# Origin-Destination (O-D) Matrix Generating and Analytical System for Road Side Surveys in Sri Lanka

P.D.J.S. Siriwardana



129172R

Dissertation submitted to the Faculty of Information Technology, University of Moratuwa, Sri Lanka for the partial fulfillment of the requirements of the Master of Science /Post Graduate Diploma in Information Technology.

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**Declaration**

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Name of the student Signature of the student



Date

Supervised by

Name of supervisor Signature of supervisor

Date

**Dedication**

This thesis is dedicated to my parent S.C. De Silva and I. S. D. De Silva and my wife S.C.P De Silva who gave me much assistance and introduced me to the joy of reading, enabling such a study to take place today.

**Acknowledgement**

My special gratitude is offered to Mr. D.K. Withanage, my supervisor of the research project, for providing me with required guidance and support in the successful completion of this final document.

Also I kindly thanks to the Prof. J.M.S.J. Bandara, at the Transportation Engineering Division of Civil Engineering Department of University of Moratuwa for providing me the necessary information and guidance in developing the system.

Also I am kindly reminding my parents, wife and friends who encouraged me to work on this project and again thanking them for the assistance and help given in whatever way to make this project a success.

**Abstract**

Transportation is one of the most development factors in Sri Lanka recently. Therefore it has also become the basic area for conducting research. Common classes of traffic engineering and transportation planning problems revolve around the estimation of an Origin-Destination (O-D) matrix for a road network. The O-D matrix is estimated using traffic counts on the link and interview data conducted by the Transportation Engineering Division at University of Moratuwa and Road Development Authority.

Much needed information are available in past O-D surveys conducted by both institute regularly but not consistently carry out O-D surveys for different project purposes. As no proper methodology is available for updating existing information (O-D data) and due to the difficulty of combining different O-D survey results easily, time and money is unnecessarily spent on collecting data over and over again. Sampling is one approach used to survey the origin-destination (O-D) trip matrix. However, when the sampling rate is not sufficiently large compared to the population, the sampling data may have missing values in O-D pairs and that makes the O-D matrix incomplete. There is no proper repository system to store these data sources. Besides, Preparing an O-D matrix manually from all surveyed data set by preventing the double counting and sample size issues is another disadvantage.

This research introduce a GIS based systematic model by extending network analysis features of ArcGIS 10.1 and Arcobject to generate O-D matrix by minimizing the double counting error. In addition to them the system provide the facilitate to manage and maintain the all past O-D information, getting them updated regularly with new O-D data and updating the O-D matrix and retrieve it by integrating with Database Management System . The model is expected to provide the suitable method for locating places for new O-D survey through the concept of minimum path and step-wise circular method. In addition, the system is introduced to provide statistical and analytical outcome from current and past data including traffic flow and usage of travel mode, distribution of trip, and attraction of trip in divisional secretary areas.

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# CHAPTER 1

# 1.0 Background and Introduction

## 1.1 Introduction

The accuracy of the modeled traffic situation depends on the quality of the available information, and how this data is combined and weighted from different sources. The travel demand is a key component and nearly every traffic model requires a table specifying the travel demand between different places in the network. Such a table is called an Origin–Destination matrix or OD-matrix for short; synonymously used terms are trip table or (origin–destination) trip matrix [39].In developing countries, changes in the land-use and economic state of affairs require momentous transportation planning. One of the most crucial requirements for the transportation planning is on arriving at the traffic pattern between various zones through Origin-Destination matrix (ODM) estimation. Traditional methods of estimating ODM are through large scale sampled surveys like home interview surveys [38].



Transport systems planning and designing are based on the application of systems of transport simulation models, whose forecast reliability and goodness-of-fit strongly influence the results and the quality of the planned/designed interventions. The implementation of a reliable and effective system of models should be based on the disaggregate estimation of each model component (supply, demand, assignment). [40]

Nowadays Sri Lanka is focused on the development of urban expressways and they are becoming the mainframe of the road system, especially for automobiles, entirely closed and access controlled. As the artery of the urban transportation and economy, urban expressways connect the main roads and the radial roads, gathering and distributing the traffic in central area and connecting the urban and suburban areas. The traffic flow features in trip distance and space on the expressway are the important basis for reducing traffic jams, ensuring the traffic service level in the city center and evaluating the transportation investment performance. Therefore, the origin–destination (OD) information of the expressway is of much importance.

## 1.2 Motivation and Background

Transportation is one of the most development factors in Sri Lanka recently. Therefore it has also become the basic area for conducting research. Transportation Engineering Division at University of Moratuwa is such an institute in Sri Lanka that contribute in many research on Transportation. In addition they have the responsibility in getting decision and conclusion and planning of future development of Transportation in Sri Lanka. Most postgraduate research and other projects are maintained by the Transportation Engineering Division.

Much needed information is available in past O-D surveys conducted and institutions such as Road Development Authority and University of Moratuwa regularly but not consistently carry out O-D surveys for different project purposes. As no proper methodology is available for updating existing information (O-D data) and due to the difficulty of combining different O-D survey results easily, time and money is unnecessarily spent on collecting data over and over again. The worst case is that estimation of o-d matrix by manually made lot of time waste and errors. Sometimes the data become larger and complex leads to face inconvenience in analyzing and estimations. Most of the traffic counts in Sri Lanka are carried out in normal manner for individual projects, research or other development purposes. Since The Traffic counts are based on these surveyed results and the worst case is the estimating O-D matrix with manually from traffic counts. Therefore proper methodology of estimation of O-D surveys and updating with existing information is needed. These problems affect to the transportation development of the country indirectly. Therefore a system is highly required to maintain the O-D data and estimation of O-D matrix by minimizing the errors cause it.



## 1.3 Aims & Objectives

Aim

The Aim of this project is to development of GIS based extension which is capable to manage road side surveyed data and estimation of O-D matrix using them by

minimizing the double counting errors. The features of GIS application are extended to estimation of the O-D matrix whereas graphical information is provided to with the other features of the GIS application.

Objectives

- ✓ Provide a methodology to eliminate inconvenience of management of raw data.
- ✓ An algorithm to estimation of O-D matrix for removing the double counting errors to eliminate the difficulties in manual estimation.
- ✓ Provide the graphical environment to represent important function that can be obtained from the raw data.
- ✓ Introduction of a method of selecting best location for conducting O-D surveys efficiently and effectively.
- ✓ Provide an analytical environment for taking decision on transportation planning.



**1.4 Proposed Solution and Methodology**

The proposed solution can be addressed as the development of management system for storing, manipulating, displaying of O-D surveyed data and use of the Network analysis features and other features to estimation of O-D matrix of them by considering the minimum path distance provide interactive map visualization and estimate the suitable location for new O-D survey. The development process went through the basic steps in incremental and iteration development process.

The first phase describes the preliminary analysis stage where the current domain was analyzed and identified the main scope of the problem domain. The Object Oriented and Analysis methodology and Techniques were proposed for deriving the functional and information mode. This phase provides the feasibility and the functional and non-

functional requirements for the system in addition the relevant materials for development of geographical Database was identified.

The second phase was to design of the functional and information model. The Object Oriented designing techniques was proposed to use for designing of the System from bottom to top. Every process was able to document and emphasize the functions for implementation model. The Entity Relationship model was proposed to model of the information for maintaining the surveyed data. The more information about the applicability of mentioned technology will be discussed in the technology chapter.

The third phase is the implementation phase. The main idea of this phase is to develop the model with the suitable programming language. Use of proper Integrated Development Environment was proposed as the visual studio IDE. For more information about this will be discussed in Technology Chapter.

The final phase was to operational and maintenance in which the system is put into some test for verification and validity and integrated with the relevant component.



### 1.4.1 Users and Functional requirements proposed

The proposed solution is expected to function with three deferent users. The following table describes the basic function that was expected from the new system.

| **User** | **Tasks** | **Features proposed** |
|---|---|---|
| Administrator | Manage Database(1) | Separate module to add/delete/update road survey information |
| | Maintain Survey reports(2) | Separate module with features to connect with file server and upload/download and manage survey reports |

| | | |
|---|---|---|
| | Manage Users(3) | Separate module to add/delete/update users and their privileges. |
| | Manage new survey entry sheets (4) | Separate module with the features of add new survey sheets |
| | Configure basic settings (5) | Separate module for Setting ftp and database server address information |
| | Reconfigure and Update the O-D matrix with current data. | Use a network analysis component features to create a modules |
| | Analytical Estimations(7) | Separate modules for each analytical estimation like travel mode behavior on a link. Minimum path estimation, trip distribution, trip attraction, charts. |
| Department Users | Manage new survey entry sheets (4) | Same modules as Administrator |
| | Configure basic settings (5) | Same as mentioned in Administrator |

| | | |
|---|---|---|
| | Maintain Survey reports(2) | Same modules as Administrator |
| | Reconfigure and Update the O-D matrix with current data. | Same as in Administrator |
| Normal Users | Analytical Estimations(7) | Same as in Administrator |

**Table 1: Users**

### 1.4.2 System requirements

The followings were identified as the Basic System Requirements for the Proposed Solution



- Corei7 processors with 180GB capacity (for File Server ) and 4 GB RAM
- Corei7 processors Computer with at least 80 GB (For primary database server) and 2 GB RAM
- Corei7 processors computer with 4GB RAM (Client Requirements )
- LAN Network Infrastructure

# CHAPTER 2

# 2.0 Literature Review

## 2.1 Introduction

The ODM (Origin Destination Matrix) estimation models can be categorized as static and dynamic based on its application. In static methods the traffic flows are considered as time-independent and an average O-D demand is determined for long-time transportation planning and design purpose. Whereas from last two decades different dynamic approaches are proposed which are meant for short-term strategies like route guidance, traffic control on freeways, intersections etc. A static ODM estimation problem does not consider the time-dependent traffic flows and is assumed to represent a steady-state situation over a time period. The average traffic counts are collected for a longer duration to determine the average O-D trips.

Initially the researchers tried to relate the trip matrix as a function of models (like thegravity models) with related parameters. Some of the researchers like Robillard (1975),Hogberg (1976) used Gravity (GR) model based approaches and some (Tamin and Willumsen, 1989; Tamin et al, 2003) used Gravity-Opportunity (GO) based models for estimating ODM. These techniques require zonal data for calibrating the parameters of the demand models. Several models have been presented in order to estimate or to update ODM from traffic counts for the networks without congestion and with congestion effects via parametric estimation techniques like; Maximum Likelihood (ML), Generalized Least Squares (GLS) and Bayesian Inference (BI).



The ODM estimation methods developed for networks with no congestion effects basically assume the route choice proportions and are independently determined outside the estimation process. For such networks Bayesians inference based approach has been first introduced by Maher (1983) for the ODM estimation. GLS estimator based approach has been studied by Cascetta (1984), Bell (1991a) etc. Bell (1991a) solved the GLS problem subject to inequality constraints and presented a simple algorithm but its application on real network has not been found in literature. Bierlaire and Toint (1995) proposed an ODM estimation method, called the Matrix

Estimation Using Structure Explicitly (MEUSE), considering the information obtained from the parking surveys. Maximum likelihood based model is studied by Spiess (1987), Cascetta and Nguyen(1988), Hazelton (2000) etc. Two classical inference approaches; the ML and the GLSmethods are derived and contrasted to the Bayesian method by Cascetta and Nguyen(1988). In all these studies, the link choice proportions used are estimated from the traffic assignment (TA) model and are assumed to be constant which may not estimate a dependable matrix. In consequence, Lo et al (1996) incorporated the randomness of the link choice proportions and discussed both Maximum likelihood and Bayesian approach for the estimation of the ODM by testing with a small network. Liu and Fricker (1996) introduced a stochastic logistic model for calculating driver's route choice behavior but it has certain drawback like all the link counts are considered to be known (further refer Yang et al, 2001). Lo et al (1999) extended the approach of Lo et al (1996) and developed a coordinate descent method using the partial linearization algorithm (PLA)for obtaining the optimum estimates and solved the new approach for large networks. Hazelton (2000) tested the performance of both multivariate normal (MVN) likelihood approximation and GLS techniques and found that the MVN method performed better.



Hazelton (2001) studied the fundamental theoretical aspects of the ODM problem based on BI, defining the estimation, prediction and reconstruction problems as a 'reconstruction' problem estimates the actual ODM occurring during the observation period, an expected number of O-D trips is obtained in 'estimation' problem and future O-D trips are obtained in 'prediction' problem. It has been shown that the estimation and reconstruction problems are different. There are some more studies (Hazelton, 2003; Van Aerde et al, 2003; Li, 2005, etc.) based on statistical approaches. Some authors included congestion effects in the estimation problem in which the dependence of the link costs, path choices and assignment fractions on link flows is considered. Equilibrium assignment approaches are particularly adopted for such cases.

Nguyen (1977) first introduced the equilibrium based approach to estimate ODM through a mathematical programme (refer Leblanc and Farhangian, 1982). Also Yang etal (1994), Cascetta and Posterino (2001) and Yang et al (2001) solved the trip

matrix estimation problem including congestion effects by considering different TA models. Cascetta and Posterino (2001) considered SUE assignment as a fixed-point problem whereas Yang et al (2001) considered the same problem of Liu and Fricker (1996)(developed without considering congestion effects) and proposed a non-linear optimization model (considering a weighted least square estimate) for the simultaneous estimation of the ODM and travel-cost coefficient based on the logit-based SUE model. For solving this non-convex optimization problem a successive quadratic programming (SQP) method (which is a descent-feasible direction algorithm solving KKT solution) has been used. Further, Lo and Chan (2003) with SUE principle (multinomial logit model) estimated both the dispersion parameter q in multinomial logit model and the trip matrix simultaneously using Quasi-Newton method.

**2.2 Discussion on reviews**

Most the approach of the researches is based on the statistical methods. Some approach provides the disadvantages.Robillard (1975),Hogberg (1976) used Gravity (GR) model based approaches and some (Tamin and Willumsen, 1989; Tamin et al, 2003) used Gravity-Opportunity (GO) based models for estimating ODM. The main drawback of the gravity model is that it cannot handle with accuracy external trip. These Gravity models are highly depends on the fact of quantity of people on particulars zone. In Sri Lanka some part of area in north this method cannot be applied due to unavailability of people some area, and also the trips generated from that area are not much concern on the people live on those zones.



The ODM estimation methods developed for networks with no congestion effects basically assume the route choice proportions and are independently determined outside the estimation process. The link choice proportions used are estimated from the traffic assignment (TA) model and are assumed to be constant which may not estimate a dependable matrix when conducting the surveys for different purposes on the same area, there is a problem accumulating double counting errors when considering trip assignment model as a constant. The Trip assignment model should be variant. Some authors included congestion effects in the estimation problem in which the dependence of the link costs, path choices and assignment fractions on link

flows is considered. The objective function considered is a likelihood function. Most of the above developed models are found to be tested using small networks. And the models do not assure their applicability for large real size congested networks.

No research has been for systematic level of generation of O-D matrix for use it in decision making. The trend GIS technology is a suitable choice of visualizes the results, rather than complex data structure and analytical estimation for decision making. Most analytical results are based on the assumptions, but this will reduce when the results are visually convenient for analysis. Therefore the GIS can be used as the best solution approach for traffic based research. The application of GIS features can be used for the creating of Trip assignment model and choose of the route estimation. There must have automation approach rather than statistical for maintainability of the surveyed data. This fact has not discussed on these reviews and this paper provides not only the estimation, but also the development of system for the road side data

# CHAPTER 3

# 3.0 Technology

## 3.1 Introduction

The ArcGIS network analysis extension allows building a network data set and performing analysis using them. The current road network of Sri Lanka (class A, class B and roads in Colombo municipal Area) can be modeled to build the road network dataset. The Network Analyst toolbox contains tools that perform network analysis and network dataset maintenance. With the tools , network datasets can be modeled and perform route, closest facility, service area, origin-destination cost matrix, vehicle routing problem, and location-allocation network analyses on transportation networks. It can use the tools in this toolbox whenever you want to perform an analysis on a transportation network.

## 3.2File Server Configuration

In order to maintain the other relevant survey reports, the separate file server is configured with suitable file server software to give the FTP service. The server can be integrated with current system through Network to get the relevant reports. There are many free file server software and included in other windows based server package Operating System like windows 2003/2008 etc. The authentication is required to connect with the file server. Golden FTP Server is one of the free software can be run in windows environment and can easily be maintained. This Server Software is proposed due to the simplest usage and can accommodate desired functionalities.



## 3.3 Development of integratedsystem

The introduction of Arcobject provides the capability for developing intergraded system with ARCGIS 10.1 .The proposed system is planned to develop a tool by extending the features of ARCGIS. ArcObjects is a library of Component Object Model (COM) components that make up the foundation of ArcGIS. To work with ArcObjects in the .NET development environment, a collection of .NET primary interop assemblies (PIAs) and COM object libraries have been generated to manage

.NET–COM interaction. ArcObjects components are installed with the ArcGIS Desktop, ArcGIS Engine, or ArcGIS Server products and can be used in a number of ways. Object oriented concepts, software engineering techniques and incremental software development process are well fit with Arcobject programming environment.

### 3.4 Database management system

Microsoft sqlserver was proposed for implementing the road side survey database. The relational database management concepts and entity relationship diagram concepts were used as the fundamental for development of the database. As a summary The Followings were technically used tools in Implementation

- Visual studio.net 2010 with ArcObject.Net 10.1
- ArcGIS 10.1
- Rational Rose 2004
- Ms SQL Server

The more information about these technical tools will be discussed in technology chapter.

# CHAPTER 4

# 4.0 Methodology

## 4.1 Introduction

As mentioned in earlier chapter the main aim is to develop integrated system to overcome problem of management of road side survey data and estimation of Origin Destination the selected domain by introducing new features. The following describes the main approach.

a. Study of the Current System and Domain analysis

b. Requirement and Technology Specification

c. Design of the Network Dataset

d. Implement of Database

e. Software design for the intergraded system and implementation.(iteration process)



## 4.2 Study of the Current System

The main deliverable of this objective is to clarify the problem domain scope for the proposed solution with basic functional and non-functional requirements. Most common fact funding techniques like questionnaires, field visiting and interviews were conducted to achieve them. Some of them are informally done. Study of all fundamental theories and other estimation and calculation modes are sub objectives.

## 4.3 Requirement and Technology Specification

The main deliverables of this objective is to finalize the all the functional requirements and then to specify the system requirements for the solution. The technical requirements and resources were specified to suite with the final solution. The following Table describes how these Technologies used in developing the final system through main objectives.

| Objective | Technology | Technology Usability | Deliverables |
|---|---|---|---|
| Analysis /Design of Process Model | Object Oriented Analysis and Design, UML Standards | OOAD is the most suitable to abstract the real world things and process directly in to the solution and The UML standards is fundamental diagramming tool are used in designing the process. These technologies help in identifying business entities and business process of the manual process and their relationship. The capability of implementation of the model through Object Oriented language is applicable | Use case diagrams<br><br>Activity diagrams<br><br>Sequence /collaboration diagrams<br><br>Package diagrams<br><br>Component diagrams |

| | | | |
|---|---|---|---|
| Data Model Design and Implementation | EER modeling techniques and relational database Management System | The features of easily generate of the relation database can easily help to implement the traffic database for the relational database management like SQLSERVER | EER Model<br><br>Road Survey Database |
| Software Modules Development Final Deployment | Visual Studio.net with ArcObject SDK ,ARCGIS10.1 | The implementation part includes design of interface and relevant coding of each module. And also extending network analysis component | UI Component and Implementation Components. |
| Distribution Reports | VB.net built-in component | Pie, line, category charts were used to help in analyzing some of the Trip counts | Vehicle Consumption Chart,<br><br>Hourly Traffic Distribution, Trend Line |



**Table 2: Usability of Technology**

# CHAPTER 5

# 5.0 System Architecture, Analysis and Design

## 5.1 Introduction

The identification of system architecture, main analysis and Design procedures are being worked on the fundamental of Object Oriented Analysis and Design with UML standards. The Design Parts are being preceded through following sub categories.

### 5.1.1 Top Level Architectural Diagram

It is a visual depiction of a system. An architecture diagram in "system architecture" is typically a technological set-up, either various computer components working together, or steps in a software process working towards a specific end result. The point of a system is that multiple single steps are put together in a process to result in a certain end goal; a system architecture diagram simply shows those steps in a visual way. The Top level diagram and the details description of the current system are included in appendix B



### 5.1.2Use case diagram

A use case diagram in the Unified Modeling Language (UML) is a type of behavioral diagram defined by and created from a Use-case analysis. Its purpose is to present a graphical overview of the functionality provided by a system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases. The main purpose of a use case diagram is to show what system functions are performed for which actor. Roles of the actors in the system can be depicted. A use case is drawn as a horizontal ellipse on a UML use case diagram use case names begin with a strong verb, name use cases using domain terminology, an actor is a person, organization, or external system that plays a role in one or more interactions with your system Associations are depicted as lines connecting two modeling elements with an optional open-headed arrow head on one end of the line indicating the direction of the initial invocation of the relationship. Apply<<include>> when you know exactly when to

invoke the use case .Apply <<extend>>when a use case may be invoked across several use case steps. Please refer to appendix B for use case diagram of The System

### 5.1.3 Use Case Specification

The Use case Specification provides more details view of each use case regarding to each Actor. It should include the basic introduction of the use case, flow of events, and alternative flow of event, post condition and pre conditions. The basic introduction part explains the use case and its main functions. The flow of events includes basic activities in that use case. The alternative flow of event describes the possible activities if some problem occurs at the main flow of event. Finally the pre-condition describes what are the constraints for fulfillment of doing the activities of the use case while post condition describes what constrained should be added after complete the activities of the use case. The following describes three main specification of use case in the system. Please refer to the Appendix B for other specifications.

#### 5.1.3.1 Manage O-D Information



Basic Description

This Use Case describes the flows of events of how to enter new conducted O-D Entry basic information in to the database through system defined survey entry sheet.

Flows of Events

- User selects the O-D Category regarding to the conducted survey sheet. (Each O-D survey Entry should have number).
- If already have records for the location the survey sheet is then new Information is maintained as future-update state such that in the future the O-D matrix will get updated with this information. Other keep it as for-update state as O-D matrix will get updated with this new data

#### 5.1.3.2 Manage O-D Survey

Basic Description

This Use Case describes the flows of events of how to enter a new conducted O-D Entry survey sheets in to the database through system defined survey entry sheet.

Flows of Events

- Select O-D No of the survey corresponds to the link number.
- Load the other generic information
- Enter the other relevant information in to the respective fields
- Set Origin and Destination
- Save the record

Alternative Flows

- As soon as the selecting the link location the ArcMap will zoom to the location to the where the links is.



Pre-Condition

- The User should be logged as Administrator or Department user.
- The Map should have loaded to the ArcMap document

Post Condition

- The data are in for-update state until the Administrator update the O-D matrix with this information

#### 5.1.3.3 Generate O-D Matrix

Basic Description:

This Use Case describes the flows of events of how to generate and display O-D matrix

Flows of Events

- Prepare  the each O-D pair that are in for-update state
- Eliminate the Error on The O-D Pair
- Calculate the minimum path of the selected pair and get the route information get the increment the trip counts between zones (Divisional Secretary area )
- Return the first and select another O-D Pair.

Alternative Flows

- The O-D pairs that are in future-update are modified with old records using computing growth rate factor with old records.

Pre-Condition

- The User should be logged as Administrator or Department user
- The Map should have loaded to the ArcMap document



Post Condition

The data that were in for-update and future-update state are now changed to the updated state (old O-D records)

**5.2 Activity Diagram**

Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency. An activity diagram shows the overall flow of control. Activity diagrams are constructed from a limited repertoire of shapes, connected with arrows.

The most important shape types:

- rounded rectangles represent activities
- diamonds represent decisions
- bars represent the start (split) or end (join) of concurrent activities
- a black circle represents the start (initial state) of the workflow

The following diagrams shows three basic activity diagrams of a work flows. The Activity diagrams give more visual representation of the use case specification. Please see the appendix B for other diagrams.

### 5.2.1 Manage O-D Information

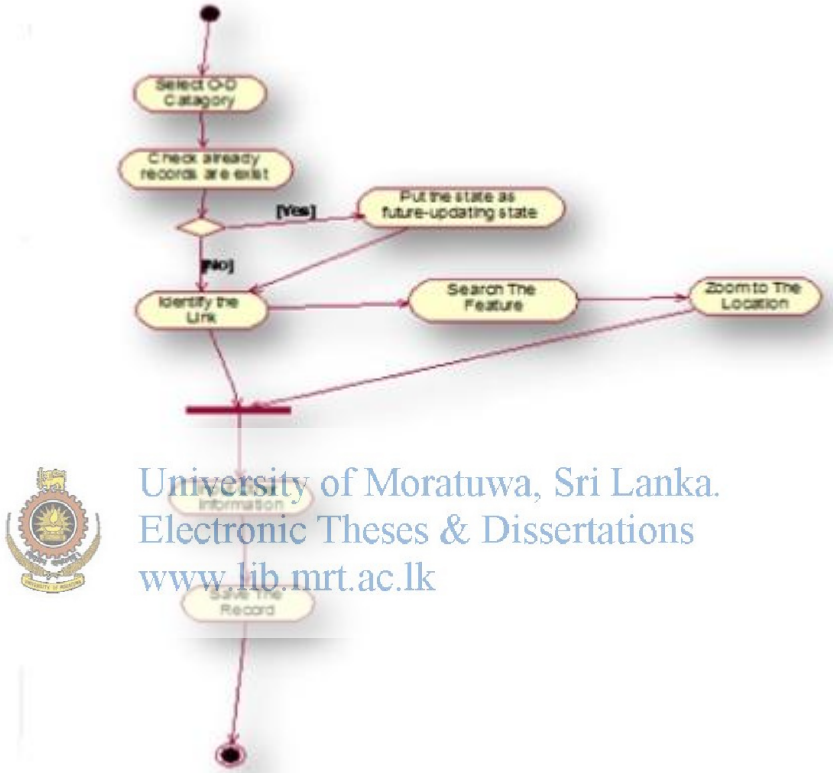




**Figure 1: Manage O-D Information**

### 5.3.2 Manage O-D Survey

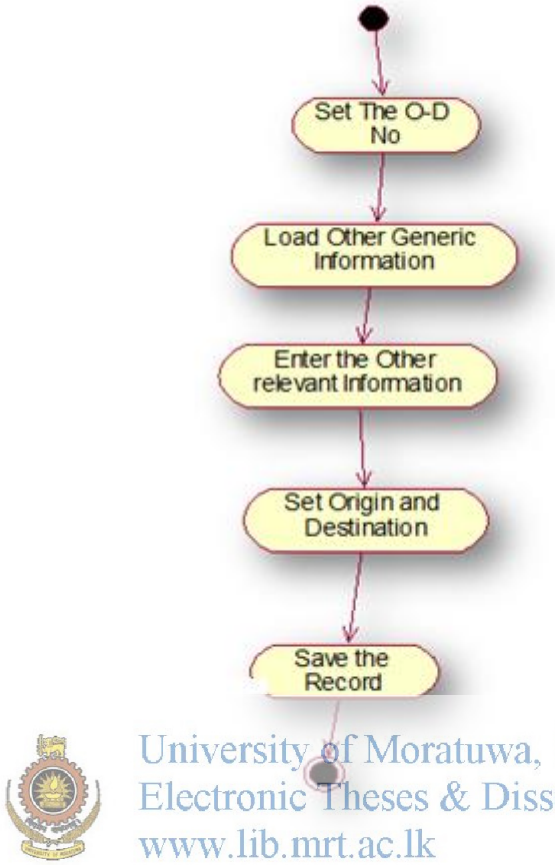




**Figure 2: Manage O-D Survey**

### 5.4 Package Diagram

A package diagram in the Unified Modeling Language depicts the dependencies between the packages that make up a model. A package is collection of classes that have common features. There are two packages were identified in the solution. Please refer to the appendix B for the system package diagram.

### 5.5 Class Diagram

In software engineering, a class diagram in the Unified Modeling Language (UML) is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, and the relationships between the classes. Pleas e refer to the appendix B for system class diagram

### 5.6 Sequence Diagram

A sequence diagram in Unified Modeling Language (UML) is a kind of interaction diagram that shows how processes operate with one another and in what order. It is a construct of a Message Sequence Chart. The following figures describe the sequence diagram for the scenario of adding new O-D survey details and O-D survey data.

### 5.7 Component Diagram

A component diagram in the Unified Modeling Language, depicts how components are wired together to form larger components and or software systems. The system can be implemented as several implementation modules called components. Some components depend on the other component and all get to gather to build the final system. The details description of all components in current system is described at implementation chapter. The following Table gives some overview about the component in the system.



| Component | Task | Dependancy |
|---|---|---|
| File Access | Provide Secure Coonection with file server and the run file Operations | - |
| OD Information Manager | Provide the facilities to manage new OD | Data Access |

| | | |
|---|---|---|
| | information | |
| Data Access | Provide connection to the database | - |
| OD Survey Manager | Manage of New OD Survey Results | Data Access,File Access |
| Trip Distribution manager | Calculate the Traffic Distribution from particular Divisional secretary area with graphical visualization | Data Access |
| Trip Attraction Manager | Calculate the Traffic attraction onto a particular Divisional secretary area with graphical visualization | Data Access |
| Trip Counts On Road | Provide Trips on Selected roads with graphical visualization | Data Access |
| Trip Counts On minimum Path | Calculate the minimum path between two nodes and traffic counts on the path and Travel modes variation in graphically | Data Access |
| Download | Provide the facility to download, upload and manage reports in the server | Data Access,File Access |
| Minimum Path Founder | Calculate and Display the Minimum Path Between two junction | |

| | | |
|---|---|---|
| Configuration Seetings | Enviornmental Varaible Seetings for the application | |
| O-D Matrix manager | Generate the Origin Destination Matrix and reupdate O-D matrix with new details | Data Access |

**Table 3: Users**

### 5.7 Component Specification

#### 5.7.1 File Access

The main purpose of this module is to provide the functionality to connect with the file server and create a stream from source to destination. A stream is flow of data from one place to another. This component is just a library component. Library component means this cannot be run but some properties can be used. This gives the functionality to download and upload of files.



#### 5.7.2 Data Access

The main purpose of this module is to maintain the secure connection with the Database and provide the service to select, retrieve, analyze data .The database consists of tables whose schema was generated by the concept of Entity relationship diagram and Relational Database Management. The Sql server is high powerful Database that provides the facility of procedures, triggers, function, indexing etc.

#### 5.7.3 Download

The main purpose of this module is to giving the facility to download and uploading of reports as necessary. The component will also provide the list of files relevant to the each O-D survey with information. The module depends on the file access module for accessing the database.

### 5.7.4 O-D Information Manager

The main purpose of this module is to provide the facility to manage the O-D survey detailed information. Before adding a new survey the basic information regarding a particular OD survey is important such as name of the survey, project associate with, date of started, type of the survey etc.

### 5.7.5 Project

The main purpose of this module is to provide to facility to input new project details. Normally O-D surveys are done for partly needed for a project. Therefore the project details are essential to store.

### 5.7.6 Trip Distribution Manager

The Main purpose of this module is to provide the facility to estimate the trip generating from a Divisional secretary area to the other divisional secretary areas. This estimated value represent as tabular forma and by graphically. The X axis being the Divisional Secretary area number while Y axis is the Trips. This component depends on the O-D Matrix manager and Data access manager.



### 5.7.7 Trip Attraction Manager

The Main purpose of this module is to provide the facility to estimate the trip generating from other Divisional secretary area to a particular divisional secretary areas. This estimated value represent as tabular form and by graphically. The X axis being the O-D Matrix manager and Data access manager.

### 5.7.8 O-D Matrix Manager

The main purpose of this module is to process of generating, updating and displaying of O-D matrix. In developing of the matrix the elimination of error for double counting concerned and with the assumption of that each trip is covering the optimum minimum path. The Matrix is two dimensional. This component depends on the data access component.

### 5.7.9 Trip counts on road

The main purpose of this module is to estimate the traffic counts on each of the links associate it. The traffic counts for each of the link are shown on a table and it will also

display on a separate chart. This component depends on the O-D Matrix manager and data access component.

### 5.7.10 Trip counts on minimum path

The main purpose of this module is to estimate the traffic counts on each of the links associated on the minimum route from origin to destination. The traffic counts for each of the link are shown on a table and it will also display on a separate chart. This component depends on the O-D Matrix manager and data access component.

## 5.8 ER Diagram

An entity-relationship (ER) diagram is a specialized graphic that illustrates the interrelationships between entities in a database. ER diagrams often use symbols to represent three different types of information. Boxes are commonly used to represent entities. Diamonds are normally used to represent relationships and ovals are used to represent attributes. Since the proposed solution is expected a database, An ER model for proposed to the current system is described in details at appendix B.

# CHAPTER 6

# 6.0 Implementation

### 6.1Introduction

This Chapter provides the details of implementation and Testing that are done by each component. The Implementation and Deployment was highly dependent on the tools regarding to the technology which was proposed in earlier chapter. The Testing is more important to make sure that all expected functionalities are achieved as desired

### 6.1.1 Hardware and Software Supported for Implementation

- Corei3 processor computer with 4 GB RAM and 160 GB of Capacity

In the Development Environment there should have a high speed computer with high Random Access Memory. ArcGIS is software that needs high consumption of memory in operating their functions. In addition the Dot Net framework 4.5 should work in a high potential environment to use system functions for the application. The operation of OD matrix generation takes much time thus at least corei3 multi processor computer needs the use of potential memory.. Since there are more than 8 modules and each has to be implemented and Test separately high speed processor also needed. In addition having 160GB potential secondary memory will assist to effective use of virtual memory at operation



- ArcGIS 10.1

Esri's ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information using maps and geographic information in a range of applications, and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

- ArcObject.Net development

ArcObjects is a library of Component Object Model (COM) components that make up the foundation of ArcGIS. To work with ArcObjects in the .NET development environment, a collection of .NET primary interop assemblies (PIAs) and COM object libraries have been generated to manage .NET–COM interaction. ArcObjects components are installed with the ArcGIS Desktop, ArcGIS Engine, or ArcGIS Server products and can be used in a number of ways

- To customize the ArcGIS Desktop applications
- To build standalone mapping applications
- To develop Web applications

This software development kit (SDK) for developing with ArcObjects in .NET will assist developers in writing their applications by providing best practices, conceptual documentation, code sections, and samples. If you are new to ArcObjects development, you should first determine what type of application you need to build to address your problem. This topic presents the different development options and will point you in the right direction.



- Golden FTP Server

Golden FTP Server is a free personal FTP server for Windows. It is extremely easy to use and can be run by any person who has the most basic computer skills. The program loads automatically on Windows startup and you can identify the files you want to share with two mouse clicks via the dialog window that works in the same way as the standard Windows "Open File…" dialog or via the Windows Explorer context menu. Golden FTP Server was used as service tool for configuring file server for the system.

- MSSQL Server

Microsoft SQL Server is a database management and analysis system for e-commerce, line-of-business, and data warehousing solutions.

- Visual Studio.net

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs for Microsoft Windows, as well as web sites, web applications and web services. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silver light. It can produce both native code and managed code. Visual Studio includes a code editor supporting IntelliSense (the code completion component) as well as code refactoring. The integrated debugger works both as a source-level debugger and a machine-level debugger. Other built-in tools include a forms designer for building GUI applications, web designer, class designer, and database schema designer. It accepts plug-ins that enhance the functionality at almost every level, including adding support for source-control systems (like Subversion) and adding new toolsets like editors and visual designers for domain-specific languages or toolsets for other aspects of the software development lifecycle (like the Team Foundation Server client: Team Explorer).Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language, provided a language-specific service exists. Built-in languages include C, C++ and C++/CLI (via Visual C++), VB.NET (via Visual Basic .NET), C# (via Visual C#), and F# (as of Visual Studio 2010). Support for other languages such as M, Python, and Ruby among others is available via language services installed separately. It also supports XML/XSLT, HTML/XHTML, JavaScript and CSS.



### 6.1.2 Component Implementation

All The components were implemented as separate modules According to the specification of the component model. All the user interface component were

integrated with the business logic component and then with database server component.

### 6.1.3 Physical Database Implementation

The ER Model discussed in the Analysis phase was implemented by converting it to the relational data model for implementation of physical database. The MSSQL server is a database management system that provides administration and other function for implementation of the relational database.

### 6.1.4 Geographical Database Implementation

The 1:50000 digitized map was converted to model the class A and B road network. The implemented components were vector shaped file that are compatible with ARCGIS 10.1.Three shape files were designed, created and implemented. The process of converting raster data to vector features is known as vectorization. Vectorization can be performed manually by interactively. Digitizing is the process by which coordinates from a map, image, or other sources of data are converted into a digital format in a GIS. This process becomes necessary when available data is gathered in formats that cannot be immediately integrated with other GIS data. Manual Digitizing is still a useful technique because of its ability to accurately copy maps in poor condition. Computers have a higher risk of error when interpreting information contained on a faded, stained, or poor quality map or image. Manual Digitization is limited by the visual acuity and accuracy of the digitizer. The information about the digitized map.

# CHAPTER 7

# 7.0 Evaluation

### 7.1Introduction

Software technologies have been evolving rapidly and for a given set of functional and non-functional requirements there usually exist several competing software products. Several software evaluation frameworks are used to make assessment of the developed software to suit the relevant requirements. It's quite different from evaluating printed materials. A good deal of the contents of a software package or website will not be immediately visible and will only appear if the user follows a particular route. In addition, there are factors such as screen design, user-friendliness and nature of the interaction to take into account.

### 7.2 Evaluation Methodology

The Following Main Factors were introduced as the major attributes for the current solution



- System was target oriented
- Usability of the System
- Comprehensibility of Information
- Clear Outcomes

Each Factor was given a set of Questionnaires

| **Evaluation Criteria** | |
|---|---|
| Excellent (E) | 10 |
| Good(G) | 7 |
| Fairly Good(FG) | 6 |
| Bad(B) | 3 |

| Target oriented | |
|---|---|
| **Criterion** | |
| Does the system gives service as you need? | E/G/FG/B |
| Is it easy to get the service from the product? | E/G/FG/B |
| Does the outcome in clear format? | E/G/FG/B |
| Does the System gives all functions as in specification? | E/G/FG/B |
| Is some functionality conflicted with one another? | E/G/FG/B |
| Are you proposing some additional to the given functionalities | E/G/FG/B |
| Is it easy to understand the steps | E/G/FG/B |

| Usability of The System | |
|---|---|
| **Criterion** | |
| Is it easy to start the program? | E/G/FG/B |
| Is the user interface easy to understand? (For example, is the screen layout clear and easy to interpret?) | E/G/FG/B |
| Is it easy to navigate through the program? | E/G/FG/B |
| Is it useable to manage activities (Add/ Delete/Update) for each modules | E/G/FG/B |
| Can you understand the detailed items functionalities (SAVE button indicates to save something etc) | E/G/FG/B |
| Are you proposing some additional to the given functionalities | E/G/FG/B |
| Is it easy to handle forms? | E/G/FG/B |
| Does the System explain what you expected? | E/G/FG/B |
| Does the System contain useful links? | E/G/FG/B |
| Does all Interfaces have proper layout? | E/G/FG/B |

| Comprehensibility of Information | |
|---|---|
| **Criterion** | |
| Is the level of language that the program offers clearly indicated? | E/G/FG/B |
| Can you seek help and understand the guides easily | E/G/FG/B |
| Can you easily read the instructions on each menus and forms | E/G/FG/B |
| Is the current layout, font and foreground is applicable for your eyes. | E/G/FG/B |
| Is the level of language that the System offers suitable | E/G/FG/B |

| Clear Outcomes | |
|---|---|
| **Criterion** | |
| Do you get a valid outcome? | E/G/FG/B |
| Are You Satisfied with the current model output format? | E/G/FG/B |
| Is the Output Format is readable and Understandable? | E/G/FG/B |
| Do you think the suitable data format is applicable? | E/G/FG/B |



**Table 4: Evaluation Criteria**

# CHAPTER 8

## 8.0 Discussion

The GIS environment can be used to for solving many transportation problems due to the fact that it is a multi-displinary application. Most important critical aspect of this development was the estimation of Origin Destination Matrix by minimizing the double counting error. By assuming the concept of minimum path of a trip will provide the way of minimization of double counting by using circular method. The programming environment of ArcObject.Net can be used to emphasis the features of the components of ArcGIS including Network Analysis. The visual studio framework can guide of the giving the development environment by integrating the component. The next part is the development of the Survey data management system inside the above solution. As a future , the system can be updated with by adding other two OD survey types as a result more functions can be added like mean occupation, travel behavior etc. Rather going for Network application, the concept, theory and techniques of Web GIS would guide for proper web solution by extending the domain requirement of the current system. The system was implemented on an ArcGIS environment, but it can be developed as a separate desktop application, web application and as a mobile application due to the fact that there are developed libraries have been provided by the ESRI for enhancement in the visual studio environment. The web application and Mobile application will provide the accessibility to the public who are interested in the gaining the information given by the product.



Present days the transportation management is highly considered on the time rather than distance.

# CHAPTER 9

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# CHAPTER 10

# 10.0 Appendixes

## 10.1 Appendix A

### A.1 Fact finding Techniques Used

Written documents and onsite observations just tell that how the system should operate. They do not include enough details to allow a decision to be made about the merits of system proposal and don't present the user views about the current system. I conducted interviews of the staff as given bellow, which were directly involved with the application.

Questionnaires

1. What are the data you need to collect?
2. Why do you need these data?
3. What are the ways of collecting them?
4. What type of system do you use correctly whether manual or automated system?
5. How do you analyze the collected data?
6. Is there a need to have another system or changing the existing system?
7. If another system is needed, what are the basic requirements of that system?
8. What are the benefits of having that system?
9. What are the draw backs of current system?
10. Can you easily access the data? Give the reasons?
11. Is the data or information you have sufficient or do you need to collect more data?
12. What are the ways of collecting data?
13. What are the requirements that the user needs?
14. What are the requirements that the system needs?

15. What are the technologies that you are planning to use for new system?
16. Is the necessary hardware configuration and software platform is already there?
17. Are you willing to bear the cost of hardware and software needs?
18. Do you need more trained users or will you be able to train existing users?
19. Are you willing to bear the training cost?

Also the regular users of the application were interviewed. Based on their viewpoints, clear system requirements were jolted down.

Analysis of gathered requirements

The main purpose of this activity is to clearly understand the exact requirements of the user/customer. The following basis questions pertaining to the project should be clearly understood by the analyst in order to obtain a good grasp of the problem.



1. What is the problem?
2. Why is it important to solve the problem?
3. What are the possible solutions to the problem?
4. What exactly are the data input to the system and exactly are data output required of the system?
5. What are likely complexities that might arise while solving the problem?

## A.2 survey conducting procedures

Survey time : 24 hours per day

Time Period : none

Counts : Detail of the Trip

Count Methodology : Manual

Survey Methodology: Measurements were carried out for one directions of travel by interviewing the vehicle passengers.

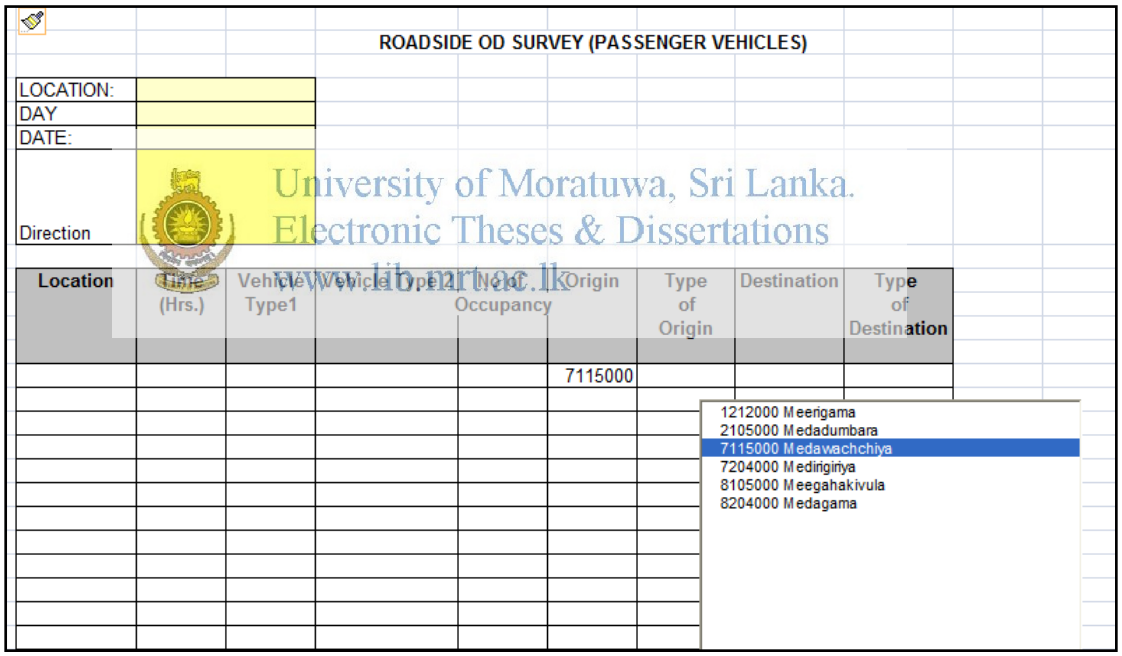




**Figure 3: O-D passenger data collection sheet**

## 10.2 Appendix B

Top Level Diagram

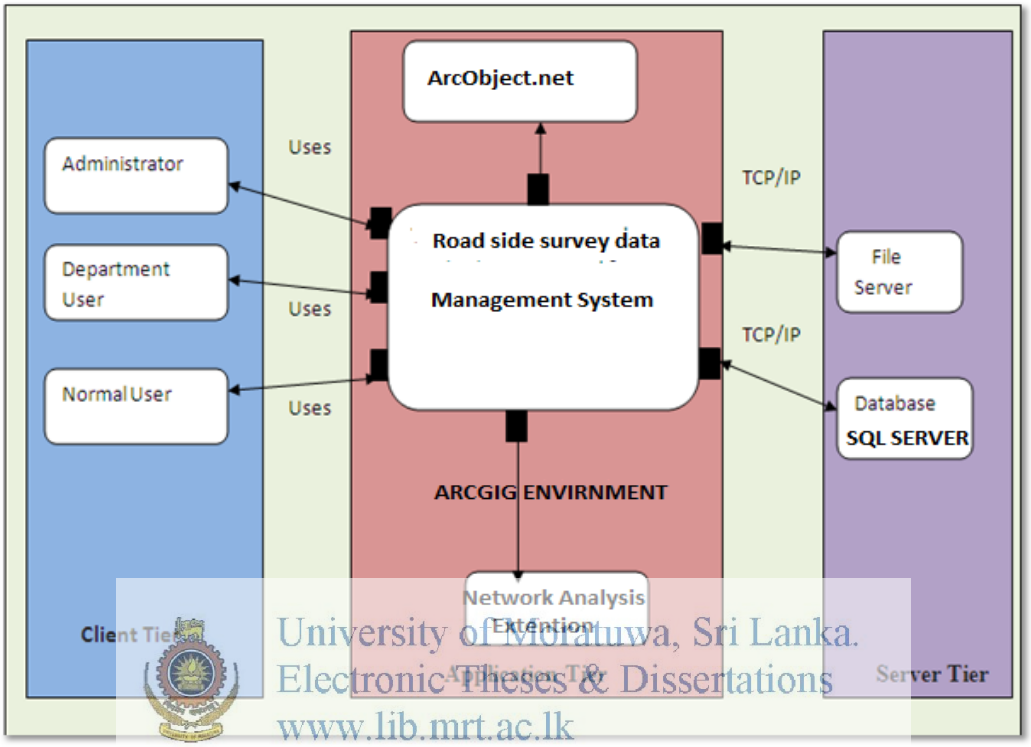




**Figure 4: Top Level Diagram**

There are three system components. Client tier represent the entire component that are to be interacted with the Administrator, Department users and Normal users. The Application Tier represents the business logic of the backend processes. The Application tier was implemented on the ARCGIS 10.1 environment and it includes the component of dealing with ARCGIS features, estimation and analysis from the data given by the client tier and data requested from the database server. The Server tier includes physical data structure and the file server that includes geo database files and reports.

## B.1 Use Case Diagram

Administrator

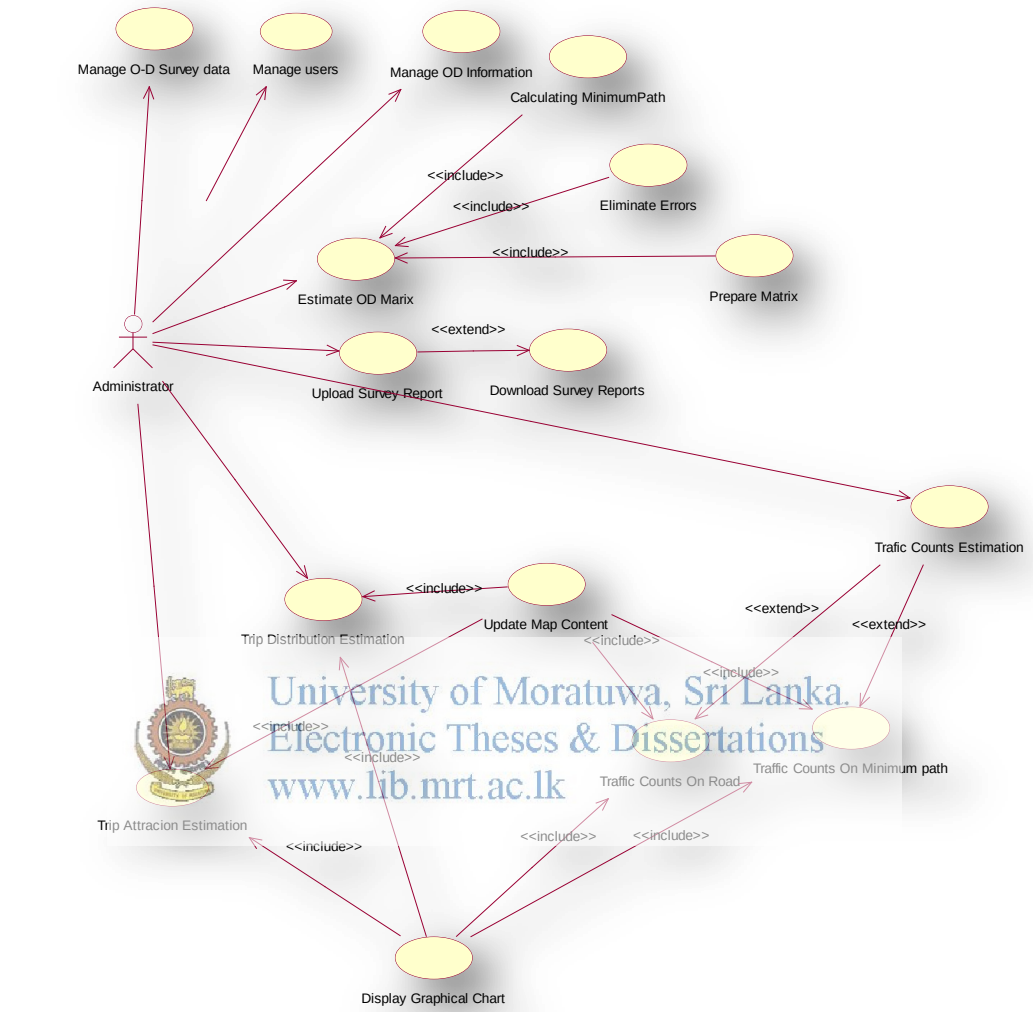




**Figure 5: Use Case-Administrator**

Department User

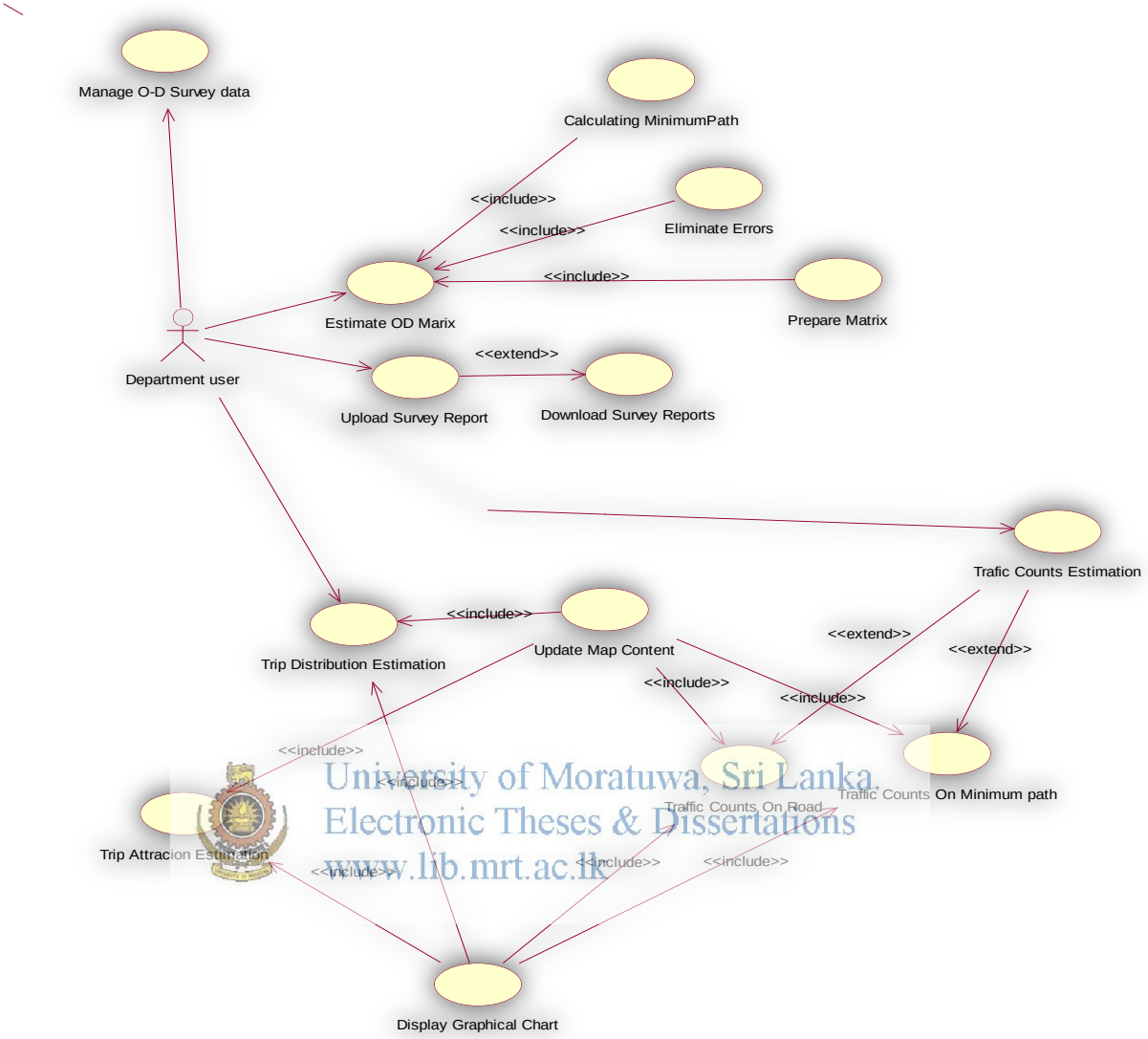




**Figure 6: Use Case -Department user**

Normal User

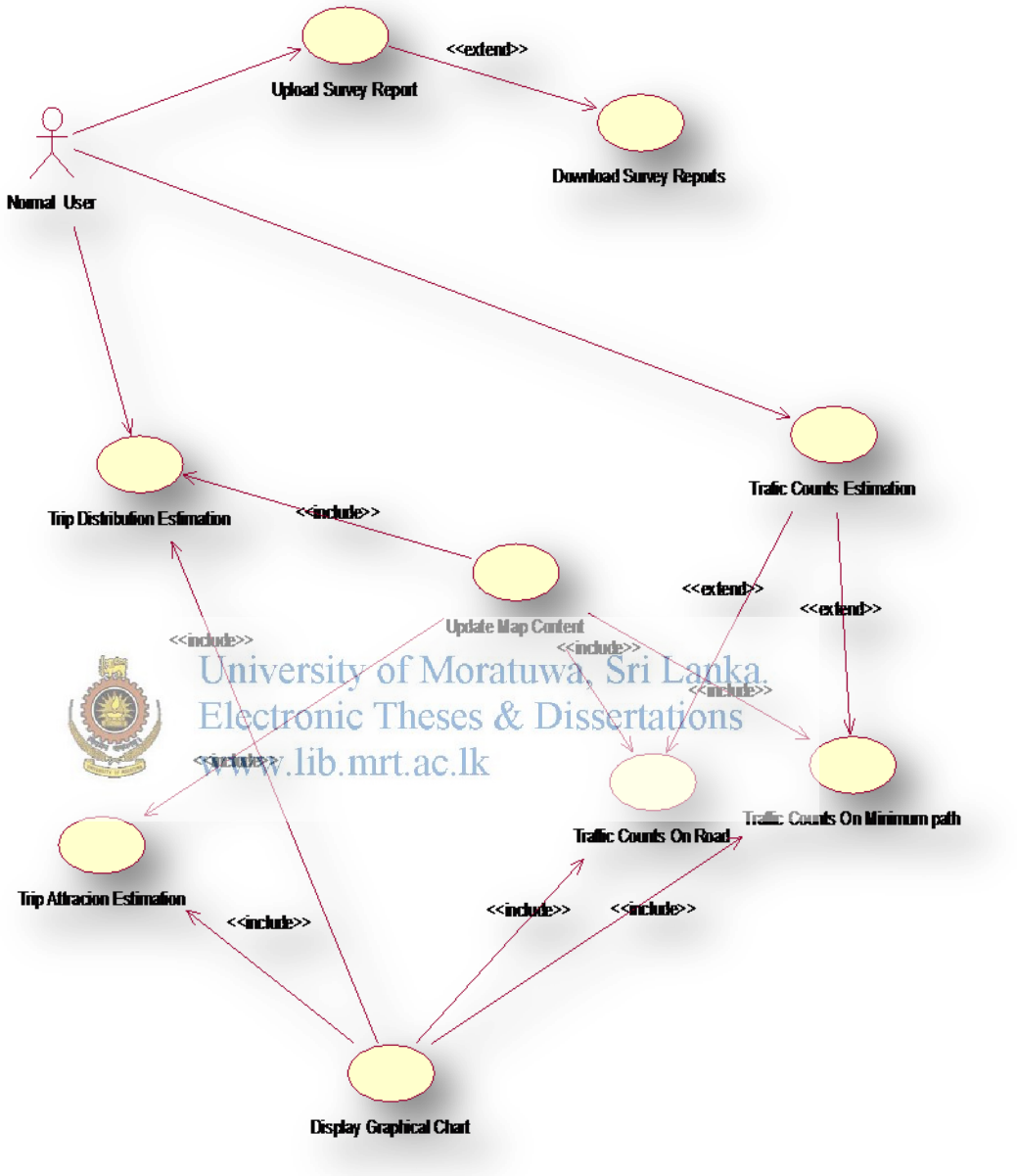




**Figure 7: Use Case-Normal User**

## B.2 Use Case Specification

### B.2.1 Prepare O-D Matrix

Basic Description:

This Use Case describes activities of how to the O-D survey data is processed to prepare the O-D Matrix

Flows of Events

- Get all the O-D information that are on the state of for-update
- Get all the O-D pairs of each of the O-D survey Sheet
- Eliminate double counting error by checking Whether there are same O-D pair was included in other updated O-D
- Calculate the minimum path of the O-D pair
- Obtain the Origin Divisional Sectary Area
- Allocate the traffic count flows at each of the Destination Divisional Secretary Areas.
- Increment the Trip Counts of the O-D table
- Continue with other O-D pair.
- Go to the 2nd step
- Load the table values to a data set
- Display the Matrix.



Alternative Flows

- If it is found that the same O-D pair is used for another O-D survey sheet that means the O-D pair is going to count twice. Stop and continue from other O-D pair.
- After completing the each of O-D pair then change the state to be updated.

Pre-Condition

- The User should be logged as Administrator.

Post Condition

- The O-D surveyed data become passed data.

### B.2.2 Trip Distribution Estimation

Basic Description:

This Use Case describes activities of how to the O-D matrix data is processed to estimate Trip Distribution

Flows of Event

- Set the District Secretary Area.
- Select the District Secretary Area from the List
- Calculate the Trips distribute from relevant selected District secretary area to the other
- Prepare the Data set and load the table
- Prepare the chart
- Display Table and the Chart.
- Zoom the Map to the respective location



Alternative Flows
None

Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None

### B.2.3 Trip Attraction Estimation

Basic Description:

This Use Case describes activities of how the O-D matrix data is processed to estimate the Trip Attraction.

Flow of event

- Set the District Secretary Area.
- Select the District Secretary Area from the List
- Calculate the Trips attractionto relevant selected District secretary area from the other
- Prepare the Data set and load the table
- Prepare the chart
- Display Table and the Chart.
- Zoom the Map to the respective location



Alternative Flows

None

Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None

### B.2.4 Manage O-D Survey data

Basic Description:

This Use Case describes activities of how the O-D surveyed data is managed

Flow of event

- Set the O-D number from O-D details
- Load the O-D Survey sheet and other generic data.
- Fill the Origin and Destination information
- Save the Record
- Update the Records.

Alternative Flows

None

Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None



**B.2.5 Manage Users**

Basic Description:

This Use Case describes activities of how the users are managed.

Flow of event

- Load the current users details in to the table
- Fill the new users information in to the necessary fields
- Check the user is already in the system
- Save the record

Alternative Flows

- If the user wants to delete a record it needs to select the particular record

- The user needs to change the particular data on the record when (s)he needs to update the record

Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None

**B.2.6 Traffic Counts On Road**

Basic Description:

This Use Case describes activities of estimating traffics on road

Flow of event



- Select the road
- Set the links on the road
- Calculate the link counts on each link
- Create Chart
- Display Chart

Alternative Flows

None

Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None

### B.2.7 Traffic Counts On Minimum Path

Basic Description:

This Use Case describes activities of estimating traffic on minimum path

Flow of event

- Select the Origin and Destination
- Calculate minimum path
- Set the links on the road
- Calculate the link counts on each link
- Create Chart
- Display Chart

Alternative Flows

None



Pre-Condition

- The User should be logged as Administrator or Department User.

Post Condition

None

## B.3 Activity Diagram

### B.3.1 Prepare O-D Matrix

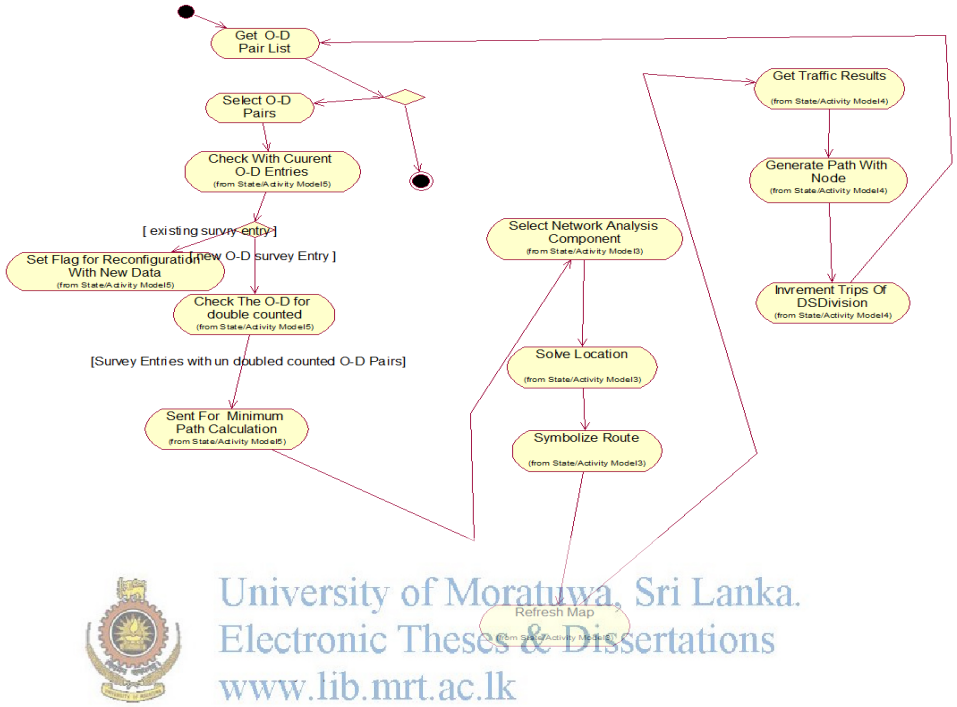




**Figure 8: Prepare O-D Matrix**

### B.3.2 Upload Reports

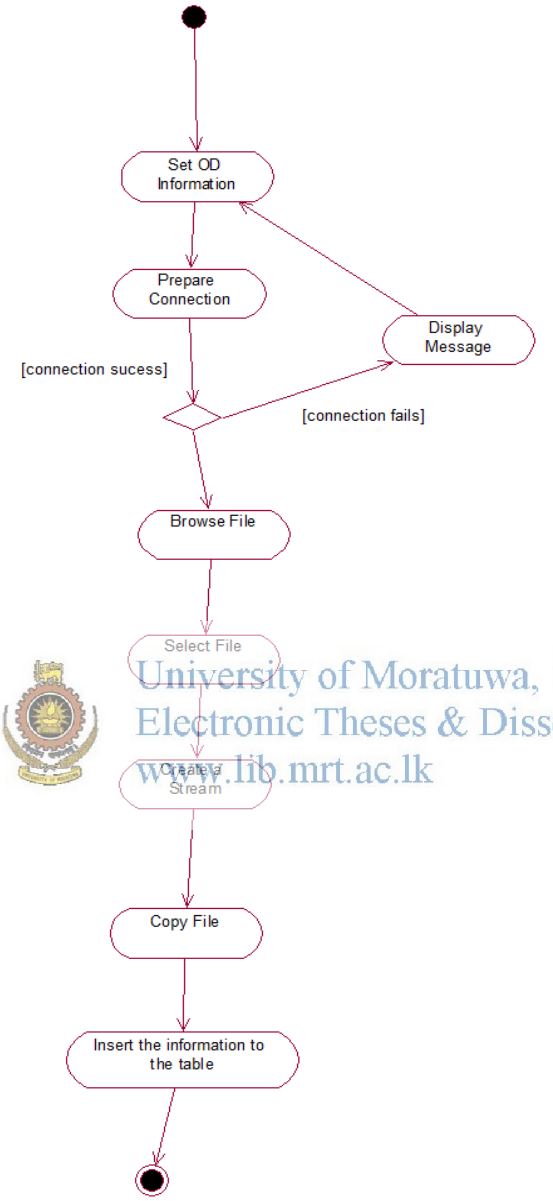




**Figure 9: Upload Reports**

### B.3.3 Manage Users

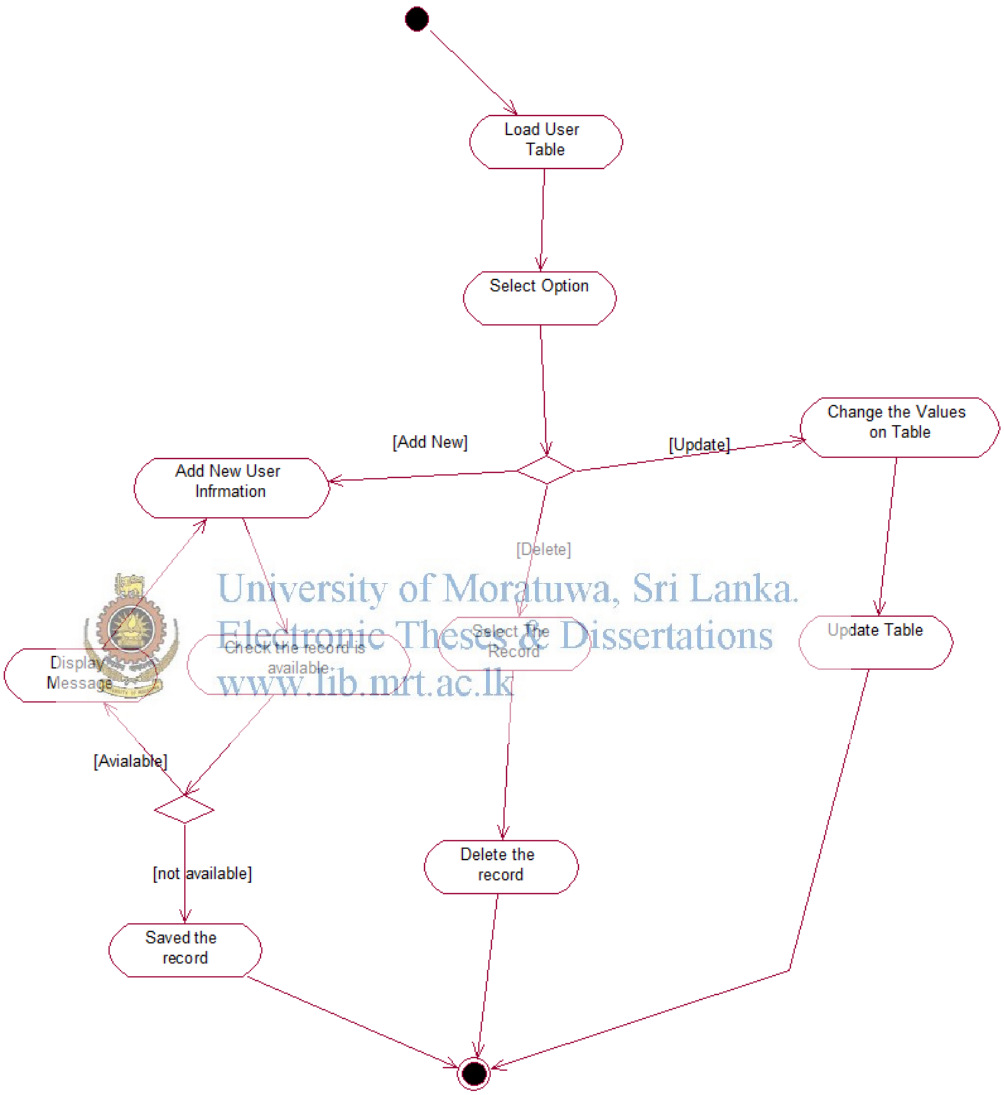




**Figure 10: Manage User**

### B.3.4 Upload Reports

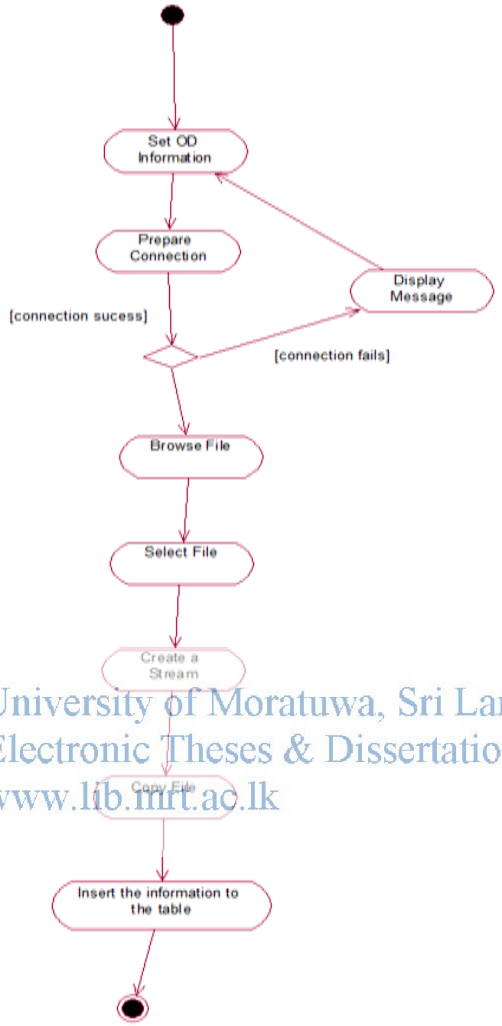




**Figure 11: Upload Reports**

### B.3.5 Download Reports

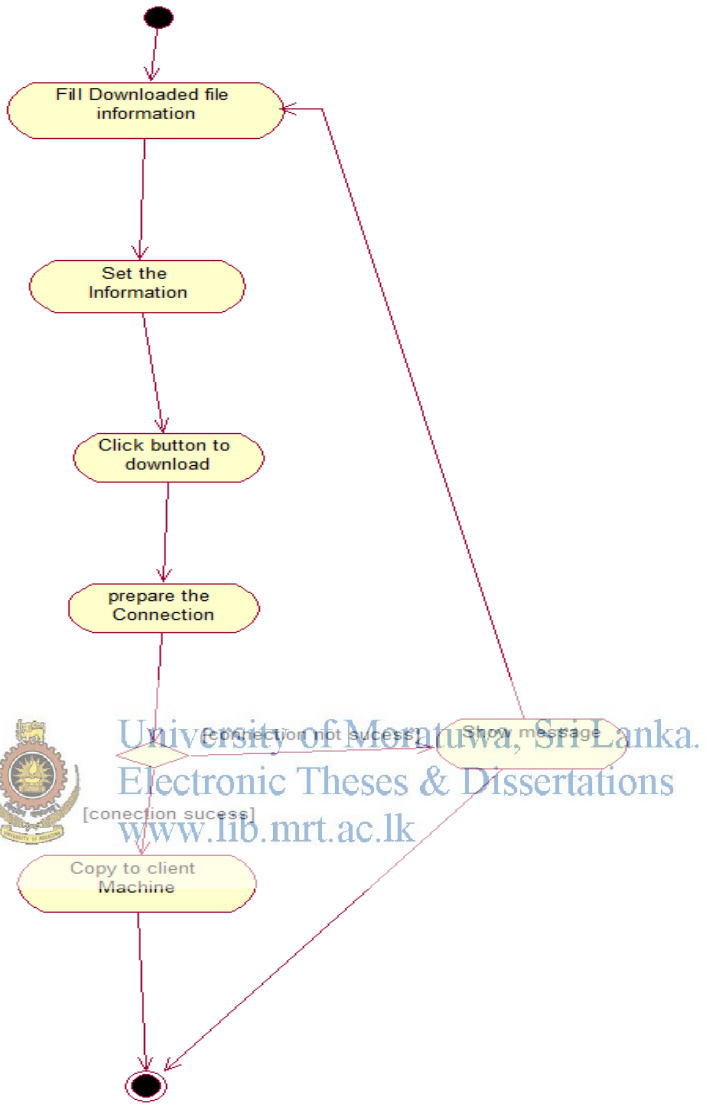




**Figure 12: Download Reports**

### B.3.6 Trip Distribution

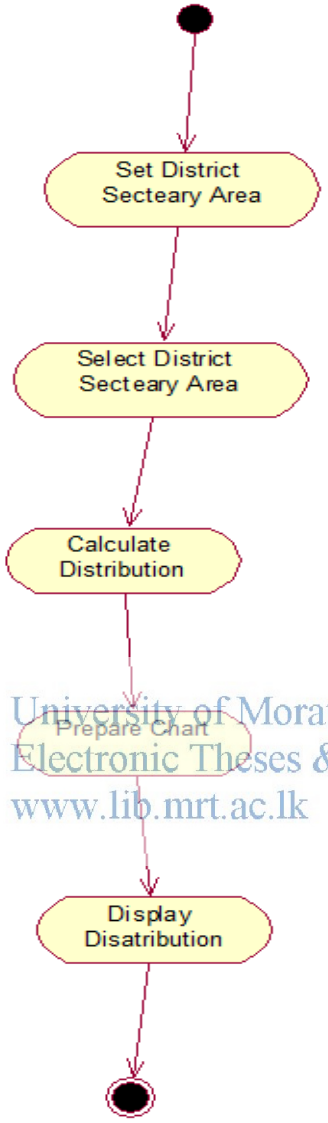




**Figure 13: Trip Distribution**

### B.3.7 Trip Attraction

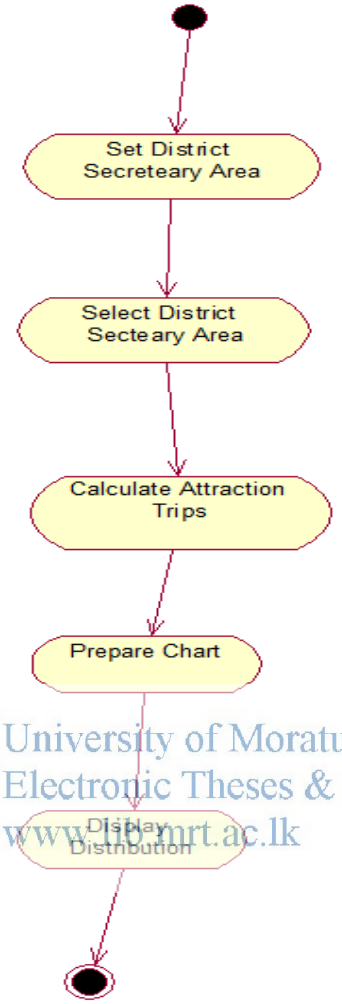




**Figure 14: Trip Attraction**

### B.3.8 Traffic on Road

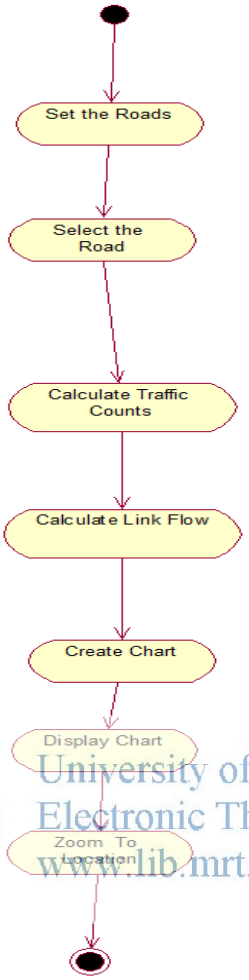




**Figure 15: Traffic on Road**

### B.3.9 Traffic on Minimum Path

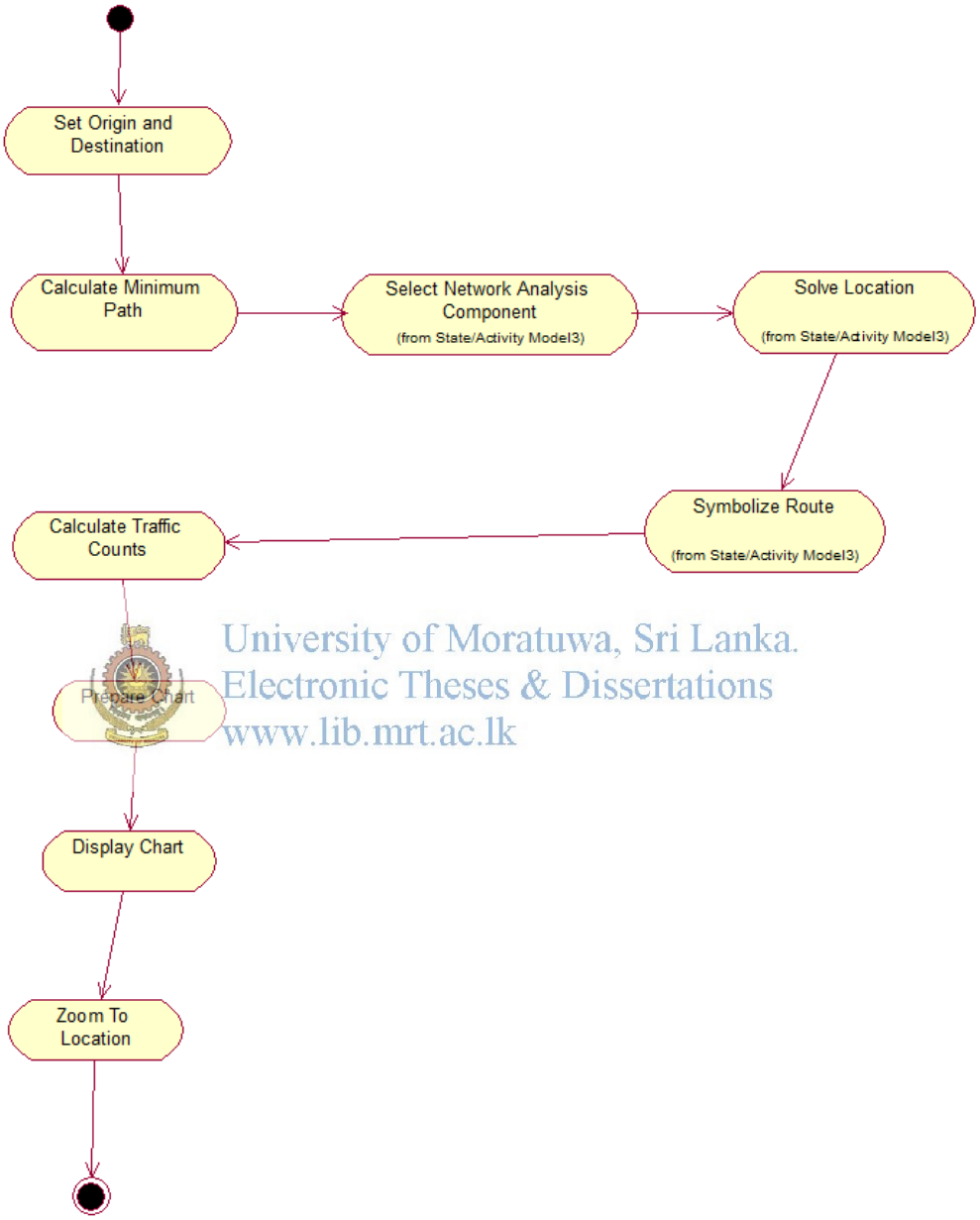




**Figure 16: Traffic on Minimum Path**

## B.4 Component Diagram

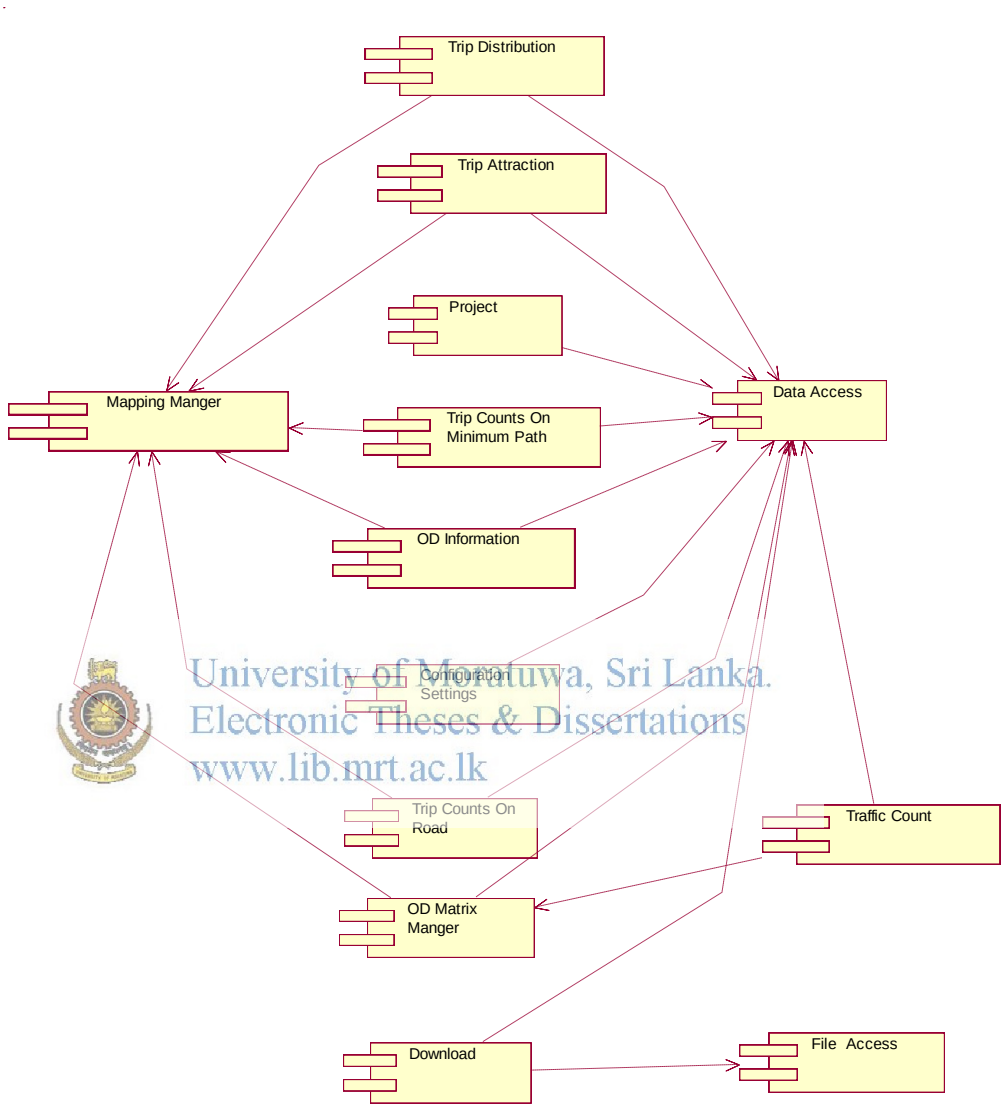




**Figure 17: Component Diagram**

**B.5 Package Diagram**

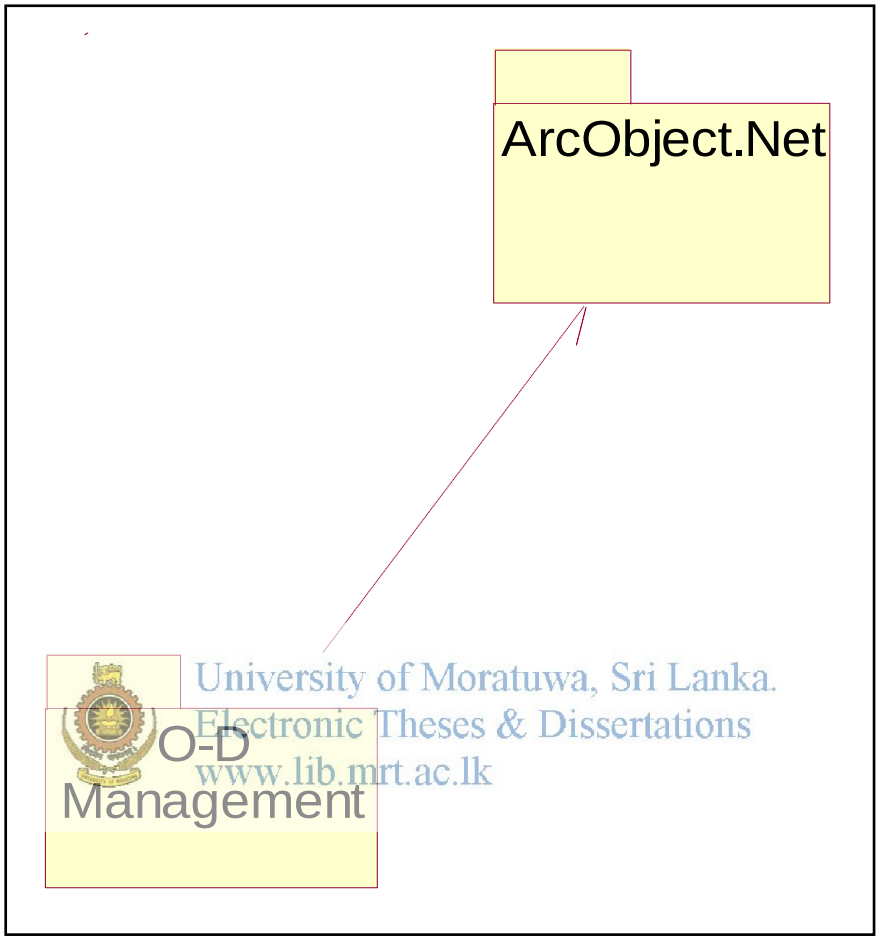



**Figure 18: Package Diagram**

## B.6 Class Diagrams

### B.6.1 ArcObject.Net

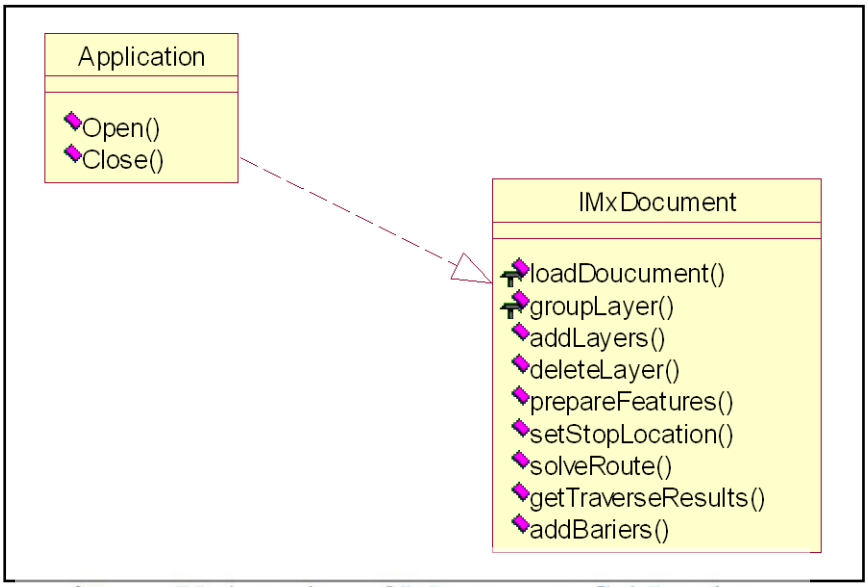




Figure 19: Class Diagram-ArcObject.Net

### B.6.2 OD Management

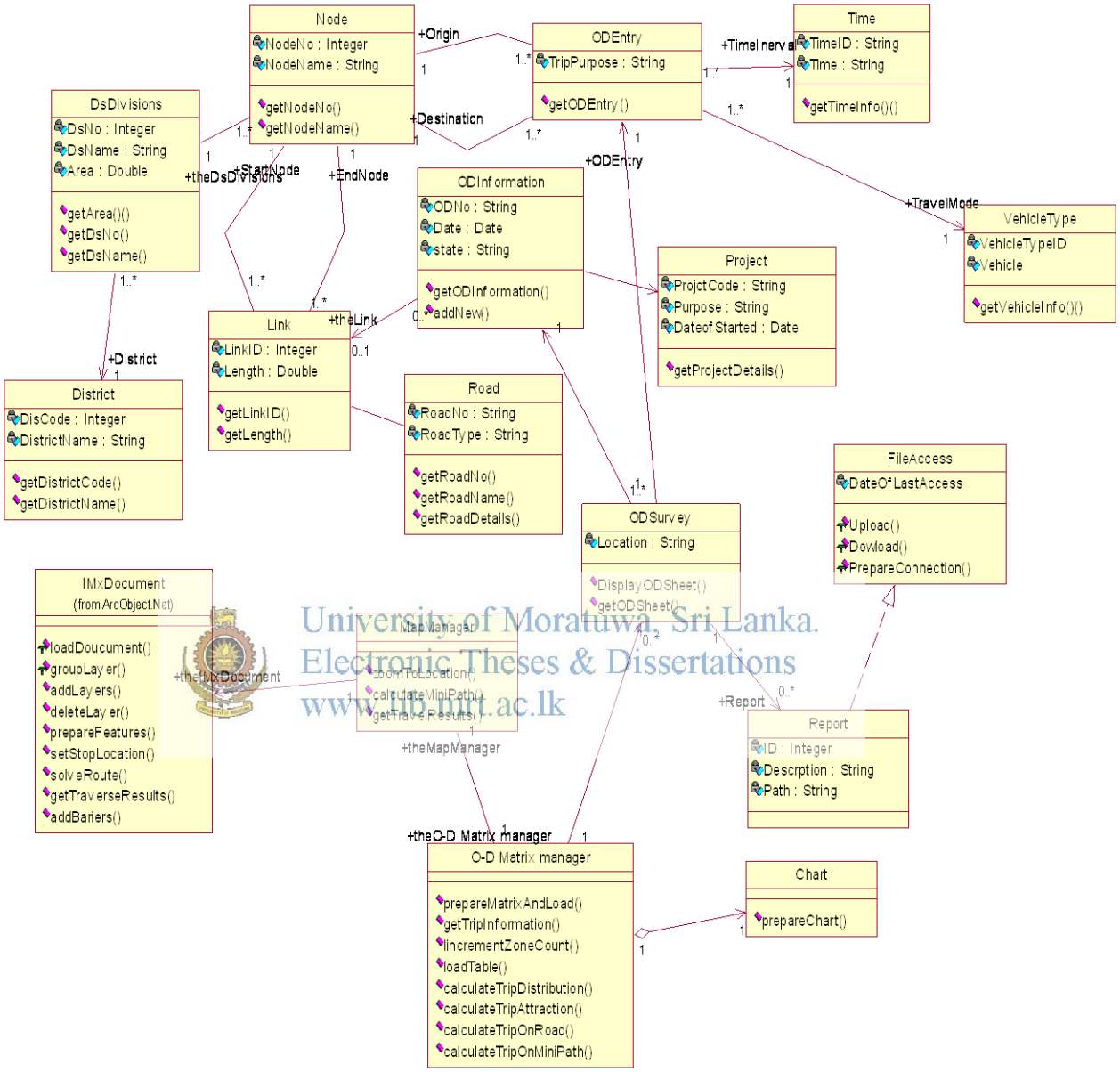




**Figure 20: Class Diagram-OD Management**

### B.6.3 ER Diagram

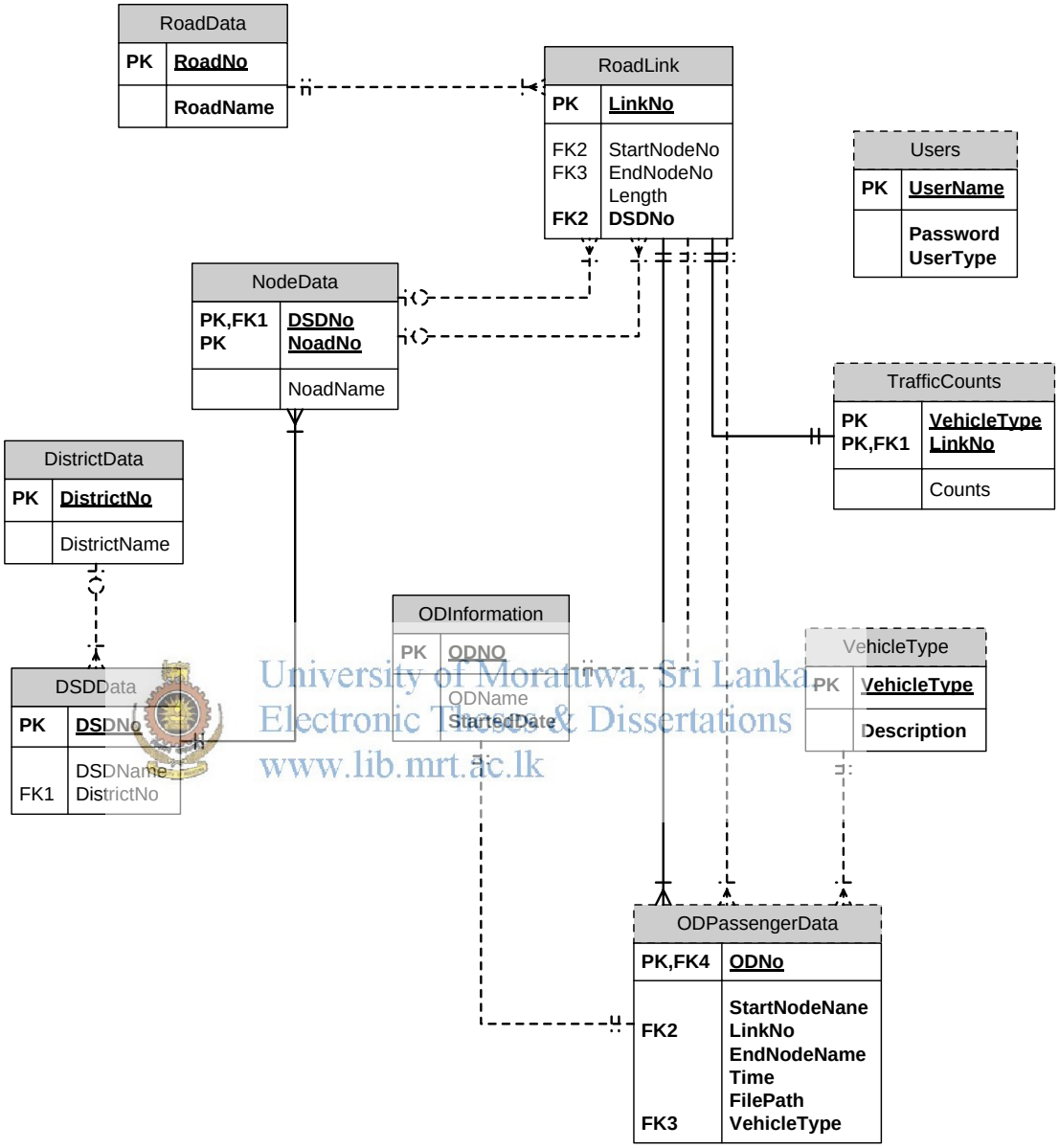




**Figure 21: ER Diagram**

## 10.5 Appendix C

### C.1 Implementation (interfaces and Diagrams)

#### C.1.1 Integrate the Software Component

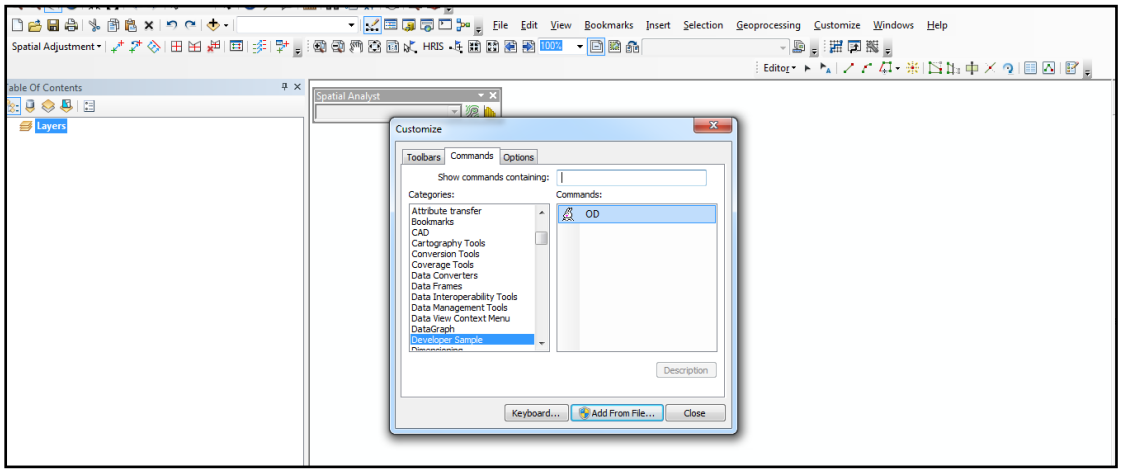




Figure 22: Integrate the Software Tool

This figure is the attempt of integrating the final software solution to the ArcMap environment

#### C.1.2 User Login

This is the first interface that meets when the system starts. This interface provides all types of users to login to the system by giving user name and password

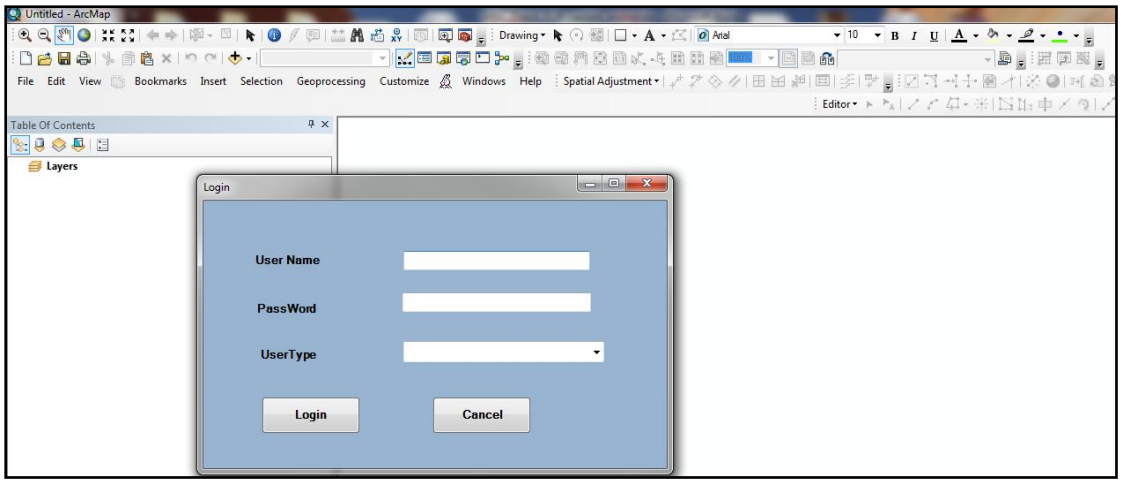


**Figure 23: User Login**

### C.1.3 Administrator Menu

This is the first interface that meets after having successful login by the administrator. This interface provides the navigation to all of the functions



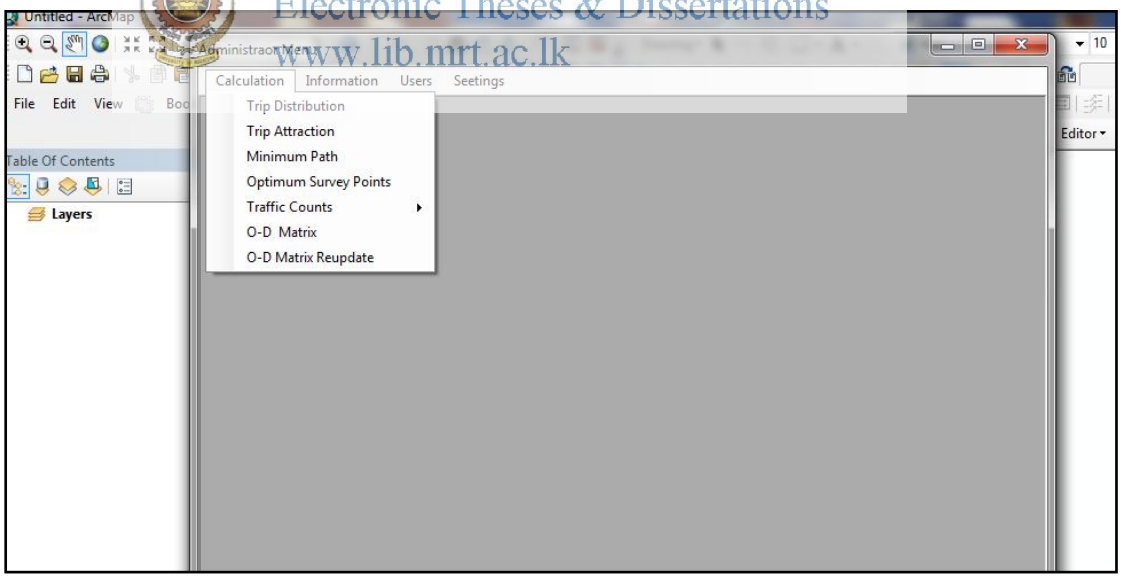


**Figure 24: Main Menu**

### C.1.3 Manage Users

This is the first interface provides the facility to add/update/delete users in the system

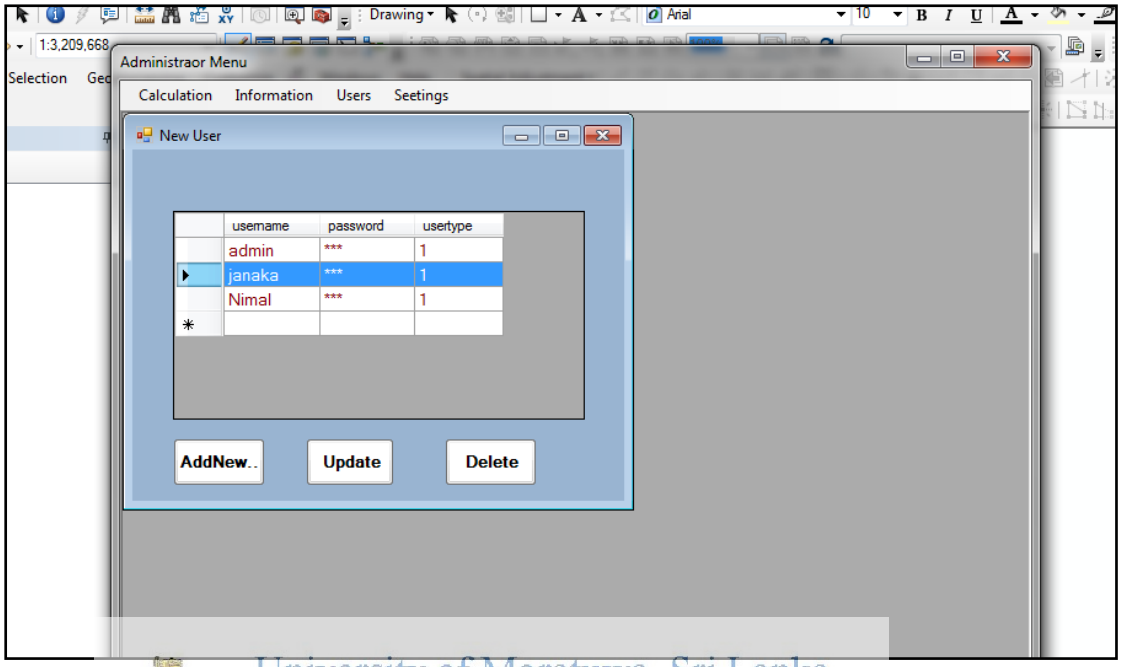




Figure 25: Manage users

### C.1.4 OD Information

This is the first interface provides the facility to add/update/delete O-D basic information.

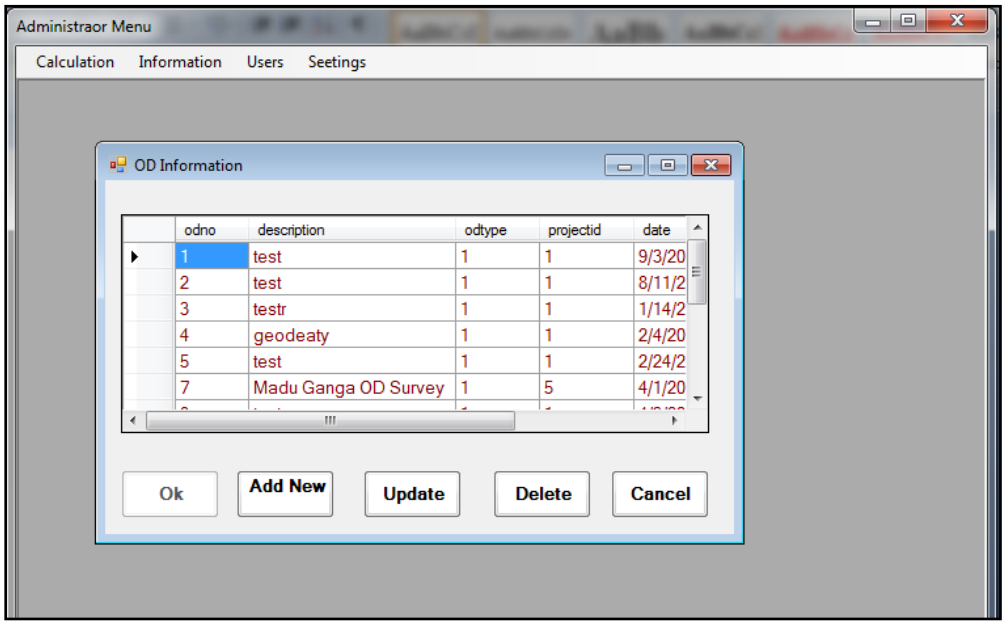


**Figure 26: Manage O-D Information**



### C.1.5 Manage New O-D Survey Sheet

This interface provides the facility to add/update/delete O-D Survey Sheet

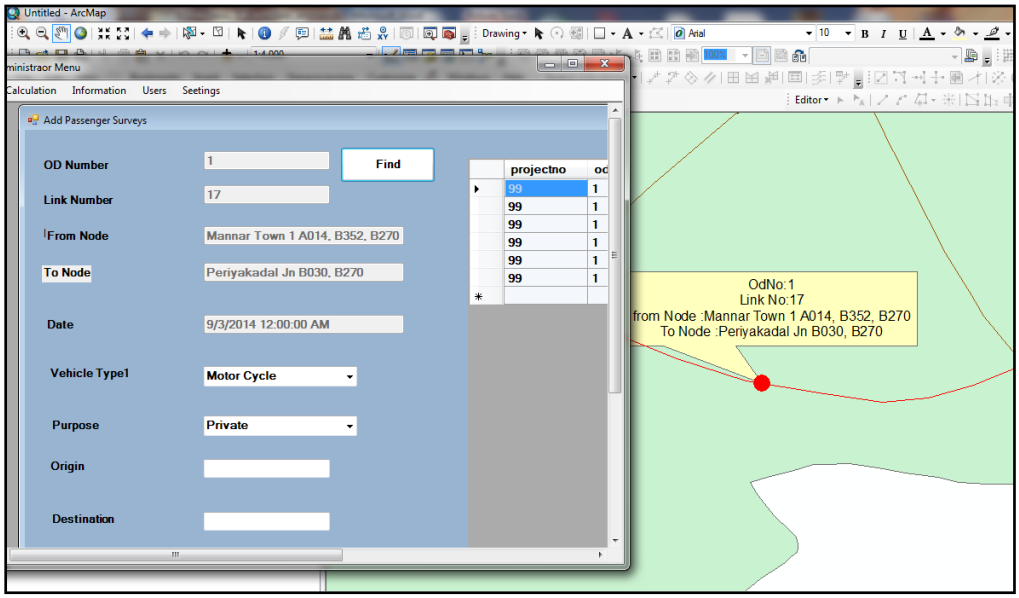


**Figure 27: Manage O-D Survey Sheet**

### C.1.5 Upload Reports

This interface provides the facility to upload reports to the file server

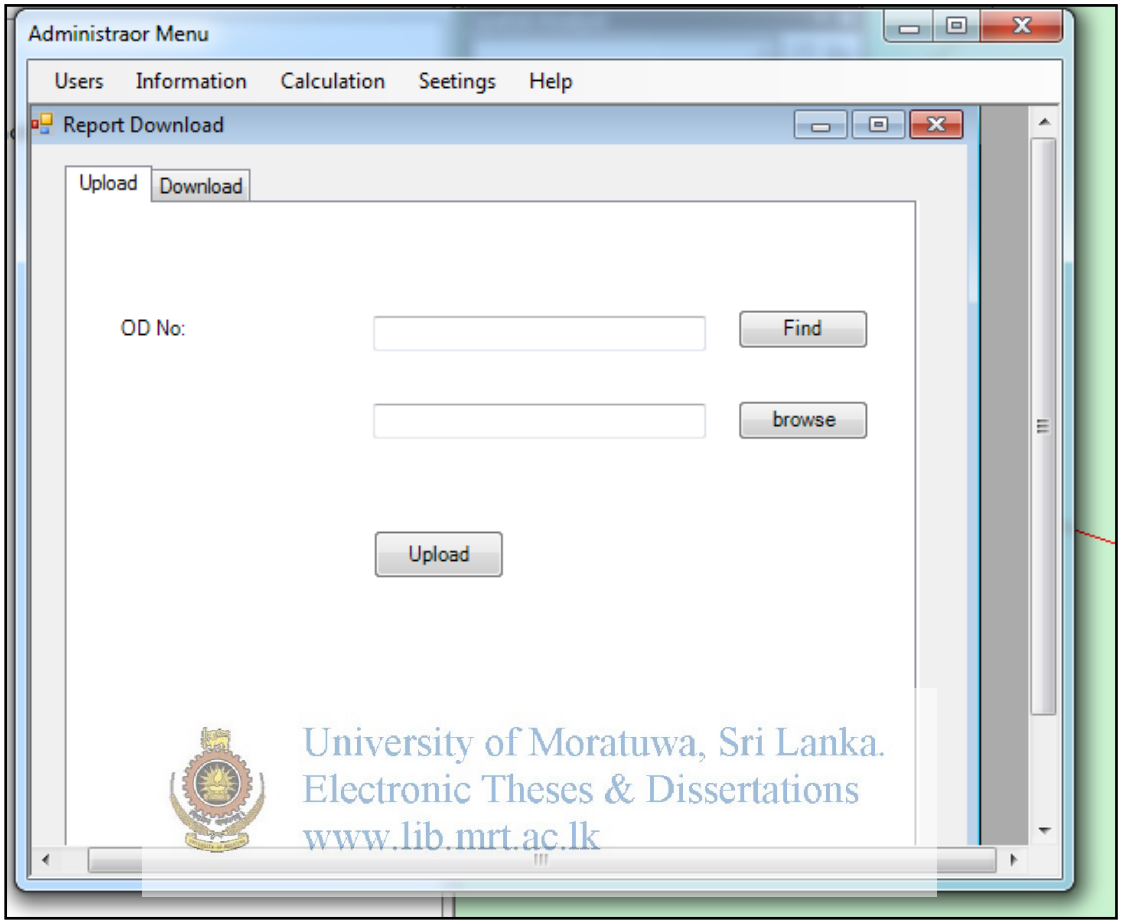




**Figure 28: Upload**

### C.1.6 Download Reports

This interface provides the facility to download reports from the file server

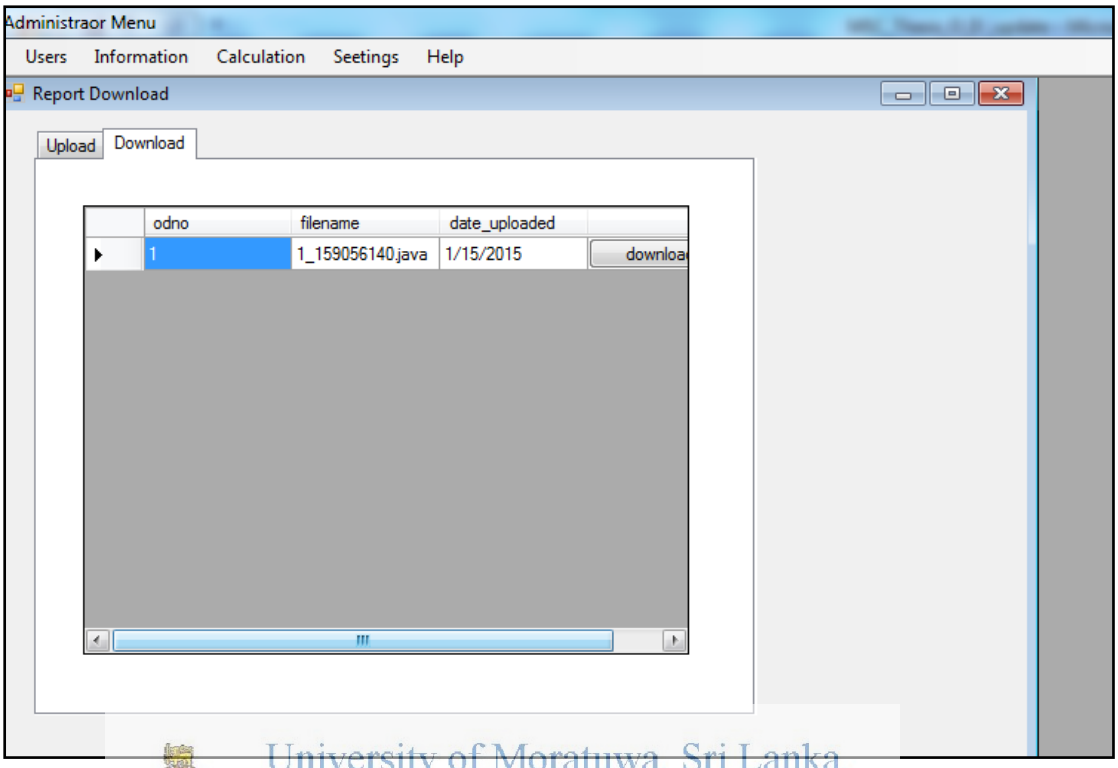




Figure 29: Download

### C.1.7 O-D Matrix manager

This interface visualizes the generated O-D Matrix as in numerical values and divisions names.

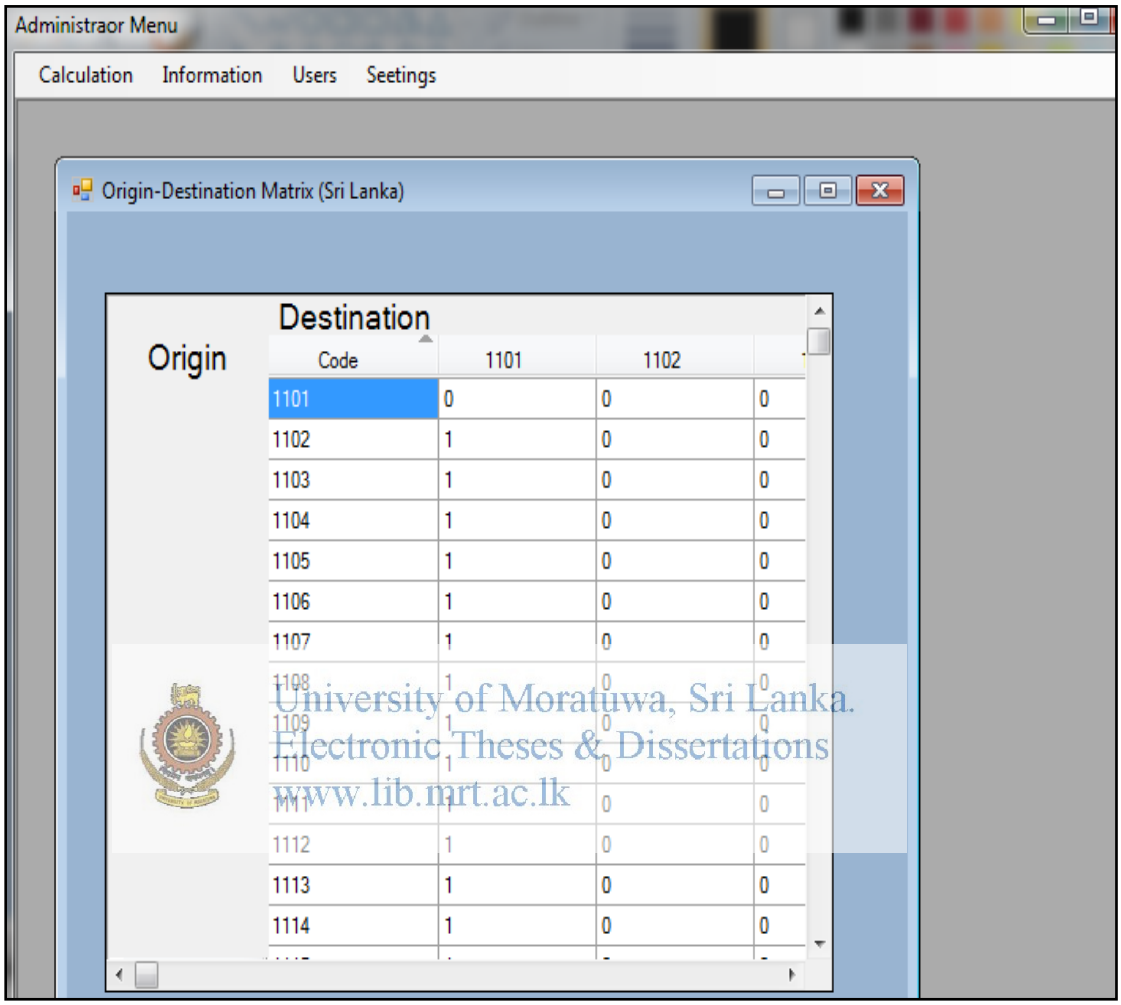


**Figure 30: O-D matrix in divisional code**

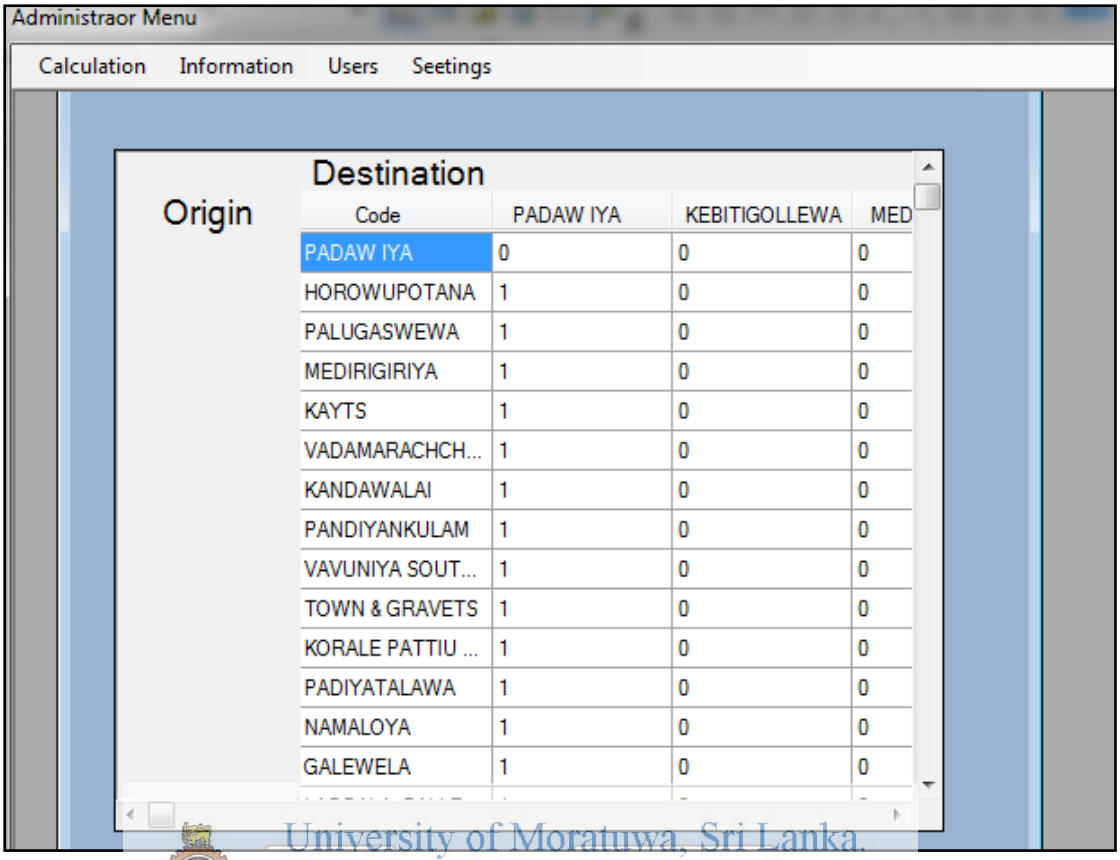




Figure 31: O-D matrix in divisional numbers

### C.1.8 Trip Distribution

This interface visualize the Trip distribution from particular Divisional Secretary Area

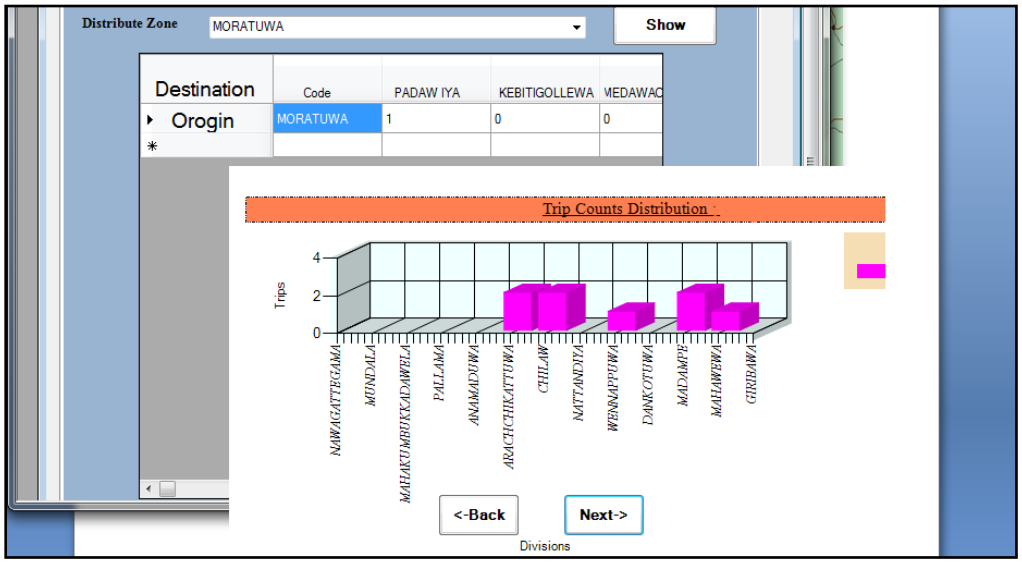


**Figure 31: Trip Distribution**



### C.1.9 Traffic Counts On Road

This interface visualize the Trip counts on a particular area

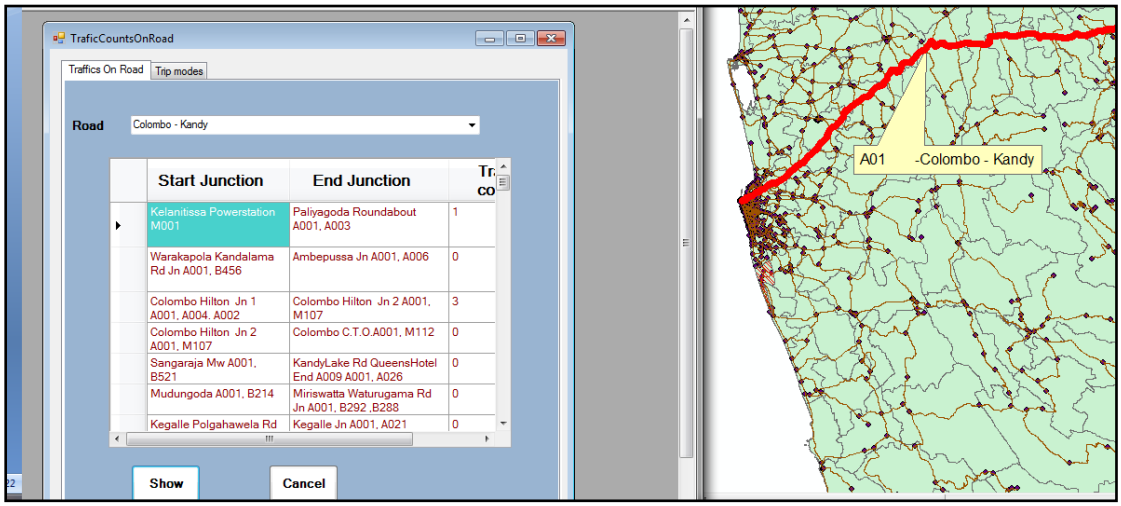


**Figure 32: Traffic Counts On Road**

## C.2.0 Traffic Counts On Minimum Path

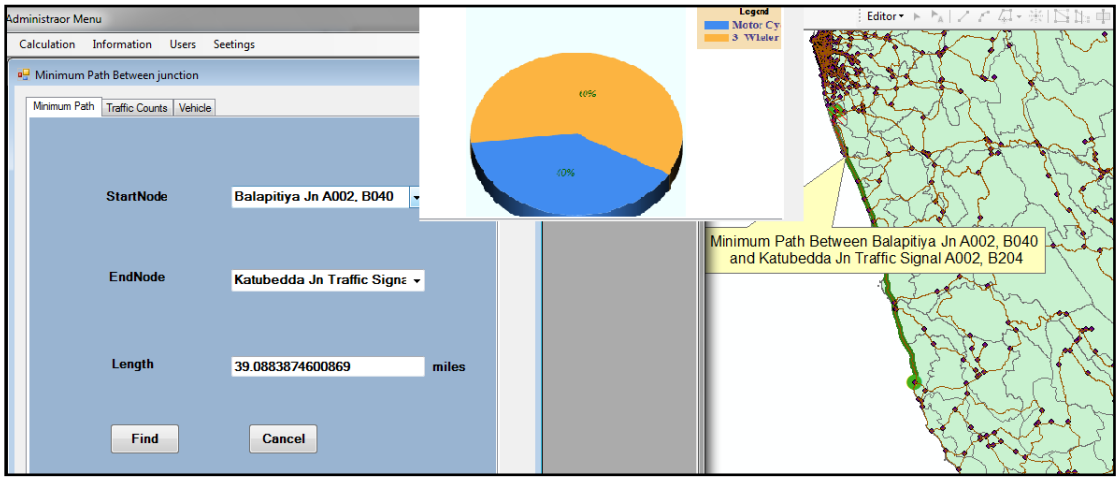


**Figure 33: Traffic Counts On Minimum Path**

## C.2.1 Traffic Counts On Links



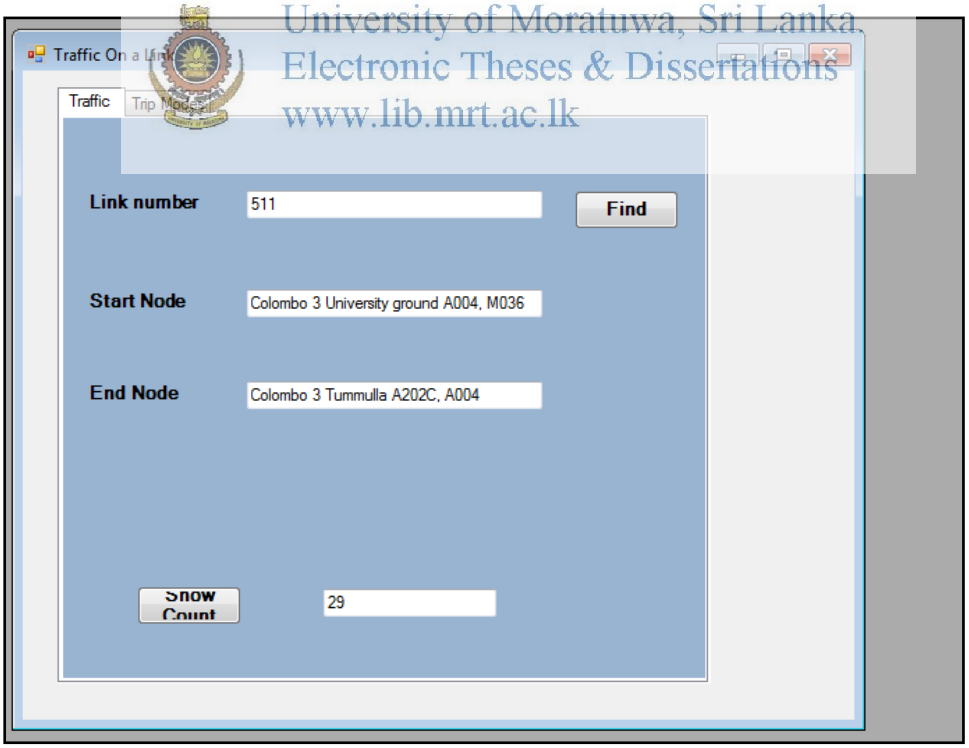


**Figure 34: Traffic Counts On Minimum Path**