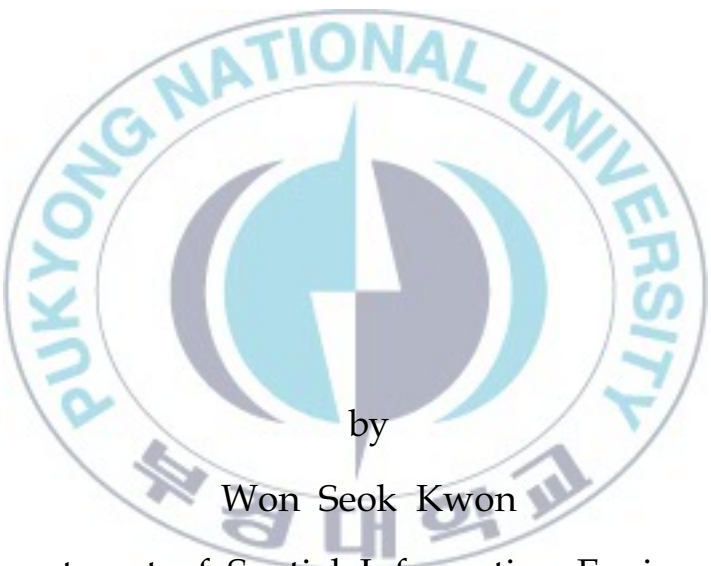
Thesis for the Degree of Master of Engineering

Development of Detour Route and Evacuation Route Guidance System using Disaster Information



by

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February 2012

Development of Detour Route and Evacuation Route Guidance System using Disaster Information
(재해정보를 이용한 우회경로 및 대피경로 안내시스템 개발)

Advisor: Prof. Young Seup Kim

by

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재해정보를 이용한 우회경로 및 대피경로 안내시스템 개발

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요 약

매년 여름마다 발생하는 태풍과 집중호우와 같은 자연재해로 인해 인명 피해 및 재산피해등 상당한 규모의 피해가 발생하였다. 부산 역시 집중호우로 인하여 침수와 산사태 등 각종 자연재해가 발생하였으며 재해에 대한 예방과 대응이 부족하여 많은 피해를 입었다. 이러한 자연재해로부터 발생하는 피해를 예측하고 피해를 절감하기 위하여 IT, 토목, 환경, 공간정보 등 다른 학문과의 융합을 통해 자연재해 예방에 관한 기술이 날로 발달해져 가고 있으며 이에 따라 재해관리시스템에 관한 연구가 활발히 이루어지고 있다. 또한 각 지방 자치 단체에서 이러한 재해피해절감 및 관리를 위한 재해관리시스템 구축을 하고 있다. 자연재해로 인해 발생하는 피해를 절감하기 위해선 과거 발생했던 재해정보를 바탕으로 위험지역에 대한 지속적인 관리와 예측을 통한 예방 및 대비가 필요하다. 그리고 재해가 발생 시 신속한 대응 및 복구가 필요하다. 이러한 자연재해의 피해는 인명 및 재산 뿐만 아니라 교통에 있어서도 막대한 영향을 준다. 집중호우로 도로 곳곳에서 침수가 발생하거나 산사태로 인해 도로가 파손 되는 사례가 해마다 발생 하고 있다. 이러한 재해들로 인해 도로 곳곳에서 정체 및 고립과 같은 피해가 발생한다. 도로 공간에서의 재난 발생은 한 지점에서 발생하더라도 추후 교통망 전체로 확산되는 특징을 가지고 있어 조기에 신속한 대응과 복구가 요구 된다. 국내에서의 재해관리는 대응 및 복구를 중심이며 예방단계 다소 부족하나 예방을 위한 연구와 기술들이 개발되어져 가고 또한 교통에서 최근 도로상에서 침수로 인한 피해를 절감하기 위한 연구로써 교통운영방법과 신호 운영을 통한 교통정체 절감과 같은 다양한 교통관리 연구가 진행되고 있다. 하지만 자연재해 관리에 대한 연구에 비해 상대적으로 부족한 실정이다.

도로침수와 같은 자연재해는 시설물에 1차적인 피해를 입히며 피해사실을 인지하지 못하는 운전자의 현장진입으로 고립, 차량 침수 등 2차 피해를 유발하게 된다. 재해 발생지역에 대한 복구도 중요하지만 이라한 2차 피해를 절감하기 위해선 사전에 우회경로 안내와 같은 서비스가 필요하며 이미 재해지역에서 고립된 차량에 대하여 추가적인 혼란을 줄이기 위해 대피경로 안내가 필요하다.

집중호우 발생 시 산사태, 침수, 해일과 같은 다양한 재해종류가 발생할 수 있기 때문에 본 논문에선 집중호우로 인해 발생할 수 있는 자연재해를 중심으로 재해위험지역, 재해이력정보와 같은 데이터를 활용하여 연구를 진행하였다. 본 연구에서 개발한 시스템을 통하여 관리자는 직접 재해정보를 입력할 수 있으며 입력받은 데이터를 기반으로 출발지와 목적지를 입력하여 최적경로 및 재해지역을 고려한 우회경로를 분석할 수 있다. 그리고 재해지역 내에 존재하는 차량들을 대상으로 주변 지역으로 대피 경로를 분석 할 수 있다. 이러한 C/S기반의 시스템에서 분석된 결과를 모바일 애플리케이션을 통해 일반 사용자들에게 대피경로를 안내 받을 수 있다.

1. Introduction

1.1. Study Background

Because of the natural disasters such as typhoons and heavy rains occurring every summer, significant damages such as loss of life and property have occurred. In Busan as well, due to heavy rain, various natural disasters such as flooding and landslides occurred, and for there were not enough measures of disaster prevention and preparation, there were a lot of damages. In order to predict and reduce damages occurred by such natural disasters, by converging other studies such as IT, civil engineering, environment and spatial information, technologies for natural disasters prevention have been advanced every day, and accordingly studies on the disaster management system have been actively conducted. In addition, each local government is constructing the disaster management system to reduce and manage such natural disaster damagers. In order to reduce damages occurring by natural disasters, it is necessary of prevention and preparation by ongoing management and prediction of hazardous areas based on information of disasters occurred in the past. In addition, it is necessary of prompt response and recovery when a disaster occurs. Such damages of natural disasters give great impacts to not only life and property but also transport. For example, due to heavy rains, roads are flooded here and there and roads are damaged by landslides every year. By such disasters, damages occur such as road

congestions and isolations all around. For disaster occurrence in road space has characteristics that the impact further spreads out over whole transportation network even if it occurs in one place, prompt response and recovery are required. The domestic disaster management is mainly of response and recovery and lacks more or less preventive phase, however studies and technologies for prevention are being developed as well as recently various traffic management studies are under progress such as traffic operation method and traffic congestion reduction by signal operation as studies to reduce damages from flooding on roads. However, they are relatively short compared to studies on natural disaster management.

Flooded roads primarily damage facilities and cause secondary damages such as isolation and vehicle water-logging by entering drivers who are not aware of damages. It is not only important to recover the disaster areas but also required of services such as detour routing guide in advance to reduce such secondary damages, and it is necessary to guide evacuation routes to reduce additional confusion for already isolated vehicles in the disaster areas.

1.2. Study Objective and Configuration

On heavy rains, various kinds of disasters may happen such as landslides, flooding and tidal waves, however in this paper, the study was conducted for flooding that may occur by heavy rains.

The study objective to develop the prototype system that analyzes

optimal route and detour route in consideration of flooded areas as the administrator directly inputs flooding information and inputs the origin and destination points based on inputted data, and that analyzes surrounding evacuation route and can provide guide services of evacuation route results analyzed by the C/S based system for vehicles existing in flooded areas by mobile application.

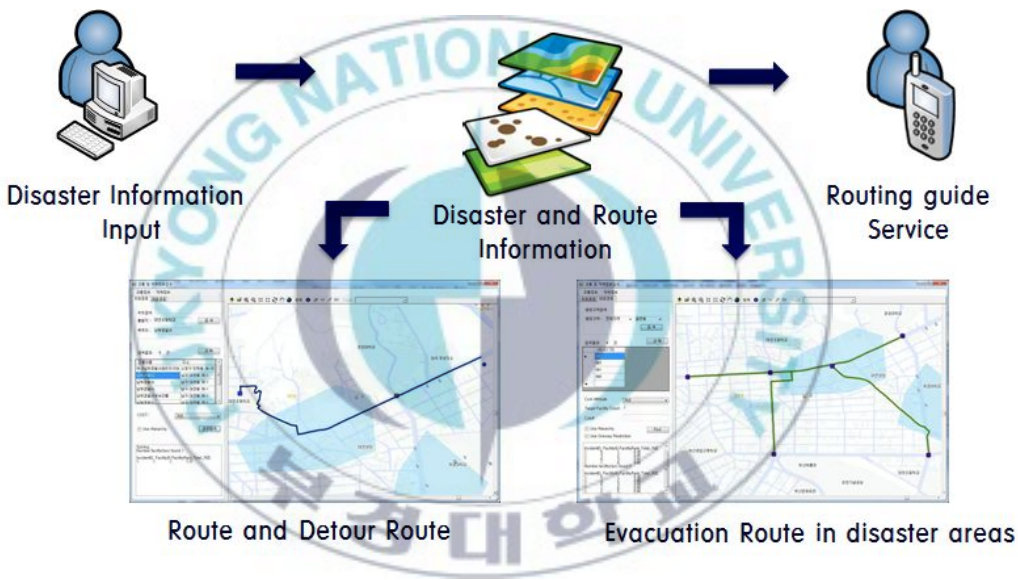

Figure 1. The study objective

This paper contents are composed as follows. In chapter 2, it describes disaster management, studies on existing disaster management system, the traffic disaster system, optimal routing algorithm, spatial database structure and spatial database utilized studies. In chapter 3, it proposes

the platform structure of C/S based application and mobile application for routing guide. In Chapter 4, it discusses implementation of the prototype system of detour routing and evacuation routing guide based on proposed platform structure. In Chapter 5, performance assessment is discussed as comparing the system developed in this paper and existing studies. And in the last chapter 6, it concludes.

2. Related Work

2.1. Disaster Management System

Recently, Natural Disasters have increased due to climate chang. Therefore, there has ben active study conducted to reduce damages and manage damage history information of natural disaster.

T.H. Kim, et al developed real-time natural disaster damage information management system based on Web GIS through real-time wireless communication. They used topographic maps such as 1:1000 and 1:5000 and IKONOS high resolution satellite image. T.G. Jeon, et al suggested construction progress of spatial database for damage history information of natural disasters and developed disaster management system which is available for damage history management. J.O. Kim et al. developed virtual disaster map based on mash-up which provides shelter, evacuation, disaster information using google map api. Moreover, domestic disaster mapping has been started in accordance with announcement that NEMA(National Emergency Management Agency) established guideline for disaster map standard.

Chungcheongnam-do constructed system based on Web GIS that provides display of disaster areas based on disaster history information in 2008 and Disaster management system based on IT in Busan was constructed to include 4 type of disasters such as flooding, landslide, storm, tsunami manage and display dangerous areas

In this year, One of the Netizen developed heavy rain damage map in Daum Agora when flooding was occurred in Seoul during heavy rain. This system provided display of photos and contents by administrator based on twitter. Technology for disaster management has developed through continuous study and construction of system.

However these studies and systems focus on reduction of casualties and properties. Studies and systems for solution of traffic congestion using disaster information were lacking, and service aspect for user was lacking except for heavy rain damage map in Daum Agora

2.2. Transportation Disaster Prevention System

Because disaster prevention system in Seoul focused on response and restoration, S.I. Shin suggested ways to apply the transportation prevention system through example that provide detour route about flood area, emergency such as fire etc.

J.Y. Toon et al. established concept of guideline for traffic management in the case of disaster. They present important details and ways of management for each step of disaster event : prevention, preparation, response and restoration.By creating Ubiquitous Transportation environment, S.R. Lee et al. proposed effective ways of controlling traffic flow in the event when natural disaster causes overflowing.

Y.T. Son selected the city of Cheongju as a study area since lots of damage resulting from natural disaster such as storm and flood have been

frequently occurred. He suggested traffic disaster prevention system for each step of disaster events that are prevention, preparation, response and restorations and analyzed its effect on signal operation to achieve high level of traffic efficiency. C.H. Yang et al. developed a specific algorithm that is based on shortest path search technique and dynamic traffic assignment to provide evacuation route and detour information only for vehicles under emergency. They performed the study case to evaluate performance of model by applying hypothetical scenario. In these previous studies, reducing disaster damage in transportation, how transportation operates when disaster occurred, generating route such as a guidance of detour route and evacuation route has been much research in progress. However they didn't construct GIS-based system and they are focused on result of analysis through simulation and suggestion which is transportation operation.

2.3. Optimal Route

Junru Cao et al. developed optimal path analysis based on Dijkstra algorithm in Zibo fire Emergency Process Information System using ArcEngine and Geodatabase. Yang et al. developed algorithm for detour route based on n-path. They evaluate detour route algorithm which is applicable to handle terror scenarios. But scenarios don't involve GIS and natural disaster information.

Network Analysis consists of five functions which are Route, Closet Facility, Service Area, Origin Destination Cost Matrix, and Vehicle

Routing Problem that are able to analyze the shortest route, optimal route, accessible areas, and so on.

With the Closet Facility in this study, it is possible to analyze the target facility in a specific location through the network analysis with the distance or time of the access as well as to assess the ranking.

3. Design of Detour Routing and Evacuation Routing Guide System

In this chapter, detour routing and evacuation routing guide system is designed. The guide system proposed in this system is to analyze evacuation route for vehicles in disaster areas searched by disaster information inputted by the administrator and to guide detour route of disaster areas when searching route. And the analyzed results can be serviced by smartphone application.

3.1. Overall System Design

This system is largely configured with a server and clients as illustrated in Figure 2. A user has access right to server data by client application and the server transmits processed result based on information requested by the user.

First, a client is largely configured with two types of modules of the DB management modules and the GIS modules in order to access the database stored in the server. The client and the database server are connected by the DB management modules, which retrieves or stores information from/to the database server. The GIS modules are the modules to perform spatial operations such as routing analysis, Buffer and Intersect by utilizing spatial database on the map. In order to get disaster information and routing guide service by the smartphone application, the

spatial database should be generated by WMS(Web Map Service), and the Map Server is used to generate WMS. And the generated WMS is served by the smartphone application.

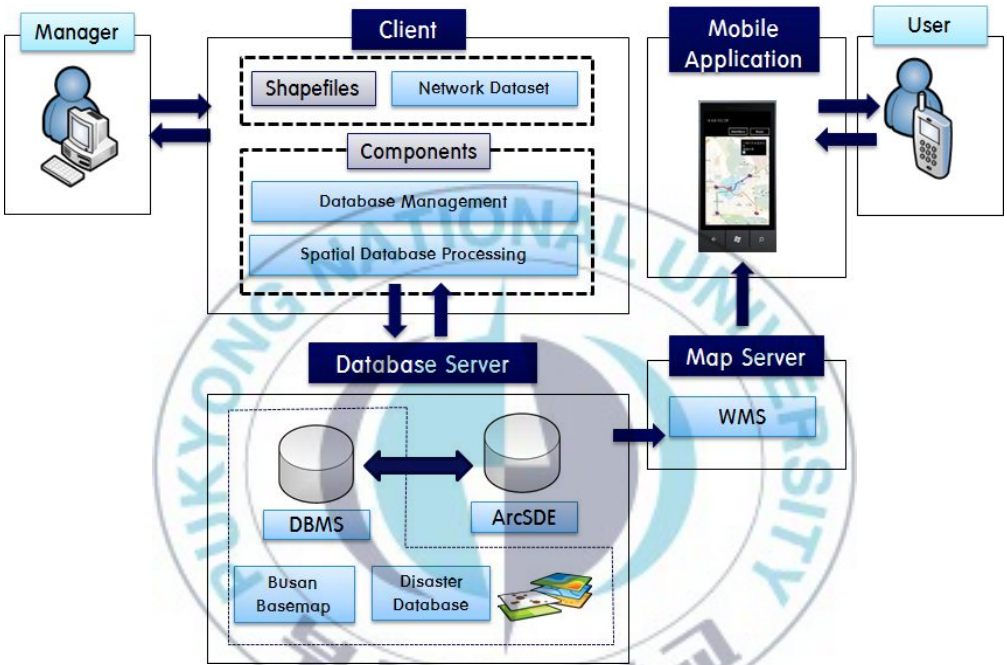

Figure 2. System architecture

3.2. Database and Data Construction

3.2.1. Database Construction

The databases existing in the DBMS (Database Management System) are configured with the general table type database and the spatial database that contains spatial information. Each of the spatial database has the Objectid and the Shape column, where the Objectid is the index of the spatial database and is Not Null, and the Shape column is ST Geometry type which ArcSDE provides. The spatial SQL utilizing the spatial database is performed by using the Shape column.

3.3.2. Spatial Database Construction

The spatial data used in this system is divided into 3 types of base map, disaster information and Network Dataset.

First, for the basic map, the map of Busan UIS (Urban Information System) was used. The Busan map is in the scale of 1:1000 and configured with layers of such as buildings, roads, major facilities locations, administrative area map, and road centerlines. Second, the disaster information used was configured with disaster risk districts, disaster history information and data inputted directly by the administrator. Lastly, it is the Network Dataset, and the Dataset needed for network analysis was generated by using road centerlines.

The Busan map used in this basic map uses ITRF2000 coordinate system, however for data sharing with further mobile applications, it was converted into WGS84 coordinate system for construction. For the spatial database, first a table was generated by using DLL (Data Definition Language), the Objectid and the spatial type column of the Shape column were generated by Sdelayer provided by ArcSDE, and data was loaded to the Shapefile by ArcCatalog.

The basic map, nodes and link data were constructed by the spatial database and the Network Dataset was constructed by using the Shapefile.

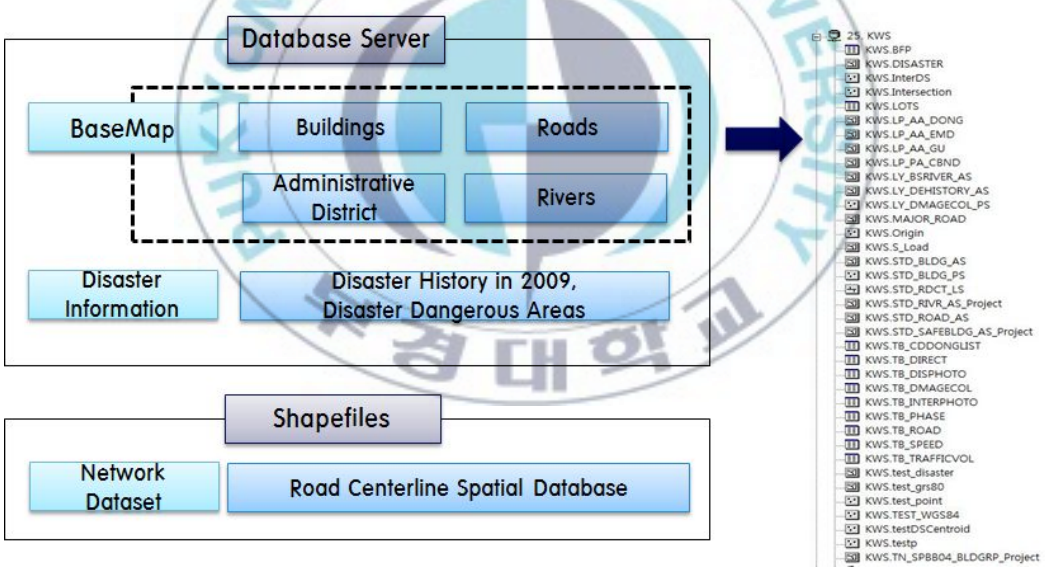

Figure 3. Spatial database construction

3.3.3. Network Dataset Generation

The Network Dataset is the data used for analysis functions such as route search, service area and O/D Matrix provided by ArcGIS Network Analysis, and is generated based on the urban road network. For network analysis function was used for route search in this study, the Network Dataset was constructed.

In this study, the Network Dataset using the Shapefile among various format types was used. To generate Network Dataset, road centerlines used among Busan map.

Before generating the Network Dataset, attribute data was added for the road centerlines. This attribute data is used for the network analysis and values of time, distance, speed and the road layer were added.

The distance among the attribute data was calculated for each object length by using the Field Calculate function, and the unit is km. And to obtain time for each road, first each segment speed was inputted, where the used value was the speed limit of each road segment, which 100Km/h for the expressway, 80Km/h for the urban expressway, 70Km/h for the major arterial, and 40km/h for the rest were designated. In order to analyze time taken for the searched route on network analysis, it was calculated by the equation of ([distance (km)])/ ([speed (km/h)/60]) by each link. Lastly, road layers were classified into 3 types of expressway, major arterial and rest, of which the corresponding code can be identified by ADD_CD.

The Network Dataset generation procedure is as illustrated in Figure 4.

First, the Connectivity that is connectivity setting with all the links was set by Any Vertex, and the Elevation and the Turn data are set to default values. Next is COST, which the value used here is the attribute value used for network analysis, and is to analyze such as the shortest distance and the optimal route over time. It was generated by using the fields of distance and time calculated for each link as above and the Hierarchy was generated for routing calculation considering road layers.

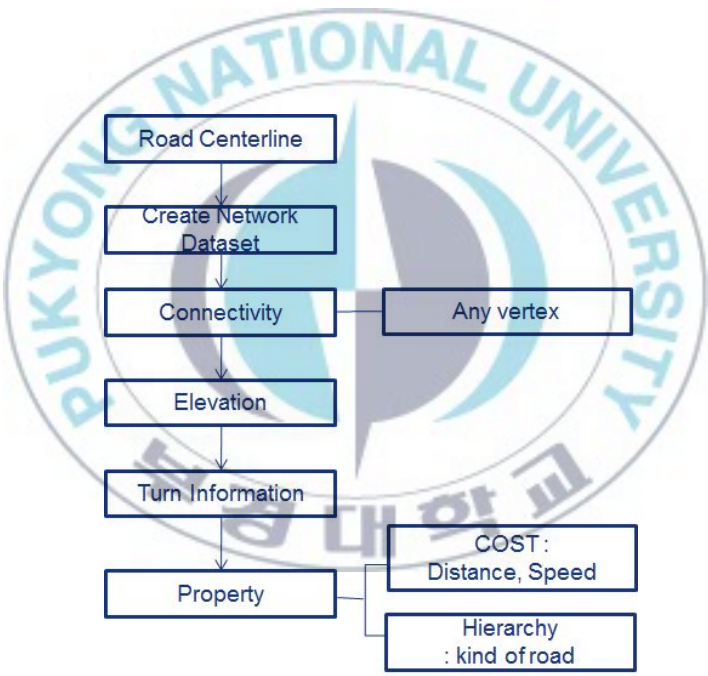

Figure 4. The process of network dataset construction

3.3. Construction of Components

The modules in this system are largely configured with the database management modules and the GIS modules. The database management modules have functions for database access, modification and addition, and the GIS modules are for routing analysis, spatial database input and spatial operation.

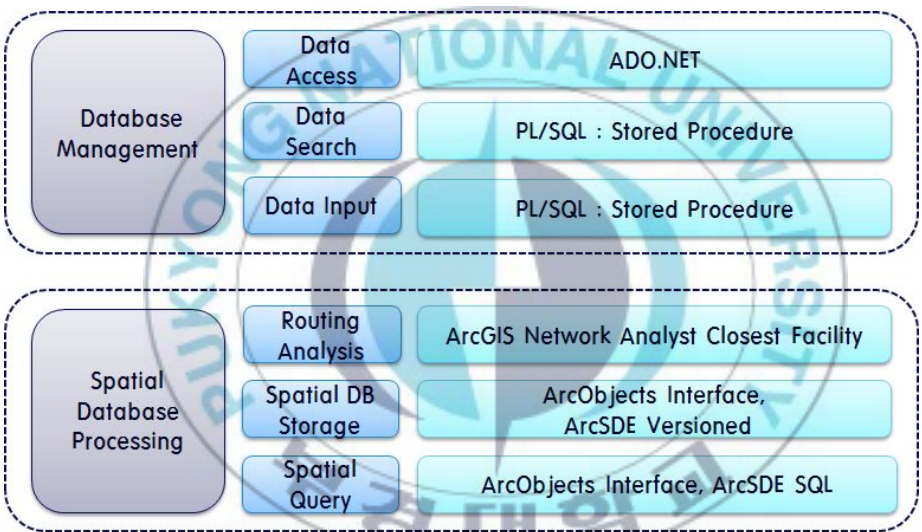

Figure 5. Each components of the system

3.3.1. Database Management

(1) Data Access

To access the database server from a client, ADO.NET was used.

ADO.NET is the latest technology of Microsoft for data access, and is the set of classes. Among the classes provided by ADO.NET, the Oracle class was used in this paper. In order to access the database, the data provider, data source to be connected and the database are defined by Oracleconnection.

(2) Data Search and Input

It is the module to operate the accessed database, and contains functions for search, input and modification. There are the information search method using SQL in the client and the method utilizing the Stored Procedure using PL/SQL. For the method utilizing the Stored Procedure, all of the instructions required for data processing when using the Stored Procedure are stored in the database server, and the client transmits only the input parameters to be processed to the database server. In the database server, after processed by the Stored Procedure, only the resulting value is transmitted back to the client. Alternatively if used SQL in the client, the SQL statement is prepared by the application and transmitted to the database server, and the processed result is received back.

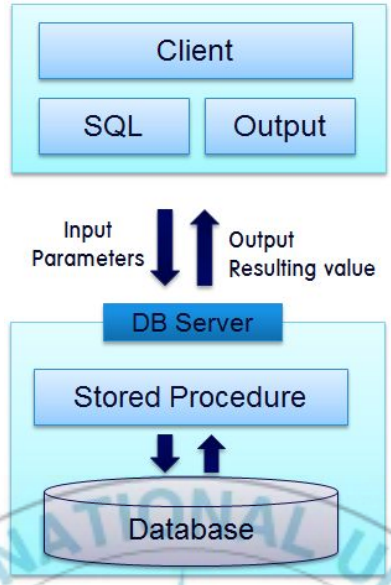

Figure 6. Database input and output

3.3.2. Spatial Database Processing

The GIS modules used are divided into 3 modules of routing analysis, database storage and spatial operation.

(1) Routing Analysis

For routing analysis, ArcGIS Network Analysis Extension was used. The Closest Facility function of Network analysis was used, which is the function analyzable of each optimal route from the user's position to surrounding facilities, and of priority based on the analyzed result to each destination, and was used for detour routing and evacuation routing analysis.

For the data used for the Closest Facility, there are Incident, Facility and Barrier, where the point type data should be used for the data retrieved from each point. The Incident is the disaster area chosen by the user, and for the disaster area is a polygon type, the polygon centroid is generated and set to the Incident. The Facility is an evacuation place and is selected from the surrounding nodes. For the selected node, a Intersection is assigned as a close node to the disaster area by spatial operation.

(2) Spatial Database Storage

For storing spatial database, there are largely 3 methods. They are using general Tools such as ArcGIS, using GIS engines and using DQL Insert statements. In this paper, for database construction stage, ArcGIS Tool was used to store data, and for data storing method of developed application, tools and interfaces provided by the GIS engine were used. First, in order to store spatial database, 'Versioned' should be configured for corresponding database on ArcSDE.

After 'Versioned' configuration finished, 'Editing' tool provided by the GIS engine was added for the user to draw wanted shapes. When using 'Editing' tool, data may be edited only when 'Start Editing' is performed. When the spatial database was drawn in the map control, 'Save' is used to store and 'Stop Editing' is used to not to be modified any more.

When using the interface provided by the GIS engine, corresponding objects are to be stored by Store the member function of IFeature.

```
public static void CreateFeature (IFeatureClass featureClass, IPolyline polyline)
{
  // Build the feature.
  IFeature feature = featureClass.CreateFeature();
  feature.Shape = geometry type // (geometry type :Polygon, Point, Polyline)
  feature.Store();
}
```

(3) Spatial Operation

There are three methods for spatial operation for analyzing relationship of the spatial database. One is Geoprocessing, the method mounting operation procedures prepared by Model Builder or the method using ArcGIS Toolbox, another is the method using spatial operation SQL provided by ArcSDE, and the last one is the implementing method using interface provided by ArcObject. In this paper, Geoprocessing and SQL were used. When analyzing evacuation route, for node search, the complex operation procedures were prepared by Model Builder and Geoprocessing was used, and for disaster search in the administrative areas, spatial operation SQL were used.

3.4. Mobile Application Configuration

Currently mobile OS's used in Korea are mainly Android and iOS. Other than those, there are Symbian, Blackberry and Windows Mobile.

Not introduced in Korea yet, however Windows Phone 7 was released and up to Version 7.5. In this chapter, the spatial information service application was to be implemented by using the platform based on Windows Phone 7.

3.4.1. Window Phone 7

Windows Phone 7 (hereinafter referred to WP7) is the mobile O/S newly released by Microsoft, and is possible to develop by using .Net Framework, C# and VB (Visual Basic). Windows Phone application is that Silverlight is mounted over .Net Framework, and the Silverlight configures the screen layer by using XAML.

To provide spatial information service with results analyzed by C/S based application formerly designed, WP7 based ArcGIS Mobile was used for implementation. ArcGIS Mobile provides 5 Assemblies, and ESRI.ArcGIS.Client.dll and ESRI.ArcGIS.Client.Toolkit were used in this paper.

Table 1. ArcGIS Mobile API Assembly

ArcGIS API Assembly	Description
ESRI.ArcGIS.Client.dll	Core library. Contains map, ArcGIS Service layers, graphics, geometry, and symbol components. Also contains common workflow tasks that support query, find, identify, and geospatial and geoprocessing operations.
ESRI.ArcGIS.Client.Bing.dll	Adds support for Bing layers and services.
ESRI.ArcGIS.Client.Toolkit	Contains a set of common controls for use with the map, such as a Legend and InfoWindow
ESRI.ArcGIS.Client.Toolkit.DataSources.dll	Contains a set of layer types that support common data sources, such as OpenStreetMap and WMS.
ESRI.ArcGIS.Client.WebMap.dll	Contains components that read and process WebMap contents and metadata. It uses the arcgis.com web map specification version 1.1.

3.4.2. Map Server Construction

To provide the spatial database to WP7, the Map Server was used. The Map Server is the server to provide services such as WMS (Web Mapping Service) and WFS (Web Feature Service) that are used for web service to publish the spatial database, and ArcGIS Server was used.

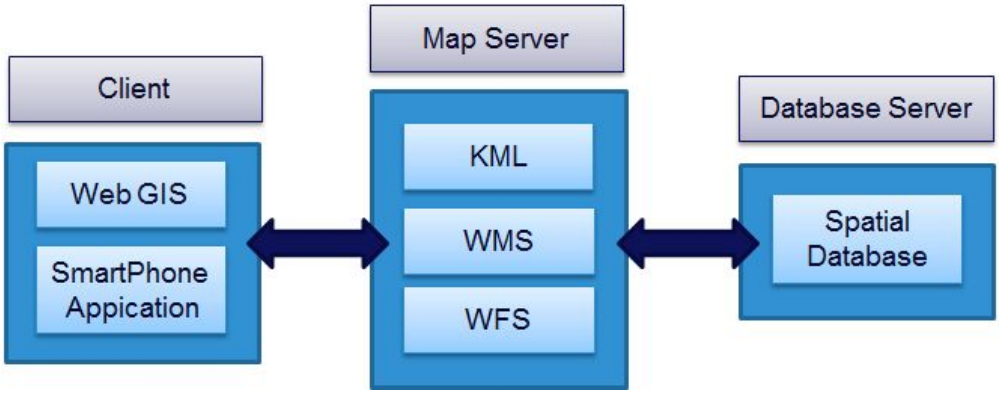

Figure 7. Transmission of mobile data using Map Sever

The spatial database needed for the map service is to be generated as a MapDocument and to be published by the Map Sever. Published WMS(Web Map Serviece) and WFS(Web Feature Service) are to be served as designating corresponding URL by XAML code on WP7.

4. Development of Detour Routing and Evacuation Routing Guide System

In this chapter, according to the system design in Chapter 3, the prototype system of the detour routing and evacuation routing guide system is to be implemented. For the system implementation, it consisted of system development environment, system UI, detour route, evacuation route and mobile application

4.1. System Development Composition

4.1.1. System Development Environment

The environment that is needed for the system development is as shown in Table 2. The system is implemented under the server environment of Windows Server 2008, Oracle 10g was used for DBMS (Database Management System), and for the spatial database middleware ArcSDE 9.3 version was used. For client application development, it was implemented by use of C# under .Net Framework 3.5 environment, and the ArGIS engine was used for the GIS Engine.

ArcSDE is the spatial database middleware that supports spatial types to DBMS's such as existing Oracle Spatial or PostGIS, and provides spatial operation SQL of the spatial database for ST-Geometry types and DBMSs. The GIS Engine is what provides libraries such as map control, legend, map view and spatial analysis for map development, and in this

study, ArcGIS Engine SDK was used along with ArcGIS Desktop SDK to generate Tools needed for map control. To implement mobile application, Windows Phone 7 was used. In addition, for map service of the spatial database, the Map Server was implemented by use of ArcGIS Server.

Table 2. System development environment

System Classification	Type	Software
Server	O/S	Windows Server 2008
	DBMS	Oracle 10g
	Spatial Middleware	ArcSDE 9.3
	Map Server	ArcGIS Server 9.3
Client	Language	C# .Net Framework 3.5
	GIS Engine	ArcGIS SDK 9.3
	Mobile Application	WindowsPhone 7 SDK

4.1.2. Components Processing

Components processing in this system like figure 8. First, user search location like origin, destination after selecting location. If detour routing case, it needs search disaster history, or if evacuation routing case, it needs search disaster location and intersection. Selected location were loaded with Network Dataset, analyzed routing. Analyzed results are stored in the database server, Stored database is created by WMS. Smartphone application loads generated WMS by Map server, and

expressed on display

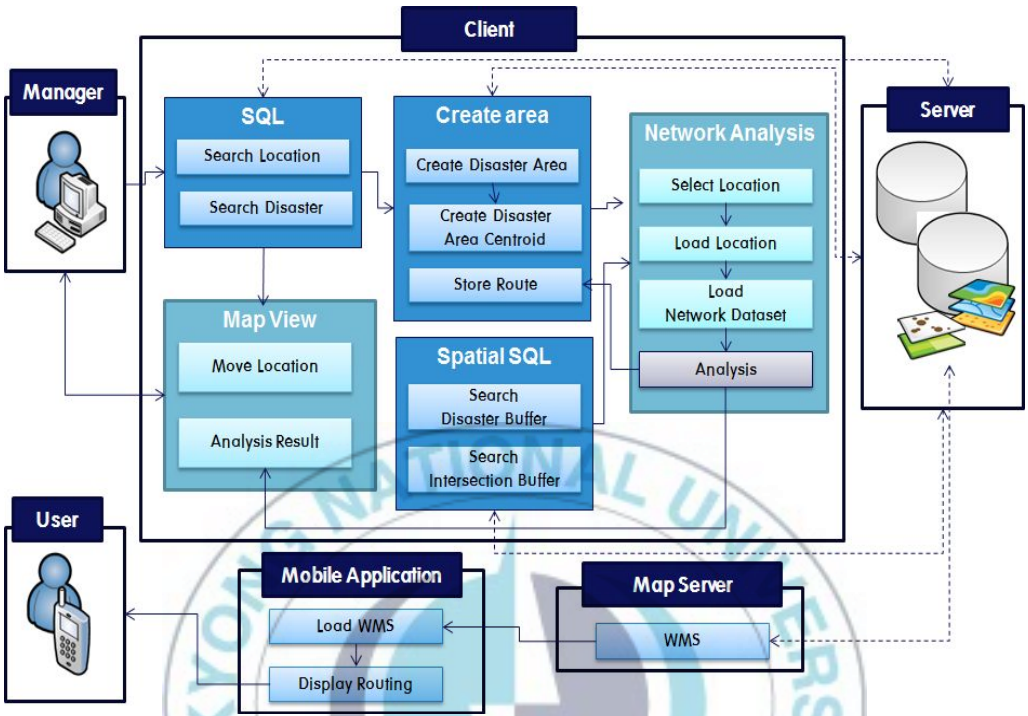

Figure 8. Data processing by components

4.1.3. Entity Relationship Diagram

This system uses 11 tables that Basemap consists of 7 tables and disaster information consists of 4 tables. Each table is set objectid as primary key and shape as geometry type. Figure 9. shows the relationship of each table.

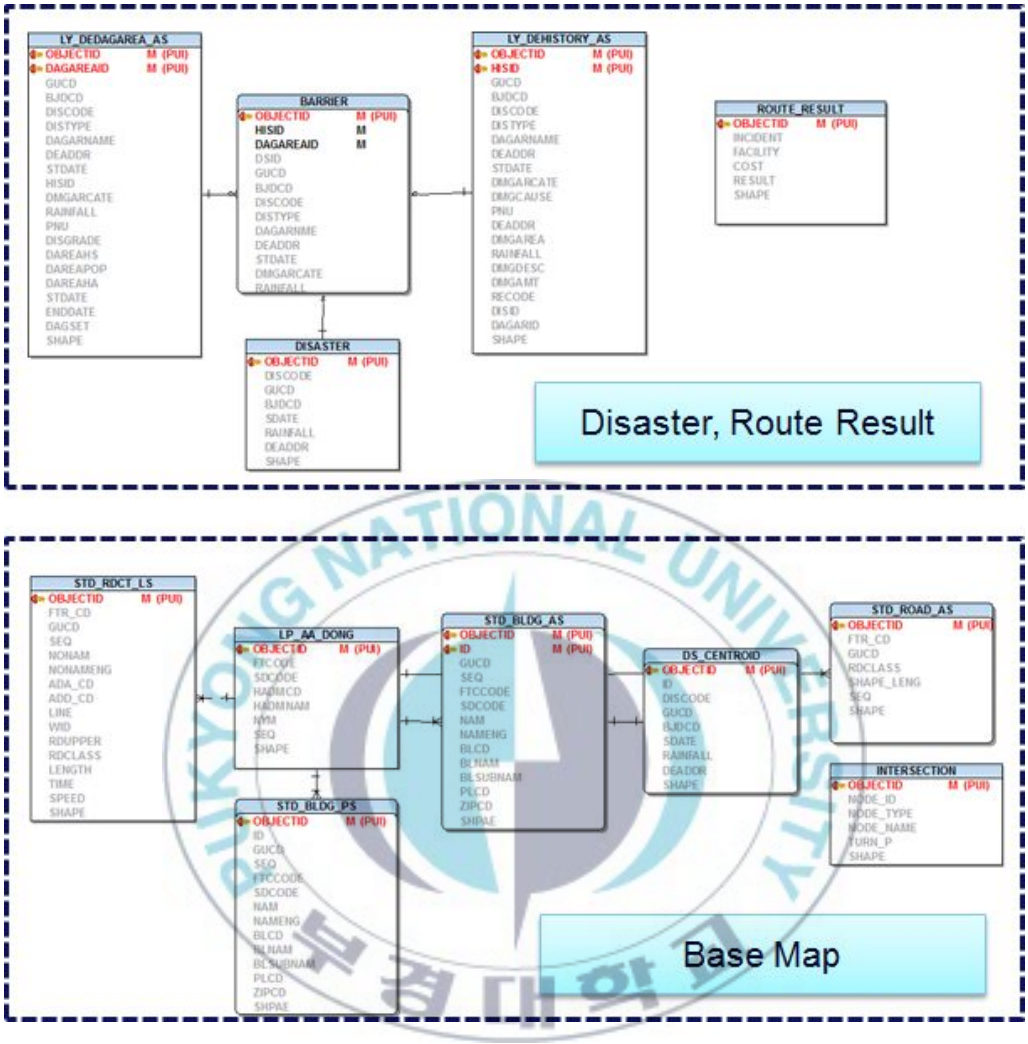

Figure 9. Logical entity relationship diagram

4.2. System Main Menu

The prototype system proposed in this study is as illustrated in Figure 10. and Figure 11. The window in the left side is for search conditions of map attribute information and output of searched results, and the map window and the toolbar for map control are configured in the right side.

The toolbar is the basic tool provided by ArcGIS Engine, and is configured of controls such as data retrieval, map zoom or move, and spatial database edition. By use of Basecommand class provided by ArcGIS Desktop was used to generate the legend window of the map layer and input tools of disaster information. In order to consider for disaster history information, this system provides search functions based on conditions like date, location, rainfall in disaster information detail windows.

Figure 10. System main display

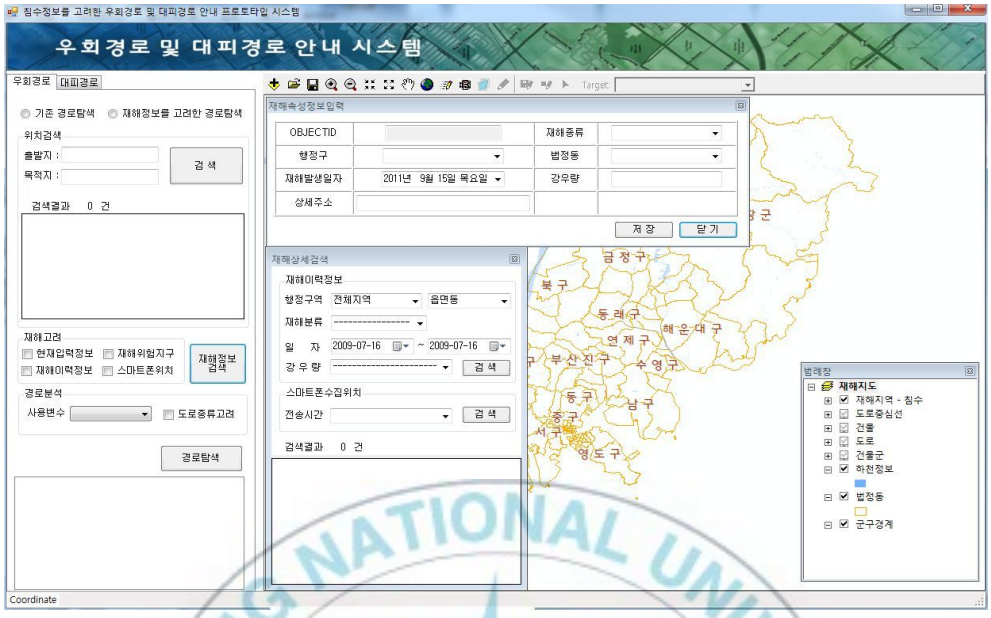

Figure 11. System Functions

4.3. Disaster Area Creation

ArcSDE is the spatial database middleware that supports spatial types to DBMS's such as existing Oracle Spatial or PostGIS. In this paper ArcSDE versioning was used to input disaster information. The administrator is to directly draw the flooded areas by sketch function of the Toolbar, where the flooded area is stored as the polygon type spatial database. When entering flooded areas by use of versioning, first 'Start Editing' should be clicked, then the sketch button should be clicked to draw the spatial database, and 'Save' icon should be clicked to save it

Figure 12. Creating spatial database using editing tool

4.4. Routing Analysis

4.4.1. Routing and Detour Routing Analysis Model

(1) Routing Analysis

When analyzed after selecting the origin and the destination points, the existing optimal route is derived. The user can choose values of time and distance at 'COST' at the bottom window and the optimal route can be derived accordingly.

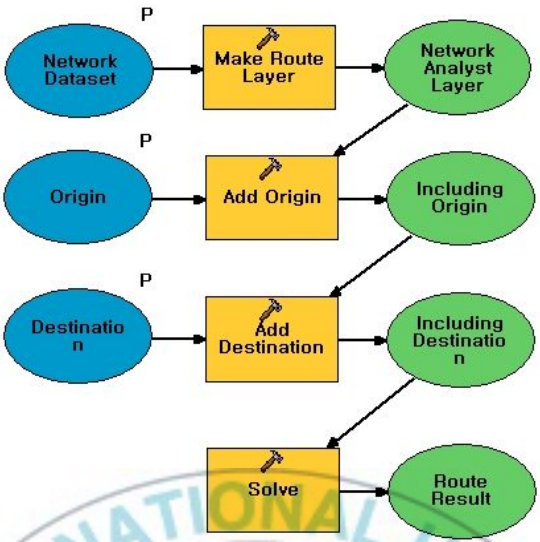

Figure 13. Model of route analysis

(2) Detour Routing Analysis

ArcGIS Network Analysis that uses Dijkstra's algorithm analyze route such as ① in Figure 14. when input origin and destination. When find detour route, if input Barrier point such as ② in Figure 14. applicable links can not access and find detour route. However, when input disaster areas by polygon type, it is difficult to find detour route using a point data. Therefore, when disaster areas are polygon, to find detour route needs 7 barriers such as ④ in Figure 14. If intersections of disaster areas and links were inputted barriers, detour route was analyzed. In this study, detour route analysis function was improved that find detour route using every links and intersections, after inputting disaster areas.

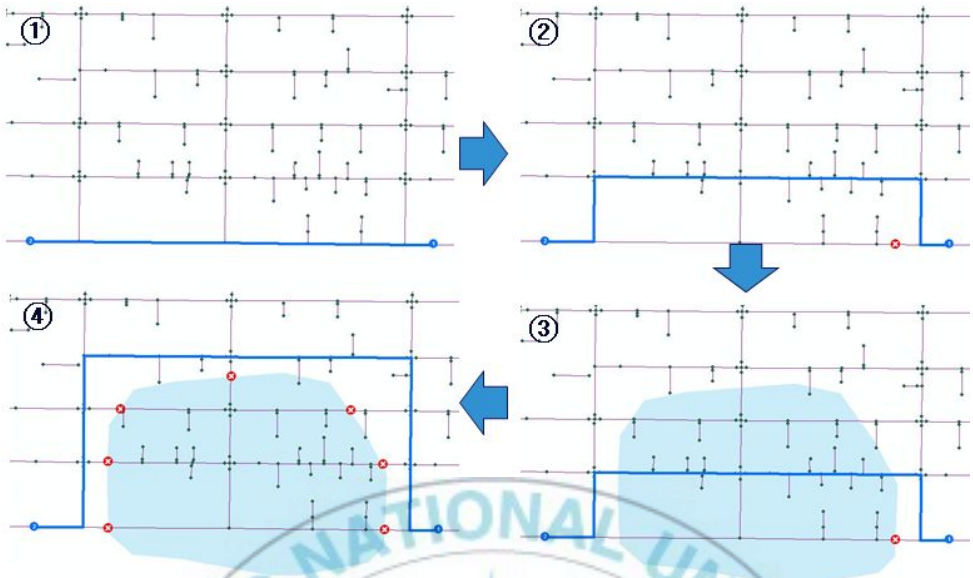

Figure 14. Find route and detour route using Network Analysis

If the checkbox of 'consider disaster' is checked in system, the detour route considering the disaster areas is derived on the map, where the model used for the analysis is as shown in Figure 15. For detour routing analysis, the origin and the destination points are entered as like the exiting routing analysis, and additionally Barrier points are to be entered. The Barrier point is the information to analyze the detour route and the routes are analyzed as the areas where corresponding locations are entered are excluded.

The Barrier point for detour routing analysis is the cross point of the road centerline and the outer line of disaster area, and the steps to find the Barrier point is as follows. First the road centerline inside of the disaster area is extracted and the end point of the line is looked for. And the cross point is searched by use of Intersect with the outer line of the

disaster area, and it is added as the Barrier point in the network analysis layer.

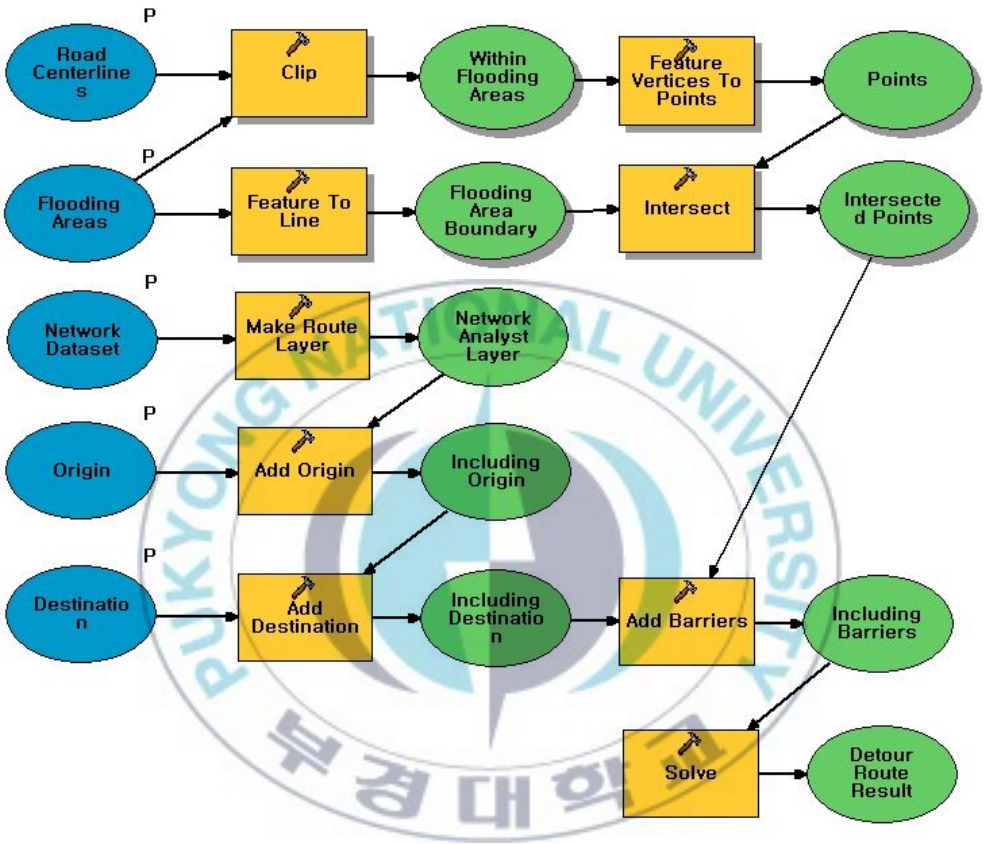

Figure 15. Model of detour route analysis

4.4.2. Routing and Detour Routing Analysis

(1) Origin and Destination Points Search

In order to search the route by network analysis, it is necessary first to input location information for the origin and the destination points, where point type data should be used for data needed to input location information. The building data contains information such as name and address of each building, and in this paper, the building layer is utilized to search the origin and destination points. For the building layer is of Polygon type, it is required to be generated into Point type data and Centroid of building Polygon is to be generated. For the Centroid generation methods, there are a method using sde.st_centroid by use of ArcSDE SQL, and another method using Feature to Point of ArcMap Toolbox. In this paper it was generated by use of latter method and the generated result is as illustrated in Figure 16.

Figure 16. Creation of building centroid

Location search was implemented searchable by use of Name column of building columns, and in the window at the bottom, building name and corresponding address are to be searchable by the searched results. It

was implemented corresponding area to be selected and doubled clicked in the search result window at the bottom to move to respective location. When the origin and destination points are selected, the layer needed for network analysis is generated and corresponding locations are indicated on the map at the same time.

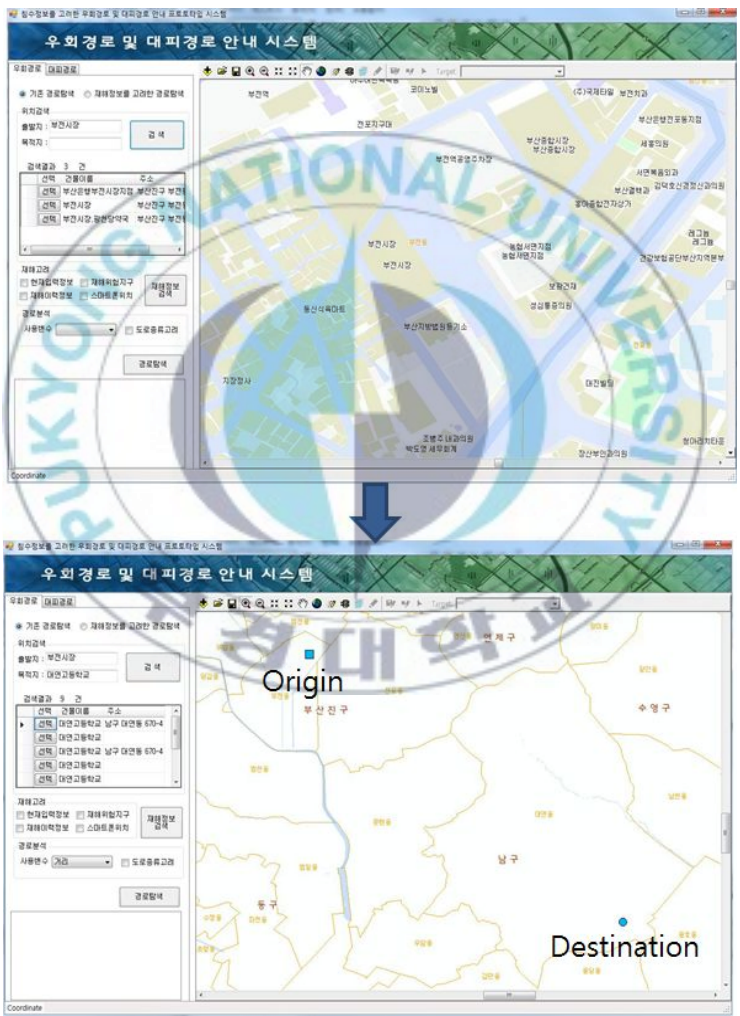

Figure 17. Searching location and Display of selected locations

(2) Routing Analysis Result

The system was tested by utilizing analysis function of implemented route. The tested area target was set from Lotte Department Store to Munhyeon Church, and analysis was conducted for the route using distance cost. The shortest route total distance was 3.515 km.

Figure 18. Result of route analysis from Lotte Department Store to Munhyeon Church

(3) Detour Routing Analysis Result

The system was tested by utilizing analysis function of implemented detour route. The tested area target was same locations from Lotte Department Store to Munhyeon Church, and analysis was conducted for the detour route using disaster dange areas and input disaster areas by administrator.

First, when considering disaster danger areas, total detour route distance was 5.535 km from Lotte Department Store to Munhyeon Church. when compared with existing shortest route and detour route considering disaster danger areas, total distance was somewhat 20m difference. However, route was different such as figure 20. Next, supposed that disaster occurs around Moonjeon Station, input disaster areas such as A district in Figure 21 by administrator. Detour route considering disaster danger areas and input disaster areas by administrator was analyzed 3.587 km. Total distance traveled was similar to detour route distance traveled considering danger areas, but route seems much of a difference with previous detour route. Figure 22/ shows comparison of route analysis result when considering each information that disaster danger areas and inputted disaster areas by administrator.

Table 3. Result of route analysis

No	Origin	Destination	Option	Route	Result : Total Distance
1	Lotte Department Store	Munhyeon Church	No option	Shortest Route	0.42 km
2	Lotte Department Store	Munhyeon Church	Considering Disaster Danger Areas	Detour Route	0.58 km
3	Lotte Department Store	Munhyeon Church	Considering input disaster area by administrator	Detour Route	0.82 km

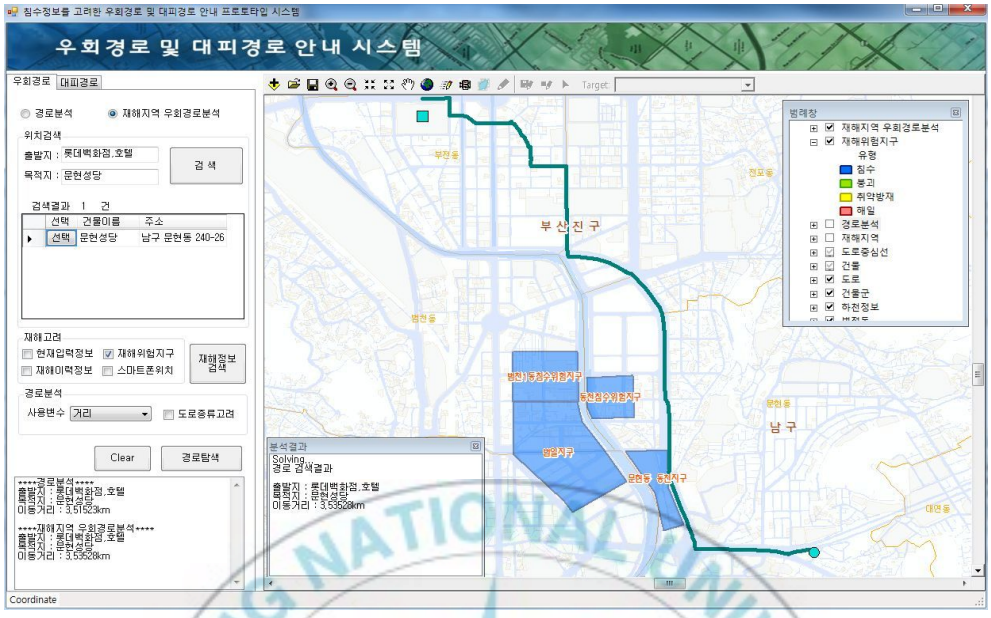

Figure 19. Result of detour route analysis using disaster dangerous areas

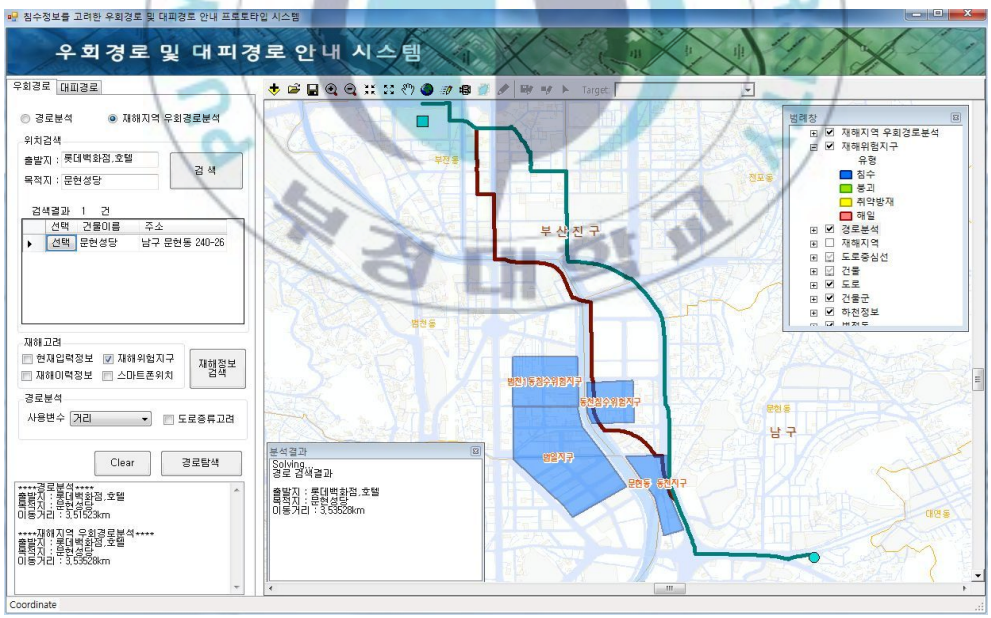

Figure 20. Comparison of route and detour route using disaster dangerous areas

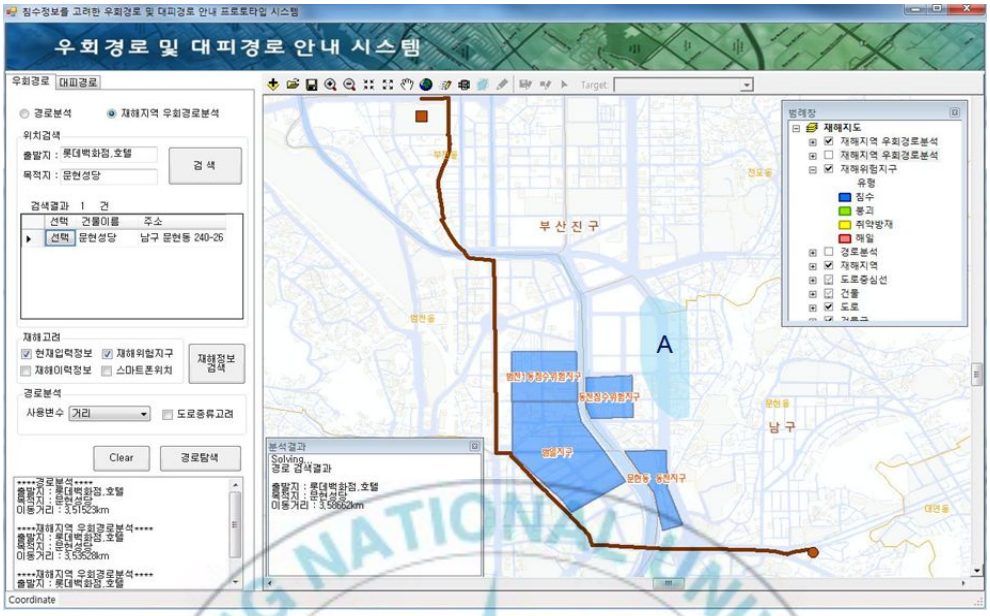

Figure 21. Result of detour route using inputted disaster area by administrator

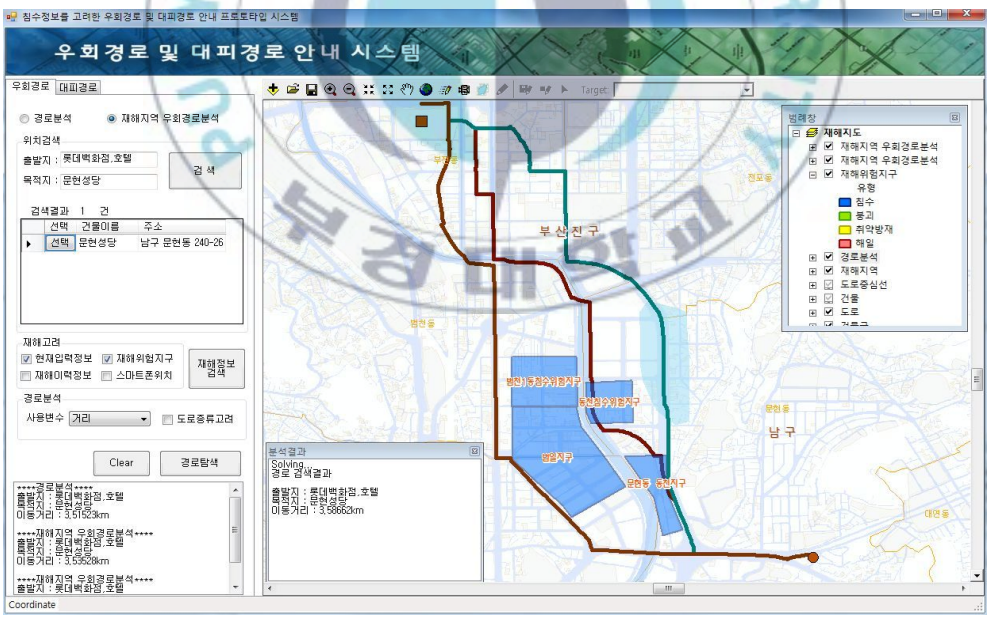

Figure 22. Comparison of every routes

4.5. Evacuation Routing Analysis

4.5.1. Disaster Area Search

The administrator can search disaster information of corresponding areas by administrative area search. For disaster information search according to the administrative areas, spatial SQL provided by ArcSDE was used. The used function was ST_Intersects, which performs operation to find overlapped area of two spatial databases. The ST_Intersects grammar is as follows, where Shape is ST_Geometry type column name used in each spatial database.

The user is to select the administrative Gu(county) by combo box and then to select legislative Dong(town) included in the corresponding Gu. The disaster areas belonged to the selected administrative areas are searched and displayed in the bottom window. If double clicked in the search result window, you can move to corresponding disaster area.

```
select unique(ds.objectid) from disaster ds, lp_aa_gu gu
where sde.st_intersects (ds.shape, gu.shape) = 1
```

4.5.2. Evacuation Route Model in the Flooded Area

The model used to analyze the evacuation routes to each node in the

flooded area is as illustrated in Figure 19. When selecting one of flooded areas searched by the administrative areas, Centroid is generated of corresponding disaster area, where Centroid is generated as same as former building Centroid generation. Closest Facility library was used from ArcGIS Network Analysis libraries used for evacuation routing analysis. The Closest Facility is the function to analyze routes and the priority according to the routes for multiple Facilities when entering one Incident by inputting Incidents and Facilities, and the Centroid of selected flooded area receives the Incident location used by the Closest Facility. And the Facility is the node for evacuation for the flooded area, and was set by the close Intersection to the flooded area.

To get the node, the administrative areas are to be searched, a buffer of radius of 1 km from the selected flooded area is to be generated and the flooded area is to be erased from the generated buffer by use of Erase. In the remained area, the location Intersected with the Intersection is to be selected and only the selected Intersection Point is to be entered as the Facility. For the Intersection Point is located at the location coincident to the road centerline when retrieving the Facility, Tolerance value was set to 1.

If all of Incidents and Facilities were retrieved, the attribute to be analyzed can be selected by COST as like the optimal route of the former chapter.

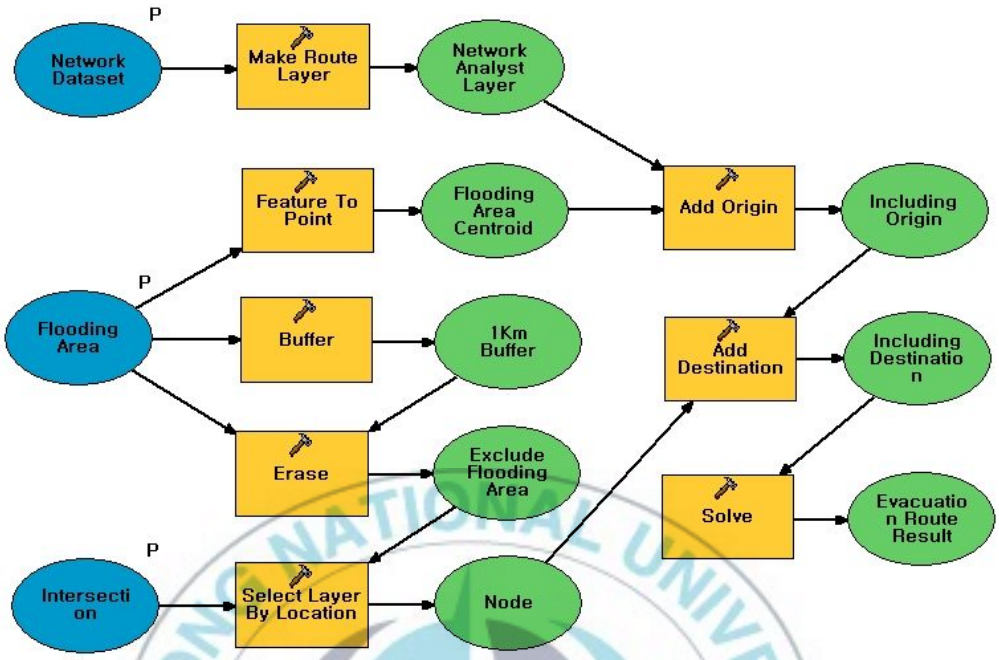

Figure 23. Model of evacuation route analysis

4.5.3. Evacuation Routing Analysis

In order to test implemented evacuation routing analysis, Daeyeon-dong, Nam-gu was set as the test area. First the administrative area was selected to Nam-gu, the administrative Dong was selected to Daeyeon-dong, and Search was clicked, The Intersections that are the nodes which had been entered as the destination points when analyzing Centroid and the evacuation routes of formerly selected flooded area were searched 4 pieces. The Centroid of the flooded area was inputted as the Incident and 4 Intersections as Facilities. The searched locations were as illustrated in Figure 22.

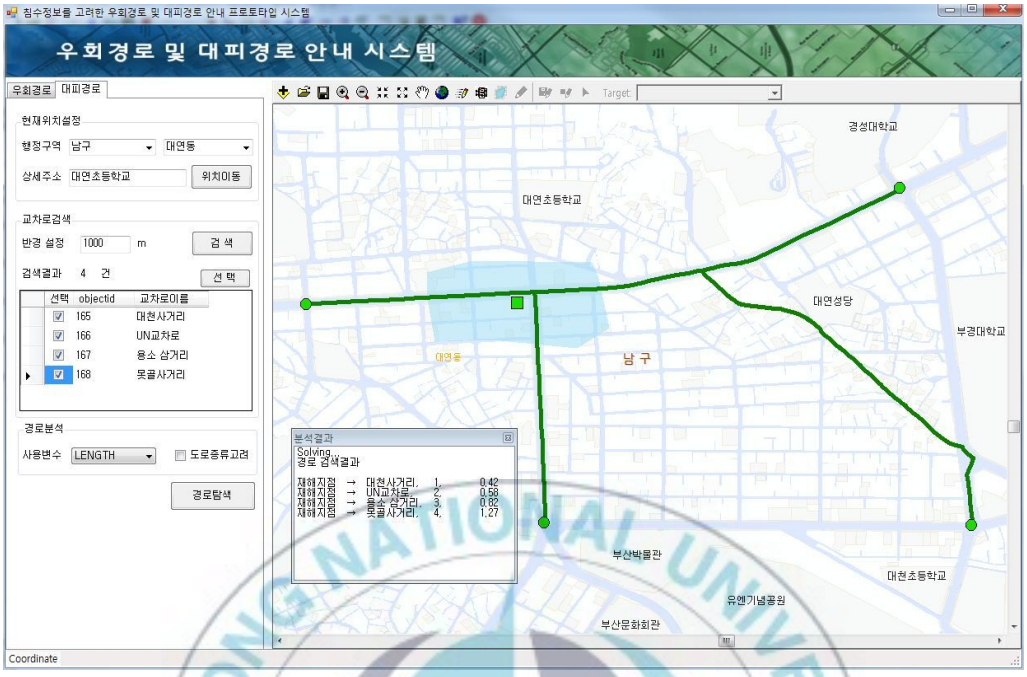

Figure 24. Result of evacuation route analysis

When each selected location was displayed, routing analysis was performed accordingly. The analysis by each Intersection is listed in Table 4, where COSTs were analyzed respectively according to time and distance as like routing analysis of previous chapter to derive results.

Table 4. Result of evacuation route analysis

Origin	Destination	Rank	Route	Result : Total Distance
Flooded Area	Motgol Intersection	1	Shortest Route	0.42 km
Flooded Area	UN Intersection	2	Shortest Route	0.58 km
Flooded Area	Yonso Intersection	3	Shortest Route	0.82 km
Flooded Area	Daechun Intersection	4	Shortest Route	1.27 km

4.6. Evacuation Routing Guide Mobile Service

To provide guide service to the smartphone with evacuation routing analysis result within corresponding area after selected flooded area in previous chapter, application on WP7 was developed.

4.6.1. WMS Generation by Use of MapServer

In order to display the spatial database on Mobile or Web, it should be generated in the form of WMS, WFS or KML. ArcGIS Server was used to generate the spatial database used for flooded areas and routing analysis into the form of WMS. GeoServiceMap provided by ESRI Korea was used for the map used as the base map in the application. Comparison between generated WMS and existing GeoServiceMap

provided is as shown in Table 5. GeoServiceMap is composed with 19 steps of Tile maps, where the Tile map means generating image for each scale in order to promptly load image according to scales when retrieving map from either Web or Mobile.

Table 5. Comparison of WMS and GeoServiceMap

Classification	Generated WMS	GeoServiceMap
View In	ArcMap, ArcGIS Explorer, ArcGIS JavaScript, Google Earth, ArcGIS.com Map	ArcMap, ArcGIS Explorer, ArcGIS JavaScript, Google Earth, ArcGIS.com Map, Bing Maps
Layers	Incident, Facilities, Flooded Areas, Intersections, roadcentlines	NationalLand
Tile Info		Height: 256 Width: 256 DPI: 96 Levels of Detail: (# Levels: 19)
Intial Extent	XMin: 129.090281593277 YMin: 35.1288133695074 XMax: 129.102129590512 YMax: 35.138006972963	XMin: 12387984.2055653 YMin: 4126320.37675042 XMax: 15897972.5444196 YMax: 5557221.54624854
Supported Image Format Types	PNG24,PNG,JPG,DIB,TIFF,EMF,PS,PDF,GIF,SVG,SVGZ,AI,BMP	PNG32,PNG24,PNG,JPG,DIB,TIFF,EMF,PS,PDF,GIF,SVG,SVGZ,BMP
Supported Interfaces	REST, SOAP, WMS	REST, SOAP

4.6.2. Application on Windows Phone 7

(1) Application Map Generation

The application on WP7 is the application to provide guide service with analyzed results to the user by the client, and the service is provided for the user approaching to the flooded area or in the flooded area. Limited to the vehicles approaching to the flooded areas, it can alert risk of flooding of surrounding area, and it was configured to provide evacuation routing guide to nearby Intersections for the vehicles in the flooded areas. In this paper, for it was tested by WP7 emulation, the operation result on the actual phone may differ.

To use the spatial database on WP7, ArcGIS API was used. When retrieving map data from WP7 by use of ArcGIS API, GeoServiceMap is retrieved by ArcGISTiledMapServiceLayer and WMS generated by ArcGIS Server is retrieved by ArcGISDynamicMapServiceLayer. The codes to retrieve each map are as follows, and it works if entering codes over XAML codes.

```
<esri:Map x:Name="MyMap" Extent="14369613.064, 4180425.804,
14372987.149, 4184863.789" >
 <esri:Map.Layers>
<esri:ArcGISTiledMapServiceLayer ID="StreetMapLayer“
Url="http://arcgis.esrikr.com/ArcGIS/rest/services/Community/GeoSe
rviceMap/MapServer" />
<esri:ArcGISDynamicMapServiceLayer ID="MapID“
 Url="http://host/ArcGIS/resr/services/Mapserver" />
 </esri:Map.Layers>
 </esri:Map>
```

The above XAML codes are for initially displaying the map when operating the application and the method to retrieve the route layer of the analysis results from application is as follows.

```
FeatureLayer featurelayer = new FeatureLayer();
featurelayer.Url = MapServer URL;
MyMap.Layers.Add(featurelayer);
```

(2) Application Implementation Result

The first operating window of implemented application on WP7 is configured with two menus of map view and disaster information. When map view was selected, a window is displayed extended to the area of Daeyeon-dong, Nam-gu. The menu is configured with main menu and

Route, and map is configured in the lower window. By listbox on the map, symbols and names of the layer display on the map currently are displayed.

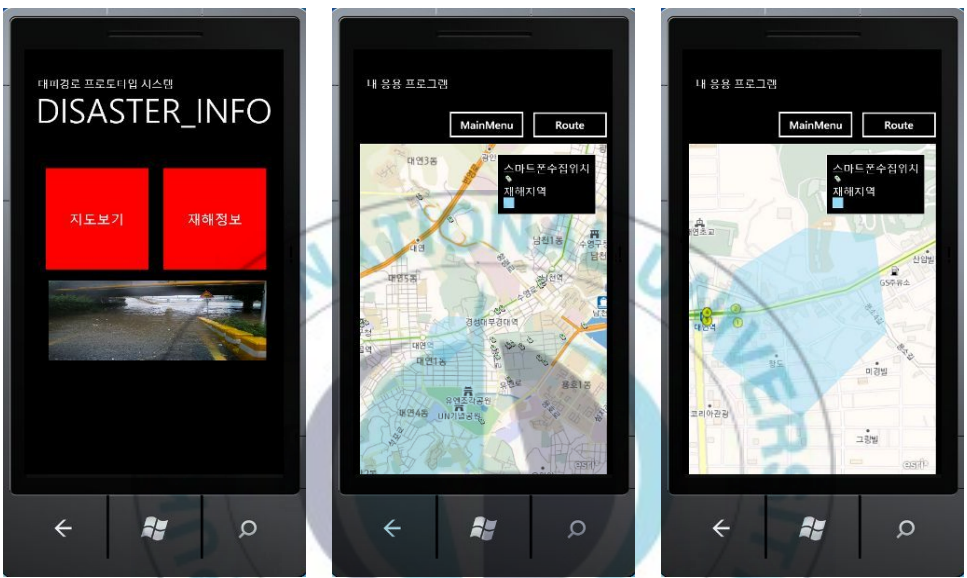

Figure 25. Mobile application display

Next, when Route was clicked, by application the analyzed result of evacuation routes in the disaster area is serviced from C/S based system. It is as shown in Figure 24, and the user may be guided from the flooded area currently isolated to the nearby Intersection.

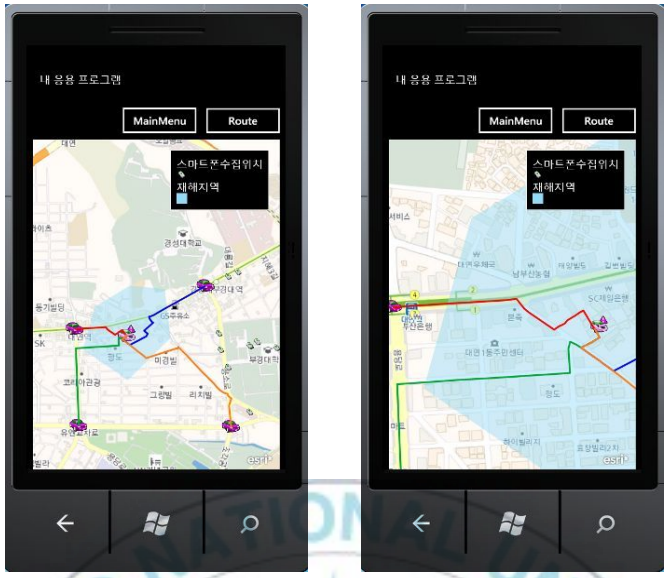

Figure 26. Evacuation route guidance service

5. Conclusion

In this paper, in order to prevent or respond vehicle isolation and congestion for road flooding frequently occurring every year recently, GIS based prototype system was developed to provide detour routing and evacuation routing guide in/from the flooded areas. To test developed system, with the target area of Nam-gu, existing routing analysis, detour routing analysis in consideration of the disaster information and evacuation routing analysis in disaster areas were performed. In addition, application to provide the analyzed results by the smartphone was development.

In existing disaster management system, the disaster history or hazardous area information were implemented and provided, and they were used for disaster management of prevention and response. In this study, the developed prototype system provides not only limited to disaster information, but also detour routing and evacuation routing analysis by utilizing disaster information data entered by the administrator, as well as they are served by smartphone application, which is considered to be more useful and efficient information supply.

However, the disaster information entry proposed in this study should be conducted by the administration, which does not provide real time information. For the method to collect disaster information such as flooding in real time, recently there are information collecting methods by SNS or by use of smartphone application. If such collecting methods are utilized to implement disaster area information in real time, it is

considered that it will be more efficient, and if flooding model is used to predict hazardous areas according to precipitation beforehand, more efficient traffic management will be achieved in the disaster prevention phase, which will contribute in reducing damages such as addition traffic congestion or isolation in the disaster areas. In addition, by saving such information, potential hazardous areas may be continuously managed in the future.

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감사의 글

2년 동안 기쁘고 좋은 일도 많았지만 힘든 일도 많았습니다. 그러한 일들을 겪어오며 제가 더 발전하였고 여기까지 온 것 같습니다. 지금의 제가 있을 수 있도록 칭찬과 격려를 아끼지 않으셨던 많은 분들께 진심으로 감사의 마음을 전하고자 합니다.

석사과정동안 두 분의 지도 교수님 덕에 많은 경험을 할 수 있었고 무사히 끝마칠 수 있었습니다. 먼저 지금의 연구실에서 공부할 수 있게끔 추천해주시고 많은 가르침과 조언을 해주시며 지원해주신 김영섭 교수님께 감사드립니다. 그리고 실질적으로 연구에 있어서 지도해주시며 많은 경험을 쌓게 해주셨고 이끌어주신 김창수 교수님께 감사드립니다. 교수님과 면담이 엊그제 같은데 벌써 2년이란 시간이 지났습니다. 표현을 잘 하지 못했지만 항상 두 분께 감사한 마음을 가지고 있습니다. 비록 연구실 세미나에는 몇 번 참석하지 못했지만 관심 가져 주시고 조언해주신 배상훈 교수님께도 감사드립니다. 그리고 학문적인 가르침을 주신 윤홍주 교수님, 최철웅 교수님, 서용철 교수님, 한경수 교수님, 이양원 교수님께도 감사의 인사를 드립니다.

제가 생활하던 UPSIL 연구실의 연구실원들께 감사드립니다. 저희들 가르치느라 고생하신 황현숙 박사님 정말 많이 배웠습니다. 쌍둥이 키우느라 고생하시는 김기욱 박사님, 연구실 와서 빵 터트리고 가는 이석철 박사님, 많은 조언과 격려 해주셨던 정동호 선생님, 정명균 선생님, 박창수 박사님, 정경훈 박사님, 전태건 박사님께도 감사드립니다. 석사 동기인 태웅, 중기, 다니엘, 은혜 2년 동안 같이 공부할 수 있어서 좋았고 정말 수고 많았다. 은미 선생님, 성제 형, 장명 형, 영학이, 현곤이 까지 지금까지 함께 했던 연구실원 모두에게 정말 감사드립니다. 그리고 저에게 또 다른 연구실인 환경원격탐사

연구실에 석사동기 나리, 많은 정보 주는 성규 형, 돈정이 형에게 감사드립니다. 그리고 정민이, 현용이, 창원이, 태성이도 고맙다.

마지막으로 항해 중에 고생하고 계실 아버지, 뒷바라지 해주시는 어머니, 논문 나올 때 전역해 있을 동생에게도 정말 감사하고 사랑합니다.