision making is rendered considerable less cumbersome for several reasons. Firstly, the user follows a logical procedure when developing a route. On the contrary, off-the-shelf software adapted to hazmat routing requires learning the general syntax of the software prior to delving into hazmat routing. Also, custom software produces a route in a timelier manner before it incorporates efficient data structures and solution algorithms. The navigational simplicity and efficiency advantages help the decision-maker focus on creating solutions, negotiating trade-offs, and evaluating scenarios.

This paper outlines two solution methods to the TCSP (Transportation, Community, and System Preservation) problem implemented in Hazmat Path. They discussed producing differentiated routes to spread risk over a larger population. In them approach, routes were interactively constructed by the decision-maker on the map window. A possible enhancement of the SDSS could involve adding a route generator to produce differentiated routes.

Nevertheless, evaluating the quality of the set of differentiated paths would require considerable computational effort during route selection. This calculation consists of creating polygon overlays, which are used for determining the overlap of link buffers.

The display of temporal link attributes is another area where the current system could benefit from future enhancements. The SDSS presently displays attributes for one user-defined time period whereas a shipment may take a considerable amount of time, possibly several days. Displaying various maps of temporal attributes in a time loop would prove to be a useful decision support tool. Such capability would require creating, storing and retrieving various bitmaps.

Durduran (2010) considered a decision making system (DMS) based on correlation-based feature selection and classifier algorithms including support vector machine (SVM) and artificial neural network (ANN) has been proposed to predict the traffic accidents identifying risk factors connected to the environmental (climatological) conditions, which are associated with motor vehicles accidents on the Konya-Afyonkarahisar highway with the aid of geographical information systems.

Locations of the motor vehicle accidents are determined by the dynamic segmentation process in ArcGIS 9.0 from the traffic accident reports recorded by District Traffic Agency. In this DMS, firstly, the number of dimension of traffic accidents dataset with five features (e.g., temperature, humidity, weather conditions, and month of occurred traffic accidents) has been reduced from five to one feature by using correlation-based feature selection (CFS). In the CFS method, the correlation coefficient between five features and outputs (the cases of without accident or with accident) has been calculated and chosen as highest. Secondly, the traffic accident cases with one feature have been classified as without accident or with accident using SVM and ANN models. The proposed DMS has obtained the prediction accuracy of 61.79% with ANN classifier and achieved the prediction accuracy of 67.42% using SVM with RBF (radial basis function) kernel. These results have indicated that the proposed DMS could be used on prediction of real traffic accidents.

Baloye, Adesina, and Kufoniyi (2010) presented the potentials of the SDSS in determining optimum sites for physical developments within the built environment was the focus of this study. The SDSS developed took into consideration existing and future planning scenarios with the purpose of creating a sustainable built environment. To do this, a framework for capturing existing land use was generated and the SDSS was used to generate physical development expansion scenarios of the Obafemi Awolowo University, Nigeria. The system facilitated integrated procedures for determining optimal sites for incremental physical development in such a way as to minimize impact on other aspects of development. The application of this system demonstrates that planning, in particular as it relates to the urban environment, can be made more flexible, dynamic and responsive to timely decisions on geographic space.

2.8.4 WSDSS for risk assessment of road accident

Ahmad and Ehsan (2002) stated that the research outcome is a comprehensive system to cover accident management and analysis, smart automated service for accident locations, accident and service diagnosis, reducing the number of accidents, increasing the level of road safety and fast delivery services e.g. insurance companies and emergency services. Also, for further works, the ability to inform clients with regard to the risk zones in all over the city using LBS (Location Based Services) services, based on the main system reports, queries and real time traffic monitoring, should be included in the system. The system classifies and categorizes the road networks into four zones, so when a vehicle enter to each zone, the system will automatically send the risk message to alert the accident risk on that particular zone or location of the city. Additionally, the system shall offer some services for clients e.g. air download client version (for PDAs or Smartphone) of application for using these LBS services. All LBS data, which will be appeared on client phone, are generated by the main system with real time updates via the Internet; therefore, the clients have real time information regarding the traffic conditions and accident risk zones around them.

Ray (2005) developed a web-based spatial decision support system for managing the movement of oversize and overweight vehicles over the State's highways. This system combines network optimization techniques and a J2EE web-architecture to give a robust, high-performance and scalable system meeting Delaware's current and future permit processing needs. The new system replaces existing manual processes, providing a number of immediate and future benefits including reducing time to calculate some permits from weeks to seconds, reducing processing costs and providing potential safety by reacting to rapidly changing highway conditions.

The previous studies can be concluded and displayed in Table 2.2

Table 2.2 Conclusion of previous studies.

Year	Name	Point of interests
2002	Ahmad and Ehsan	The research outcome is a comprehensive system to cover accident management and analysis to increasing the level of road safety and fast delivery services. The ability to inform clients with regard to the risk zones in all over the city using LBS.
2003	Jones and Jørgensen	Introduce the potential of a recently developed form of multi-level regression models, for quantifying the various influences on accident casualty outcomes.
2008	Erdogan et al.	Develop a system the hot spots in the highways calculated for the expected distribution based on Poisson distribution. The system were explored and determined with two different methods of Kernel Density analysis and repeatability analysis.
2010	Gundogdu	The methods developed to obtain maps to determine traffic Hot Spots. The Hot Spot analysis using a number of statistical methods to determine the Highest Potential Hot Spots, which are inter-sectional clusters, and to use different parameters.
2010	Durduran	Considers a decision making system (DMS) based on correlation-based feature selection and classifier algorithms including support vector machine and artificial neural network has been proposed to predict the traffic accidents.

Table 2.2 Conclusion of previous studies (Continued).

Year	Name	Point of interests
2009	Hermans et al.	The road safety performance of countries is conducted by combining seven main risk indicators. The expert weights and ordered weighted averaging operators are explored, evaluated and integrated resulting in a ranking of countries based on a road safety index.
2010	Jantakat et al.	Rank road sections in terms of risk together with ranked weights of factors. The highest risk to the lowest risk using OWA decision rule.
2011	Dinu and Veeraragavan	The study is an attempt to employ random parameter modeling for accident prediction on two-lane undivided rural highways in India.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Conceptual framework

The research procedure was designed to meet the main objective of the study which is the development of a web-based spatial decision support system for the risk assessment of road accidents. The flow chart of the procedure is displayed in Figure 3.1. The procedure covers study highway selection, data collection and extraction for spatial database construction. They become input data of models available in the model base component of the system. The system developed is capable for users to interactively select input data. The system can provide warning information of road segments for the highway users and model to operate and also allow results to be compared through interface developed.

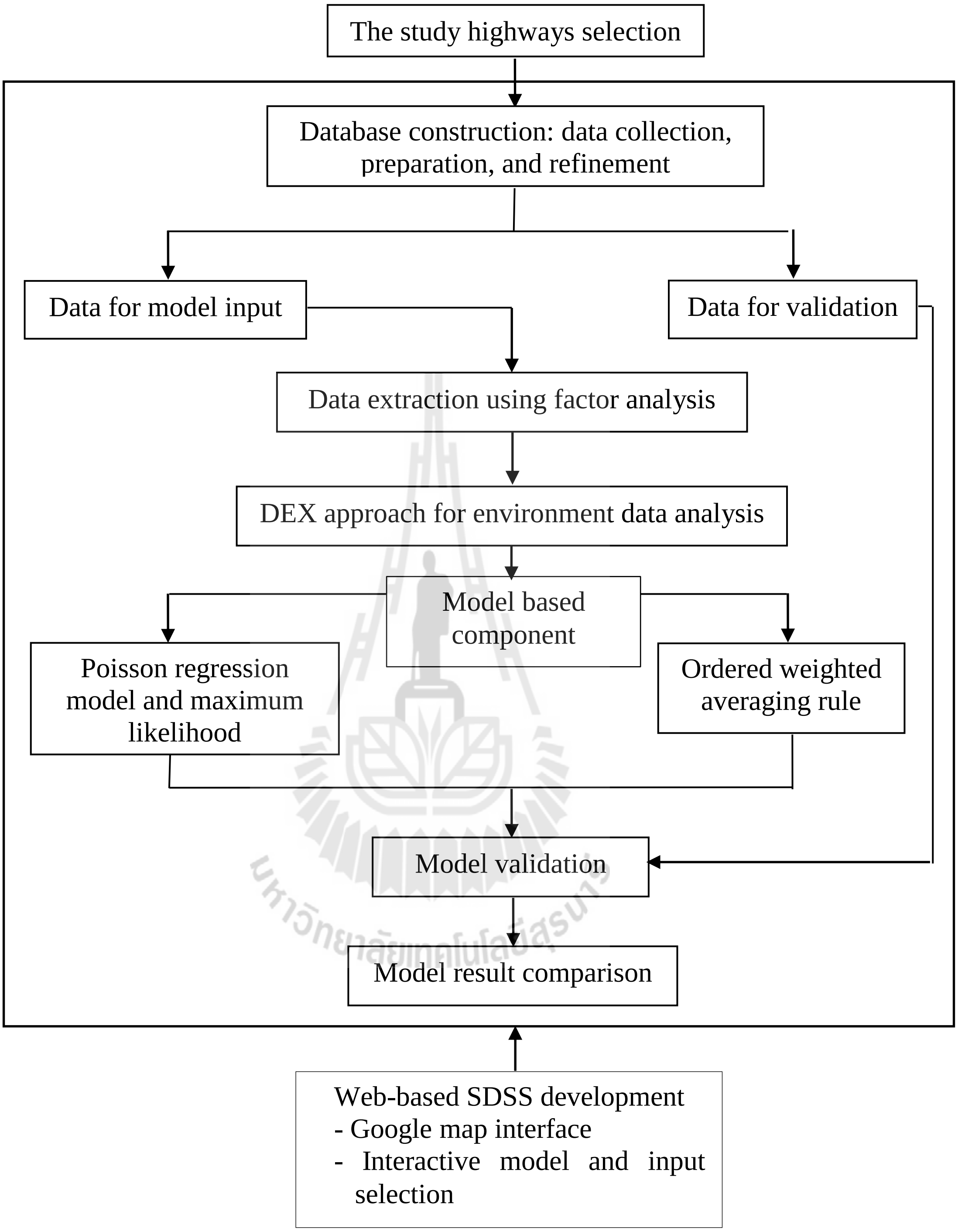

Figure 3.1 Research framework.

3.2 The study highway selection

The study highways were selected by considering the number and the severity of the accidents which were obtained from the number of injuries and deaths as described in the study area section. By this reason the routes 2, 224, and 304 were selected as the roads for this study.

3.3 Data collection, preparation and refinement

In this study, each segment of road is independent from each other and has a value of road geometry to facilitate and standardize the preparation of the data for each segment. Therefore, each segment is designed to have a length of 1 kilometer representing its unique attribute. The data used for research can be described into 4 groups below:

3.3.1 Road accident data

The databases of road accident contains data of each road segment about the number of road accidents occurred and other associated attributes such as date and time, road geometry, type of road surface (pavement), the location of the accident, road situations and severity of accidents etc. These data were used as explanatory variables in road accident prediction model.

3.3.2 Road geometry data

The review of the research report showed that the routing data such as, the island in the middle, width of traffic and intersection of the road are the major factors affecting the accident this can be provided in the form of spatial data to analysis and perform geographic information system.

All these attributes were attached to each 100-m road segment in the database of highway no. 2, 224, and 304. The data on road accidents (2009 - 2012) contain a number of accidents and data describe detail conditions while accidents occurred such as date and time, road surface condition, location, etc. The road geometry data were obtained from road design blue print.

3.3.3 ADT

The review of the research report showed that volume of traffic was the most influential factor in causing the risk of accidents with average daily traffic and the proportion of large vehicles which were analyzed in the form of statistical data to predict the risk of accidents told increasing when it was time at the traffic routing there were many cars or large vehicles.

ADT of each 1-km road segment was compiled by the Highways Statistics Unit, 8 Highways Bureau, Nakhon Ratchasima based on raw data from the six survey points (four inside and two outside the study area).

3.3.4 Environment condition

The climate was another factor which affect to the accident condition there was change all time and including effect of able to vision and able to control of car. Some condition there was rainy or during day or night also the climate over time taken into developing in the model. The environment condition is a factor that changes according to the input of a user which can affect the occurrence of accidents. When the user specifies the weather condition to the system, it will apply to every segment.

All factors can be concluded and displayed in Table 3.1.

Table 3.1 Factor used for the research.

Factor group	Factor	Factor source
Road accident data	- Date/time of accident - Location of accident - Number of accident	Road accident database developed by the DOH.
Road geometry data	- PW : Pavement Width - SW : Shoulder Width - DS : Design Speed - HC : Degree of Horizontal Curve - VG : Percentage of Vertical Grade - UT : Number of U-turn - RC : Number of Road Connection - IN : Number of Intersection	Extracted from the road construction plan.
ADT	- Traffic volume (ADT)	- Extracted from ADT database developed by the DOH. - Traffic data observation from stations by the DOH.
Environment condition	- Weather - Road light - Pavement conditions	Road accident database developed by the DOH.

From the four factors listed above, the information of them in period of 3 years was used. They are in forms that cannot be used immediately. It is required to prepare and manipulate data into 2 groups for use in the development of a web-based spatial decision support system for the risk assessment of road accident, which are described below (Figure 3.2).

1) A period of two years data is exercised for creation of model.

2) A period of one year data is utilized for model validation.

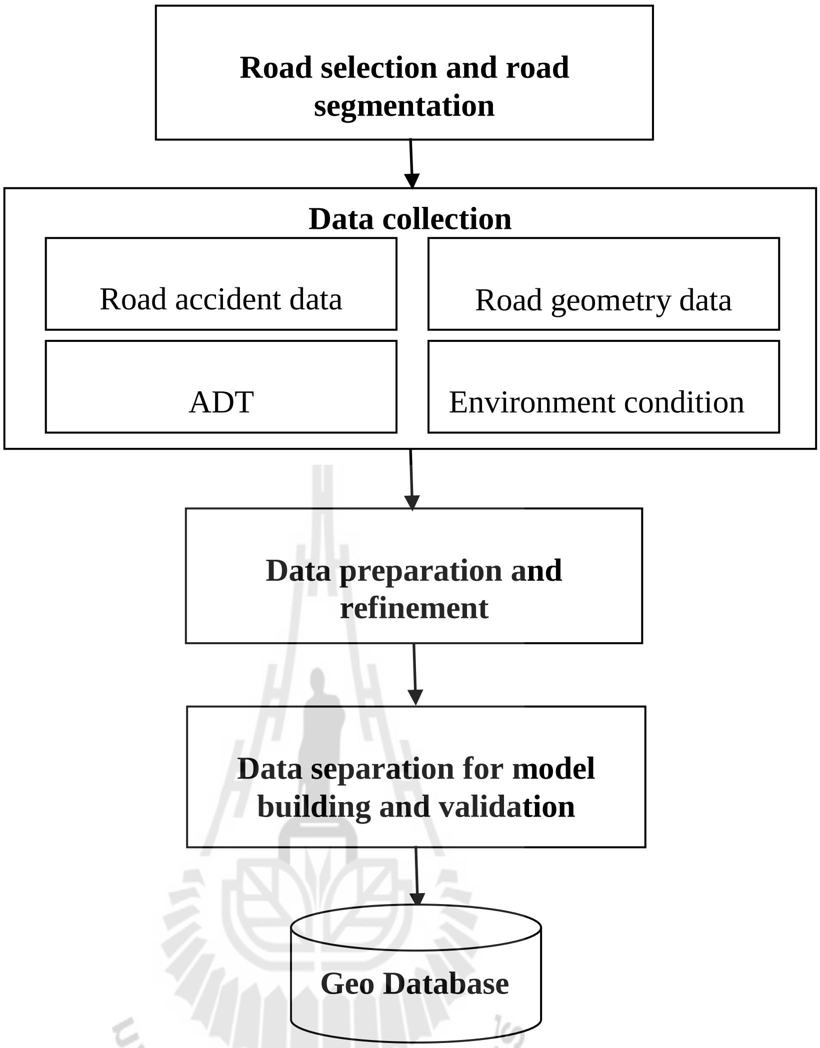

Figure 3.2 The study area selection and data collection.

3.4 Factor extraction

Factor extraction is a method to determine the optimal number of factors by examining data. For any given set of correlations and number of factors there are actually an infinite number of ways that can define factors and still account for the same amount of covariance in measures.

The research regarding the risk assessment of road accidents has used the process of exploratory factor analysis (EFA) to identify the number of common factors influencing a set of measures. Input, process, and output of factor extraction can be described as follows.

(1) Input: data of factors involved in the accidents which have undergone data collection, preparation and refinement.

(2) Process: the correlations matrix is established to determine the relationship of common factors in each factor to easily organize and analyze the data elements by considering the eigenvalues and conducting factors rotation in order to differentiate these elements. The final step is to define these elements and to choose the factors of element to use.

3) Output: group of factors that have been screened and associated with the accidents.

The approach of factor analysis is processed by the following stages shown in Figure 3.3.

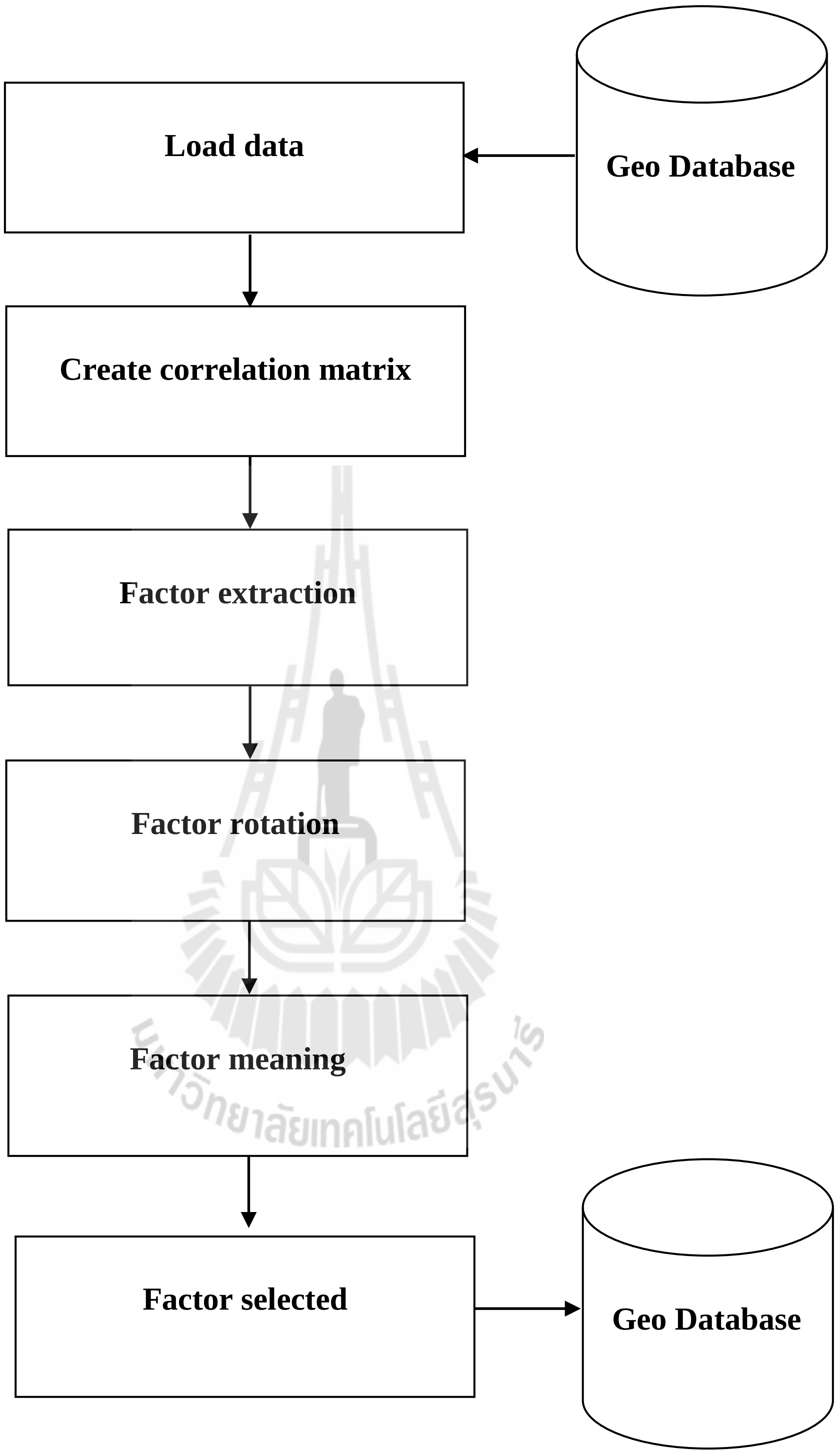

Figure 3.3 Factor analysis approach.

3.5 MADM using DEX approach and rule based construction

A new approach and contribution to model the risk assessment of road accidents suggest that it would be more suitable to model the accident frequency with MADM using the DEX approach to develop a system that allows environmental factors to be adjusted. These factors can stimulate the results according to values of the factors that have changed the risk assessment of road accidents. Input, process, and output of factor extraction can be described as follows.

(1) Input: environment factors involve in the accidents and can cause variation of frequency and intensity of accident are time, weather and light conditions.

(2) Process: collecting and verifying information, identifying options (alternatives), anticipating consequences of decisions, making the choice using sound and logical judgement based on available information, justification and informing others of the decision, evaluating decisions and their consequences.

(3) Output: level of risk for environment situation from user and-expert opinions.

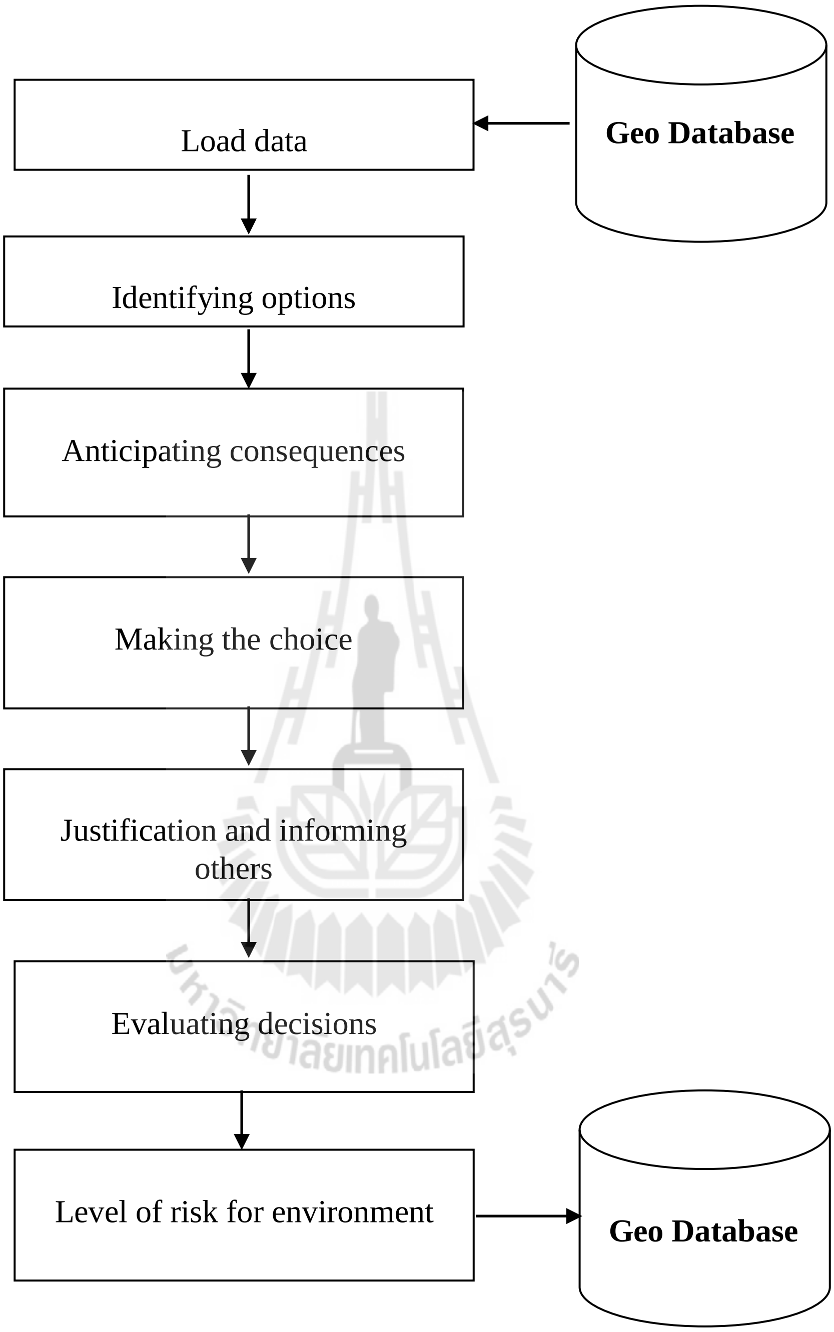

Figure 3.4 MADM using DEX approach.

3.6 Poisson regression model

Poisson Regression Model is considered for identifying the relationship between the number of accidents and some covariates. Count-data modeling techniques are commonly used for accident frequency analysis because the number of accidents on roadway segments per unit of time is a non-negative integer. Count data are generally modeled with a Poisson regression model. Input, process, and output of the model can be described of the following procedures.

(1) Input: group of factors that have been screened and associated with the accidents.

(2) Process: factors used in each segment are considered to conduct the parameter estimation using the maximum likelihood method. Then, the Poisson regression model is developed using the goodness of fit test to determine the parameters which correspond to the distribution of the data. If this is accepted, then the probability of occurrence of accidents is calculated in the Poisson regression model.

(3) Output: probability of accidents of each segment in the Poisson regression model.

The Poisson regression model analysis is executed by the following stages shown in Figure 3.5.

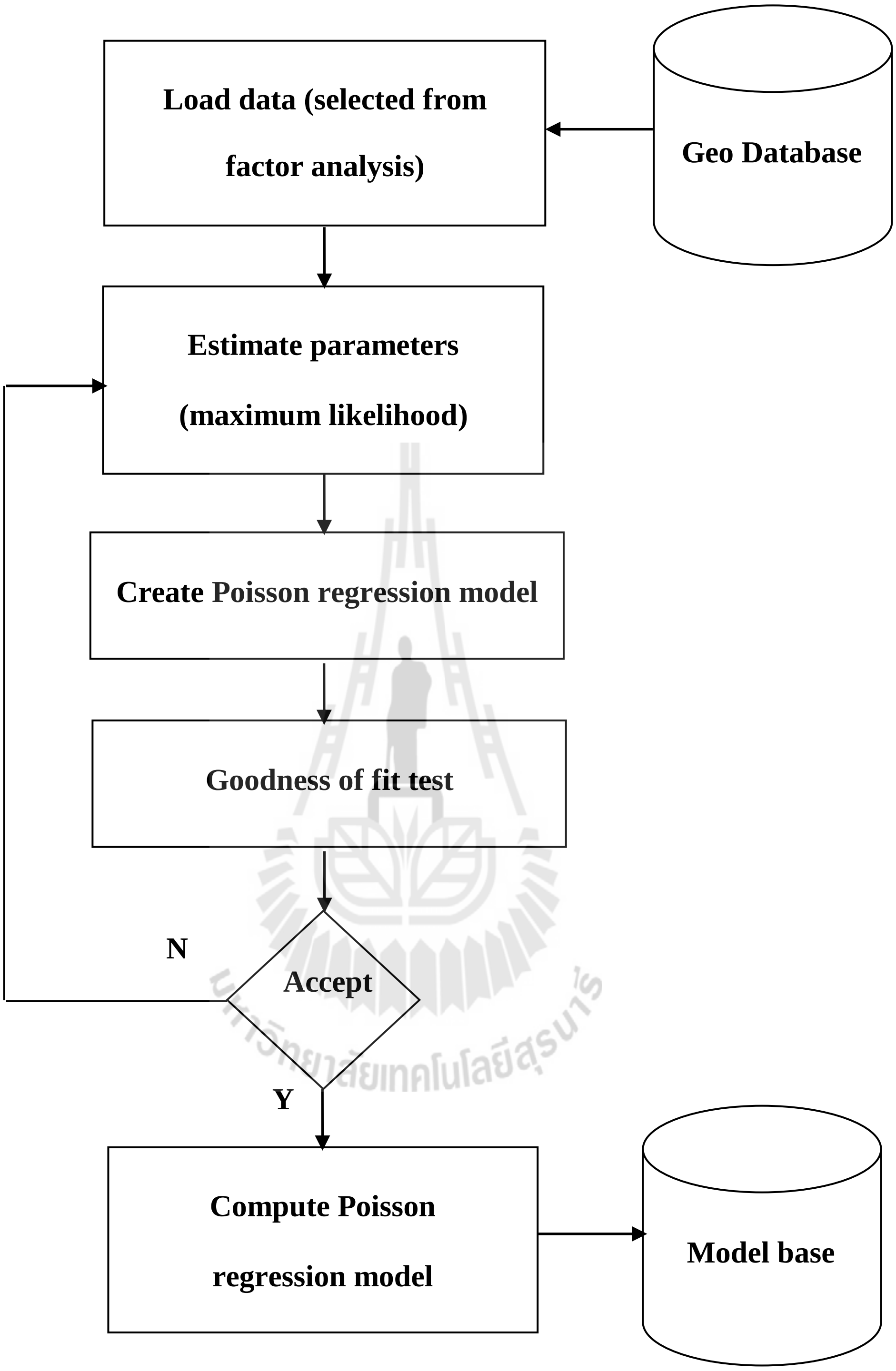

Figure 3.5 The Poisson regression model analysis.

3.7 Ordered weighted averaging (OWA)

The OWA is a multi-criteria evaluation procedure or a decision rule using fuzzy combination operators. The OWA performs to identify rank of risk factors of for road segment into order before assigning fuzzy weights and aggregate operation. Input, process, and output of the technique can be described below.

(1) Input: group of factors for each road segment that have been screened and associated with the accidents.

(2) Process: factors used in each segment are normalized and arranged in order. Then, fuzzy sets of weights are applied to ranked attribute values for each alternative and sum up. Finally, alternatives and their order criteria are ranked.

(3) Output: sequence of segments ranking based on the risks of accidents.

The OWA analysis is performed by the following stages shown in Figure 3.6.

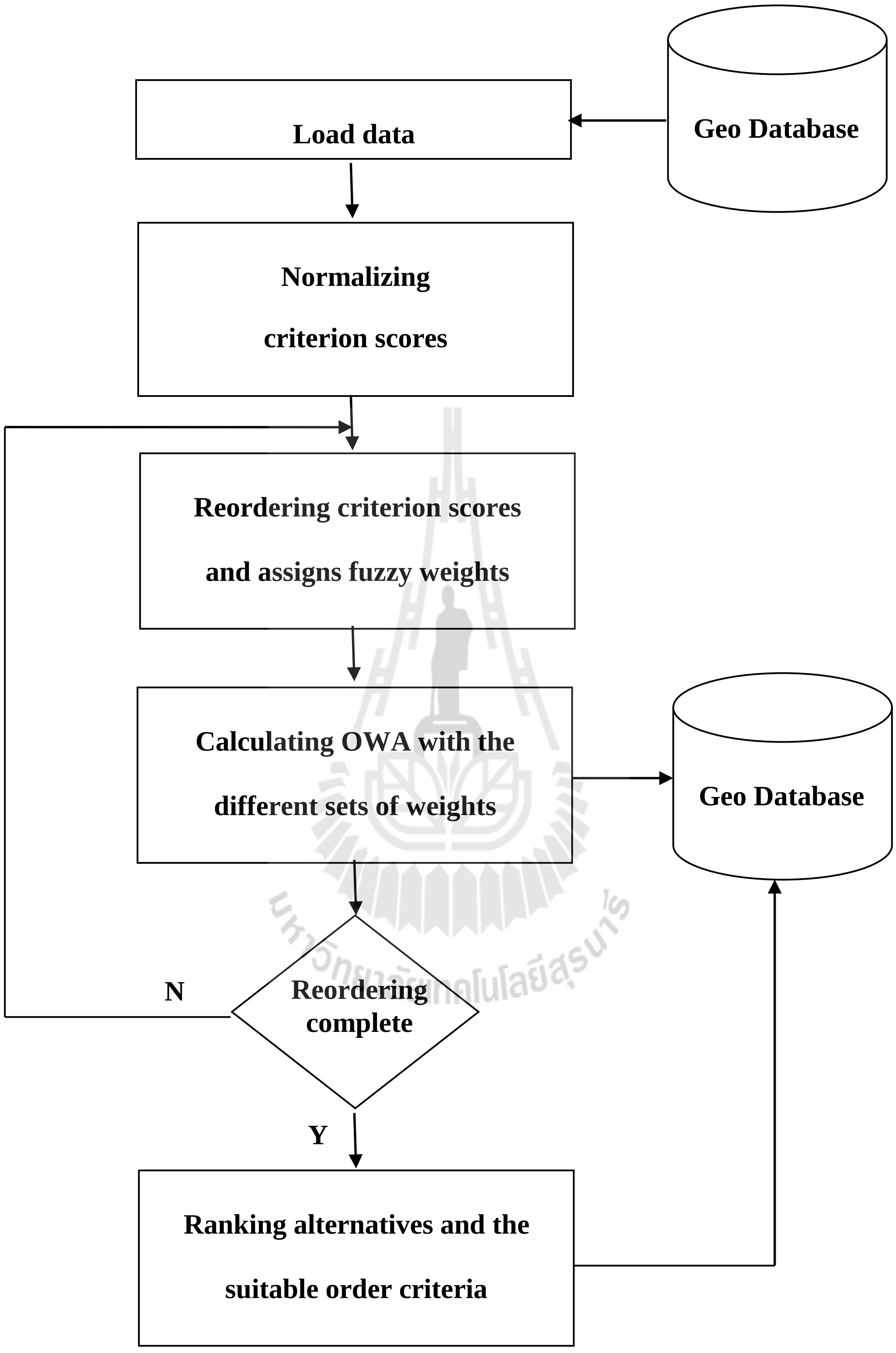

Figure 3.6 OWA method.

3.8 Model validation

Model validation is considered an important step in the model building sequence. The Poisson Regression Model and the OWA Model are used to assess the risks of accidents. These models are different in their concepts. It is thus interesting that when these models are validated with actual data of accidents, what the results include:

Poisson Regression Model

The result from the Poisson Regression Model is the probability of accidents of each segment. Experts will consider the probability obtained and determine the cut off value to the system e.g. 60%. That is, if segment A is 40%, it is not considered an accident (0), and if segment B is 80%, it is considered an accident (1), then the values of accidents are compared with actual data of each segment and the percentage of accuracy is calculated.

OWA Model

The result from the OWA model is the sequence of segments based on the risks of accidents. Values obtained will be in the form of Fuzzy (Min, Tradeoff, Max), in which the defuzzification will be performed using average values. Experts will consider the probability obtained and determine the cut off value to the system as same as the Poisson Regression Model and then the values of accidents are compared with actual data of each segments and the percentage of accuracy is calculated.

3.9 Model result comparison

The results of both models (Poisson Regression Model and OWA) are compared using Root Mean Square Error (RMSE) to measure of the differences between values predicted by a model and actual accident values. The results of accuracy comparison will be presented in WSDSS.

3.10 Web-based spatial decision support system development

The system will be developed on the basis of a web-based which will work to import the data and requirements of users. The processing of the order and the performance of the model according to requirement of users are using the Google Maps for user interaction and management system environment. Developing web-based spatial analysis for road accident risk assessment includes the following allowances. The user can import the information in order to show the images of simulated the results through interaction with the user on a Google map. Users can choose any model for analysis from the model base which herein contains Poisson regression model and OWA. Users can adjust the values of the data on the basic factors which in turn change the simulated results according to values of the factors adjusted.

The WSDSS supports three levels of users: 1) decision makers and supporters who can access the data, determine the decision criteria and make any decision on the information obtained from the system, 2) officer who can edit some data to calculate models and 3) general users who can access to display the data and result.

The PHP and HTML are the main programming language for developing interface and engine system of the WSDSS. MySQL is used to provide an environment to generate databases that can be accessed from the internet via Apache is a web server application and set of feature extension modules.

CHAPTER IV

RESULTS AND DISCUSSION

The aim of the present chapter is to present the results of the thematic content analysis conducted from the data gathered. The system developed can identify the factors and positions at risk of accidents on Highway 2; 224; and 304 based on the situations varied according to the requirement of individual users. The results expressed herein were output of the experiment conducted based on the methods described in Chapter 3 (Research methodology) to serve the objectives of the study.

4.1 WSDSS design for development and implementation

A web-based SDSS was designed to use a central web server to provide a shared analysis platform for users. The system can provide services of data management, model execution and result visualization. Since the system is hosted on a server, upgrading the system or part of the system is fast and simple. The web-based system provides easy access since the access of such system only requires a web-browser and the internet connection, which are now widely available.

The objective of this SDSS design and construction is to develop a system that allows users to perform an analysis of the risk assessment of road accident through a web application. Several requirements were defined to meet this objective. The first is the data management requirements. The system should support the management of various data sets, including embedded and user-created both spatial and non-spatial data. The database is expected to relieve users' burden of data management. The system should also allow users to create their own spatial and non-spatial data and separate user-specific data from other users'. The second is the interface design requirements. The interface should support data editing and model analysis through a web browser.

The interfaces should also support result visualization in the form of tables, description, and maps. The third is the system integration requirements. All spatial analysis, data management, model execution, and result visualization should be transparent to users. Users can select their inputs and action by simple actions, such as clicking or simply typing, and then the system should automatically execute the analysis. The fourth is the help system requirements. The system should provide several help methods to guide users through the analysis and solving possible problems in implementation.

4.1.1 WSDSS Architecture

The web-based SDSS uses a client-server model to communicate between users and the SDSS servers. More specifically, the client/server model takes three-tier architecture (Figure 4.1). The three tiers include the interface, process and data tiers. The interface tier, also called presentation tier, is to provide user services to manage the session, inputs and display. Users can activate events and issue requests to the servers through these interfaces. The servers are the ports through which the SDSS provide services. There are two types of servers to serve the web page. The web page server provides dynamic pages of text, figures, and tables. The map server provides the map based web page. The process tier, also called the middle tier, contains all middleware that provides the communications between web pages and application processes that specify the detailed implementation for each application. This SDSS includes two major models. The Poisson regression model and OWA model are used to assess road accident risk and result in form of spatial locations of road segments with accident risk intensity.

The third tier is the data tier. This SDSS uses two types of data storage, the database and model base. The MySQL database server is used to manage non-spatial data, spatial data, and model data in this SDSS. The communication between model and the database is through the database system.

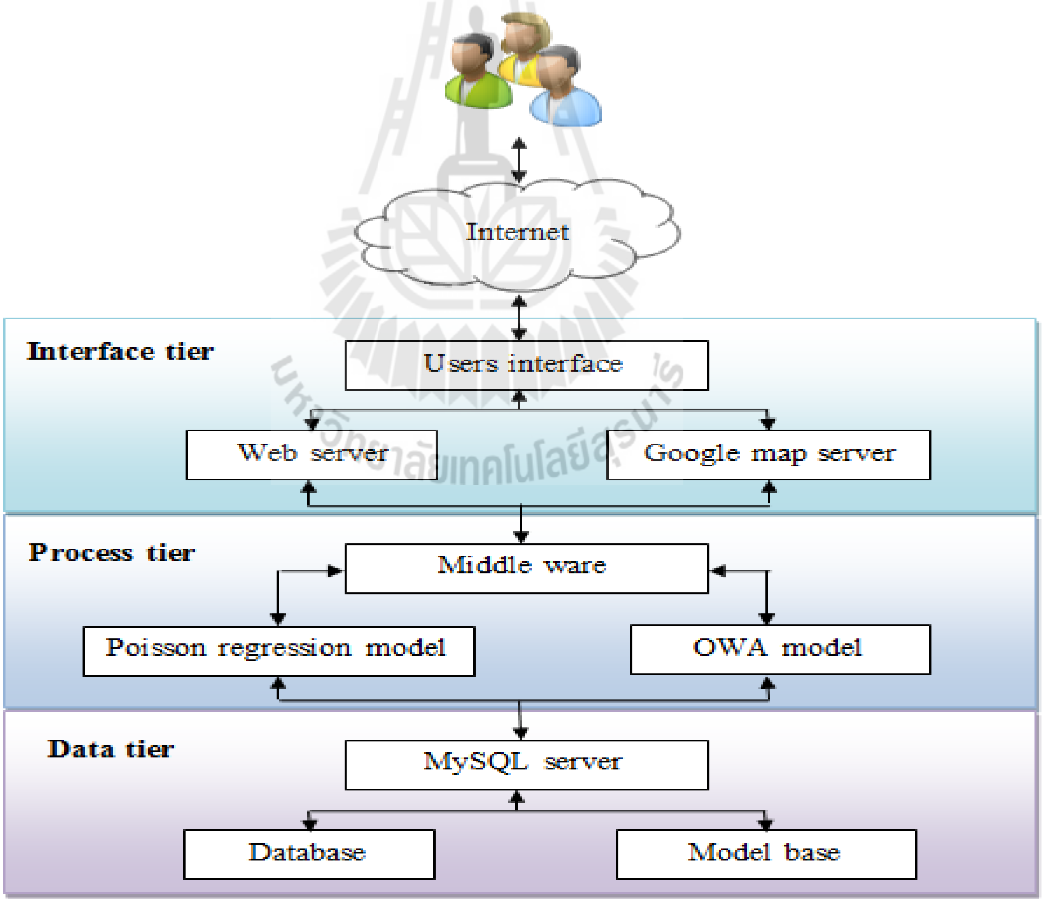

Figure 4.1 Architecture of the SDSS.

4.1.2 System Architecture

The information system has been developed with a web-based, client-server architecture. All data storage and processing are done on the server side, while data input and display are done on the client side. Server application works on a web server and supported by a relational database management system (RDBMS) for data storage and retrieval. Client application works on web browsers and communicates with the server application synchronously and asynchronously through the Internet. For mapping purposes an external Internet Map Server is used. Simplified architecture of the information system is given in Figure 4.2.

The front-end consists of an HTML file with Google Map loaded, a search form and pre-defined data sets, and a JavaScript script. The client-side HTML and JavaScript files make requests to the server. The server-side consists of a PHP file which bridges the gap between Ajax and connects to a MySQL database. The result is returned as an XML response to the Ajax engine. Users can search the database, view the results, view individual documents, edit or transcribe them, delete existing postings or add new ones.

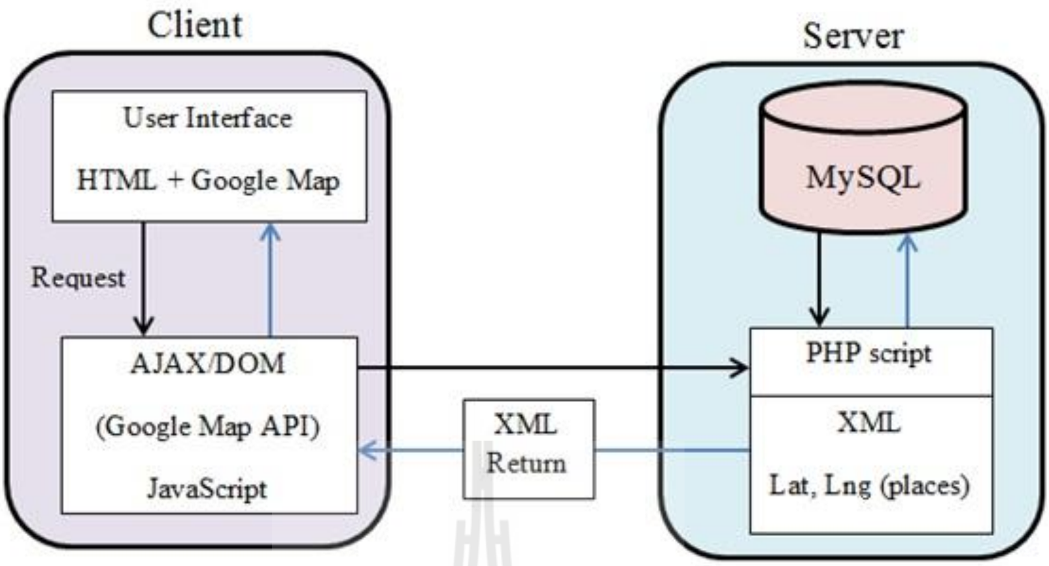

Figure 4.2 System architecture.

Server application of the information system works on Apache Web Server and has been developed using PHP programming language. Client side application (user interface) of the system has been prepared using XML markup language and supported by DOM (Document Object Model) Level 1 based, interactive scripts in JavaScript programming language.

XML codes describing the user interface elements and behavior are generated dynamically by the server application. Similarly, graphical elements, such as line plots, histograms and icons are either generated by the system or loaded from files stored in the native file system. In order to provide asynchronous data flow between client and server, AJAX technology has been utilized. Client side application is fully XML 1.0 Transitional compliant and works on all major web browsers, independent of the operating system and hardware configuration. Compatibility tests have been made with Mozilla Firefox, Microsoft Internet Explorer and Opera web browsers on Microsoft Windows operating system.

Among the data storage engines provided by MySQL storage engine, which supports relational database tables with transaction-safe queries, has been used. Owing to relational database structure with foreign key constraints, all actions on records have been controlled at the database level and overall data integrity has been protected.

In order to display geographic information, the information system utilizes Google Maps, which is a widely used, free online mapping service provided by Google. A custom dynamic map window gadget has been developed, which allows maps displayed on the user interface to be moved and resized freely for better navigation. The system also supports data entry in multiple coordinate formats.

During the development of the system, no automatic code has been generated. The systems has been used and all codes has been written manually in 3 years. The system includes over 15,000 lines of PHP and JavaScript codes, excluding external programming libraries. Programming libraries are mainly used to perform data visualization and enhancement of user interface elements.

The database of the information system includes 10 data tables, which are organized in a relational structure. six tables store data entered to the system through data entry forms. Hence, they are dynamic in size and number of records in the tables is growing within the life time of the information system. Remaining 4 tables contain supplementary data, which do not change frequently.

4.1.3 Functionality and analysis flow

Functional and performance requirements at any level in the system were developed from user requirements. The system requirements were allocated and defined in sufficient detail to provide design and verification criteria to support the integrated system design.

- **Multiuser support**

The basic design objective of the system is to facilitate data sharing on technological accidents by creating a collaborative, open-content environment. For this purpose, the system has been developed to support multiple users concurrently. Three different user types with different levels of user rights and privileges are:

- Administrators,
- Editors, and
- Application users.

Administrators are responsible for the management of the information system and have complete control over the system components. They can add, update, and delete all kinds of records regardless of record specific user privileges and locking mechanism applied by the system. There are also particular record types and tasks that can only be edited and performed by the administrators, respectively.

Main duties of the administrators can be listed as follows:

- Updating the record of model data,
- Updating the list of geometry data of each road segment,
- Managing the property estimators supported by the system,
- Managing the registered users by setting editor privileges and assigning users as responsible persons of facilities,

• Keeping track of records entered or updated by the editors and correction of improper entries, and

• Following up data collection process and verification of data integrity.

Editors are a special class of registered users who have data entry and update rights, hence can contribute to the contents of the information system. Following the basic principle of open-content systems, most of these record types are allowed to be added and updated by the editors.

Restricted record types are those that result from statistical calculation such as maximum likelihood estimator. They are created parameter coefficients which can be created or updated only by administrators to protect compliance with the regulations. Editors are designated by the administrators from the registered users.

This results in a collaborative framework for information sharing and facilitates accumulation of validated data. Primitive record types, such as constants, equations, units and labels, generally do not require further editing once created. Therefore, such record types are allowed to be edited only by their owners.

Application users, or called key users of the system are ones who can take benefit from the system analytical results as guidance to perform their roles properly. Key users can be separated to be:

1. General users / people who use for traveling. They can know about risk of road segment based on their own interest or actual situations.
2. Traffic officer who can take benefit from the system analysis and use the result as a guide for traffic managing, escort for traffic movement, road safety outpost etc.

3. Highway-maintenance officers who can use the analytical result to prioritize which segment should be of maintenance first and how to maintain.

All users can customize requirements of environment settings according to their preferences. The information system includes more than 270 difference input data records for which data can be entered by the users, for example, highway, weather, and time. User settings are stored in the database and maintained between sessions.

- **Analysis flow**

This design is a holistic design for the new system in logical and physical parts shown in form of Data Flow Diagrams (DFD). The DFD of WSDSS was studied and analyzed into 2 parts of Level 0.

1) Context diagram

The context diagram of WSDSS explains relationship of users and the system in terms of data request and data management as shown in Figure 4.3.

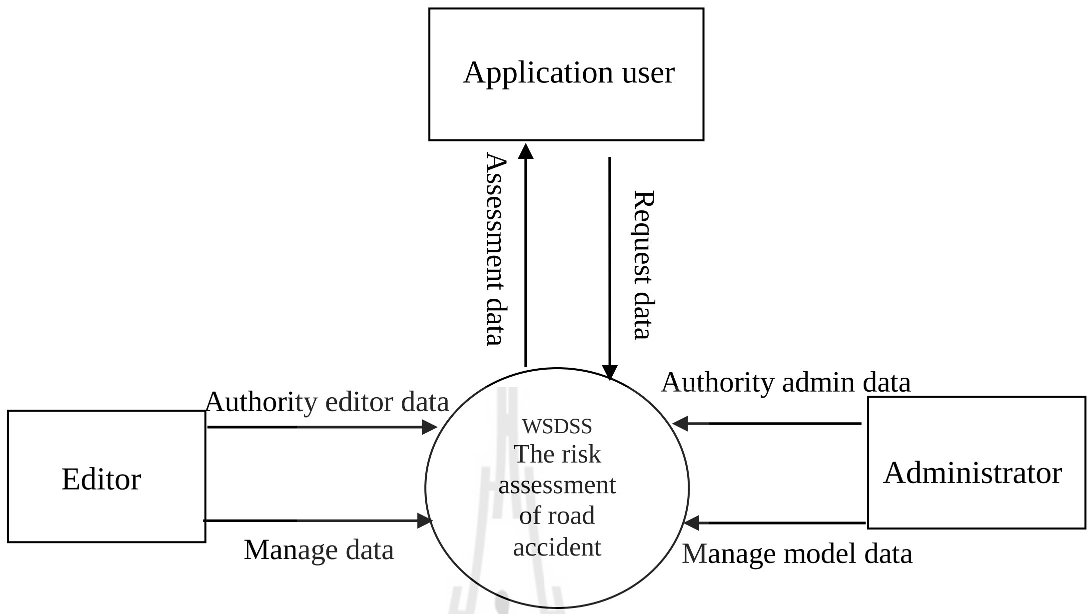

Figure 4.3 Context Diagram.

WSDSS composed of three external entities that are groups of users performing information exchange according to their roles and results from the system. They have different roles as follows:

Administrator focuses on extra task of management models,

Editor focuses on extra task of overseeing the information required in the system, and

Application users need data assessed from system to provide the benefits.

2) Data flow diagram level 1

The DFD of this level shows relationship of main processes of different types of users. These processes cover authority verification, data management, and data report as shown in Figure 4.4.

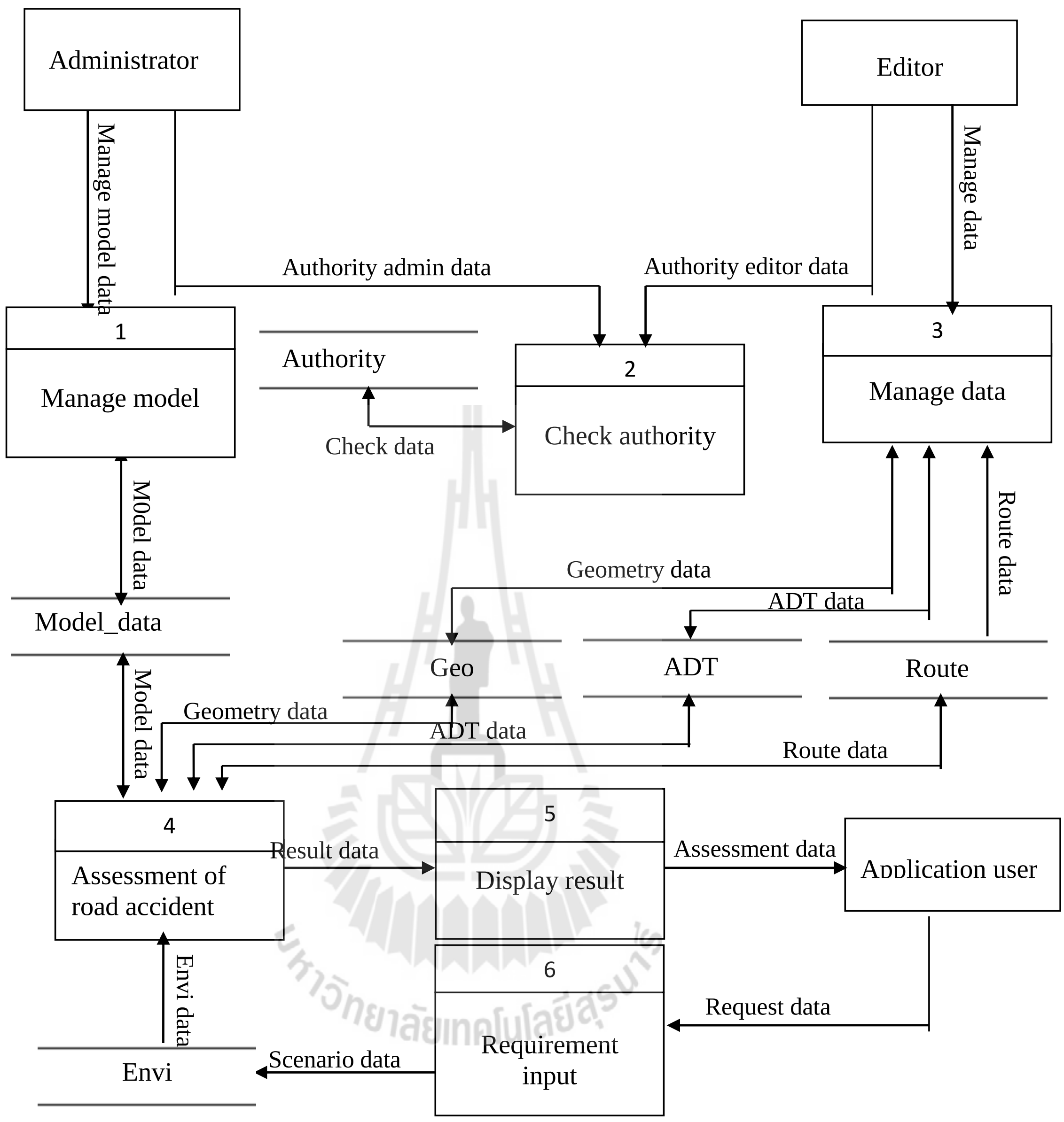

Figure 4.4 DFD level 1.

DFD level 1 represents the information flows within a system including main 6 processes of Check authority, Manage data, Manage model, Assessment of road accident, Display result, and Requirement input. The system provides data from 6 data stores: Authority, Geo, ADT data, Route, Model_data, and Envi.

With different roles, Administrator can manage data in model data. Editor can insert and update geometry data, ADT data, and route data in data stores. Application user can initiate assessment of road accident interactively by selecting optional classes of climate, period of time, and road conditions. The result of assessment shows on the interface of Google maps as the interaction response of users and the system developed.

3) Data flow diagram level 2 (Process 4 Assessment of road accident)

Figure 4.5 shows the level 2 DFD, which is the decomposition of process 4: Assessment of road accident shown in the DFD level 1. It is the actual road assessment process dealing with all input options and model requested from key users and return result. The diagram is composed of 4 sub-processes i.e. factor analysis, Poisson regression modeling, OWA modeling, validating and comparison. For this process, five data stores include Model data, Geo, ADT, Route and Envi.

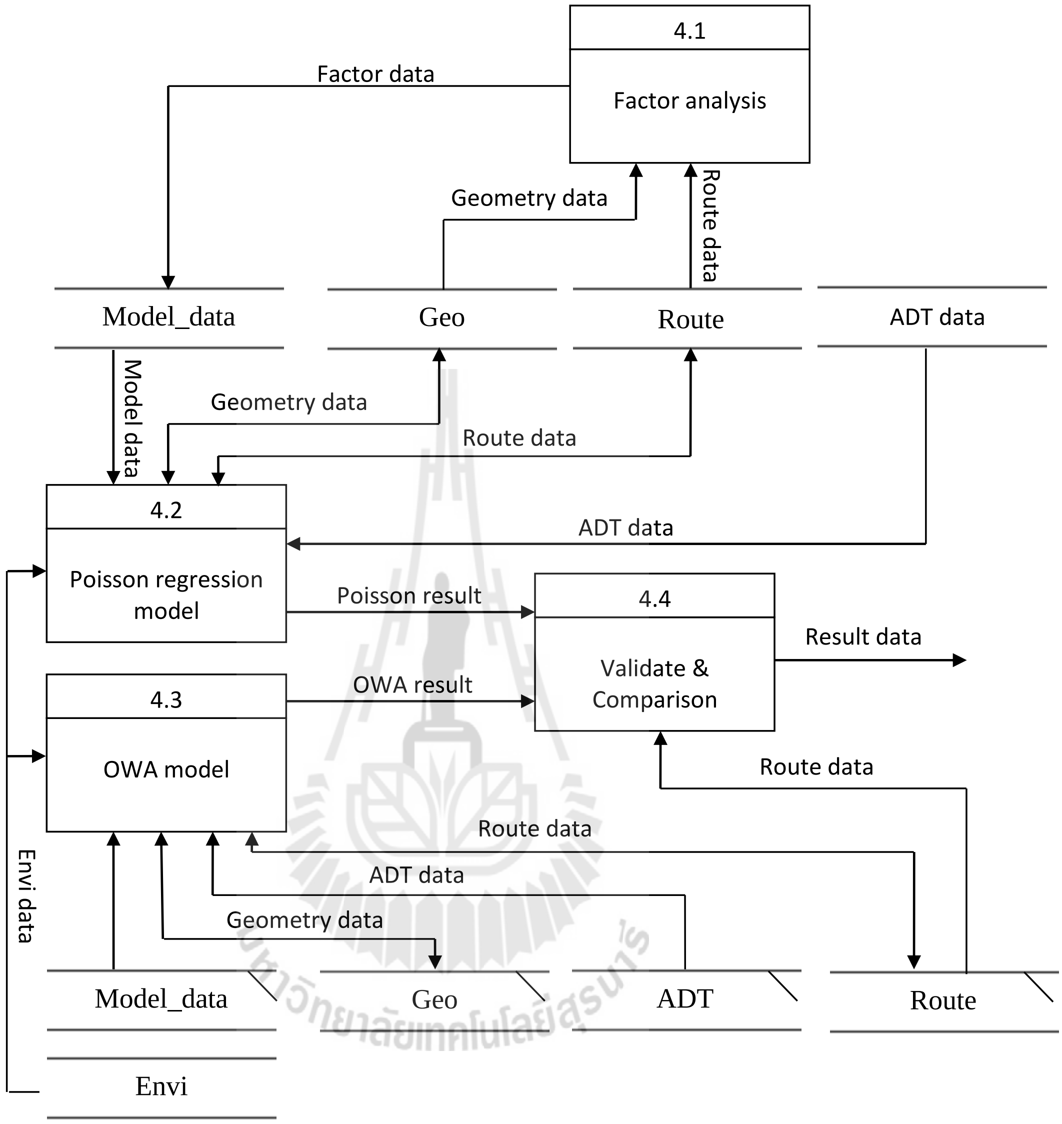

Figure 4.5 Data Flow Diagram level 2 (Process 4 Assessment of road accident).

4.2 Interface development and implementation

The interfaces of a SDSS provide the link between users and the analysis models. A well designed interface would help users in making analyses and presenting results efficiently. The interface design is especially important for the applications intended for inexperienced users. In this study, the interfaces are a series of customized web-pages that allow the users to create inputs, run models, and view results.

The web pages are the digital media to convey information on the Internet. A web page can take diverse formats to present information. Web page designs need to select the best combination of techniques to present their information. This SDSS uses web page technology to create interactive and customized web pages.

4.2.1 Web page design technology

Several web techniques are used to create the web pages. Most of the web pages are dynamic web pages created on the fly. This WSDSS uses three major techniques to create dynamic web-pages: PHP, JavaScript, and Google map API.

PHP

The reason for selecting PHP is that it is open source and it can run on many internet server such as Apache, Netscape/iPlanet, Microsoft IIS etc. The system also includes JavaScript language to create more efficient web browsing interface on the web browser. Figure 4.6 is an example of PHP script in this study for showing marker in Google map.

```
<?php
$showIcon = "";
for($i_place=1;$i_place<=mysql_num_rows($Chk_list);$i_place++){
          $query_place = mysql_fetch_array($result_place, MYSQL_ASSOC);
          $place_latlng = $query_place["place_latlng"];
          if($place_latlng==""){
                              $place_latlng = "14.98278182524803, 102.10761040039062";
                    }
                    if($query_place["place_pic"]==""){
                              $place_pic = "images/noimage.jpg"; $place_pic
                    }else{                    $place_pic = $query_place["place_pic"];
          }
                    $showIcon .= 'text = "<div class=\'text_detail_gmap\'>"
                       +"<B>Segment no. :
</B>'.$query_place["place_name"].'<br/><B>Risk level :
</B>'.$query_place["place_address"].'<br />"+"<B>Risk factor :
</B>'.$query_place["place_address"].'<br />"+"<B>No. of accidents :
</B>'.$query_place["place_count"].' <br />";
               bigImg = \'<table><tr><td><img
src="'.$place_pic.'"/></td></tr></table>\';
               html = "<div class=\'gmap_main\'><div
class=\'big_img_gmap\'>"+bigImg+"</div>"+text+"</div>";';
                                        $showIcon .= 'var point = new
GLatLng('.$query_place["place_latlng"].'); ';
                    $showIcon .=
'map.addOverlay(createMarker(point,html,"'.$query_place["place_icon"].'"));';
?>
```

Figure 4.6 PHP script.

JavaScript

JavaScript is mainly client-side dynamic web page technology. Client-side JavaScript can implement minor operations on client machine, thus the response is fast. The combination of server-side JSP/Servlet and client-side JavaScript can help to create customized web pages to support diverse functionality for user access. Figure 4.7 shows an example of Java script in this study for preparing map content.

```
<script language="javascript">
                function getCookie(c_name)
                {
                if (document.cookie.length>0)
                  {
                  c_start=document.cookie.indexOf(c_name + "=");
                  if (c_start!=-1)
                        {
                        c_start=c_start + c_name.length+1;
                        c_end=document.cookie.indexOf(";",c_start);
                        if (c_end==-1) c_end=document.cookie.length;
                        return unescape(document.cookie.substring(c_start,c_end));
                        }
                  }
                return "";
                }
                function setCookie(c_name,value,expiredays){
                        var exdate=new Date();
                        exdate.setDate(exdate.getDate()+expiredays);
                        document.cookie=c_name+ "="
+escape(value)+((expiredays==null) ? "" : ";expires="+exdate.toGMTString());
                }
</script>
```

Figure 4.7 Java script.

Google map API script

The Google map API is used to display the KML file in the database, whereas the OpenLayers APIs in charge of the drawing functions for different tools. ExtJS has been chosen as the layout framework for constructing user interface component. The JSON format is used as the standard format for representing spatial objects with non-spatial attributes. This fits nicely with client-side components implemented in most JavaScript languages. Moreover, it is easy to convert from vector layers to JSON files in OpenLayers. Moreover, the JSON format structure can be easily transformed to

XML format, used for the work flow defined before. Figure 4.8 displays an example of Google map API script in this study for creating marker in Google map.

```
$point = "";
if(isset($_REQUEST["edit_place"])){
		$point .= "markerPoint = new GMarker(new 
GLatLng(".$place_latlng."), {draggable: true});\n";
		$point .= "map.addOverlay(markerPoint);\n";
}else{
		$point .= "markerPoint = new GMarker(map.getCenter(), {draggable: 
true});";
		$point .= "map.addOverlay(markerPoint);\n";
}
```

Figure 4.8 Google map API script.

4.2.2 Interface implementation

Page layouts

Each web page in this SDSS includes 3 sections (Figure 4.9). The left section includes the WSDSS logo and the menu system is on the middle of left column consisting of user input requirements of model selection, highway, weather, and time. The major contents of the web pages are on the right column. It shows the result from models on Google map interface. The detail of road risk assessment on each segment shows on the bottom of right column.

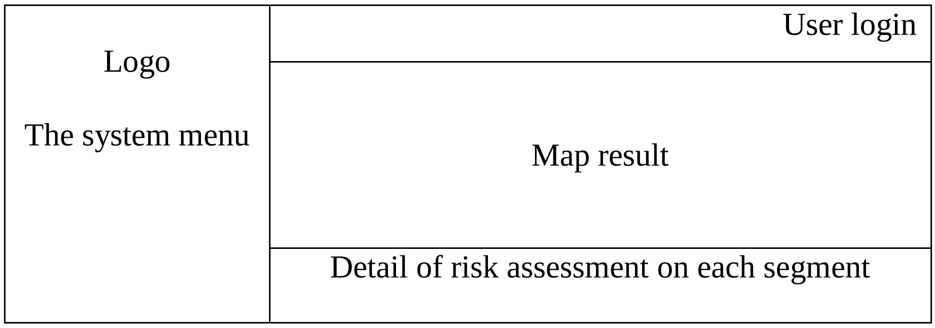

Figure 4.9 Web page layouts.

The system menu

The system menu divides into 2 parts, the menu for main control and more information about the web site (Figure 4.10). It consists of “Home” (the first page of web site), “About Application” (information of the system), “Manual” (user manual of the system) and “Sitemap” (list of pages of a web site accessible). The second part is menu for user requirement to interact with the system in terms of varying environment scenarios. It consists of pull-down menus for “Model” (Poisson Model and OWA model), Highway (Highway 2, 224 and 304), “Weather” (clear, mist and rain), and “Time” (time period).

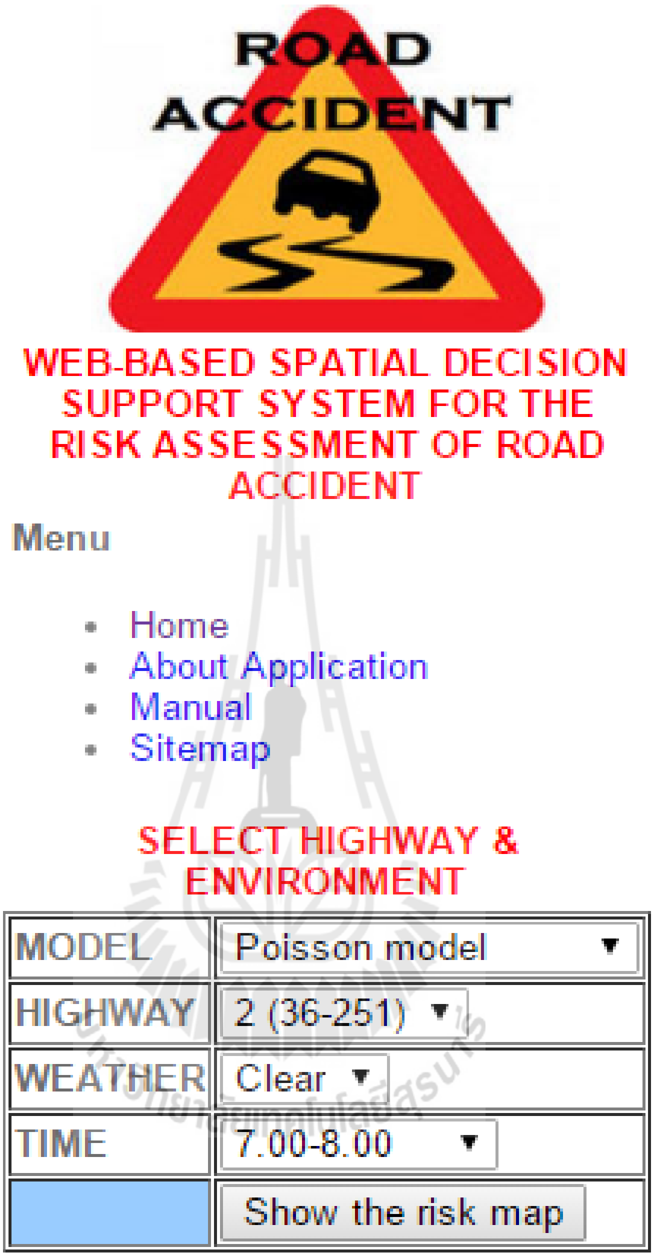

Figure 4.10 The system menu.

Map result

The system was developed as a web-based application interactively working with imported attribute data and users' requirements on variation of environmental attributes. The result was displayed on the Google Maps for user interaction.

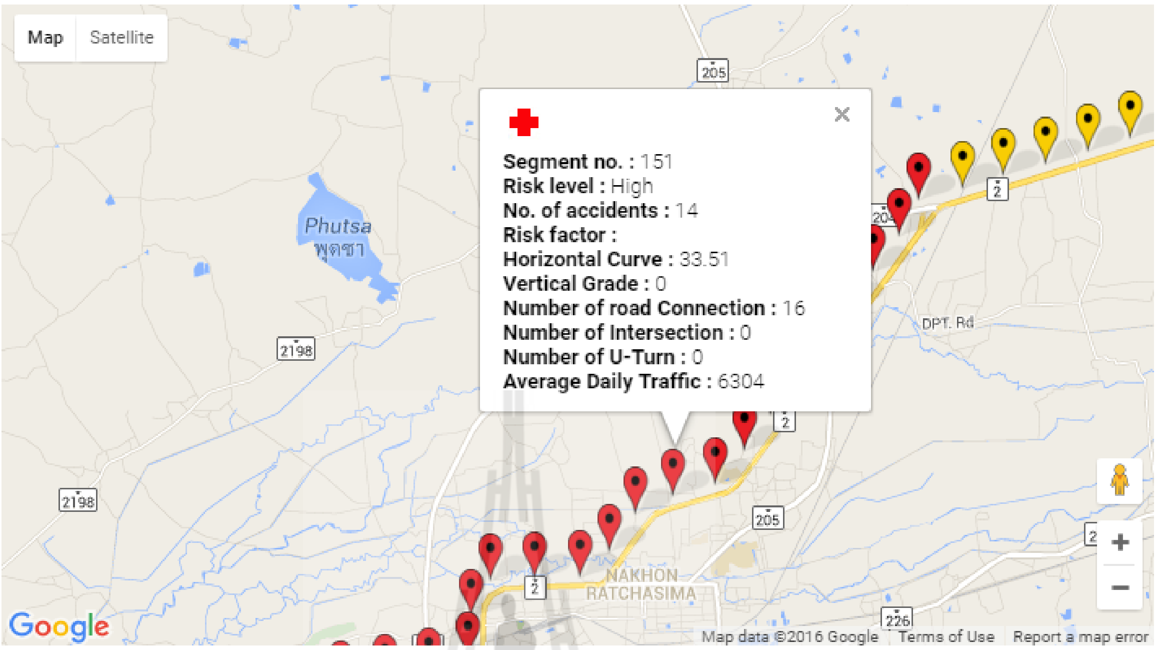

Figure 4.11 Map result.

As an example of interactive result shown in Figure 4.11, each point of symbol, representing a segment, shows predicted risk of road accident in form of colors for different intensity levels and detail attributes of the segment. Red, yellow, and green are for high, moderate, and low risk of accident, respectively.

A number of actual accidents, location, and risk assessment on each 100 meters are constantly shown on each 1-km segment (Figure 4.12). Additionally, the system shows also useful information of risk factors, specifically when they have values above their average in the same highway. The user can use the result as a guide for alert driving, traffic managing, escort for traffic movement, and safety maintenance.

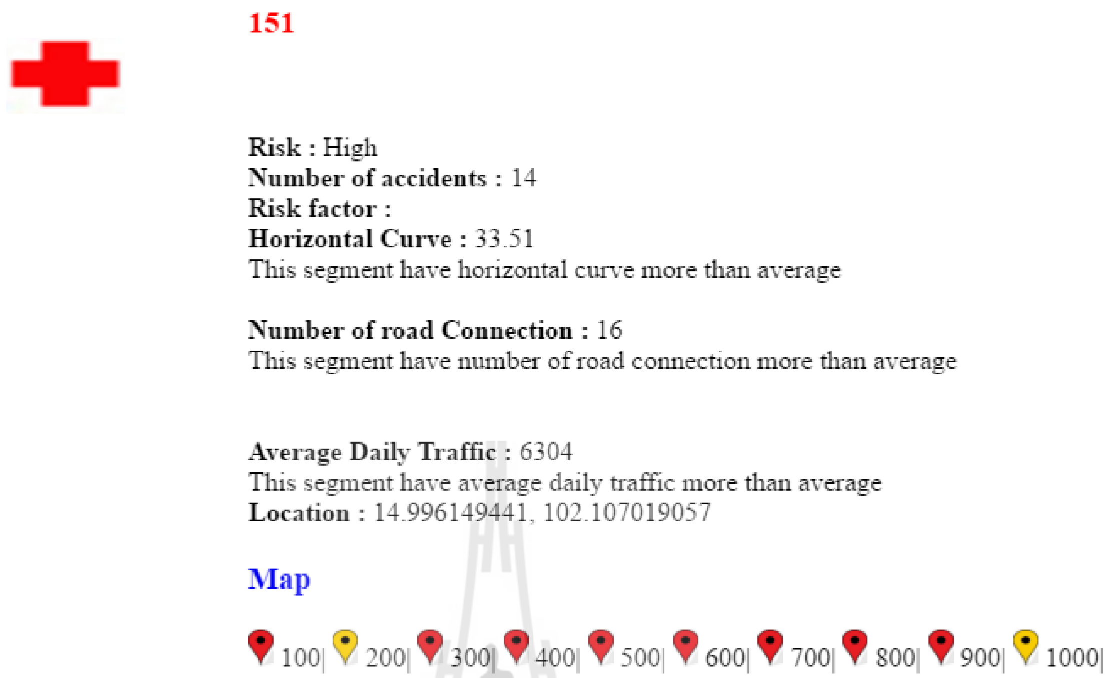

Figure 4.12 Detail of risk assessment on each segment.

Menu System

The menu system is used to provide neat organization and quick access of different web pages. Compatible with the functionality, this WSDSS uses a two level menu structure (Figure 4.13). The first level menu lists the function groups, and the second level menus list all web pages /functions in each group of the first level menu. The menu system was created using Cascading Style Sheets (CSS). The menu system is displayed in each JSP web page. The two-level menu structure allows users to access other functionality at no more than two steps.

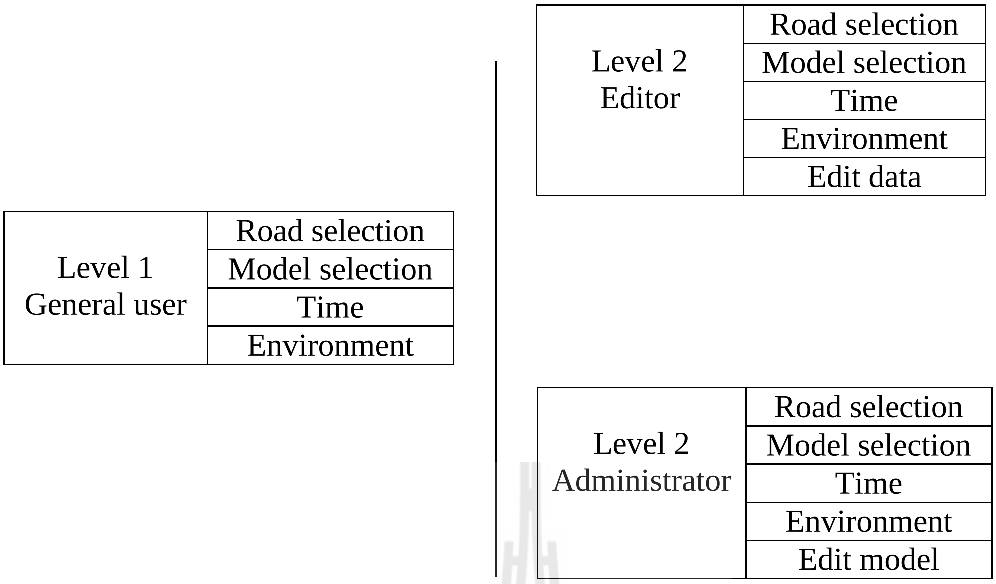

Figure 4.13 WSDSS menu structure.

4.3 Database development and Implementation

The database is the major tool to manage the data in this WSDSS. Current database management technologies have a solid theoretical basis and many mature DBMS are available to manage data. This WSDSS uses MySQL web database server as the DBMS. A typical database design and implementation includes requirements analysis, conceptual design, logical design, and implementation.

The requirements can be defined by section 4.1.3 Functionality and Analysis Flow. This section described the database requirement of the WSDSS. In the following sections, analysis flow is first described to understand the major analytical process related with database operation. Then application logic, conceptual design, logic design, and database implementation are discussed.

From previous studies, factors relevant to evaluating risk of accident can be numerated as shown in Table 3.1. All these attributes were captured as database and attached to each road segment of highway, with a certain length of 100 meters. The data on road accident (2009 – 2012) contain a number of accidents and data describe detail conditions while an accident occurs such as date and time, road surface condition, location, etc. The road geometry data were obtained from road design blue print. ADT of each 1 km. road segment was compiled by the Highways Statistics Unit, 8 Highways Bureau, Nakhon Ratchasima.

4.3.1 Collecting data to database

Road accident data

Details of accident data values are dependent on road environment in each country. In this study, accident data values were adopted from Thailand DOH. All accident data examples guide to the essential accident data (Figure 4.14). These accident data sets were refined for required accident data selection. Ten required accident data were selected. The required accident data in the report form should consist of these elements.

1) Date and time of accident-time reference when accident occurred

2) Location of accident - for black spot identification

3) Accident category by accident severity - for black spot identification

4) Number of casualty - for accident lost calculation

5) Type of traffic units - for involved traffic unit classification

6) Characteristic of accident location - for basic accident contribution analysis

7) Pavement conditions - for basic accident contribution analysis

8) Visibility conditions - for basic accident contribution analysis

9) Weather conditions - for basic accident contribution analysis

10) Accident contributions - for accident counter measure decision

After the accident was reported by the developed form, it was entered to computer data file.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1	C	R(	C(	KM						TIME	L																	C	V									D	DA			NAMET
115	612	2	200	35772	21	2	52	7	1	700	800	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	100	112	0	0	0	0	0	0	0	0	68	150	96	C	มวกเหล็ก - ปากช่อง
116	612	2	200	37690	21	2	52	7	1	1510	680	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	100	411	0	0	0	0	0	0	0	0	53	100	84	C	มวกเหล็ก - ปากช่อง
117	612	2	200	37710	18	2	52	4	2	1630	8G0	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	100	112	0	0	0	0	0	0	2	0	40	500	55	8	มวกเหล็ก - ปากช่อง
118	612	2	200	47450	16	2	52	2	2	814	800	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	112	0	0	0	0	0	0	1	0	21	100	96	C	มวกเหล็ก - ปากช่อง
119	612	2	300	62860	8	1	52	5	2	1945	800	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	122	0	0	0	0	0	0	0	0	17	100	84	C	ปากช่อง - ทางแยกไปชัยภูมิ
120	612	2	300	99372	15	1	52	5	2	1600	A00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	F00	112	0	0	0	0	0	0	0	0	61	35	56	C	ปากช่อง - ทางแยกไปชัยภูมิ
121	612	2	402	118962	6	2	52	6	2	1830	800	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	100	132	0	0	0	0	0	0	0	0	17	15	56	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
122	612	2	402	121862	1	1	52	5	1	1130	8A0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	E00	112	0	0	0	0	0	0	1	0	48	50	56	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
123	612	2	402	127962	10	2	52	3	2	2010	800	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	100	132	0	0	0	0	0	0	0	0	7	20	56	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
124	612	2	402	128962	27	1	52	3	2	520	800	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	132	0	0	0	0	0	0	0	0	4	30	82	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
125	612	2	402	130462	1	1	52	5	1	2105	800	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	200	122	1	0	0	0	1	0	0	0	0	100	96	3	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
126	612	2	402	139337	16	2	52	2	2	300	800	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	122	0	0	0	0	0	0	0	0	48	100	84	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
2828	612	2	200	40450	11	3	52	4	2	1530	800	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	100	112	0	0	0	0	0	2	2	0	39	350	51	8	มวกเหล็ก - ปากช่อง
2829	612	2	300	58600	1	5	52	6	2	300	800	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	100	122	0	0	0	0	0	0	0	0	65	100	82	C	ปากช่อง - ทางแยกไปชัยภูมิ
2831	612	2	300	87775	1	5	52	6	2	1030	800	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	C00	112	0	0	0	0	0	0	2	1	36	56	51	8	ปากช่อง - ทางแยกไปชัยภูมิ
3636	611	2	600	207803	12	5	52	3	2	1830	200	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	100	112	0	0	0	0	0	0	0	0	8	0	21	8	ทางแยกไปพิมาย - สีดา
3637	611	2	600	208331	25	6	52	5	2	2000	200	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	100	122	0	0	0	0	0	0	1	3	59	0	21	8	ทางแยกไปพิมาย - สีดา
5631	612	2	300	91725	2	6	52	3	2	2315	A00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	122	0	0	0	0	0	0	0	0	46	36	56	C	ปากช่อง - ทางแยกไปชัยภูมิ
5632	612	2	402	141817	27	4	52	2	2	310	G00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	100	122	0	0	0	0	0	0	0	0	38	100	55	C	ทางแยกไปสูงเนิน - ทางแยกต่างระดับนครราชสีมา
5633	612	2	403	145637	17	5	52	1	1	1340	800	0	0	0	0	0	5	0	1	1	0	0	0	0	0	0	0	100	112	0	0	0	0	0	0	0	0	72	400	51	8	ทางแยกต่างระดับนครราชสีมา - สะพานลำตะคอง
5634	611	2	500	156987	1	1	52	5	1	1350	800	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	E00	112	0	0	0	0	0	0	2	6	0	1	52	8	สะพานลำตะคอง - ทางแยกไปพิมาย
5635	611	2	500	171812	19	1	52	2	2	802	800	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	112	0	0	0	0	1	0	0	0	16	0	56	C	สะพานลำตะคอง - ทางแยกไปพิมาย
5636	611	2	600	219042	3	1	52	7	1	1400	200	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	100	112	0	0	0	0	1	0	0	0	91	0	56	C	ทางแยกไปพิมาย - สีดา
5637	611	2	600	231912	9	1	52	6	2	2325	A00	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	200	442	0	0	0	0	0	0	1	0	6	0	41	8	ทางแยกไปพิมาย - สีดา
5638	611	2	600	209366	22	2	52	1	1	25	800	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	C00	132	0	0	0	0	0	0	1	0	6	0	55	C	ทางแยกไปพิมาย - สีดา
5639	611	2	701	235814	8	3	52	1	1	1000	800	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	B00	112	0	0	0	0	0	0	0	0	7	0	51	8	สีดา - หนองแวงโสกพระ
5640	611	2	701	238864	11	1	52	1	1	520	800	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	B00	432	0	0	0	0	0	0	0	0	49	0	84	C	สีดา - หนองแวงโสกพระ
5897	612	2	300	73840	22	7	52	4	2	500	800	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	E00	122	0	0	0	0	0	0	0	1	36	47	55	C	ปากช่อง - ทางแยกไปชัยภูมิ
5898	612	2	300	88400	22	8	52	7	1	1530	700	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	E00	411	0	0	1	0	0	0	0	0	15	45	78	C	ปากช่อง - ทางแยกไปชัยภูมิ

Figure 4.14 Road accident data from DOH.

Road geometry data

The road geometry data were extracted from road design blue print (Figure 4.15). All these attributes were attached to each 100-m road segment in the database.

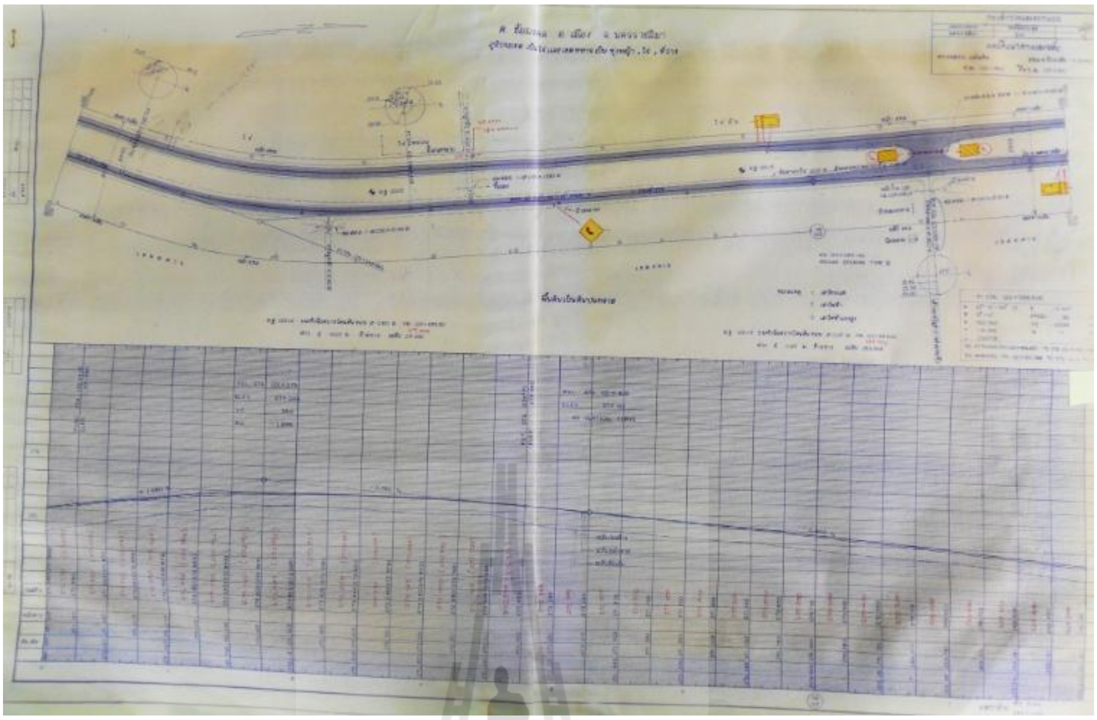

Figure 4.15 Road design blueprint.

From previous studies, factors relevant to evaluating risk of accident can be listed as follows:

- PW; pavement width,
- SW; shoulder width,
- DS: design speed,
- HC: degree of horizontal curve,
- VG: percentage of vertical grade,
- RC: number of road connection,
- IN: number of intersection, and
- UT: number of U-turn.

ADT

ADT of each 1-km road segment was compiled by the Highways Statistics Unit, 8 Highways Bureau, Nakhon Ratchasima based on raw data from the survey points as examples shown in Figure 4.16.

แบบสรุปสำรวจปริมาณการจราจร กรมทางหลวง

สำนักทางหลวงที่ 8 สำนักงานบำรุงทางนครราชสีมาที่ 3 .ริ่มใช้เมื่อ ม.ค.2545

ทางหลวงหมายเลข 304 หมายเลขควบคุม 0904 ตอน จุดสุดทางเลี่ยงเมืองปักธงชัย - กม.131+000 (ต่อเขตแขวงฯนครราชสีมาที่ 2) จำนวน 4 ช่องจราจร

สำรวจที่ กม. 117+500 ที่ สถานี ☑ หลัก ☐ ย่อย ☐ อื่น ๆ

ประจำงวดที่ 2 ระหว่างวันที่ 25 ถึง 25 เดือน เมษายน พ.ศ. 2555

ทิศทางขาเข้า (จาก จุดสุดทางเลี่ยงเมืองปักธงชัย ไป กม.131+000 (ต่อเขตแขวงฯนครราชสีมาที่ 2))

เวลา	(1) จักรยาน 2 ล้อ และ จักรยาน 3 ล้อ	(2) สามล้อ เครื่อง และ จักรยาน ยนต์	(3) รถยนต์ นั่ง (ไม่เกิน 7 คน)	(4) รถยนต์ นั่ง (เกิน 7 คน)	(5) รถ โดยสาร ขนาด เล็ก	(6) รถ โดยสาร ขนาด กลาง	(7) รถ โดยสาร ขนาด ใหญ่	(8) รถบรรทุกขนาด เล็ก (4 ล้อ)	(9) รถบรรทุกขนาด 2 เพลา (6 ล้อ)	(10) รถบรรทุก ขนาด 3 เพลา (10 ล้อ)	(11) รถบรรทุก พ่วง (มาก กว่า 3	(12) รถบรรทุกกึ่งพ่วง (มากกว่า 3 เพลา)	(13) รถ เครื่อง จักร และ รถ	รวม (1)-(13)
07.00-08.00	17	333	264	169	31	17	26	364	50	34	12	50	10	1,360
08.00-09.00	10	269	209	171	35	15	29	284	51	37	22	45	15	1,192
09.00-10.00	11	167	164	105	30	8	27	245	38	35	14	50	13	907
10.00-11.00	9	125	183	112	27	12	24	254	49	29	15	40	18	888
11.00-12.00	14	122	201	124	25	18	27	248	41	31	22	42	12	927
12.00-13.00	19	132	225	145	27	21	28	267	46	39	23	34	11	1,017
13.00-14.00	10	114	152	129	14	17	32	267	57	35	17	32	12	888
14.00-15.00	8	116	143	129	11	11	29	261	55	30	26	43	8	870
15.00-16.00	10	112	161	114	16	18	31	204	61	32	25	36	11	831
16.00-17.00	11	126	181	123	17	24	35	219	64	28	17	48	16	909
17.00-18.00	24	139	170	141	17	17	29	226	62	45	23	45	8	946

Figure 4.16 Raw data from the survey points.

This study used twenty six survey points; it can be classified as follows.

Highways 2 have thirteen survey points (eleven inside and two outside the study area).

Highways 224 have seven survey points (five inside and two outside the study area).

Highways 304 have six survey points (four inside and two outside the study area).

Due to limited available data, the few data outside and next to the study area were included.

Environment data

The weather is a factor that changes according to the input of a user which can affect the occurrence of accidents. When the user specifies the weather condition to the system, it will be applied to every segment. It can be found that the rainy weather is more likely to increase the risk of accidents than the misty and the clear weather, respectively.

4.3.2 Application logic

Regarding database operation, this SDSS includes 2 major activities, query and editing data (Figure 4.17). User information management is used in the whole process to identify users and create customized web pages. After login, users can view data through web pages. Users first send a request for data, then the web server queries the database according to the request, the DBMS server queries current database and returns required data to the web server, the web server organizes the data into a formatted web page and returns it to users.

Users can change the data through editing data and running projects. Users first send requests to insert, update, or delete data. The web server translates the request into an SQL command and executes the SQL in DBMS. When users send a request to run a project, the web server first queries the database to prepare the required input for a project. After running a project, the web server put the results back to the database. Then the results are available for query.

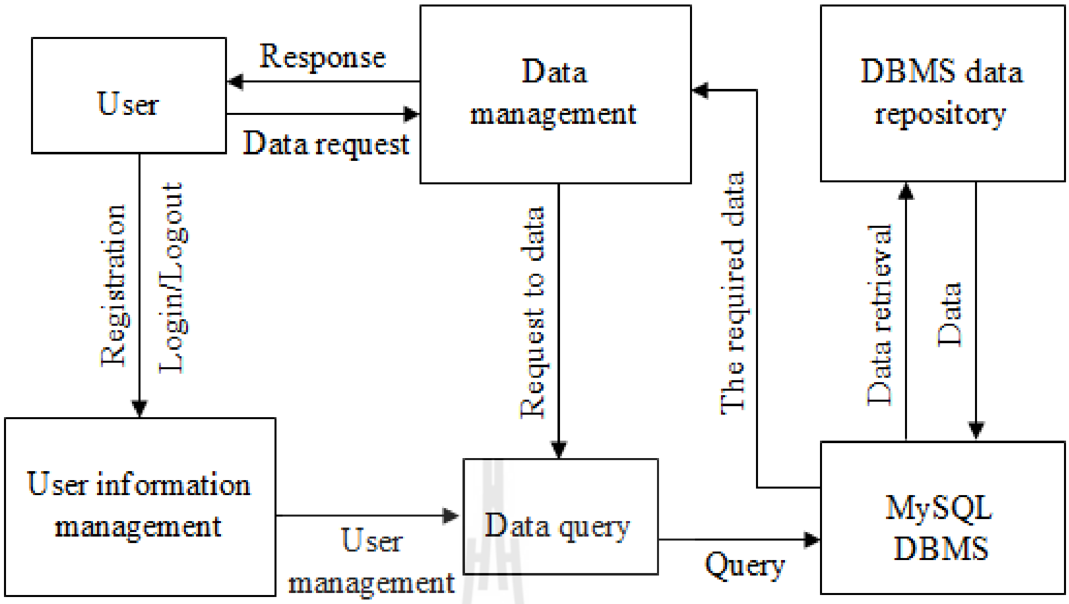

Figure 4.17 Application logic of the WSDSS.

4.3.3 Conceptual design

Conceptual design defines the abstract model of data organization. The design depends on the objectives of a database and application logic. The E-R diagram for this WSDSS is shown in Figure 4.18.

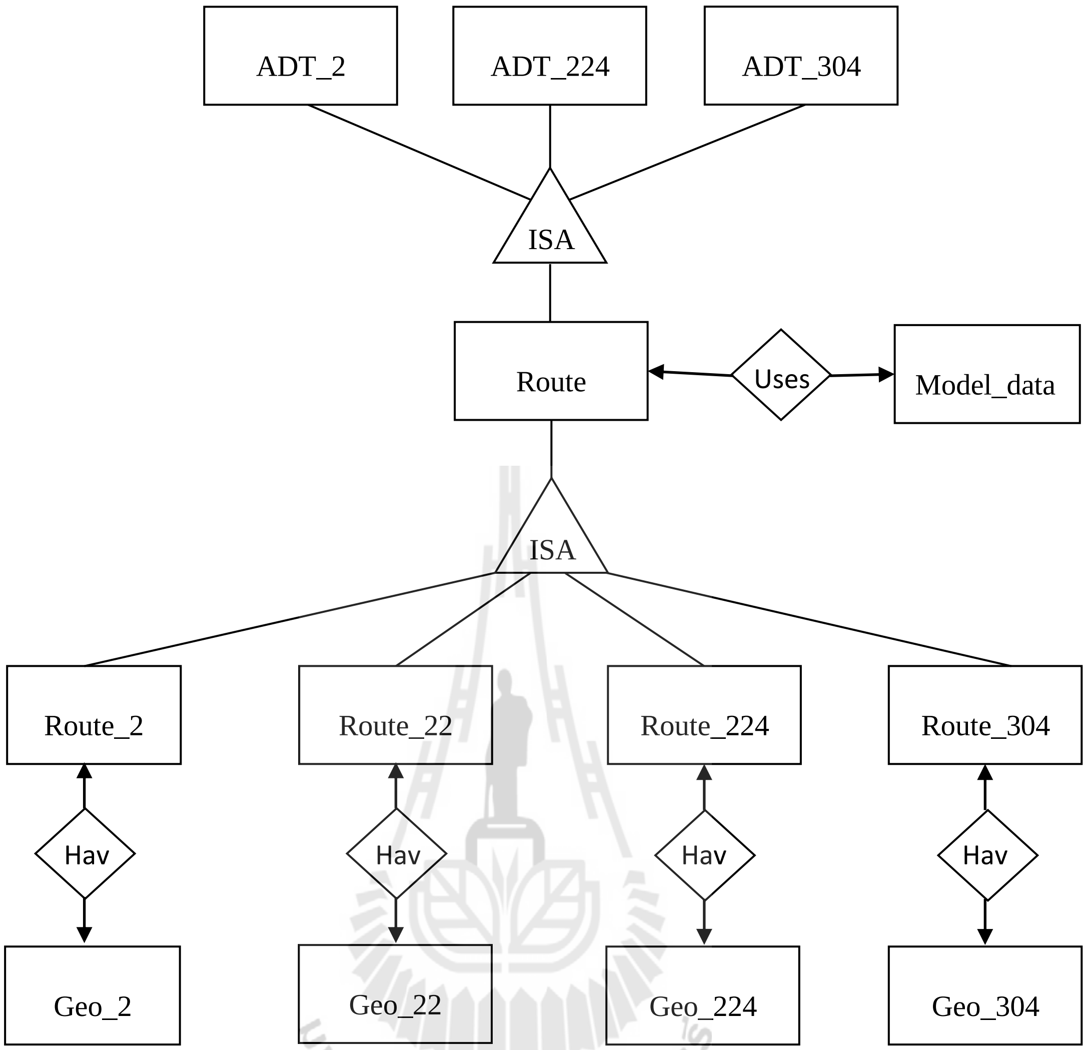

Figure 4.18 E-R diagrams.

This database use ISA relationship to express relations. A set of subclasses can be specified to relate to a class in form of ISA relationship. There are 3 sets of ADT data of 3 highways, displayed in form of entity ADT (highway), having ISA relationships to entity Route while there are 4 sets of Route (highway) having ISA relationships to entity Route. Each set of ADT data shares the common structure design of ADT for entity Route. Similarly, each set of route data shares the common structure design of route data for entity Route. Every Route (highway) has its own geometric data.

4.3.4 Logical design

Logical design defines the operational relationships among different entities in a database. In this study, the logic to create new data is enforced through explicit validation checks. Before inserting a new record, a SQL query is made to check the format, redundancy and possible conflicts. The deletion logic is implemented explicitly through SQL created by middleware. The deletion is implemented in a cascade pattern.

All data tables with data description are shown below: (PK : Primary key, FK : Foreign Key)

Table 4.1 Data description of table route.

Filed name	Type	Size	Key	Null	Description
routeid	varchar	5	PK	no	Route identification code
name	varchar	30		no	Route name
info	varchar	100		yes	Route information

Table 4.2 Data description of table route_x.

Filed name	Type	Size	Key	Null	Description
place_id	integer	11	PK	no	Segment identification code
place_icon	text			no	Risk icon of segment
place_latlng	varchar	100		no	Segment location
Place_pic	text			no	Risk picture of segment
Place_name	varchar	200		no	Segment name
Place_address	text			no	Segment risk

Table 4.2 Data description of table route_x (Continued).

Filed name	Type	Size	Key	Null	Description
Place_count	integer	11		no	Actual accident on segment
remark	float			no	Poison score
Owa_1	float			no	OWA score min
Owa_2	float			no	OWA score semi 1
Owa_3	float			no	OWA score semi 2
Owa_4	float			no	OWA score average
Owa_5	float			no	OWA score semi 3
Owa_6	Float			no	OWA score semi 4
Owa_7	Float			no	OWA score max
routeid	varchar	5	FK	no	Route identification code

Table 4.3 Data description of table geo_x.

Filed name	Type	Size	Key	Null	Description
Geo x_id	integer	11	PK	no	Geometry identification code
place_id	integer	11		no	Segment identification code
hc	float			no	Degree of Horizontal Curve
ds	integer	3		no	Design Speed
pw	float			no	Pavement Width
sw	float			no	Shoulder Width
vg	float			no	Percentage of Vertical Grade
nc	integer	2		no	Number of Road Connection
inters	integer	2		no	Number of Intersection
ut	integer	2		no	Number of U-turn
Remark_100	float			no	Poison score in (100 meter)
Owa1_100	float			no	OWA score min (100 meter)
Owa2_100	float			no	OWA score semi 1 (100 meter)
Owa3_100	float			no	OWA score semi 2 (100 meter)
Owa4_100	float			no	OWA score average (100 meter)

Table 4.3 Data description of table geo_x (Continued).

Filed name	Type	Size	Key	Null	Description
Owa5_100	float			no	OWA score semi 3 (100 meter)
Owa6_100	float			no	OWA score semi 4 (100 meter)
Owa7_100	float			no	OWA score max (100 meter)
place_id	integer	11	FK	no	Segment identification code

Table 4.4 Data description of table ADT_x.

Filed name	Type	Size	Key	Null	Description
ADTx_id	integer	11	PK	no	ADT identification code
7_8	integer	11		no	ADT of 7 am.to 8 am.
8_9	integer	11		no	ADT of 8 am.to 9 am
9_10	integer	3		no	ADT of 9 am.to 10 am
10_11	integer	11		no	ADT of 10 am.to 11 am
12_13	integer	11		no	ADT of 12 am.to 1 pm
13_14	integer	11		no	ADT of 1 pm.to 2 pm
14_15	integer	11		no	ADT of 2 pm.to 3 pm
15_16	integer	11		no	ADT of 3 pm.to 4 pm
16_17	integer	11		no	ADT of 4 pm.to 5 pm
17_18	integer	11		no	ADT of 5 pm.to 6 pm
18_19	integer	11		no	ADT of 6 pm.to 7 pm
19_21	integer	11		no	ADT of 7 pm.to 9 pm
21_7	integer	11		no	ADT of 9 pm.to 7 am
Route_id	integer	11	FK	no	Segment identification code
light	integer	1		no	Light on segment

Table 4.5 Data description of table factor.

Filed name	Type	Size	Key	Null	Description
Model_id	varchar	5	PK	no	Route identification code
f1	varchar	5		no	Factor number 1
mf1	float			no	Efficiency of Factor number 1
f2	varchar	5		no	Factor number 2
mf2	float			no	Efficiency of Factor number 2
f3	varchar	5		no	Factor number 3
mf3	float			no	Efficiency of Factor number 3
f4	varchar	5		no	Factor number 4
mf4	float			no	Efficiency of Factor number 4
f5	varchar	5		no	Factor number 5
mf5	float			no	Efficiency of Factor number 5
f6	varchar	5		no	Factor number 6
mf6	float			no	Efficiency of Factor number 6
f7	varchar	5		no	Factor number 7
mf7	float			no	Efficiency of Factor number 7
conts	float			no	Constant value
Route_id	integer	11	FK	no	Segment identification code

4.4 Model result

The results of system include factor analysis to manage data redundancy, the Poisson regression modeling and OWA modeling to assess risk of routes no.2, 224, and 304. The risk assessment is designed to perform under 3 environment scenarios: Environment 1 (good environment), Environment 2 (moderate environment) and Environment 3 (poor environment).

4.4.1 Factor analysis results

The factor analysis used statistical package STATA 10.0 for Windows to determine how many factors are needed to explain the set of variables and to removes redundancy or duplication from a set of correlated variables. From result of factor analysis, components with eigenvalue more than 0.85 are selected to be effective components of the model. To eliminate data redundancy, factors or variables with loading more than +/- 0.3 are correlated variables and selected to represent each component. The factor analysis result of each route is shown below:

In Figure 4.19, Route 2 is composed of 5 components (Eigenvalue more than 0.85) which can explain 81.63% of data. The variables involved in each component are:

Component 1 is composed of pw, sw, and ut and can be represented by:

((0.4762*pw)+(0.5856*sw)+(0.5118*ut)).

Component 2 is composed of hc and ds and can be represented by:

((-0.6436*hc)+(0.6628*ds)).

Component 3 is composed of vg.

Component 4 is composed of inter.

Component 5 is composed of nc.

Principal components/correlation   Number of obs = 2171
Number of comp. = 8
Trace = 8
Rotation: (unrotated = principal)   Rho = 1.0000

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.9262	.368711	0.2408	0.2408
Comp2	1.55748	.375822	0.1947	0.4355
Comp3	1.18166	.175167	0.1477	0.5832
Comp4	1.0065	.148181	0.1258	0.7090
Comp5	.858315	.220665	0.1073	0.8163
Comp6	.63765	.211741	0.0797	0.8960
Comp7	.425909	.019621	0.0532	0.9492
Comp8	.406288	.	0.0508	1.0000

Principal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Unexplained
hc	0.1194	-0.6436	0.2461	0.0723	-0.2905	0.0153	0.5915	0.2669	0
ds	-0.2262	0.6628	-0.0270	-0.0230	-0.0120	-0.0755	0.6342	0.3164	0
pw	0.4762	0.1077	0.3266	-0.0073	0.1401	-0.7890	-0.0660	0.0916	0
sw	0.5856	0.1836	-0.1344	0.0299	-0.1319	0.1939	0.3571	-0.6495	0
vg	-0.1760	-0.0031	0.7060	-0.1338	0.5477	0.2405	0.1411	-0.2736	0
nc	0.2680	-0.2060	-0.2873	-0.1419	0.7247	0.0762	0.1816	0.2531	0
inter	0.0054	0.0370	0.0240	0.9767	0.2025	0.0485	-0.0039	0.0265	0
ut	0.5118	0.2393	0.2783	-0.0364	-0.1103	0.5176	-0.2512	0.5087	0

Figure 4.19 Factor analysis of route 2 by STATA 10.0 for Window.

In Figure 4.20, Route 224 is composed of 5 components (Eigenvalue more than 0.85) which can explain 85.80% of data. The variables involved in each component are:

Component 1 is composed of pw, sw, and ut and can be represented by:

((0.5923*pw)+(0.5824*sw)+(0.3143*ut))

Component 2 is composed of hc and ds and can be represented by:

((0.6539*hc)+(-0.6514*ds))

Component 3 is composed of vg.

Component 4 is composed of inter.

Component 5 is composed of nc.

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.09808	.255155	0.2623	0.2623
Comp2	1.84292	.834149	0.2304	0.4926
Comp3	1.00878	.0207171	0.1261	0.6187
Comp4	.988059	.0619399	0.1235	0.7422
Comp5	.926119	.0767982	0.1158	0.8580
Comp6	.849321	.684005	0.1062	0.9642
Comp7	.165316	.0439097	0.0207	0.9848
Comp8	.121406	.	0.0152	1.0000

Principal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Unexplained
hc	-0.2672	0.6539	0.0219	0.0328	0.0098	0.0072	-0.0074	0.7066	0
ds	0.2732	-0.6514	-0.0148	-0.0195	0.0082	-0.0048	-0.0156	0.7072	0
pw	0.5923	0.2468	0.0362	0.1032	-0.0727	-0.2435	-0.7152	-0.0144	0
sw	0.5824	0.2328	0.0110	0.1617	-0.1148	-0.2877	0.6960	0.0088	0
vg	-0.0988	-0.0853	0.2201	0.9257	0.2606	0.0946	-0.0250	-0.0131	0
nc	0.2309	0.0996	0.1395	-0.2688	0.9042	0.1580	0.0483	-0.0103	0
inter	0.0461	-0.0021	0.9371	-0.1687	-0.2394	0.1829	0.0226	-0.0002	0
ut	0.3143	0.1259	-0.2278	0.0642	-0.1963	0.8891	0.0188	0.0003	0

Figure 4.20 Factor analysis of route 224 by the STATA 10.0 for Windows.

In Figure 4.21, Route 304 is composed of 5 components (Eigenvalue more than 0.85) which can explain 85.80% of data. The variables involved in each component are:

Component 1 is composed of pw, sw, and ut and can be represented by:

((0.5923*pw)+(0.5801*sw)+(0.5454*ut))

Component 2 is composed of hc and ds and can be represented by:

((0.6779*hc)+(-0.6761*ds))

Component 3 is composed of vg.

Component 4 is composed of inter.

Component 5 is composed of nc.

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.6768	.664326	0.3346	0.3346
Comp2	2.01247	.977638	0.2516	0.5862
Comp3	1.03483	.0421931	0.1294	0.7155
Comp4	.99264	.0942246	0.1241	0.8396
Comp5	.898415	.615393	0.1123	0.9519
Comp6	.283022	.225808	0.0354	0.9873
Comp7	.0572139	.0126048	0.0072	0.9944
Comp8	.044609	.	0.0056	1.0000

rincipal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Unexplained
hc	-0.0776	0.6779	0.0997	0.0865	-0.1195	0.0071	0.6949	0.1406	0
ds	0.0711	-0.6761	-0.1128	-0.0983	0.1310	-0.0244	0.6985	0.0992	0
pw	0.5923	0.0551	0.0131	-0.0296	0.0168	-0.3216	-0.1263	0.7249	0
sw	0.5801	0.1014	0.0096	-0.0320	0.0208	-0.4473	0.1108	-0.6628	0
vg	-0.0182	0.2549	-0.2905	-0.2573	0.8048	0.0812	-0.0133	0.0029	0
nc	0.0133	-0.0634	0.8279	0.2134	0.2130	0.0393	0.0070	-0.0056	0
inter	0.0602	-0.0165	-0.2727	0.8984	0.2230	0.0162	0.0031	-0.0020	0
ut	0.5454	0.0287	0.0124	-0.0250	-0.0848	0.8291	0.0262	-0.0746	0

Figure 4.21 Factor analysis of route 304 by STATA 10.0 for Windows.

From factor analysis result found, Route 2, 224 and 304 are composed of 5 components which can explain more than 80% of data. These variables involved in each component are component 1: pavement width, shoulder width, and U-turn, component 2: design speed and degree of horizontal curve, component 3: percentage of vertical grade, component 4: number of road connection, and component 5: Intersection.

4.4.2 MADM using DEX approach results

MADM using DEX approach for environment factor extracted from the experts' opinions was surveyed through a questionnaire (Appendix B). The experts include the experts of the Department of Highway and the Department of Transportation of various universities. The questionnaire was designed based on developed rules that expressed the relationship of attributes and sub-attributes for classifying environment factor. The relationship of the rules and expected outputs were prepared in form of a tree of attributes as shown in Figure 4.22.

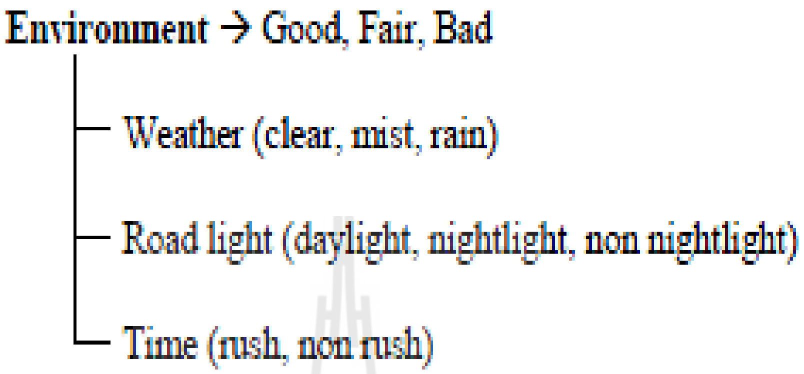

Figure 4.22 Tree of environment attributes.

The combination from tree of attributes was established in DEXi software to create decision rules as shown in Figure 4.23. The decision rules extracted from all of conditions were coded for WSDSS application as shown in Figure 4.24.

	weather	road light	time	environmer
1	Clear	Day_light	rush_hour	good
2	Clear	Day_light	Non_rush	good
3	Clear	Night_light	rush_hour	fair
4	Clear	Night_light	Non_rush	good
5	Clear	Night_no_ligh	rush_hour	bad
6	Clear	Night_no_ligh	Non_rush	fair
7	Mist	Day_light	rush_hour	fair
8	Mist	Day_light	Non_rush	fair
9	Mist	Night_light	rush_hour	bad
10	Mist	Night_light	Non_rush	fair
11	Mist	Night_no_ligh	rush_hour	bad
12	Mist	Night_no_ligh	Non_rush	bad
13	Rain	Day_light	rush_hour	fair
14	Rain	Day_light	Non_rush	fair
15	Rain	Night_light	rush_hour	bad
16	Rain	Night_light	Non_rush	bad
17	Rain	Night_no_ligh	rush_hour	bad
18	Rain	Night_no_ligh	Non_rush	bad

Figure 4.23 The combination from tree of attribute in DEXi.

```
if ($row_envi['envi_weather'] == 1 && $n_d == 1)
$envi = '1';
else
if ($row_envi['envi_weather'] == 1 && $envi_light == 1 && $rush == 1)
$envi = '1';
else
if ($row_envi['envi_weather'] == 1 && $rush == 1)
$envi = '1';
else
if ($row_envi['envi_weather'] == 1 &&  $envi_light == 1 && $rush == 0)
$envi = '2';
else
if ($row_envi['envi_weather'] == 1 &&  $envi_light == 0 && $rush == 1)
$envi = '2';
else
if ($row_envi['envi_weather'] >= 2 &&  $n_d == 1)
$envi = '2';
else
if ($row_envi['envi_weather'] == 2 &&  $n_d == 0 && $envi_light == 1 && $rush == 1)
$envi = '2';
else
if ($row_envi['envi_weather'] == 2 &&  $n_d == 1 && $rush == 1)
$envi = '2';
else
if ($n_d == 1 && $envi_light == 0 && $rush == 0)
$envi = '3';
else
if ($row_envi['envi_weather'] >= 2 && $n_d == 0 && $rush == 0)
$envi = '3';
else
if ($row_envi['envi_weather'] >= 2 &&  $envi_light == 0)
$envi = '3';
else
if ($row_envi['envi_weather'] == 3 && $n_d == 0)
$envi = '3';
```

Figure 4.24 The decision rule coding in WSDSS application.

The attributes of environment factors, which represented the skeleton of the multi-attribute model, and the expected final outcomes, included “low risk” (good), “moderate risk” (fair) or “high risk” (bad).

4.4.3 Poisson regression model results

Poisson regression model of route 2 is created from parameters estimated using maximum likelihood of statistical package STATA 10.0 for Windows. The results (Figures 4.25 - 4.27) show coefficients of each factor/component and constants for model construction of routes 2, 224, and 304 as shown below:

```
Iteration 0:   log likelihood = -1349.1037
Iteration 1:   log likelihood = -1332.3597
Iteration 2:   log likelihood = -1332.2694
Iteration 3:   log likelihood = -1332.2693

Poisson regression                                Number of obs   =       2166
                                                  LR chi2(6)      =     254.30
                                                  Prob > chi2     =     0.0000
Log likelihood = -1332.2693                       Pseudo R2       =     0.0871

------------------------------------------------------------------------------
         acc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          f1 |  -.2632963   .0550587    -4.78   0.000    -.3712094   -.1553832
          f2 |   .0245172   .0035438     6.92   0.000     .0175714    .0314629
          f3 |  -.1190057   .0568051    -2.09   0.036    -.2303417   -.0076697
          f4 |   .1679209    .047829     3.51   0.000     .0741778     .261664
          f5 |   .4490866   .3456087     1.30   0.194    -.2282939    1.126467
         adt |   .0003088   .0000356     8.66   0.000      .000239    .0003787
       _cons |   .6146326   .4178632     1.47   0.141    -.2043641    1.433629
------------------------------------------------------------------------------
```

Figure 4.25 Estimated coefficients and constant for Poisson regression model of route 2 using maximum likelihood.

$$E(Y) = EXP\ ((0.0003088*ADT)+(-0.2632963*f1)+ (0.0245172*f2)+ (-0.1190057*f3)+(0.1679209*f4)+(0.4490866*f5)+1.034825)$$

Where E(Y) = Expected value of accident in each segment (λ) of route 2.

```
poisson acc f1 f2 f3 f4 f5 f6

Iteration 0:   log likelihood = -565.46582
Iteration 1:   log likelihood = -393.27354
Iteration 2:   log likelihood = -308.70827
Iteration 3:   log likelihood = -304.28484
Iteration 4:   log likelihood = -303.51858
Iteration 5:   log likelihood =  -303.3951
Iteration 6:   log likelihood = -303.39012
Iteration 7:   log likelihood = -303.39012

Poisson regression                                Number of obs   =       1060
                                                  LR chi2(6)      =     158.41
                                                  Prob > chi2     =     0.0000
Log likelihood = -303.39012                       Pseudo R2       =     0.2070

------------------------------------------------------------------------------
         acc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          f1 |   .2691559   .0572409     4.70   0.000     .1569659    .3813459
          f2 |   .0357791   .0043337     8.26   0.000     .0272853     .044273
          f3 |   .0046627    .095193     0.05   0.961    -.1819122    .1912375
          f4 |   .4920039   .1391409     3.54   0.000     .2192928     .764715
          f5 |  -.5628542   1.007724    -0.56   0.576    -2.537957    1.412248
          f6 |   .0005332   .0001962     2.72   0.007     .0001486    .0009177
       _cons |  -2.226347   .4873264    -4.57   0.000    -3.181489   -1.271205
------------------------------------------------------------------------------
```

Figure 4.26 Estimate parameters (maximum likelihood) of route 224.

E(Y) = EXP ((0.0005332*ADT)+(-0.2691559*f1)+ (0.0357791*f2)+

(0.0046627*f3)+(0.4920039*f4)+(-0.5628542*f5)-2.226347)

Where E(Y) = Expected value of accident in each segment (λ) of route 224.

```
Iteration 0:   log likelihood = -349.23172
Iteration 1:   log likelihood = -346.08048
Iteration 2:   log likelihood = -346.00882
Iteration 3:   log likelihood = -346.00879

Poisson regression                                Number of obs   =        760
                                                  LR chi2(6)      =     175.90
                                                  Prob > chi2     =     0.0000
Log likelihood = -346.00879                       Pseudo R2       =     0.2027

------------------------------------------------------------------------------
         acc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          f1 |   -.152692   .1055361    -1.45   0.148    -.3595389    .0541548
          f2 |   .0544803   .0064326     8.47   0.000     .0418726     .067088
          f3 |   .1966903   .0908617     2.16   0.030     .0186046     .374776
          f4 |    1.70277   .5246366     3.25   0.001     .6745011    2.731039
          f5 |   .0177315   .1179319     0.15   0.880    -.2134108    .2488739
         adt |   .0003779   .0000337    11.22   0.000     .0003119    .0004439
       _cons |   1.034825    .745641     1.39   0.165    -.4266044    2.496254
------------------------------------------------------------------------------
```

Figure 4.27 Estimate parameters (maximum likelihood) of route 304.

$$E(Y) = EXP\ ((0.0005332*ADT)+(-0.2691559*f1)+ (0.0357791*f2)+ (0.0046627*f3)+(0.4920039*f4)+(-0.5628542*f5)-2.226347)$$

Where E(Y) = Expected value of accident in each segment (λ) of route 304.

Then λ of each segment was further used to calculate Poisson distribution probability value on each segment. The higher probability indicates higher risk of accident.

To be comparable the risk of accidents in different environment scenarios will setup environment of 3 routes as follows:

Good environment scenarios: weather is clear, and time is 13.00-14.00,

Moderate environment scenarios: weather is mist, and time is 7.00-8.00,

Poor environment scenarios: weather is rain, and time is 18.00-19.00.

Result of route 2

Table 4.6 shows top 25 ranking of segments on route no. 2 based on Poisson values and different environment scenarios.

Table 4.6 Top 25 ranking of segments on route no. 2 from Poisson result.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
144	4.88363	147	7.63949	147	9.3987
143	4.86146	144	7.55518	145	9.3757
146	4.85445	151	7.54409	148	9.3689
150	4.84152	143	7.52729	143	9.3564
145	4.84106	146	7.52264	150	9.3556
151	4.80903	145	7.4965	144	9.3432
148	4.74763	152	7.48832	146	9.3281
147	4.74019	150	7.43014	149	9.2618
149	4.72071	153	7.38427	151	9.1017
152	4.71998	149	7.2894	133	8.99156
133	4.68605	148	7.25061	158	8.99125
153	4.64044	133	7.24034	152	8.98385

Table 4.6 Top 25 ranking of segments on route no. 2 from Poisson result (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
135	4.62022	156	7.22787	153	8.97078
68	4.58273	135	7.20185	156	8.95784
134	4.55763	68	7.17244	159	8.9373
69	4.51546	158	7.15538	135	8.92215
156	4.51064	155	7.13772	160	8.88967
139	4.50748	139	7.13367	68	8.87954
136	4.49316	69	7.11647	134	8.84142
67	4.48293	134	7.11627	157	8.83397
158	4.47015	74	7.11361	172	8.83397
137	4.4631	159	7.09098	69	8.80933
74	4.44842	142	7.08353	155	8.80452
71	4.43897	136	7.08086	139	8.79911
72	4.42203	67	7.06937	161	8.79387

Result of route 224

Table 4.7 shows top 25 ranking of segments on route no. 224 based on Poisson values and different environment scenarios.

Table 4.7 Top 25 ranking of segments on route no. 224 from Poisson result.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
2	4.43808	2	7.35568	2	9.96415
1	4.39834	1	7.33135	1	9.9404
4	4.34421	4	7.29422	4	9.84735
6	4.21189	6	7.16841	6	9.68597
3	4.10563	3	7.03309	3	9.60403
5	4.05239	5	7.00883	5	9.53851
7	3.84724	7	6.84655	7	9.30318
19	3.72509	19	6.7305	19	9.12043
8	3.67798	8	6.63573	8	9.12042
9	3.62627	9	6.58325	9	9.06529
11	3.56791	32	6.52868	11	8.99965
32	3.49009	11	6.51651	32	8.88376
12	3.44126	33	6.37118	12	8.86633
20	3.43527	12	6.35409	20	8.83975

Table 4.7 Top 25 ranking of segments on route no. 224 from Poisson result (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
33	3.38032	20	6.28043	27	8.79078
27	3.37807	31	6.22658	33	8.78696
29	3.36234	18	6.20719	29	8.76945
18	3.33599	29	6.19133	18	8.73744
30	3.32117	30	6.18436	30	8.72255
31	3.31018	27	6.1745	31	8.70705
10	3.26999	10	6.15267	10	8.69521
21	3.26447	13	6.13646	13	8.68163
13	3.26337	21	6.08407	15	8.674
15	3.26272	15	6.04905	21	8.67097
14	3.23173	14	6.02892	14	8.63919

Result of route 304

Table 4.8 shows top 25 ranking of segments on route no. 304 based on Poisson values and different environment scenarios.

Table 4.8 Top 25 ranking of segments on route no. 304 from Poisson result.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
132	4.97533	132	7.61837	131	9.2586
131	4.8363	131	7.58362	130	9.228
130	4.67995	130	7.52134	132	9.1867
127	4.45018	127	7.43567	129	9.1372
129	4.3678	129	7.41855	128	9.0981
128	4.34868	128	7.41693	127	9.0976
126	4.18641	126	7.29189	126	8.89085
125	4.02612	125	7.19945	125	8.70516
124	3.95705	124	7.11725	124	8.60822
122	3.79172	122	6.89932	122	8.34993
123	3.67907	123	6.85006	123	8.27192
121	3.67879	121	6.74491	121	8.19787
109	3.49996	109	6.63407	120	8.00074
120	3.49465	120	6.61893	109	7.92322
105	3.46442	110	6.56787	105	7.86913
77	3.40847	105	6.56221	58	7.85797

Table 4.8 Top 25 ranking of segments on route no. 304 from Poisson result (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
66	3.40818	118	6.46613	66	7.8444
110	3.38638	107	6.45699	69	7.82904
69	3.38418	119	6.44868	118	7.81647
58	3.38366	108	6.42991	110	7.81645
118	3.3561	117	6.41585	77	7.80457
119	3.33444	106	6.36532	119	7.80276
107	3.33229	115	6.3501	117	7.7787
117	3.32572	116	6.34515	107	7.74508
108	3.30739	102	6.33519	116	7.72922

4.4.4 OWA model results

To be comparable the risk of accidents in different environment scenarios will setup environment of 3 routes as follows:

Good environment scenarios: weather is clear, and time is 13.00-14.00,

Moderate environment scenarios: weather is mist, and time is 7.00-8.00,

Poor environment scenarios: weather is rain, and time is 18.00-19.00.

Result of route 2

Table 4.9 shows the ranking top 25 of average OWA values on route no.2.The finding based on values of different environment scenarios.

Table 4.9 Ranking top 25 of average OWA values on route no.2.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
147	3.629164	148	3.959761	149	4.801696
148	3.627106	149	3.804028	148	4.781412
149	3.527361	70	3.800689	150	4.755142
150	3.506711	38	3.681258	147	4.698076
38	3.451063	150	3.665102	144	4.671209
70	3.305799	147	3.316132	151	4.654337

Table 4.9 Ranking top 25 of average OWA values on route no.2 (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
151	3.223886	151	3.291662	39	4.644924
152	3.117671	152	3.129224	146	4.608445
153	3.007595	153	2.899473	145	4.590796
154	2.921779	154	2.726313	143	4.498697
144	2.911237	55	2.719834	152	4.490633
146	2.900279	82	2.66112	153	4.47252
143	2.884607	54	2.644136	160	4.447916
157	2.856285	144	2.621412	161	4.414129
158	2.817762	146	2.609798	158	4.406842
156	2.802608	39	2.591031	154	4.385681
159	2.758932	143	2.568707	157	4.377138
145	2.745346	81	2.555265	159	4.365592
155	2.744709	157	2.503785	156	4.365395
160	2.621736	52	2.468201	38	4.364402
170	2.508838	155	2.448602	114	4.265623
172	2.476855	156	2.423384	155	4.260601
112	2.470329	37	2.400091	113	4.25211
161	2.467498	158	2.378174	171	4.249142
115	2.454994	79	2.371727	112	4.222788

Result of route 224

Table 4.10 shows the ranking top 25 of average OWA values on route no. 224. The finding based on values of different environment scenarios.

Table 4.10 Ranking top 25 of average OWA values on route no. 224.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
1	3.665029214	1	3.949171	1	4.993858
2	3.392583286	2	3.71836	2	4.750233
3	3.155834243	3	3.626319	3	4.659231
4	2.897337143	4	3.424611	4	4.585658
6	2.895678509	6	3.358626	5	4.445834
19	2.607801857	33	3.348302	7	4.424421
5	2.555096714	19	3.180715	6	4.286172
7	2.522915957	5	3.174324	9	4.152733
33	2.466263556	32	3.128358	8	4.147237
8	2.235244086	34	3.03187	33	4.057349

Table 4.10 Ranking top 25 of average OWA values on route no. 224 (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
34	2.166303254	7	2.990864	19	4.053591
9	2.129130057	8	2.818331	11	3.99772
32	2.061770114	35	2.780136	12	3.981822
18	2.0593713	9	2.775064	34	3.969852
89	2.047560254	89	2.731371	13	3.953775
11	1.940437443	18	2.702522	32	3.949119
91	1.925049493	91	2.619007	16	3.945898
12	1.76623	11	2.604477	20	3.926747
15	1.749485414	69	2.458018	10	3.907716
27	1.7475715	10	2.44431	18	3.892791
69	1.685545714	12	2.404382	29	3.87079
29	1.637539786	85	2.312258	30	3.836012
17	1.633237831	31	2.309598	21	3.817463
35	1.629909429	27	2.299033	17	3.812691
61	1.5382818	65	2.278421	14	3.803368

Result of route 304

Table 4.11 shows the ranking top 25 of average OWA values on route no. 304. The finding based on values of different environment scenarios.

Table 4.11 Ranking top 25 of average OWA values on route no. 304.

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
132	4.237167	132	4.712739	132	4.935888
131	4.203741	131	4.506482	129	4.872496
126	4.143379	129	4.449163	131	4.8074
129	4.136241	127	4.364757	120	4.746775
130	4.060165	130	4.36431	130	4.673801
127	4.028912	120	4.351224	127	4.661172
120	3.956869	126	4.340209	119	4.615589
128	3.904971	119	4.231403	126	4.556796
119	3.818276	128	4.227348	128	4.530466
125	3.802437	125	4.160327	125	4.445959
121	3.721747	121	4.106388	121	4.376091
123	3.679146	123	4.056593	123	4.335628
63	3.645783	100	4.011276	63	4.331123
67	3.642886	67	3.937846	67	4.317931

Table 4.11 Ranking top 25 of average OWA values on route no. 304 (Continued).

Good environment		Moderate environment		Poor environment	
Segment	**Scores**	**Segment**	**Scores**	**Segment**	**Scores**
100	3.601254	63	3.933322	59	4.296621
59	3.600923	59	3.885697	57	4.262449
57	3.553828	98	3.877844	100	4.262286
75	3.5318	57	3.849049	71	4.223005
71	3.521165	71	3.844727	75	4.202785
58	3.516775	75	3.82865	58	4.184824
98	3.472	94	3.811266	61	4.184336
61	3.468571	124	3.802253	81	4.173846
81	3.463014	81	3.793429	98	4.16959
124	3.443956	96	3.786169	94	4.145457
94	3.435839	61	3.783362	89	4.117112

The above results from tables show the sequences of 25 top segments of study routes ordering based on the risk probability of accidents on different scenarios of environment attributes varying according to user requirements. It is noted that these segments have traffic volume and road geometry contributing to high risk. The environment condition is a factor that changes according to the input of a user which can affect the occurrence of accidents. When the user specifies the weather condition to the system, it will apply to every segment.

The results from both models are different sets of values that art not comparable because of having different concept and method to calculate. It can only be relatively compared in their one sets.

4.5 Model validation and result comparison

Due to the fact that probability and ranking index achieved from Poisson regression model and OWA model, respectively, are resulted from individual methods so they are not directly comparable in absolute condition but in relative.

Therefore, to make them comparable, result from each method was divided into 3 levels: low, moderate, and high, and scored as 1, 2, and 3, respectively. These scores of segments were used to validate results from both models by comparing with the data of actual incidents of the year 2012.

The highest numbers of annually actual incidents on a segment of Highways no. 2, 224, and 304 are 17, 10, and 11 cases, respectively, while the lowest of them is 0. To be comparable, a number of incidents in a year to be validated should be classified and scored as shown in Table 4.12.

Table 4.12 Classified and scored number of incidents for validation.

Highway no.	The highest number of actual incidents	Accidents represent	Risk scored
2	17	0-3	1
		4-7	2
		>7	3
224	10	0-2	1
		3-5	2
		>5	3
304	11	0-2	1
		3-5	2
		>5	3

Then, an evaluation was conducted using the root mean square error (RMSE) to determine the difference between the actual and the estimated scores of the model. The data from 2009 - 2011 are for model construction while the data from 2012 are for model validation.

Due to having a limited number of accidents in a validating year, the environment scenarios cannot be separated into poor, moderate, and good. Therefore, the environment scenarios for model input were setup to be poor, moderate, and good instead. The RMSEs of the results from each scenario level of both models and the levels of actual accident of validating year were estimated and the results are shown in Tables 4.13 - 4.15.

Table 4.13 Comparison of RMSE for model validation of the same environment scenarios on highway no. 2.

Environment	Poisson regression model	OWA model
Poor	0.2949	0.3594
Moderate	0.2442	0.2718
Good	0.3778	0.3225
Average	0.3056	0.3179

Table 4.14 Comparison of RMSE for model validation of the same environment scenarios on highway no. 224.

Environment	Poisson regression model	OWA model
Poor	0.0566	0.1981
Moderate	0.0943	0.1698
Good	0.0566	0.1886
Average	0.0691	0.1855

Table 4.15 Comparison of RMSE for model validation of the same environment scenarios on highway no. 304.

Environment	Poisson regression model	OWA model
Poor	0.1315	0.3157
Moderate	0.2631	0.2763
good	0.1184	0.3026
Average	0.1710	0.2982

From Tables 4.13-4.15, the RMSE validation of both models on the same environment scenario found that Poisson regression model on highway 224 provided the highest accuracy (0.0691) and highway 304 showed the lowest accuracy (0.3056). OWA model on highway 224 provided the highest accuracy (0.1855) while on highway 2 showed the lowest accuracy (0.3179). Results from the Poisson regression model were more accurate than from OWA model in every highway. The main reason why Poisson regression model have more accuracy than OWA may come from many minimum values of geometry data in OWA model was estimated to be 0 due to limitation of data availability. This caused the results from OWA models were not as they should be.

CHAPTER V

CONCLUSIONS AND RECCOMENDATIONS

5.1 Conclusions

The main objective of the study is to develop web-based decision support system integrating the MADM using the DEX approach with Poisson regression model and OWA model to assess the risk of road accidents. The system allows database and rule base to be updatable. It also allows user to interact with the system in form of varying environment scenarios and result observation on Google Map. This leads to the conclusion that the identification of highly accidental potential of road segments is adequate for planning and management in road accident reduction. The benefit of the system can support 3 types of key users successfully as guidance to perform their roles. General user can use this application for traveling. They will know and make use of risk of road segment based on their own interest or actual situations. Traffic officer can take benefit from the system analysis using the result as a guide for traffic management, escort for traffic movement, road safety outpost etc. Highway-maintenance officers can use the analytical result to prioritize which segment should be of maintenance first and how to maintain. The results of the study can serve all research objectives.

Synthesis of the geometry data, they are constant according to the actual road conditions, regardless of the change of time or weather. Each segment of the road has a number of fixed factors that has a positive impact on the risk of accidents (higher value represents higher risk), including the degree of horizontal curve, percentage of vertical grade, a number of road connections, a number of U-turns and a number of intersections. A number of fixed factors that has a negative impact on the risk of accidents (higher value represents lower risk) includes the pavement width and shoulder width. Further factor analysis was operated to group these parameters to be components fit for model analyses.

Factor analysis of geometry data revealed that routes 2, 224 and 304 are composed of the same 5 components with factor loadings, which can explain more than 80% of geometry data. Variables involved in each component are: component 1- pavement width, shoulder width, and U-turn, component 2- design speed and degree of horizontal curve, component 3- percentage of vertical grade, component 4- number of road connection, and component 5- Intersection.

Dealing with environmental attributes, varying weather conditions (clear, mist, rain) and the time periods of a day are specified and analyzed in the hierarchical decision model (DEX). The road light existing in some segments is taken into consideration based on the period of time. The result from the DEX provide a level of weather conditions of each segment to be good or fair or poor. This result will apply to every segment and be used as input for model analysis. It is evident that the rainy weather is more likely to increase the risk of accidents than the misty and the clear weather, respectively.

The system will retrieve the geometry, environment condition, and ADT data according to the time specified from the database and analyzes in the Poisson regression model and OWA model. The ADT data will change based on the time specified in the system by the user. In this study, it is found that the risk of accidents is higher in areas with a high ADT value.

The results presented that the risk of accidents will vary according to the data on road geometry, ADT, weather, and time of each segment. The model indicates that the road segments with high risk of accidents are in the community areas of Nakhon Ratchasima, where there is the traffic congestion and there are a number of connections to various blocks.

In the study area, the risk is reduced when the distance is away from the community areas. This means that the road segments in community areas have a high traffic volume and thus are more at risk of accidents. The results were consistent with Lord (2002), Martin (2002) and Pande and Abdel-Aty (2006). In addition, the weather and time that changes according to the requirements of users can affect the change in the risk of accidents in each segment.

The validation of the system results was performed using estimated results of each road segment from 2009 – 2011, in three environment scenarios, and incident levels of 2012. The validation of RMSE result on the same scenario (rush time 8.00-9.00) found Poisson regression model more accuracy than OWA model in every highways.

Poisson regression model indicates that the spatial accuracy in term of identifying highly accidental potential of road segments is considered acceptable for the study of road accident assessment. Therefore, it can be concluded that the model developed in the system is reliable.

Through the web-based application developed, the results obtaining from the models are based on every 100-meter road segment data and concluded to display for each 1-km segment on Google Map. The bottom right of map page also displays a result of each 100-meter segment. Resulting three levels of risk of accidents are colored as green for low risk, yellow for moderate risk and red for high risk. Furthermore, the system also shows values of risk factors which are above average in the same highway.

5.2 Recommendations

Parts of input geometry data of Highway 2 are not updated or missing. The data have to be estimated from other data, such as images from Google Earth. Therefore, only parts with complete data were taken into account for the study. If, however, the complete road blueprint data were available, risk assessment of some segments would be more accurate.

The ADT data are available only in a survey of the Department of Highways during time period of 7.00 a.m. - 19.00 p.m. This means that the results from the models will rely on this effective time of the day. If the ADT data of 24 hours were available, risk assessment of a whole day would be possible.

The OWA model did not give appropriate risk assessment results since certain factors were Boolean (0/1). When multiplied by the weight, factor values became significantly different. If, however, the Boolean factor values would not be used, the OWA results could be more accurate.

The factors of geometric data in this study do not cover all factors concerning accidental causes due to the limit on data access and availability, for example visibility of segments. The only data used in this study was obtained from related offices whose data were available and could be measurable. More factors involved in the analysis can expect more accuracy.

Fruitful success of the study will be added if the further development of the application could be moved on mobile devices. They can be carried conveniently while traveling and connecting to the navigation system of a vehicle in order to access and display real-time location with the information of each segment from the system.

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APPENDICES

APPENDIX A

THE APPLICATOIN CODING EXPLAINED

Description

To set up index or main page.

Synopsis

```
<head>
<meta http-equiv="Content-Type" content="text/html; charset=tis-620" />
<title>road map</title>
</head>
 <frameset cols="240,*" framespacing="1" frameborder="yes" border="1"
bordercolor="#000000">
  <frame src="left.html" name="leftFrame" scrolling="No" noresize="noresize"
id="leftFrame" title="left" />
  <frame src="main.php" name="mainFrame" id="mainFrame" title="main" />
 </frameset>
<noframes>
<body>
</body>
```

Result

The main page have 2 columns: main.php and left.html.

Description

To set up to database connection.

Synopsis

```
<?php
session_start();
require("sysconfig.ini.php");
require("connect_db/connect.php");
global $connect;
mysql_select_db($db,$connect) or die("Couldn't find any Dababase!!");
?>
```

Result

The system can access and manage database via MySQL database server.

Description

To set up left page.

Synopsis

```
<body>
<table width="220" border="0">
  <tr>
    <td><div align="center"><img src="images/1.jpg" width="160" height="120"
/></div></td>
  </tr>
 <form method="post" action="main.php"  target="mainFrame"></form>
  <tr>
    <td><div align="center"><span class="style1">WEB-BASED SPATIAL DECISION
SUPPORT SYSTEM FOR THE RISK ASSESSMENT OF ROAD
ACCIDENT</span></div></td>
  </tr>
  <tr>
    <td><div align="center"><span class="style1">SELECT HIGHWAY &
ENVIRONMENT</span></div></td>
  </tr>
 <form id="form1" name="form1" method="post" action="envi_save.php">
 <table width="50" border="1" cellspacing="1" cellpadding="1">
 <tr>
 <td width="20"bgcolor="#FFFFFF"><strong>MODEL</td>
 <td width="50"><select name="model">
 <option value="1">Poisson model</option>
 <option value="2">OWA model</option>
 <option value="3">Decision tree model</option>
 </select> </td>
 </tr>
 <tr>
 <td width="20"bgcolor="#FFFFFF"><strong>HIGHWAY</td>
 <td width="50"><select name="highway">
 <option value="1">2 (36-251)</option>
 <option value="2">2 (251-36)</option>
 <option value="3">224</option>
 <option value="4">304</option>
 </select> </td>
 </tr>
 <td width="20"bgcolor="#FFFFFF"><strong>WEATHER</td>
 <td width="50"><select name="en_weather">
 <option value="1">Clear</option>
 <option value="2">Mist</option>
```

```
<option value="3">Rain</option>
</select> </td>
</tr>
<tr>
<td width="20" bgcolor="#FFFFFF"><strong>TIME</td>
<td width="50"><select name="en_time">
<option value="1">7.00-8.00</option>
<option value="2">8.00-9.00</option>
<option value="3">9.00-10.00</option>
<option value="4">10.00-11.00</option>
<option value="5">11.00-12.00</option>
<option value="6">12.00-13.00</option>
<option value="7">13.00-14.00</option>
<option value="8">14.00-15.00</option>
<option value="9">15.00-16.00</option>
<option value="10">16.00-17.00</option>
<option value="11">17.00-18.00</option>
<option value="12">18.00-19.00</option>
<option value="13">19.00-21.00</option>
<option value="14">21.00-7.00</option>
</select> </td>
</tr>
<tr>
<td width="20" bgcolor="#99CCFF"> </td>
<td width="50"><input type="submit" name="submit" value="Show the risk map" id="submit"/></td>
</tr>
</table>
</form>
```

Result

The left page setup to allow user interacting with the system by choosing options of model, highway, weather condition, and time period.

Description

To set up right page.

Synopsis

```
if(isset($_COOKIE["menuSelected"])&&$_COOKIE["menuSelected"]!=""){ menuSelected
                                        if($_COOKIE["menuSelected"]=="logout"){
                                                require("logout.php");
                                        }else
if($_COOKIE["menuSelected"]=="placeManagement"){
                require("placeManagement_304.php");
        }else{ require("showMaps_Poisson_2.php");                               }
}else{require("showMaps_Poisson_2.php");                        }
```

```
                        }else{

        if(isset($_COOKIE["menuSelected"])&&$_COOKIE["menuSelected"]!=""){
                                        if($_COOKIE["menuSelected"]=="login"){
                                                require("loginForm.php");
                                        }else{
                                                require("showMaps_Poisson_2.php");
                                        }
                                }else{
                                        require("showMaps_Poisson_2.php");
                                }
                        }
                        ?>
<td align=left style="background:#FFFFFF;border:##3333CC 1px solid;">
                        <?php
                        if(isset($_SESSION["authen_admin"])){ //ถ้ามีการ login แล้ว

        if(isset($_COOKIE["menuSelected"])&&$_COOKIE["menuSelected"]!=""){
                                if($_COOKIE["menuSelected"]=="logout"){
                                require("logout.php");
                                        }else
if($_COOKIE["menuSelected"]=="placeManagement"){  placeManagement
                                                require("placeManagement_304.php"); //
                                        }else{
                                                require("showMaps_Poisson_2.php");
                                        }
                                }else{
                                        require("showMaps_Poisson_2.php");
                }
                        }else{

        if(isset($_COOKIE["menuSelected"])&&$_COOKIE["menuSelected"]!=""){
                                        if($_COOKIE["menuSelected"]=="login"){
                                                require("loginForm.php");
                                        }else{
                                                require("showMaps_Poisson_2.php");
                                        }
                                }else{
                                        require("showMaps_Poisson_2.php");
                                }
                        }
                        ?>
                </td>
```

Result

Set up right page for checking authority and calling show_map.php.

Description

To set up environment factor.

Synopsis

```
$place_id = $row_place['place_id'];
            $geo_id = $row_place['geo_2_id'];

            $sql_aadt  = "SELECT * FROM aadt_2 WHERE aadt2_id = '".$place_id."'";
            $result_aadt = mysql_query($sql_aadt,$connect);
            $row_aadt = mysql_fetch_array($result_aadt);
            $envi_light = $row_aadt['light'];

            $envi_time = $row_envi['envi_time'];
            $rush = '0';

            if ($envi_time >= '1' && $envi_time <= '11') $n_d = '1';
            else $n_d = '0';

            if ($envi_time == '1') $addt_time = $row_aadt['7_8'];
            else
            if ($envi_time == '2') {
            $addt_time = $row_aadt['8_9'];
            $rush = '1';
            }
            else
            if ($envi_time == '3') {
            $addt_time = $row_aadt['9_10'];
            $rush = '1';
            }
            else
            if ($envi_time == '4') {
            $addt_time = $row_aadt['10_11'];
            $rush = '1';
            }
            else
            if ($envi_time == '5') $addt_time = $row_aadt['11_12'];
            else
            if ($envi_time == '6') $addt_time = $row_aadt['12_13'];
            else
            if ($envi_time == '7') $addt_time = $row_aadt['13_14'];
            else
            if ($envi_time == '8') $addt_time = $row_aadt['14_15'];
            else
            if ($envi_time == '9') $addt_time = $row_aadt['15_16'];
            else
            if ($envi_time == '10') {
            $addt_time = $row_aadt['16_17'];
            $rush = '1';
            }
            else
            if ($envi_time == '11') {
            $addt_time = $row_aadt['17_18'];
```

```
$rush = '1';
}
else
if ($envi_time == '12') {
$addt_time = $row_aadt['18_19'];
$rush = '1';
}
else
if ($envi_time == '13') $addt_time = $row_aadt['19_21'];
else
if ($envi_time == '14') $addt_time = $row_aadt['21_7'];

$envi = 'X';

if ($row_envi['envi_weather'] == 1 && $n_d == 1)
$envi = 1;
else
if ($row_envi['envi_weather'] == 1 && $envi_light == 1 && $rush == 1)
$envi = 1;
else
if ($row_envi['envi_weather'] == 1 && $rush == 1)
$envi = 1;
else
if ($row_envi['envi_weather'] == 1 &&  $envi_light == 1 && $rush == 0)
$envi = 2;
else
if ($row_envi['envi_weather'] == 1 &&  $envi_light == 0 && $rush == 1)
$envi = 2;
else
if ($row_envi['envi_weather'] >= 2 &&  $n_d == 1)
$envi = 2;
else
if ($row_envi['envi_weather'] == 2 &&  $n_d == 0 && $envi_light == 1 &&
$rush == 1)
$envi = 2;
else
if ($row_envi['envi_weather'] == 2 &&  $n_d == 1 && $rush == 1)
$envi = 2;
else
if ($n_d == 1 && $envi_light == 0 && $rush == 0)
$envi = 3;
else
if ($row_envi['envi_weather'] >= 2 && $n_d == 0 && $rush == 0)
$envi = 3;
else
if ($row_envi['envi_weather'] >= 2 &&  $envi_light == 0)
$envi = 3;
else
if ($row_envi['envi_weather'] == 3 && $n_d == 0)
$envi = 3;
```

Result

Environment factor is set up from user requirement using DEX approach (show_map.php). The combination from tree of attribute will establish in DEXi software to create the decision rule. The decision rule extracts all of conditions to codding in WSDSS application.

Description

To calculate Poisson model.

Synopsis

```
$f1 = ($row_place['pw'] * f3) + ($row_place['sw'] * f4) + ($row_place['ut'] * f8);
        $f2 = ($row_place['hc'] * f1) - ($row_place['ds'] * f2);
        $lamda = exp(($row_place['vg'] * (mf3)) + ($row_place['nc'] * mf4) +
($row_place['inters'] * mf5) - ($f1 * mf1) + ($f2 * mf2) + ($addt_time * mf6) + const);
        if ($row_place['acc'] = '0' || $row_place['acc'] = '1')
        $fact = '1';
        else
        if ($row_place['acc'] = '2')
        $fact = '3';
        else
        if ($row_place['acc'] = '3')
        $fact = '6';
        else
        if ($row_place['acc'] = '4')
        $fact = '24';
        else
        if ($row_place['acc'] = '5')
        $fact = '120';

        $poisson = (pow($lamda,$row_place['acc'])/$fact) *
(1/pow(2.7182,$lamda));
        $poisson = ($poisson*0.7) + ($envi*0.3);
        $poisson = abs($poisson);
        $update_remark100 = "UPDATE geo_2_dt SET remark_100 = '$poisson'
WHERE geo_2_id = '$geo_id'";
        $dbquery = mysql_query($update_remark100);
        if ($count < 10) {
        $t_risk = $t_risk + $risk;
        $p_risk = $p_risk + $poisson;
        $count = $count + 1;
        if ($rf1 < $row_place['hc']) $rf1 = $row_place['hc'];
        if ($rf2 < $row_place['vg']) $rf2 = $row_place['vg'];
        $rf3 = $rf3 + $row_place['nc'];
```

```
$rf4 = $rf4 + $row_place['inters'];
$rf5 = $rf5 + $row_place['ut'];
if ($rf6 < $addt_time) $rf6 = $addt_time;
}
else {
if ($p_risk >= 4.25){
$update_risk = "UPDATE rute_2 SET place_icon = 'uploadicons/dang.png', place_pic = 'uploadicons/d_icon.png', place_address = 'High' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_risk);
$count = '1';
$update_remark = "UPDATE rute_2 SET remark = '$p_risk' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_remark);
$t_risk = '0';
$p_risk = '0';
$update_rf1 = "UPDATE rute_2 SET rf1 = '$rf1' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf1);
$update_rf2 = "UPDATE rute_2 SET rf2 = '$rf2' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf2);
$update_rf3 = "UPDATE rute_2 SET rf3 = '$rf3' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf3);
$update_rf4 = "UPDATE rute_2 SET rf4 = '$rf4' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf4);
$update_rf5 = "UPDATE rute_2 SET rf5 = '$rf5' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf5);
$update_rf6 = "UPDATE rute_2 SET rf6 = '$rf6' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf6);
}
else
if ($p_risk >= 3.75 && $p_risk < 4.25){
$update_risk = "UPDATE rute_2 SET place_icon = 'uploadicons/orange.png', place_pic = 'uploadicons/y_icon.png', place_address = 'Medium' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_risk);
$count = '1';
$update_remark = "UPDATE rute_2 SET remark = '$p_risk' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_remark);
$t_risk = '0';
$p_risk = '0';

$update_rf1 = "UPDATE rute_2 SET rf1 = '$rf1' WHERE place_id = '$place_id'";
$dbquery = mysql_query($update_rf1);
$update_rf2 = "UPDATE rute_2 SET rf2 = '$rf2' WHERE place_id =
```

```
'$place_id'";
                $dbquery = mysql_query($update_rf2);
                $update_rf3 = "UPDATE rute_2 SET rf3 = '$rf3' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf3);
                $update_rf4 = "UPDATE rute_2 SET rf4 = '$rf4' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf4);
                $update_rf5 = "UPDATE rute_2 SET rf5 = '$rf5' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf5);
                $update_rf6 = "UPDATE rute_2 SET rf6 = '$rf6' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf6);
                }
                else
                if ($p_risk < 3.75){
                $update_risk = "UPDATE rute_2 SET place_icon =
'uploadicons/green.png', place_pic = 'uploadicons/g_icon.png', place_address = 'Low'
WHERE place_id = '$place_id'";
                $dbquery = mysql_query($update_risk);
                $count = '1';
                $update_remark = "UPDATE rute_2 SET remark = '$p_risk' WHERE
place_id = '$place_id'";
                $dbquery = mysql_query($update_remark);
                $t_risk = '0';
                $p_risk = '0';
                $update_rf1 = "UPDATE rute_2 SET rf1 = '$rf1' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf1);
                $update_rf2 = "UPDATE rute_2 SET rf2 = '$rf2' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf2);
                $update_rf3 = "UPDATE rute_2 SET rf3 = '$rf3' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf3);
                $update_rf4 = "UPDATE rute_2 SET rf4 = '$rf4' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf4);
                $update_rf5 = "UPDATE rute_2 SET rf5 = '$rf5' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf5);
                $update_rf6 = "UPDATE rute_2 SET rf6 = '$rf6' WHERE place_id =
'$place_id'";
                $dbquery = mysql_query($update_rf6);
```

Result

Poisson value on each segment and updateable to database (show_mapPoisson.php). The result show coefficients of each factor and constant for construct the model to find the expected value of accident in each segment (λ) and then take λ to calculate Poisson value on each segment.

Description

To calculate OWA model.

Synopsis

```
$var=array($vg_n,$nc_n,$inters_n,$f1_n,$f2_n,$addt_n,$envi_n);
                    sort($var);
                    $owa1 = ($var[0]*1);
                    $owa2 = ($var[0]*0.7)+($var[1]*0.15)+($var[2]*0.1)+($var[3]*0.05);
                    $owa3                                                              =
($var[0]*0.4)+($var[1]*0.25)+($var[2]*0.15)+($var[3]*0.1)+($var[4]*0.05)+($var[5]*0.025)
+($var[6]*0.025);
                    $owa4                                                              =
($var[0]*0.142)+($var[1]*0.142)+($var[2]*0.142)+($var[3]*0.142)+($var[4]*0.142)+($var[5
]*0.142)+($var[6]*0.142);
                    $owa5                                                              =
($var[6]*0.4)+($var[5]*0.25)+($var[4]*0.15)+($var[3]*0.1)+($var[2]*0.05)+($var[1]*0.025)
+($var[0]*0.025);
                    $owa6 = ($var[6]*0.7)+($var[5]*0.15)+($var[4]*0.1)+($var[3]*0.05);
                    $owa7 = ($var[6]*1);
                    $update_owa100 = "UPDATE geo_304_dt SET owa1_100 = '$owa1'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa2_100 = '$owa2'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa3_100 = '$owa3'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa4_100 = '$owa4'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa5_100 = '$owa5'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa6_100 = '$owa6'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);
                    $update_owa100 = "UPDATE geo_304_dt SET owa7_100 = '$owa7'
WHERE geo_304_id = '$geo_id'";
                    $dbquery = mysql_query($update_owa100);

                    $owa100 = ($owa1+$owa2+$owa3+$owa4+$owa5+$owa6+$owa7)/7;
                    $update_owa100 = "UPDATE geo_304_dt SET owa100_avg = '$owa100'
```

```
WHERE geo_304_id = '$geo_id'";
            $dbquery = mysql_query($update_owa100);
            if ($count < 10) {
            $owa1_risk = $owa1_risk + $owa1;
            $owa2_risk = $owa2_risk + $owa2;
            $owa3_risk = $owa3_risk + $owa3;
            $owa4_risk = $owa4_risk + $owa4;
            $owa5_risk = $owa5_risk + $owa5;
            $owa6_risk = $owa6_risk + $owa6;
            $owa7_risk = $owa7_risk + $owa7;
            $count = $count + 1;
            }
            else {
            $update_owa1 = "UPDATE rute_304 SET owa_1 = '$owa1_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa1);
            $update_owa2 = "UPDATE rute_304 SET owa_2 = '$owa2_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa2);
            $update_owa3 = "UPDATE rute_304 SET owa_3 = '$owa3_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa3);
            $update_owa4 = "UPDATE rute_304 SET owa_4 = '$owa4_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa4);
            $update_owa5 = "UPDATE rute_304 SET owa_5 = '$owa5_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa5);
            $update_owa6 = "UPDATE rute_304 SET owa_6 = '$owa6_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa6);
            $update_owa7 = "UPDATE rute_304 SET owa_7 = '$owa7_risk' WHERE
place_id = '$place_id'";
            $dbquery = mysql_query($update_owa7);
            $owa_total                                                    =
($owa1_risk+$owa2_risk+$owa3_risk+$owa4_risk+$owa5_risk+$owa6_risk+$owa7_risk)/7
;
            $update_owaavg = "UPDATE rute_304 SET OWA_Avg = '$owa_total'
WHERE place_id = '$place_id'";
            $dbquery = mysql_query($update_owaavg);
            if ($owa_total >= 4.0){
            $update_risk = "UPDATE rute_304 SET place_icon =
'uploadicons/dang.png', place_pic = 'uploadicons/d_icon.png', place_address = 'High'
WHERE place_id = '$place_id'";
            $dbquery = mysql_query($update_risk);
            $owa1_risk = '0';
            $owa2_risk = '0';
            $owa3_risk = '0';
            $owa4_risk = '0';
            $owa5_risk = '0';
            $owa6_risk = '0';
            $owa7_risk = '0';
```

```
			$count = '1';
			}
			else
			if ($owa_total >= 3.5 && $owa_total < 4.0){
			$update_risk = "UPDATE rute_304 SET place_icon = 'uploadicons/orange.png', place_pic = 'uploadicons/y_icon.png', place_address = 'Medium' WHERE place_id = '$place_id'";
			$dbquery = mysql_query($update_risk);
			$owa1_risk = '0';
			$owa2_risk = '0';
			$owa3_risk = '0';
			$owa4_risk = '0';
			$owa5_risk = '0';
			$owa6_risk = '0';
			$owa7_risk = '0';
			$count = '1';
			}
			else
			if ($owa_total < 3.5){
			$update_risk = "UPDATE rute_304 SET place_icon = 'uploadicons/green.png', place_pic = 'uploadicons/g_icon.png', place_address = 'Low' WHERE place_id = '$place_id'";
			$dbquery = mysql_query($update_risk);
			$owa1_risk = '0';
			$owa2_risk = '0';
			$owa3_risk = '0';
			$owa4_risk = '0';
			$owa5_risk = '0';
			$owa6_risk = '0';
			$owa7_risk = '0';
			$count = '1';
			}
			}
```

Result

Calculate for OWA value on each segment and update to database (show_mapOWA.php). Factors used in each segment are normalized and arranged in order. Then, fuzzy sets of weights are applied to ranked attribute values for each alternative and sum up. Finally, alternatives and their order criteria are ranked. Output is the sequence of segments ranking based on the risks of accidents

Description

To show result on google map.

Synopsis

```
$showIcon = ""; for($i_place=1;$i_place<=mysql_num_rows($Chk_list);$i_place++){
        $query_place = mysql_fetch_array($result_place, MYSQL_ASSOC);
        $place_latlng = $query_place["place_latlng"];           if($place_latlng==""){
                        $place_latlng = "14.98278182524803, 102.10761040039062";
                }
                if($query_place["place_pic"]==""){
                        $place_pic = "images/noimage.jpg"; $place_pic
                }else{
                        $place_pic = $query_place["place_pic"];              }
                $showIcon .= 'text = "<div class=\'text_detail_gmap\'>"
                 +"<B>Segment no. : </B>'.$query_place["place_name"].'<br /><B>Risk
level : </B>'.$query_place["place_address"].'<br />"+"<B>No. of accidents :
</B>'.$query_place["place_count"].' <br />";
             bigImg = \'<table><tr><td><img src="'.$place_pic.'"/></td></tr></table>\';
             html = "<div class=\'gmap_main\'><div
class=\'big_img_gmap\'>"+bigImg+"</div>"+text+"</div>";';
                $showIcon .= 'var point = new GLatLng('.$query_place["place_latlng"].');
';
                $showIcon .=
'map.addOverlay(createMarker(point,html,"'.$query_place["place_icon"].'"));';
                ?>
```

Result

Show icon on google map and show description of each segment (show_map.php). Red, yellow, and green are for high, moderate, and low risk of accident, respectively. Furthermore, the system can show value of risk factor on each segment.

Description

To show detail of risk assessment on each segment.

Synopsis

```
<TABLE cellSpacing=0 cellPadding=0 width="100%" border=0>
<TBODY>
<TR style="BORDER-BOTTOM: #d4d4d4 1px solid">
                <TD vAlign=center height=100>
                                <TABLE    class=list    cellSpacing=0    cellPadding=0
width="100%" border=0>
                                <TBODY>
```

```
<TR>
	<TD vAlign=top> </TD>
	<TD> </TD>
	<TD> </TD>
	<TD align=middle> </TD>
	<TD align=middle> </TD>
	<TD align=middle> </TD>
</TR>
<TR>
	<TD vAlign=top width=176 rowSpan=2>
		<TABLE height=128
cellSpacing=0 cellPadding=0  width=176 border=0>
		<TBODY>
		<TR>
			<TD
align=middle>

	<?php if($query_place["place_pic"]==""){?>

	<IMG alt="<?=$query_place["place_name"]?>" src="images/noimage.jpg"
width="70" height="45" border=0>

	<?php }else{?>

	<IMG alt="<?=$query_place["place_name"]?>" src="<?=$place_pic?>" width="70"
height="45" border=0>

	<?php }?>
			</TD>
		</TR>
		</TBODY>
		</TABLE>
	</TD>
	<TD width=20 rowSpan=2> </TD>
	<TD rowSpan=2>
		<SPAN
class=subhead><h3><font
color=red><?=$query_place["place_name"]?></font></h3><BR></SPAN><BR>
		<STRONG>Segment
:</STRONG> <?=$query_place["place_address"]?><BR>
		<STRONG>Number of
accidents  :</STRONG> <?=$query_place["place_count"]?><BR>
		<!--<STRONG>Risk
:</STRONG> <?=$query_place["place_cause"]?><BR>-->
		<STRONG>Location
:</STRONG><?=$query_place["place_latlng"]?><BR>
		<h3><a href="#"
onclick="gotoLatLng(<?=$query_place["place_latlng"]?>,'<?=$query_place["place_name"]?
>')">Map</a></h3>
```

```
<?php
        $place100 = $query_place["place_name"];

        $sql_geo100  = "SELECT * FROM geo_304_dt where place_id = '".$place100."'";

        $result_place100 = mysql_query($sql_geo100,$connect);

        $count100 = 100;
?>
<?php
        while($row_place100 = mysql_fetch_array($result_place100)) {
        $geo_100 = $row_place100['owa100_avg']; ?>
        <?php
              if ($geo_100 >= 0.4){
        ?>
         <IMG src="images/d.jpg" width="15" height="22" border=0>
        <?php } ?>
        <?php
        //else
        if ($geo_100 >= 0.35 && $geo_100 < 0.4){
                                                    ?>
        <IMG src="images/y.jpg" width="15" height="22" border=0>
        <?php } ?>
        <?php
        //else
        if ($geo_100 < 0.35){
        ?>
         <IMG src="images/g.jpg" width="15" height="22" border=0>
        <?php } ?>

        <?php echo $count100;
        echo '|';
        $count100 = $count100 + 100;
                                                }
                                                ?>



                                                </TD>
                                    </TR>
                                    <TR>
                                                <TD vAlign=top> </TD>
                                                <TD> </TD>
                                                <TD> </TD>
                                                <TD align=middle> </TD>
                                                <TD align=middle> </TD>
                                                <TD align=middle> </TD>
                                    </TR>
                                    </TBODY>
                                    </TABLE>
                        </TD>
</TR>
<tr>
```

Result

Show detail of each 1-km segment; it consists of a number of actual accidents, location, and risk assessment on each 100 meters. It can show value of risk factor on each segment same on the map result (show_map.php).

Description

Some of Cascading Style Sheets (CSS) code.

Synopsis

```
TD {
	FONT-SIZE: 11px; FONT-FAMILY: Tahoma, Arial, sans-serif;color:#468237;
}
div.scroll_object
{
	width: 100%;
	height: 450px;
	position: relative;
	overflow:auto;
}
.errorBox {
	FONT-WEIGHT: bold; FONT-SIZE: 16px; BACKGROUND: #ffb3b5; FONT-
FAMILY: Tahoma, Arial, sans-serif
}
.stockWarning {
	FONT-SIZE: 16px; COLOR: #cc0033; FONT-FAMILY: Tahoma, Arial, sans-serif
}
.productsNotifications {
	BACKGROUND: #e2dfd2
}
.orderEdit {
	FONT-SIZE: 16px; COLOR: #ff7a04; FONT-FAMILY: Tahoma, Arial, sans-serif;
TEXT-DECORATION: none
}
.infoBox {
	BACKGROUND: #e2dfd2
}
.infoBoxContents {
	FONT-SIZE: 16px; BACKGROUND: #ffffff; FONT-FAMILY: Tahoma, Arial, sans-
serif
}
FORM {
	DISPLAY: inline
```

Result

CSS used for describing the presentation of a document written in a markup language.

Although most often used to set the visual style of web pages and user interfaces (stylesheet.css).

APPENDIX B

THE QUESTONNAIRE SURVEY THE EXPERTS' OPINIONS

แบบสอบถามสำหรับผู้เชี่ยวชาญเพื่อการประเมินสภาพสิ่งแวดล้อมที่ส่งผลต่อการเกิดอุบัติเหตุ

แบบสอบถามต่อไปนี้เป็นแบบสอบถามความคิดเห็นจากผู้เชี่ยวชาญที่มีต่อสภาพสิ่งแวดล้อมซึ่งส่งผลต่อการเกิดอุบัติเหตุบนทางหลวงในเขตจังหวัดนครราชสีมา โดยแนวคิดของงานวิจัยนี้จะพิจารณาความเสี่ยงการเกิดอุบัติเหตุด้านสภาพสิ่งแวดล้อมของถนนคือ คุณลักษณะของสภาพสิ่งแวดล้อมของถนน สภาพอากาศ สภาพแสงสว่างและช่วงเวลา ซึ่งมีผลต่อความเสี่ยงในการเกิดอุบัติเหตุ

1.1 Weather คือสภาพอากาศ ประกอบด้วย clear (โปร่งใส), mist (มีหมอก), rain (มีฝน)
1.2 Road light คือสภาพแสงสว่างบนถนน ประกอบด้วย day_light (แสงกลางวัน), night_light (กลางคืนมีไฟสว่าง), night_non_light (กลางคืนไม่มีไฟสว่าง)
1.3 Time periods คือช่วงเวลาเร่งด่วน rush (ช่องเวลาเร่งด่วน), non_rush (ช่วงเวลาไม่เร่งด่วน)

สามารถสรุปเป็นแผนภาพได้ดังนี้

— **Environment** → Good , Fair , Bad
- Weather (clear, mist, rain)
- Road light (day_light, night_light, night_non_light)
- Time (rush, non_rush)

ในการได้มาของความเสี่ยงการเกิดอุบัติเหตุอันเกิดจากสภาพสิ่งแวดล้อมในแต่ละ segment นั้น จะทำการสร้างต้นไม้ของการตัดสินใจ (decision tree) ซึ่งได้ประยุกต์มาจะแนวคิดของ DEXi (A Program for Multi-Attribute Decision Making) โดยได้เพิ่มเติมความสามารถให้ผู้ใช้งานสามารถโต้ตอบกับระบบเพิ่มปรับเปลี่ยนปัจจัยด้าน Environment ซึ่งอาจมีการเปลี่ยนแปลงได้ตลอดเวลาและสร้างสถานะการณ์จำลองเพื่อคาดการณ์ความเสี่ยงการเกิดอุบัติเหตุในสถานะการณ์ที่แตกต่างกันได้

ผู้เชี่ยวชาญโปรดใส่ค่าน้ำหนัก (weight) ของปัจจัยในแต่ละข้อหัว โดยคิดเป็น 100 คะแนน ในแต่ละหัวข้อ และโปรดแสดงความเห็นในสถานะการที่เกิดขึ้นตามเงื่อนไขและตัวเลือกที่กำหนดให้

Environment → <u>Good (G), Fair (F), Bad (B)</u>

- Weather (clear, mist, rain) weight____________
- Road light (day_light, night_light, night_non_light) weight____________
- Time (rush, non_rush) weight____________

Weather	Road light	Time	**Environment**
clear	day_light	rush	
clear	day_light	non_rush	
clear	night_light	rush	
clear	night_light	non_rush	
clear	night_non_light	rush	
clear	night_non_light	non_rush	
mist	day_light	rush	
mist	day_light	non_rush	
mist	night_light	rush	
mist	night_light	non_rush	
mist	night_non_light	rush	
mist	night_non_light	non_rush	
rain	day_light	rush	
rain	day_light	non_rush	
rain	night_light	rush	
rain	night_light	non_rush	
rain	night_non_light	rush	
rain	night_non_light	non_rush	

APPENDIX C

THE APPLICATOIN HELP

The system has been developed in a form of the Web Spatial Decision Support System (WSDSS), which supports the changes of different factors affecting the road accident. This may help users employing highways with more safety.

Poisson regression and OWA models are used to assess risk of accident of road segment and display the result on Google Map. The system allows users to choose highway, time period, and weather condition interactively.

The basic design objective of the system is to facilitate data sharing on technological accidents by creating a collaborative, open-content environment. For this purpose, the system has been developed to support multiple users concurrently. Three basic key users of this application include:

1. General users / people who use for traveling. They can know about risk of road segment and help in alert driving.
2. Traffic officer who can take benefit from the system analysis and use the result as a guide for traffic managing, escort for traffic movement, road safety outpost etc.
3. Highway-maintenance officers who can use the analytical result to prioritize which segment should be of maintenance first and how to maintain.

The system menu

The system menu divides into two parts, the menu for main control and more information about the web site (Figure 5). It consists of “Home” (the first page of web site), “About Application” (information of the system), “Manual” (user manual of the system) and “Sitemap” (list of pages of a web site accessible). The second part is menu for user requirement to interact with the system in terms of varying environment scenarios. It consists of pull-down menus for “Model” (Poisson Model and OWA model), Highway (Highway 2, 224 and 304), “Weather” (clear, mist and rain), and “Time” (time period).

Figure C-1 The system menu.

Map result

The result will display on the Google Maps for user interaction (as Figure 6).

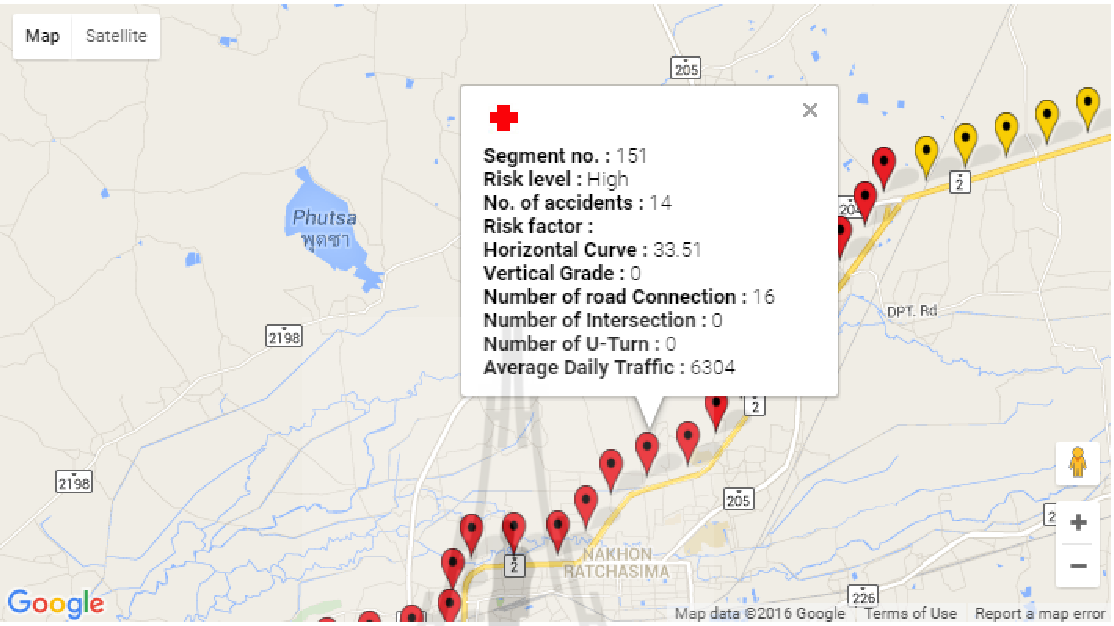

Figure C-2 Map result.

Each point of symbol, representing a segment, shows predicted risk of road accident in form of colors for different intensity levels and detail attributes of the segment. Red, yellow, and green are for high, moderate, and low risk of accident, respectively.

A number of actual accidents, location, and risk assessment on each 100 meters are constantly shown on each 1-km segment (Figure 7). Additionally, the system shows also useful information of risk factors, specifically when they have values above their average in the same highway.

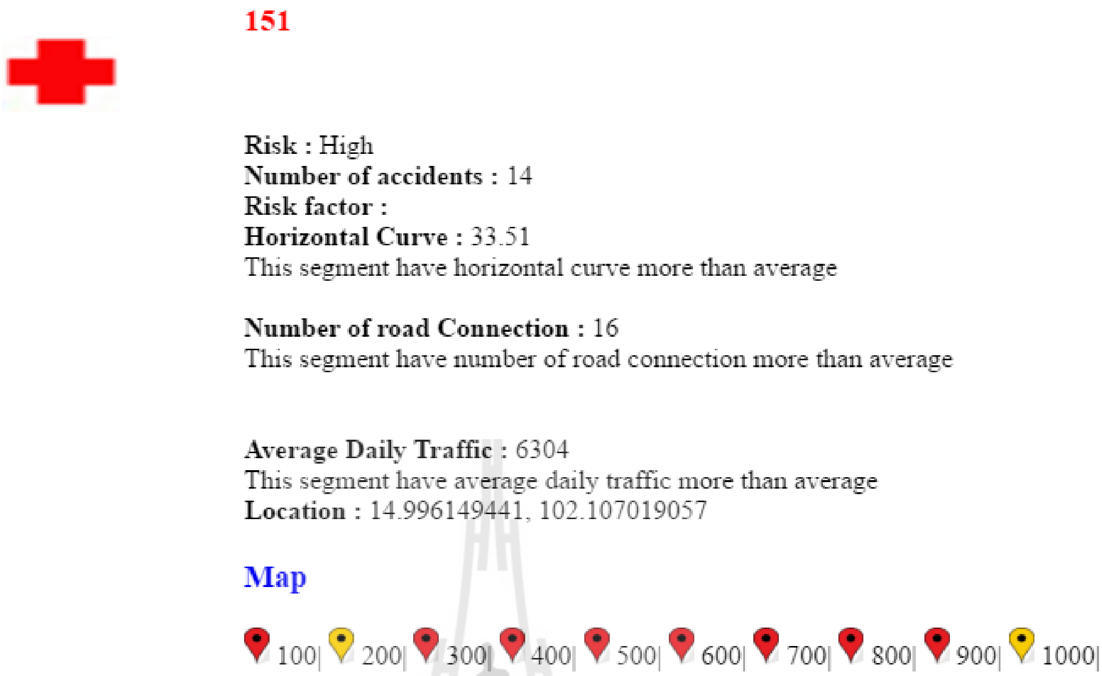

Figure C-3 Detail of risk assessment on each segment.

By using data of highway no. 2, 224, and 304 of years 2009-2011 for model building and 2012 for validating, results from the Poisson regression model seem to be more accurate than OWA model. However, results from both models are offered and users might make use of them for individual purposes based on different backgrounds.

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