PREFACE:

This report is the outcome of my Master Thesis which is an essential part in Master of Transportation sciences Program offered by Hasselt University. The domain of specialization is in transportation mobility management. The tile of the project is Traffic Assignment Model using DTALite and NEXTA: A model setup for Flanders. Exploring the new software related to transportation science is always fascinate me and this is the reason why I selected this topic. This research topic is a mixture of technical and social aspect of sciences which ranging from basic transportation management concepts to model human behavior in practical life. The project enriches my capabilities to explore more new things and made me more practical to face difficulties. I have enjoyed the work and I am confidently looking forward to continue it afterwards where necessary.

After thanking Allah Almighty and my parents for their endless support, I would like to thank a few people without whom this thesis would not have been possible. I am really grateful to my promotor (Prof.ir Dr. Davy Janssens) and supervisors (Dr. ir. Bruno Kochan) for their guidance. I am also obliged to Ir. Luk Knapen for his inspirational assistance at each and every step of this project. These people were always present to help me with my research whenever I needed them. Working on this project in this professional environment and with these professional people was a remarkable experience for me. This experience does not only enhance my research capabilities but also enable me to understand the different dimension of transportation science in the real mobility world.

Syed Muhammad Noman

August 2015

SUMMARY:

The rapid increase in the motorization rates over the last few decades have posed a wide range of serious challenges to the mankind ranging from environmental and energy concerns to negatively influencing the quality of human life in terms of extravagated congestion levels and increased crash fatalities and injuries. In this rapidly worsening situation, the decision makers and transport planners have to manage the increasing travel demands efficiently. For this purpose, transport planners and researchers have employed various methods and modelling techniques to predict and plan for such drastic changes in the transportation demands for the future years.

A number of modeling approaches such as 4-stage travel demand modeling process which is the conventional and widely used technique for modeling a transportation system are being used by the transport planners and researches for a number of years. Apart from it, nowadays various softwares with each having its own specialization and specification with respect to the level of use, are also available that make this modeling process much easier. Some softwares are best for microscopic level where others are only designed to simulate the traffic environment on a macroscopic level. The use of these software also depend on the availability of data for production of specific output or the data requirement of software for the particular output.

The last step of travel demand modeling process is traffic assignment. In this thesis, a dynamic traffic assignment modeling process was done using OD demand matrix of Flanders Area. For this modeling task, dynamic traffic assignment modeling softwares i.e. DTALite and NEXTA were used for the development of model for Flanders region. DTALite is an open source Dynamic Traffic assignment Modeling tool whereas NEXTA is used as a visualizing and evaluating tool that use the output of dynamic traffic assignment model from DTALite.

As the modelling process on the given softwares required a high processing power especially for a large area having more than 30k nodes and links, therefore the study area for the thesis was limited only to the city of Hasselt in Flanders region. The model was developed using 24 hour OD matrix for Hasselt. The report starts with a general introduction of travel demand modeling followed by traffic assignment and dynamic assignment. After that, an in-depth explanation of the model development process using DTALite and NEXTA is carried out followed by some results, discussion and analysis.

Results obtained from the simulation describe the behavior of the traffic in the study region with the help of various traffic stream characteristics such as speed, travel distance, number of vehicle etc. The selected parameters describe the traffic behavior with respect to different time and travel intervals. As the project is still in its initial stages, therefore a lot of technical difficulties were encountered during the process e.g. the simulation results for travel time parameter were wrongly estimated by the software as the values were too large as compared to the time given

by google earth. However, this project can provide valuable knowledge and can serve as a starting point for future studies like in-depth behavioral estimation of traffic stream with respect to emission levels and value of time estimation.

Table of Contents

LIST OF FIGURE:

LIST OF TABLES:

ABBREVIATION:

BPR	Bureau of public roads-type
DTA	Dynamic traffic assignment
DTALite	Light-weight dynamic traffic assignment engine
DUE	Dynamic user equilibrium
FHWA	Federal highway administration
GPL	General public license
GUI	Graphical user interface
HOV	Single occupancy Vehicle
MOE	Measure of effectiveness
NEXTA	Network explorer of traffic assignment
SOV	Single occupancy Vehicle
SUE	Stochastic user equilibrium
TDMOE	Time dependent measure of effectiveness
TDSP	Time dependent shortest path
UE	User equilibrium
VOT	Value of time

CHAPTER 1: INTRODUCTION

1.1 General Review:

Problems faced by rapid urbanization are not new for managing and planning authorities. Transportation systems also suffer by this issue, with increasing travel demand problems and other incremental integrated issues. The transportation planners and researchers are constantly making efforts to cope with it. In contrast with transportation travel demand management, planning and prediction, researchers have developed new softwares and modeling techniques that facilitate the process more efficiently and in a more convenient manner.

One of the conventional developments was the four step travel demand modeling process which was introduced in last century. Conventional four stage travel demand modeling is defined as trip generation, trip distribution, mode choice and trip assignment. These are four basic components of most of the traffic models which enable the planners to understand about the number of people travelling, where are they going, their transportation mood and what route will they take to get there. (G.Willumsen, 2011).

The trip generation process of the four step travel demand model uses the data of socioeconomic characteristics to estimate the number of trips generated by a zone or any other geographic division used for traffic analysis. After determining the number of trips produced by the zone, trip distribution step determines where the trip will go. It also includes the number of trips produced and attracted by each traffic analysis zone.

In the next step, the trip mode choice that is utilized in a trip from one zone to another zone, is determined. Mode choice can be either extremely simple or very complex depending upon the nature of the model being developed e.g. some models do not have a significant effect of transit modes because of their unavailability in the study area while some models have a very complex mode choice process like model of Chicago that includes a number of modes such as autos, subway transit and other rail system.

Trip generation is the final step of the four step model. In this step, the data generated from the previous steps is used to assign the trips to the transportation network. With the development of GIS (Geographical information system), this process is more graphical than text based. Figure 1, summaries the four step modeling. (G.Willumsen, 2011).

This modeling process has seen a number of developments and enhancements over the years. These include the incorporation of time-of-day modeling as compared to earlier where the entire average of week was used, supplementary models to support the four stage modeling like in mode choice vehicle availability model, in same step inclusion of non-motorized and etc. (NCHRP, 2012)

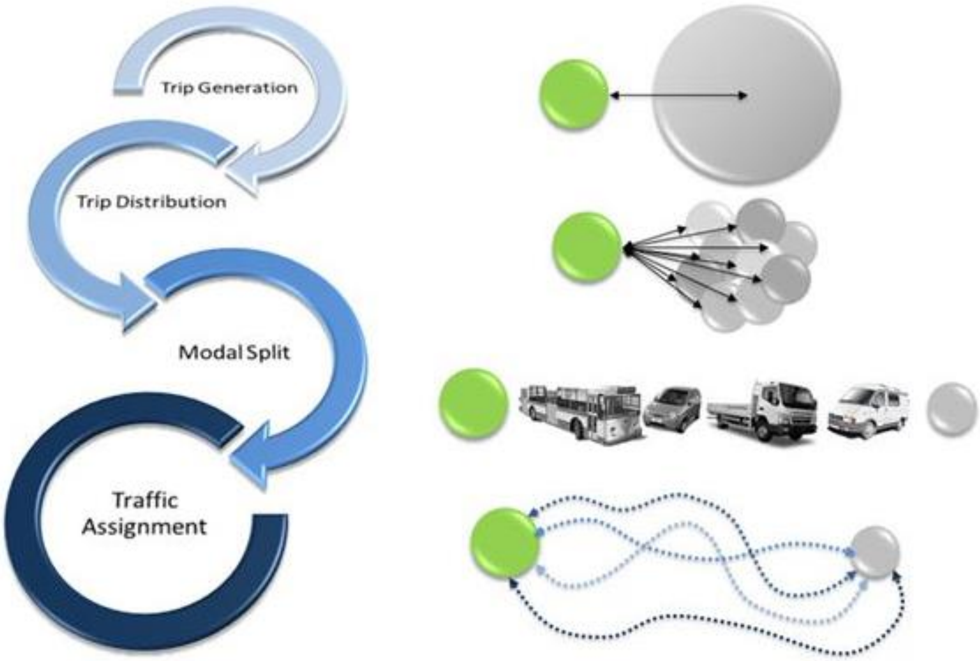

Figure 1: Four step modeling process

This report mainly focuses on the last step of four stage travel demand modeling especially dealing with Dynamic Traffic Assignment, DTA. The dynamic traffic assignment is a type of Traffic Assignment; commonly called as network assignment, assignment, route choice or traffic assignment.

Traffic assignment model is a key component in travel demand forecasting process. The traffic assignment model predicts the network flows that are associated with future planning scenario, and generates estimate of the link travel time and related attributes that are the basis for benefits estimation of air quality impact. The traffic assignment model is also used to generate the estimates of the network performance. Commonly traffic assignment model use static demand input which is way too different from reality as the traffic flow differ with respect to the time; the introduction of dynamic traffic assignment model makes it more realistic.

DTA model incorporates the time variability effect as compared to static traffic assignment. The advancement in conventional modeling process has now made this step as a separate domain of dynamic traffic assignment modelling. DTA modelling is not new but earlier it only included the text based features, however with the advancement in technology the process has become more graphical with the help of various tools such as GIS and other geographical tools. The visualization is possible through different softwares which enable the users to export certain type of data and use fusion tables to integrate with the google maps specifically for DTA lite.

Many softwares have been introduced to cater the complexity of the process and reduce the level of effort required to achieve the modelling tasks in simple manner and convenient to understand. The selection of the software mainly depends on the availability of data for production of specific output or the data requirement of software for the particular output. For instance, micro-simulation models include particular car-following, vehicle performance, and lane changing algorithms to model the performance and behavior of an individual vehicle. On the other hand, macro simulation models emphasize on whole traffic stream and deal with it at an aggregate level by taking into account a group of vehicles instead of a particular individual vehicle. In contrast, these aggregate level or macro level softwares usually requires a small amount of data and a much lesser coding effort, however the level of output and detail as compared to disaggregate level or micro level software is also limited. (Jones, 2004)

1.2 Purpose:

The purpose of this project is to study the dynamic traffic assignment modelling using DTALite and NEXTA softwares. Dynamic traffic modelling is closer to reality as compared to static assignment as it incorporates the dynamic nature of a traffic stream. To work on any modeling software, input data requirement and preparation plays a vital role. In this research project, DTALite was setup to explore for dynamic traffic assignment modelling. The initial understanding of DTA model development for Flanders area using DTALite was done in this project which will prove to be helpful for future studies and will lead to a more detailed research. The software is good for preparing the DTA model for large area and is famous for its quick estimation method (QEM) that provides a fast and easy platform for modeling like single phase timing development (NEXTA, 2015). However, the software needs to run on a high processing machine. Besides developing the DTA model, the objective of the project was to discover the difficulties and criticalities that occurred in the process. The software package also enables to use emission level and VOT estimation options as well. As a whole, the project purpose was to make the software package operational and workable for DTA modeling, explore the difficulties faced and enable the package to be used for further research at IMOB.

1.3 Overview:

This report covers all the detailed procedure involved in the development of this model. Apart from it, a basic understanding about the software workflow along with encountered difficulties is given a special consideration. Discussion and analysis of the results obtained from the simulation run in DTALite software is also a part of this report.

CHAPTER 2: BACKGROUND STUDY

2.1 Introduction:

The last process of four stage travel demand modeling is traffic assignment. With the advancement the assignment application evolve further and named as Highway assignment model, transit assignment model etc. Traffic assignment processes are widely spread under different methods to achieve the rout assignment task. These method and types were discuss later in this chapter. There are many types of assignment used frequently all over in field of transportation science to estimate network characteristics. Major types are all-or-nothing assignment, capacity restraint assignment, incremental assignment, user equilibrium assignment (UE), system optimum assignment (SO), stochastic user equilibrium assignment (SUE) etc.

Traffic assignment usually refer to the process in which given sets of trip interchanges are assign to the specified transportation system. In traffic assignment the aim is to reproduce the transportation system and then analysis the result accordingly. The output is usually in the form of trip matrix or matrices which illustrate the travel demand patter between origin and destination. The major aims of traffic assignment procedures are: (Mathew K. V., 2007) (Mathew D. T., 2008)

Traffic volume estimation on the links of the network and possibly the turning movements at intersections.

- *To furnish estimates of travel costs between trip origins and destinations for use in trip distribution.*
- *To obtain aggregate network measures, e.g. total vehicular flows, total distance covered by the vehicle, total system travel time.*
- *To estimate zone-to-zone travel costs (times) for a given level of demand.*
- *To obtain reasonable link flows and to identify heavily congested links.*
- *To estimate the routes used between each origin to destination (O-D) pair.*
- *To analyses which O-D pairs that uses a particular link or path.*
- *To obtain turning movements for the design of future junctions*. (Mathew D. T., 2008)

2.2 Review on Traffic Assignment:

With the rapid increment of congestion in the busy unban environment, the use of vehicle has become unavoidable for every movement in the road network. The study of transportation and traffic network with respect to congestion and demand is very essential. Estimation and prediction of traffic flow in this regard is quite helpful in managing the traffic congestion. Traffic assignment tool provides this facility to estimate the network characteristics.

The research in traffic assignment field started during the first half of last century with wardrop's principle. The basic algorithm, principle and model with respect to planning of transportation system and networks were developed in early stage. An English analyst John Glen Wardrop took a first step towards the mathematical investigation of the problem in 1952 (Wardrop, 1952). First and second principle of equilibrium traffic assignment were developed by John Glen Wardrop which are famous with the name of First and second Wardrop's principle of equilibrium. These equilibrium models are regularly use for the prediction and analysis of traffic patterns in transportation network.

First Wardrop's Principle stated the route choices made by the driver on congestion situation on the network. The principle states:

"*The journey times in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route*" (Wardrop, 1952). This means that each driver non-cooperatively tries to minimize his travel cost, until the situation stabilizes to an equilibrium state, where no user may lower his travel time by unilaterally changing his current route. Traffic flow which satisfies Wardrop's first principle is generally referred to as flows at "User Equilibrium" state (Sheffi, 1985) (Bergomi, 2009).

The Second Wardrop's Principle describes the optimal use of the whole network. The principle states: "*At equilibrium, the average journey time is minimum*" (Wardrop, 1952). In this principle its illustrate that every individual driver behaves cooperatively in choosing their route to ensure an optimal use of entire network. In conclusion the sum of all drivers travel time is minimized (Bergomi, 2009).

In previous studies, a wide variety of traffic assignment have been developed and applied. There are many earlier traffic assignment methods that have been used had undesirable properties and should be replaced in future work.

Some methods like All-or-Nothing, ignore the fact that link travel time are flow dependent (i.e., that it is a function of link volume) when there is congestion, or that multiple paths are used to carry traffic for each specific O-D pair. Incremental method and old-fashioned capacity restrain will not achieve the equilibrium solution. Equilibrium method use the volume based travel time, and estimate the link flow and travel time. This method use iteration for assigning flow and calculating loaded travel time on given network. (Corporation, Caliper, 2007).

Traffic assignment algorithm assigns route to individual travelers and aggregate them for network traffic assignment. User equilibrium assignment takes account the key behavior that individual has perfect information regarding the characteristics of alternate routes. As discussed earlier the first principle proposed by Wardrop (Wardrop, 1952), at user equilibrium, the individual driver cannot reduce their travel time alone by changing path (Sheffi, 1985). All path in UE assignment have same minimum cost for an O-D pair but this may not be the enough realistic to describe the loaded traffic network in reality (Salvin H, 1996)

Another attempt was made by (Daganzo C., 1977) to propose an alternative of equilibrium method called as Stochastic User Equilibrium or SUE, this model has assumption that individuals have imperfect information about network path, or have variation in their perception of network attributes. In this approaches traveler believe that changing path cannot increase their expected utility. Because of variation in traveler perception and also in the level of service, utilized path do not necessarily have identical generalized costs. The Stochastic User Equilibrium is consistent with the concept of applying discrete choice model for the choice of route, but with the necessary aggregation and equilibrium (Corporation, Caliper, 2007).

Further in this chapter the discussion about the types of traffic assignment that are commonly used which then followed by detail about dynamic assignment.

2.3 Types of Traffic Assignment:

2.3.1 Equilibrium Traffic Assignment Method:

Following are the traffic assignment type based on the methods of single class of traffic or equilibrium base approaches. In most of the case user equilibrium assignment is the recommended method for traffic assignment unless a more advance model is need.

i. User Equilibrium (UE):

The user equilibrium assignment state that *no individual driver can minimize their travel cost by shifting to another route* (Wardrop, 1952). This is basically Wardrop's first principle.

By taking the assumption that the driver have complete knowledge about the network travel cost and chooses the rout according to Wardrop's first principle that is best. This user behavioral assumption describe the deterministic user equilibrium. The mathematical optimization of this problem were well stated by Dr. Methew, which are following; (Mathew D. T., 2008),

$$f_k(c_k - u) = 0 : \forall k \quad (1)$$

$$c_k - u >= 0 : \forall k \quad (2)$$

Where f_k is the flow on path k, c_k is the travel cost on path k, and u is the minimum cost

This equation has two states,

IF $c_k - u = 0$, from equation (1) $f_k \geq 0$ this means that all used path will have same travel time.

IF $c_k - u \geq 0$, then from equation (1) $f_k = 0$.

For all path that are unused will have travel time greater than the minimum cost Path.

The basic assumptions in User Equilibrium Assignment are;

- Individual traveler has perfect knowledge travel cost on the network.
- Travel time on a given link is a function of the flow for that link only.
- Function of travel time are positive and increasing.

ii. Stochastic User Equilibrium (SUE):

User equilibrium assignment process based on Wardrop's principle (Wardrop, 1952) assume that all drivers perceive costs in an identical manner which is opposite to the real situation. A solution to assignment problem on this basis is an assignment in which no driver can reduce his journey cost by unilaterally changing route. Stochastic user equilibrium describe that *the travelers do not have accurate information concerning network attributes and/or they perceive travel cost in different ways* (Mathew K. V., 2007). SUE assignment procedure provides more realistic results than the deterministic UE model (Corporation, Caliper, 2007). The reason of realistic result is that SUE allows the use of less attractive as well as most–attractive routes. Less attractive routes will have lower numbers of travelers while similarly the less cost route will have higher use.

iii. Origin User Equilibrium:

Origin user equilibrium (OUE) can achieve much higher levels of convergence in less computing time than traditional assignment algorithms. This method is proposed by (Bar Gera H., 1999) (Dail R, 2006) the idea behind origin-based assignment is that the equilibrium solution for each origin is an acyclic graph. Origin-based methods maintain acyclic solution by processing origin sub network. OUE methods achieve equilibrium for each origin and prohibit flow from link that are part of cycles which give greater computational efficiency. Instead of keeping track of all the path for each origin destination pair, one keeps the solution of each pair. (Corporation, Caliper, 2007).

iv. System Optimum Assignment:

The system optimum assignment is based on Wardrop's second principle, which states *that drivers cooperate with one another in order to minimize total system travel time*. This type of assignment leads towards an unrealistic situation as the assignment considers that congestion of network minimizes with the change in selected travel routes in order to cooperate with each other. The base condition makes it behaviorally impractical but it can be helpful for the researcher and transportation planners to understand the way to minimize the travel cost of traffic, thereby achieving an optimum social equilibrium.

2.3.2 Non-Equilibrium Traffic Assignment:

There are number of other traffic assignment model which are not currently used and not recommended in most of the traffic modeling process. Some of them are follows.

i. <u>All-or-Nothing Assignment:</u>

In All-or-Nothing Assignment the entire flow of travelers in between O-D pairs are assigned to the shortest paths present in origins and destination. Means the trips from any origin zone to any destination zone are loaded onto a single path and the path is also the minimum cost path between them. This model is unrealistic in the manner that only one path between the O-D pair is used for traveler, even if there is another path with the same line or nearly the same travel time or cost. (Corporation, Caliper, 2007)

In this assignment technique the traffic on a link is assigned without consideration of whether or not there is adequate capacity or heavy congestion. Another flow is that the travel time is a fixed input and does not vary with the change on the congestion on a link. However, this model may be reasonable in some extent on uncongested networks where there are few alternative routes and they have a large difference in travel cost. This model may also be used to identify the desired path of the driver that individual would like to use in the absence of congestion. This assignment technique is also important in practical applicability like it can acts as a building block for other types of assignment techniques. Limitation of this assignment is, it ignores the fact that link travel time is a function of link volume and when there is a congestion or that multiple paths are used to carry traffic. (Mathew D. T., 2008).

ii. <u>STOCH Assignment:</u>

Another better assignment technique proposed by (Dial, 1971) in which the trip between O-D pairs are divided among multiple alternative paths that connect the O-D pairs. The proportion of trips that is assigned to a particular path equals the choice probability for that path, which is calculated by a logit route choice model.

STOCH assignment, however, does not assign trips to all the alternative paths, but only the path containing link that are considered “reasonable” (Dial, 1971). A reasonable link is one that takes the traveler farther away from the origin and/or further close to the destination. In this assignment link travel time is fixed input and is not dependent on link volume.

iii. <u>Incremental Assignment:</u>

In this assignment model as describe by the name traffic volume is assigned to network in the step wise manner. In incremental assignment every step uses a fixed proportion of traffic of the total demand which process according to all-or-nothing assignment. Calculations are made on loading link travel time and link volume. With the same loading increment the method may look like the equilibrium assignment, however the assignment does not produce the equilibrium result (Mathew D. T., 2008). This incremental loading leads towards unrealistic situation and shows inconsistency between link volume and travel times. In order to understand the traffic congestion, traffic flow and traffic capacity relationships the assignment can perform significant role (Bergomi, 2009).

iv. Capacity Restrain:

Capacity restraint assignment attempts to approximate an equilibrium solution by in cooperating travel time calculation based on traffic congestion. This is done by repeating all-or-nothing traffic loadings with recalculation of link travel times based on a congestion function that reflects link capacity. Unfortunately, this method does not converge and can flip-flop back and forth in loadings on some links (Sheffi, 1985). The method does not converge to an equilibrium solution and has the additional problem that the result is highly dependent on the specific number of iterations run. Performing one or more or less iteration substantially changes the result (Bergomi, 2009).

2.4 Traffic Assignment Tools:

Earlier the techniques of traffic assignment limited to the theoretical aspect. The implementation of traffic assignment modelling techniques are made through different softwares. The development of softwares in the field of modelling are not new. Researchers and software developers are continuously enhancing the capability of software to make their work easy and efficient. The significance of modelling techniques is also quite significant in other fields of science such as Maintenance, Construction management, Surveying, Highway design, Bridge design, Pavement design, Hydraulics, Safety and accident records, Traffic engineering, Transit, and urban Planning. According to Center of Microcomputers in transportation (McTrans) there are over 475 software tool available in all these areas. (Dr Ziad Sabra, 2000). The developments in software are made in various manners. In the field of transportation science some modelling software are based on programming language which provides easy access to alter the basic function in the software likewise some softwares based on C++, Java, Python, VB, VB.net, C/sharp and etc. which enables user to modify accordingly with the help of programming language. Some of the softwares limit the user to use available option or if needed contact the software developer for some alteration according to the need of projects.

The purpose of modelling in transportation sciences is to model the traffic behavior and understand the interaction between different attributes in order to predict the future condition of the traffic. The main goal of modelling traffic assignment is to determine the network traffic flow and other respective attributes. The result of modelling describes the traffic flow parameters obtained from the mutual interaction of route selection by the individual with other behavioral influence that the individual driver may consider in selection of route. This modelling task can be performed by using many softwares available in the market. There are number of available softwares that provide different level of platform to researcher to perfume their modelling task. Some of them are available free as open source software and some are need to purchase or for testing the free trail are provided with limited option. These softwares are famous in the different aspects like some are good in signal design, some are good in simulating different scenario and some provides significant interaction between different software that support the modelling task at large scale. Selection of the software for modelling task is based on the required output needed and the input data required for that particular output. It also emphasis on the detail input and algorithm used to produce specific output. For dynamic traffic assignment the generally used algorithm are discussed in detail in chapter 3.

Selection of dynamic traffic assignment modelling software was not included in this study project. DTALite and NEXTA were prescribed to for dynamic traffic assignment modelling. These softwares package have significant importance in the field of DTA analysis and simulation and also famous for its easy and convenient procedure. It also provides easy access to user to visualize the result for analysis. Detail discussion about the working on software packages are mention later in this report.

This chapters covers some of the software packages that are used parallel for the same purpose. These software are also wieldy use for simulation traffic environment and performed modelling task at different level of analysis. The discussion provides the general introduction about the software with their some specialize feature along with the visualization how it works and look like. The discussion are as follows;

2.4.1 DYNASMART-P:

This software package has ability to perform the simulation and model the traffic environment for large planning task. The acronym of DYNASMART-P is Dynamic Network Assignment-Simulation Model for Advanced Roadway Telematics (planning version). DYNASMART-P version 1.3.0 was released by the Federal Highway Administration through McTrans in February 2007. Later on, this software package faced some problem in implementing real environmental issues with some practicality problem. So with the help of funding from Federal Highway Administration another project were started that encounter these problem, DTALite and NEXTA are the result of this project.

The software is still in use and has following significance in this release, (Mactrans, 2007)

- *Convenient import of network and demand data from other planning models*
- *Click-and-drag network/control creation and editing interface based on background imagery*
- *Easy conversion of baseline static OD matrix to time-dependent OD matrices*
- *Generation of default movements and signal control data for fast deployment*
- *Improved loading and display speed for large-scale network datasets*
- *Calculation and display of link- and network-level toll revenue for HOT or tolling applications*
- *Easy redistribution of user classes within vehicle and path files. This allows for flexible implementation of various planning scenarios*
- *Capability of modeling large networks*

This software package is available in various prices depending on the use and the requirement of various features. The software organization is also provide technical assistance for free on full package purchase.

The software provides help in decision making on transportation network planning and traffic operations. Simulation-based dynamic traffic assignment enables to evaluate ITS deployment options. This package uses demand forecasting procedures for planning applications in conjunction with dynamic network assignment models. DYNASMART-P enables the user to evaluate the traffic characteristics in the given traffic network. The flow obtained from the decision of individual traveler seeking for best suitable path between origin and destination on a given network. Figure 2 shows the user interface of the software package.

The input data requirements for DYNASMART-P are similar with other traditional traffic assignment and simulation models that takes network related input and demand on the network with the loading patterns. The input data requirement vary with the analysis level of network and also by output requirement. This software package also is capable to deal with complexity of the network like High-Occupancy Toll (HOT) lanes, ramp metering, High-Occupancy Vehicle (HOV) lanes, transit service, incidents and surface street interaction with controlled intersection. Applications of the latest version can performed simulation of metropolitan and regional networks with up to 30000 nodes and 10,000 links with more the 500000 vehicle. This can possibly take several hour on normal PC. At maximum it can deal with 40k nodes, 100k link and more than a million of vehicles (Mactrans, 2007).

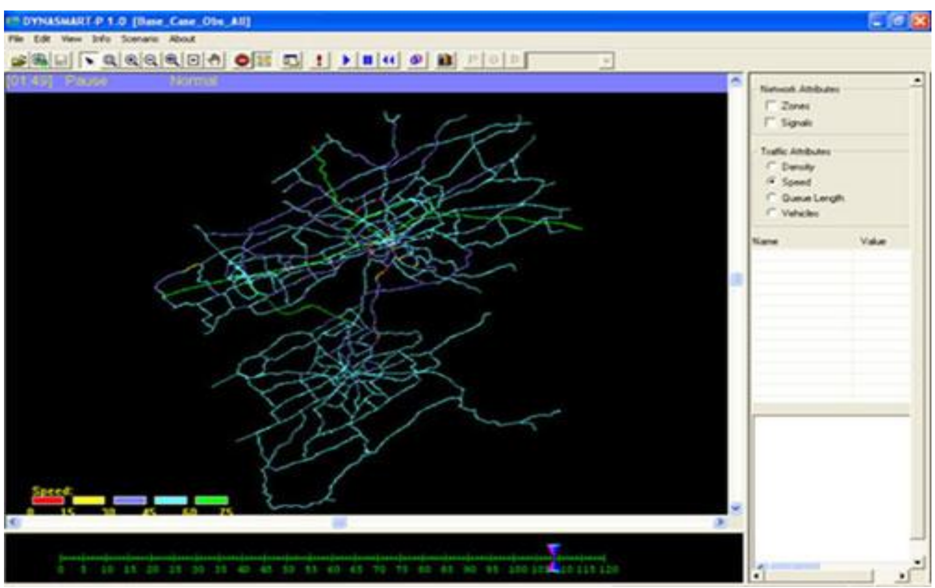

Figure 2: Interface of DYNASMART-P (FHA, 2015)

2.4.2 AIMSUN:

Traffic modelling software Aimsun is famous in analysis and performing task in very simple and user friendly environment. The software ranks as sixth major commercial modelling software in long term research program at university of Catalonia (Jordi Casas, 2010). The acronym of AIMSUN is Advance interactive microscopic simulator for urban a non-urban networks.

Aimsun package provides large scale application in traffic operation and planning. This is a commercial software so mainly offer the features that help widely in transportation system management. The most common applications are as follows, (aimsun, 2015)

- *Highway capacity manual analysis*
- *Assessment of Bus Rapid Transit and Signal Priority scheme.*
- *Optimization and feasibility analysis of High occupancy vehicle (HOV) and high occupancy toll (HOT).*
- *EIA (environmental impact assignment) and traffic safety analysis.*
- *Construction work zone analysis and management and etc.*

The software also provides the functionality to perform four stage travel demand modelling and also the integration with other processes. The use of this software enables the software to start the transportation modelling from scratch, from stretch by processing the raw geographical and socio economic data. This package can perform all tasks with in the project without using any other outsources help. Figure 3, shows the working interface of AIMSUN software. To use the software the user needs to perform small programing tasks to give function to the models in any aspect. Familiarization with the basic programming is the pre request of this software.

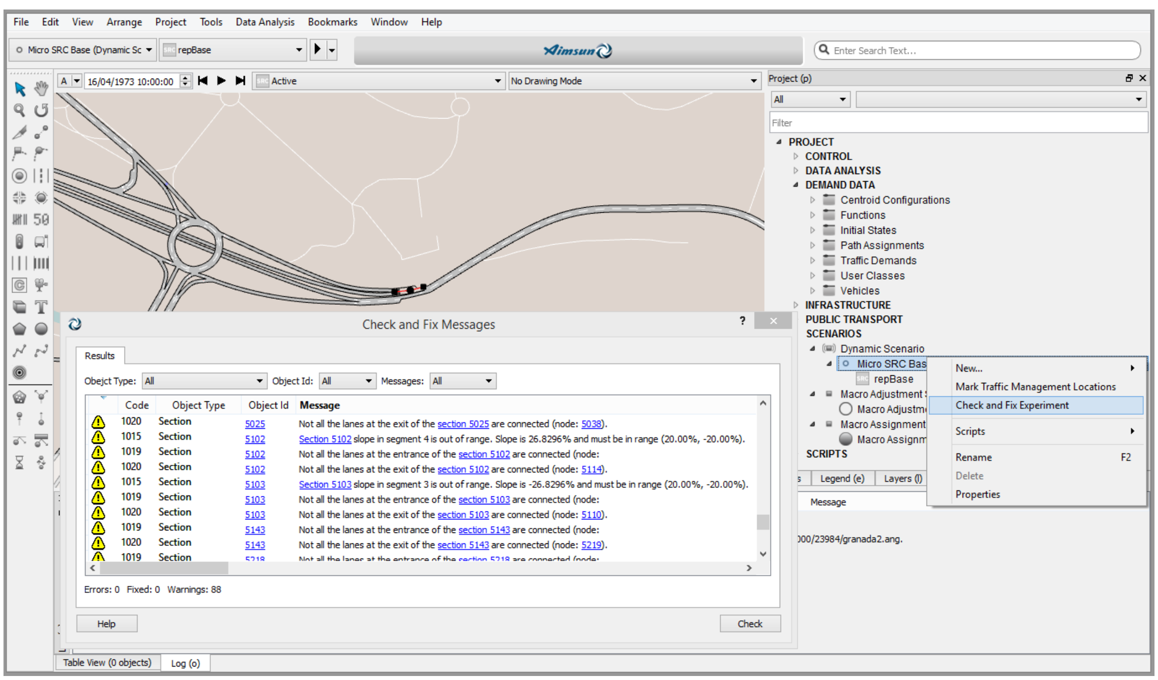

Figure 3: Working interface of Aimsun (aimsun, 2015)

In the domain of Dynamic Traffic assignment modelling the software package provides both stochastic and discrete route choice model at the level of microscopic and mesoscopic modelling. Aimsun gives the flexibility to perform recurring and non-recurring condition in the traffic environment with an appropriate level of accuracy. It also performs the dynamic traffic assignment with the general algorithm of deploying the individual on the network and then process accordingly. The general processes with in the Aimsum to perform the dynamic traffic assignment are shown in Figure 4.

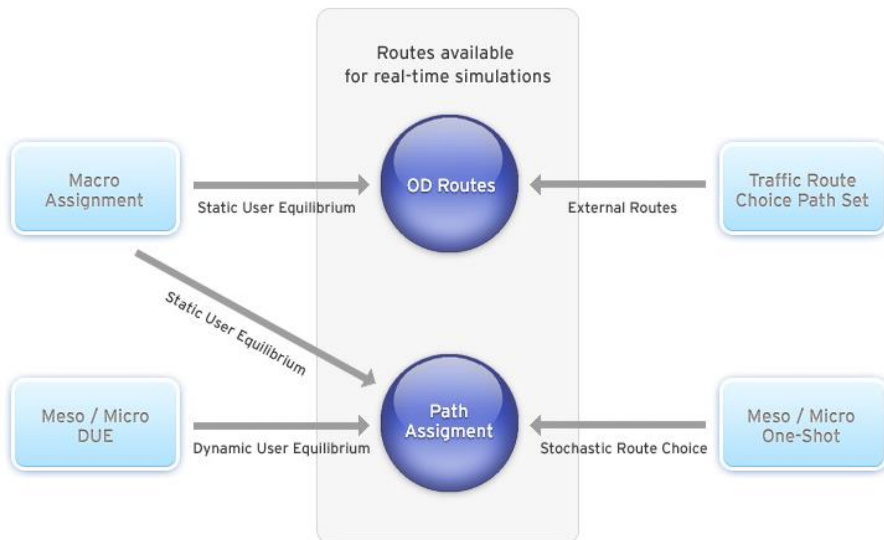

Figure 4: Dynamic traffic assignment process in Aimsun (aimsun, 2015)

2.4.3 Trans CAD:

TransCAD is highly capable and most efficient software which enables the user to integrate with many other software with flexibility. It is a comprehensive flexible tool to perform travel demand modeling. This software also provides wide range application in transportation filed like four-step travel demand models, travel demand modeling including sketch planning methods, activity models and other advanced disaggregate modeling techniques (Corporation, 2014). In the traffic assignment workability the package provides the extensive sets of option to perform the assignment task. It can also enables the user to compare the result in between the result obtained from these assignment. In assignment capability TransCAD can perform the modeling of intercity passengers and freight traffic. Figure 5 shows the working interface of software.

TransCAD dynamic traffic assignment model addresses the problem that is faced in the static assignment by dividing the OD departure by time period. In modelling it assign the OD trip by time period and effectively manages the trip introduce in the network at different time periods. Along with other algorithmic approaches the software also provides the in depth clarification of each calculation performed in the modelling process. There are many other features available in the package that make it different from other available softwares.

2.4.4 VISUM:

VISUM is a behavior based multi-purpose traffic simulation program. It is a tool which gives a chance to do optimization of complex technical systems with the help of simulation. It deals with a variety of urban and highway applications, by integrating public and private transportation. Complex scenarios can be visualized to an extent of detail to demonstrate the operational aspects of the traffic model. It also provides with the opportunity to model other pedestrians and cyclists and to replicate their behavior to simulate a real life like situation. This software is also wieldy use for commercial purposes. Figure 6 shows the user interface of the software.

Visum also uses the 4 step travel demand modelling to perform the modelling. Along with other dynamic traffic assignment software visum use the general DTA algorithm to perform the task.

2.4.5 MATSIM:

MATSim is also a fast dynamic and agent based traffic simulation software it takes couple of minutes for a single simulation of a complete day of traffic. It enables the user to implement agent-based transport simulations on large-scale. The software provides the additional functionality as modular that allow user to add your own algorithms for agent-behavior and plug them into MATSim. Currently, MATSim offers a framework for demand-modelling, agent-based mobility-simulation (traffic flow simulation), re-planning, and a controller to iteratively run simulations as well as methods to analyses the output generated by the modules. The software has capability to run scenarios with millions of agents or a network with thousands of link but it also need a fast desktop with high processing memory. It can also enables the user with its fast visualizer to view the agent activity in simulation. The software is an open source software and can used free of charge.

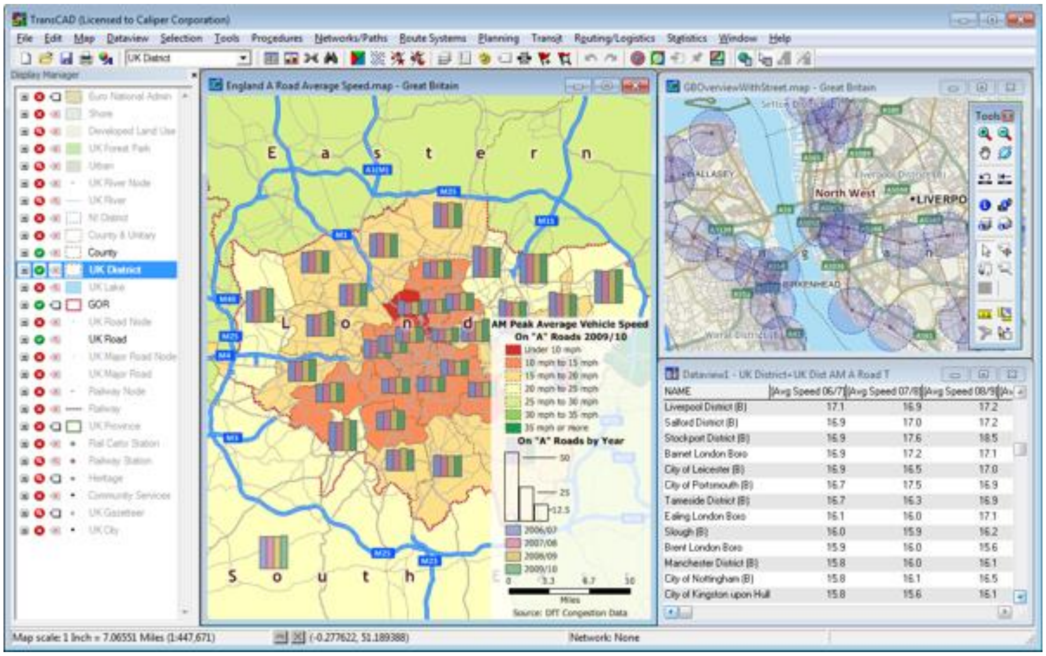

Figure 5: Working interface of TransCAD (Corporation, 2014)

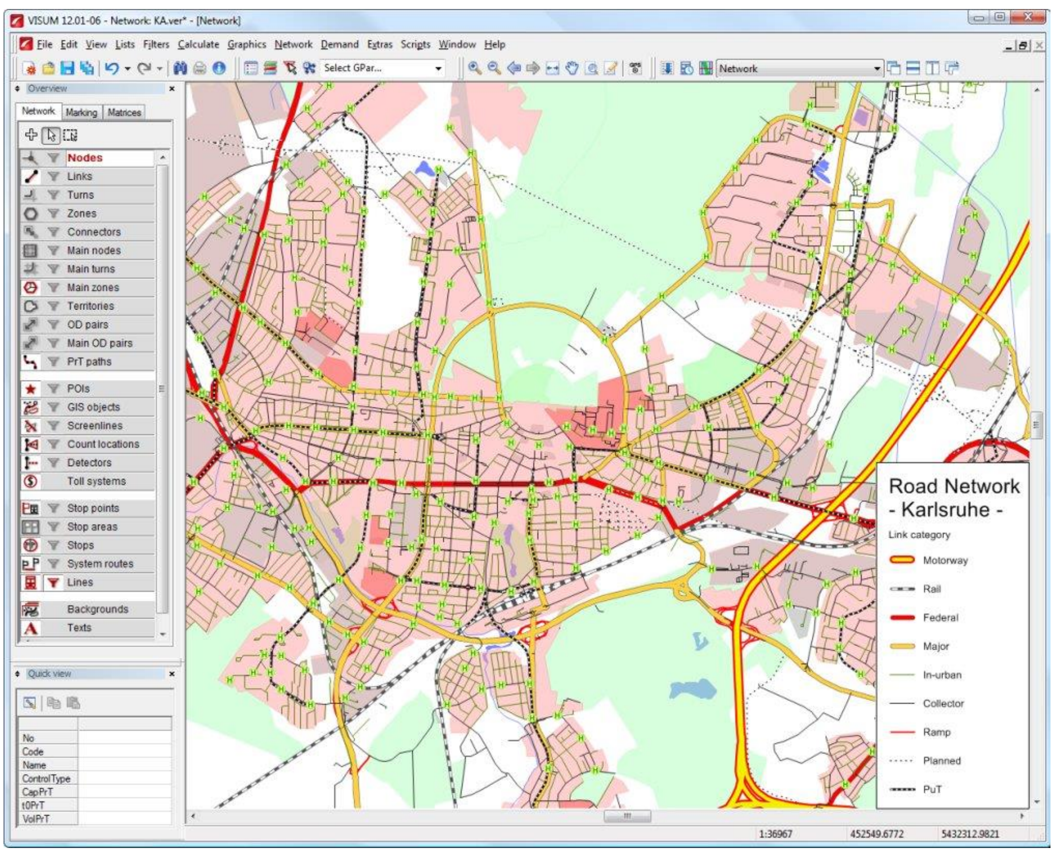

Figure 6: VISUM user interface (PTV, 2015)

CHAPTER 3: DYNAMIC TRAFFIC ASSIGNMENT

3.1 General

From the perspective of travel forecasting and regional planning, the Dynamic traffic assignment (DTA) model is more effective in use than static network analysis. The DTA provides the details of travel choices, traffic flows, time and cost measures, and other specific outputs depend on the use of the software. The output obtained from the DTA is more realistic on the inputs of time variability of traffic. The results output from the DTA are used to evaluate many meaningful measures related to the individuals' travel time and cost, and also for the regional planning of the network measures.

The Dynamic traffic assignment, in the state of flux, has evolved significantly since the important work of (Merchant D.k and G L, 1978). There is still interest in the DTA, particularly in the development of approaches that can be set up for the planning and real-time applications. Many practitioners are still developing and enhancing the capability of the software by means of the integration with other softwares. It increases the associability of realistic results in less effort. In addition, researchers became even more aware of the theory of DTA and is still relatively undeveloped. New approaches are needed that account for the challenges of the application domains and for the fundamental questions related to tractability and realism (Zilialaskopoulos, 2001). Next section includes the review on dynamic traffic assignment along with the basic concept of static assignment.

3.2 Introduction and Review:

Both the models (normally traffic assignment and the conventionally traffic assignment) proceed the network capacity and O-D demand as constant and unvarying w.r.t. the time interval provided. In the unrealistic approach, all the O-D matrix trips are completed within the same time period (as assumed by the slandered or static traffic assignment models). The temporal distribution of the demand over the period must vary significantly, along with the numerous levels of flow, traffic jam, and short and long traffic congestion (Corporation, Caliper, 2007). In addition, there are many O-D trips which have higher travel time that leads to wrong computation of results. This problem can be resolved by dividing the O-D departures by time periods, where the time period is referred to the start and finish time of journey during the day. It has been proven and observed from the related research that the flow and congestion result are representing more real condition than the standard traffic models (Corporation, 2014). Figures 7 and 8 show the flow profile of conventional assignment i.e. the static and dynamic traffic flows respectively.

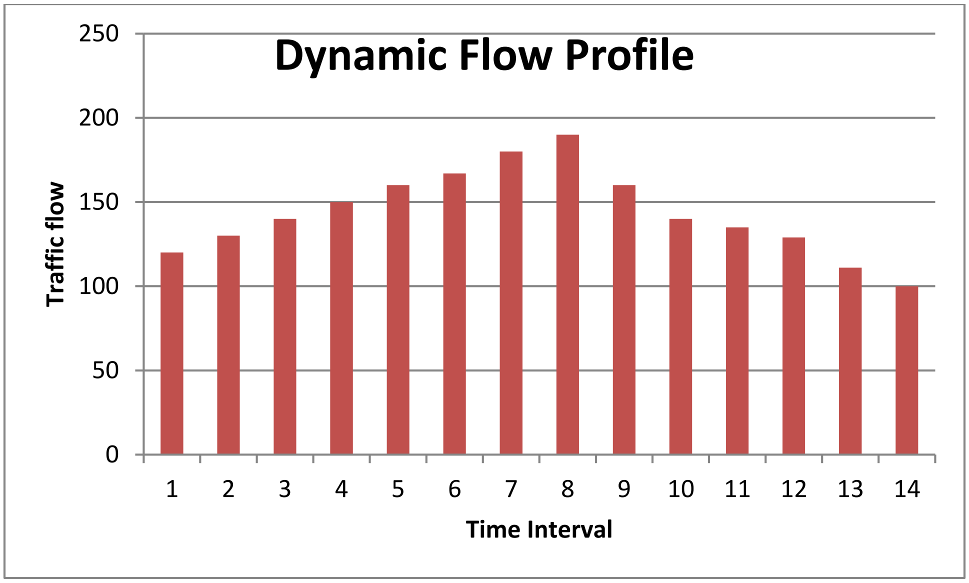

Figure 7: Dynamic Flow Profile

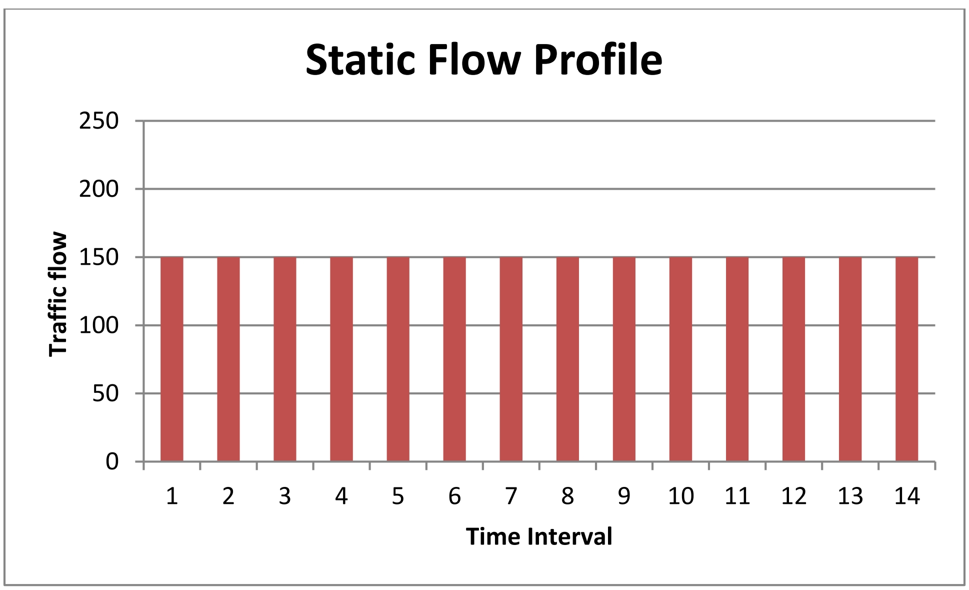

Figure 8: Static Flow Profile

The conventional static traffic assignment model is based on Wardrop's first principle (Wardrop, 1952). It has been acknowledged in the field of transportation planning and designing. A simple traffic assignment model covers the interaction between the supply and demand for a traffic network. On supply side, the collection of individual users' route choice determine condition on network links i.e. congestion and on the demand side, each user seeks the minimum cost route non-cooperatively. A user equilibrium state reach when no individual can reduce his/her travel cost by unilaterally changing route or when the journey time in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route. This is actually Wardrop's first principle.

A static assignment model considers steady-state or constant traffic flow condition over the study time period: preferable design based on AM (morning flow) or PM (evening flow) or average peak hour. The solution of link flows, link cost and other quantities can be viewed as averages over the analysis period. However this condition is questionable during highly congested time (Salvin H, 1996).

It is often observed that travel time at a given link is increased than reaching at the end. If we analyze it as a whole network, different locations became the problematic areas due to high congestions level at different times. Clearly the assumption of uniform O-D during the peak period can be defended with empirical evidence. (Corporation, Caliper, 2007)

By ignoring the temporal distribution of traffic, a static assignment model tends to underestimate travel times as a link performance function. It is generally convex and travel at the average flow value which is less than average travel time. Temporal aggregation errors are more complicated to analysis if put in equilibrium assignment context. As travelers route choices and network performance, interact in non-linear way. Aggregation errors are conceivably dependent on the data and the actual DTA models employed.

To portray a more realistic traffic situation, a dynamic model is required. In general a dynamic traffic assignment model takes trip O-D departure by time period and outputs dynamic link flows, link cost and other required variable as input. The requirements of input vary with respect to the output needed and also with the requirement of the software. Like output of emission on each link or agent needed, the emission data on each mode is used in the network. An equilibrium dynamic model is an extension of static user equilibrium condition: at each departure time, no individual user can reduce his/her experienced travel cost by unilaterally changing routes. Usually the temporal granularity of the dynamic model is relatively short. Perhaps it ranges from a minimum of 1 minute to a maximum of 15 minute interval. This should definitely increase the computation burden for equilibrium DTA model.

3.3 DTA Modeling:

In a modeling process, the aim of assignment modelling is to estimate the condition of road traffic network that is obtained from the mutual interactions among the choice of routes that individual travelers used to commute from their origins to destinations, and the traffic condition i.e. congestion that comes from their travel choice over the network. To fulfill this requirement, the result in every scientific method several assumptions need to be developed in traffic assignment modelling. Especially regarding how traveler route choice behavior is modeled and how traffic flows and conditions are represented.

As discussed earlier, the behavioral assumption: the road users choose the available route that have minimum travel time in between their O-D trips. The aim of individual traveling is not only reach to the destination but also involve the travel time, travel cost or other disutility that travelers need to avoid. In general individuals are assumed to choose the route having the minimum time and cost, or the minimum disutility. According to the research (YI-CHANG CHIU, 2011), congestion also effects the route choice and hence increase the impedance variability of particular route to avoid the travelers realistic route choice. Each traveler succeeds or moreover every route used between O-D has the same travel time then the condition is User equilibrium (UE). Traffic assignment algorithms find these connection to determine link volumes, travel times and route that satisfy this equilibrium condition by iterative procedures.

According to the simplifying assumptions, the concept of equilibrium is meaningful for several reasons that benefit in the understanding and modeling which shows nearly the real picture of the behavior. Other major assumption in the traffic assignment concerns the manner of representing the traffic flow and conditions—that is, the way that travelers' route choices are related to the network wide congestion and travel times. Historically, traffic assignment methods focused on representing the average or the steady-state conditions over an analysis time period that was long compared to the time scale of traffic dynamics. Due to these difficulties, travel times and volumes on links and routes can be considered to be constant over the analysis period.

However, a static approach by definition, cannot reflect either variations over time in traffic flows and conditions, or changes over time in characteristics of transportation system components. Thus, static assignment is ill suited to analyze either traffic congestion effects at a fine-grained temporal level, or many of the measures that can be taken to address congestion.

Started in the late 1970s, research into DTA, by representing time variations in traffic flows and conditions, has tried to reflect the reality that traffic networks are generally not in a steady state. To retain the advantages of an equilibrium approach, the notion of user equilibrium needed to be extended in two ways.

The first extension generalizes the static model's perfect traveler information assumption and route choice criterion, recognizing that travel times on network links vary over time. Travelers are assumed to know or anticipate future travel conditions along with the journey (through learning from the past trials) and, in choosing an O-D route. They are assumed to minimize the O-D travel time that they will actually experience; this extension required the development of describing time-varying network traffic condition efficiently and finding shortest (least time) routes in networks where link travel times change over time.

The second extension recognizes that, in a dynamic approach, the user equilibrium condition of equal travel times on used routes applies only to travelers who are assumed to depart at the same time between the same O-D pair. This extension disaggregated the equilibrium condition, so that the equilibrium condition is to be established for each departure time (typically ranging from a few seconds to several minutes) rather than over the entire analysis period. This result is known as dynamic user equilibrium (DUE) (YI-CHANG CHIU, 2011) (Jaimison Sloboden, 2012).

Finding a DUE solution that satisfy DUE condition for a given network and time-varying O-D demand pattern is a non-trivial exercise. Figure 9 shows the characteristics of solution.

- Vehicle departing at different time are assigned with different routes.
- Vehicles departing at the same departure time between the same O-D pair but taking different routes should have the same experienced travel time.
- Experienced travel time cannot be realized at departure, but only at the end of the trip.

Figure 9: Characteristics of solution (YI-CHANG CHIU, 2011)

Figure 10 shows the common steps of equilibrium findings in dynamic traffic assignment and is presented in literature related to DTA modeling. The figure shows three common algorithmic component which are applied in sequence iteratively, until an equilibrium criterion is satisfied (Jaimison Sloboden, 2012) (YI-CHANG CHIU, 2011) (Zilialaskopoulos, 2001).

Network loading step provides a set of route choices, routes flow and characteristics are presented and also showed the route travel times after the selection of the route. In the route evolution step, set of route choice provided with respect to the network loading process. There are many analytical and simulation based approaches that represent change in minimum time (in seconds) interval.

Path set update give the current route travel times by analyzing the result by network loading like traffic congestion pattern and different identified travel time, for each departure time or assignment interval, the shortest experience travel time are found in this step by TDSP (time dependent shortest path) algorithm. The newly established TDSP for a particular origin and destination are update in this step for each iteration.

After the establishment of the shortest path, all individuals select the optimized route that is specific route, no longer efficient and may face longer travel time and high congestion. So Path assignment adjustment step performed logically from path set update results. Therefore not all the individuals are assigned to the route which has shortest travel time, in order to avoid overcorrection. This step generally refine with respect to the number of iterations. In every iteration, the least travel time or high performing route is increased by assignment flow and underperforming or high travel time route decrease with flow.

After performing the last step the algorithm turns back to the first step of the route evaluation step for finding a new traffic flow pattern which came from the route choice made.

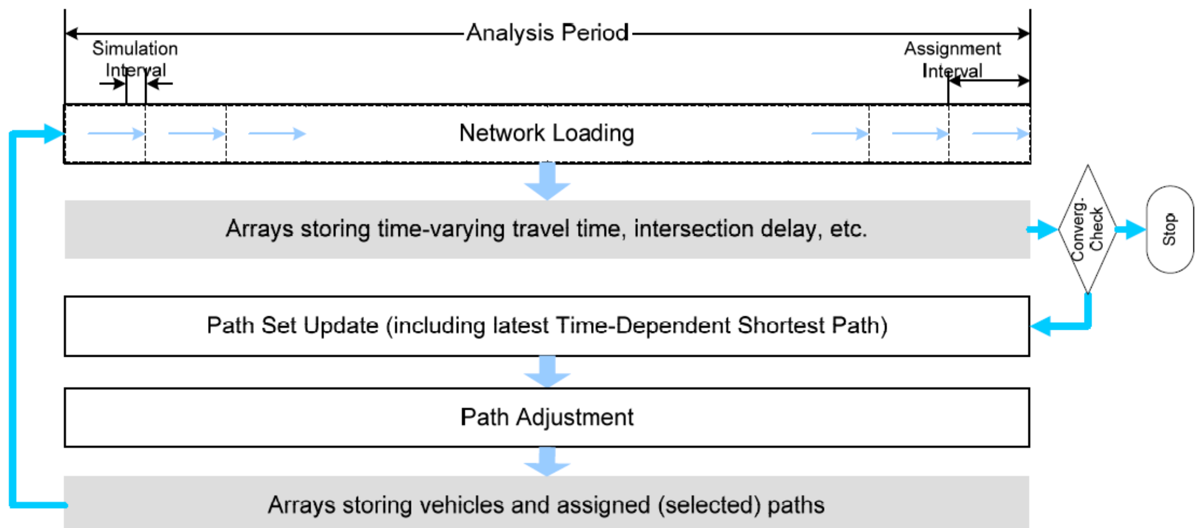

Figure 10: Dynamic traffic assignment Algorithm

3.4 DTA Modeling Applicability:

With application, DTA can be applied to models of different sizes and resolutions and to different contexts for analysis time frames. These three considerations are shown along different axes in Figure 11.

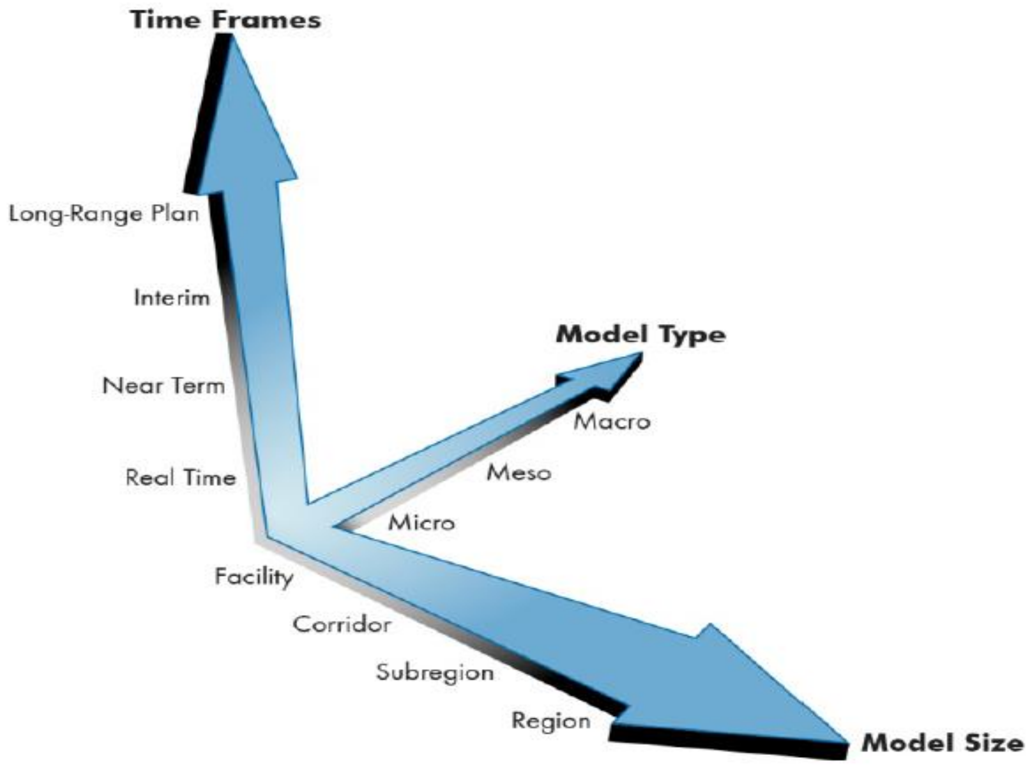

Figure 11: DTA Modeling Considerations (source Cambridge Systematics, Inc.)

DTA provide the variety of level of project from micro level model to macro level model, from facility to regional level and from long-range plan to a real time frame models.

3.4.1 Model Size

The size of model networks can vary significantly when dynamic traffic assignment tool is applied. Route choice is a major estimation of dynamic traffic assignment analysis, the size of the model network should include alternate routes to allow occur to choose route.

Improving software and computing capabilities are making it possible to apply DTA at different scales. Figure 12 is an illustration of how different scales of DTA could be applied.

Model Timeframes and Analysis Contexts: DTA can be applied for various time periods and time intervals. DTA also can be applied to short-term and for long-range plans, to fine tune travel demand estimates, and to conduct operational analysis on design improvements. DTA may be incorporated into macroscopic, mesoscopic, and microscopic models.

- Macroscopic models: For the purpose of this document, macroscopic models refer to regional travel demand models for both traditional trip-based models and Activity-Based Models (ABM).

- Mesoscopic models: These models use aggregated flow relationships and include more precise representation of traffic operations than travel demand models. DTA applications are strongly associated with mesoscopic type modeling software.
- Microscopic models: These models simulate individual vehicle-to-vehicle interactions and traffic control strategies. DTA applications in microscopic models provide the most complex analysis of all the model types.

Traffic modeling often involves a combination of some or all of these model types. This concept is referred to as Multi-Resolution Modeling (MRM).

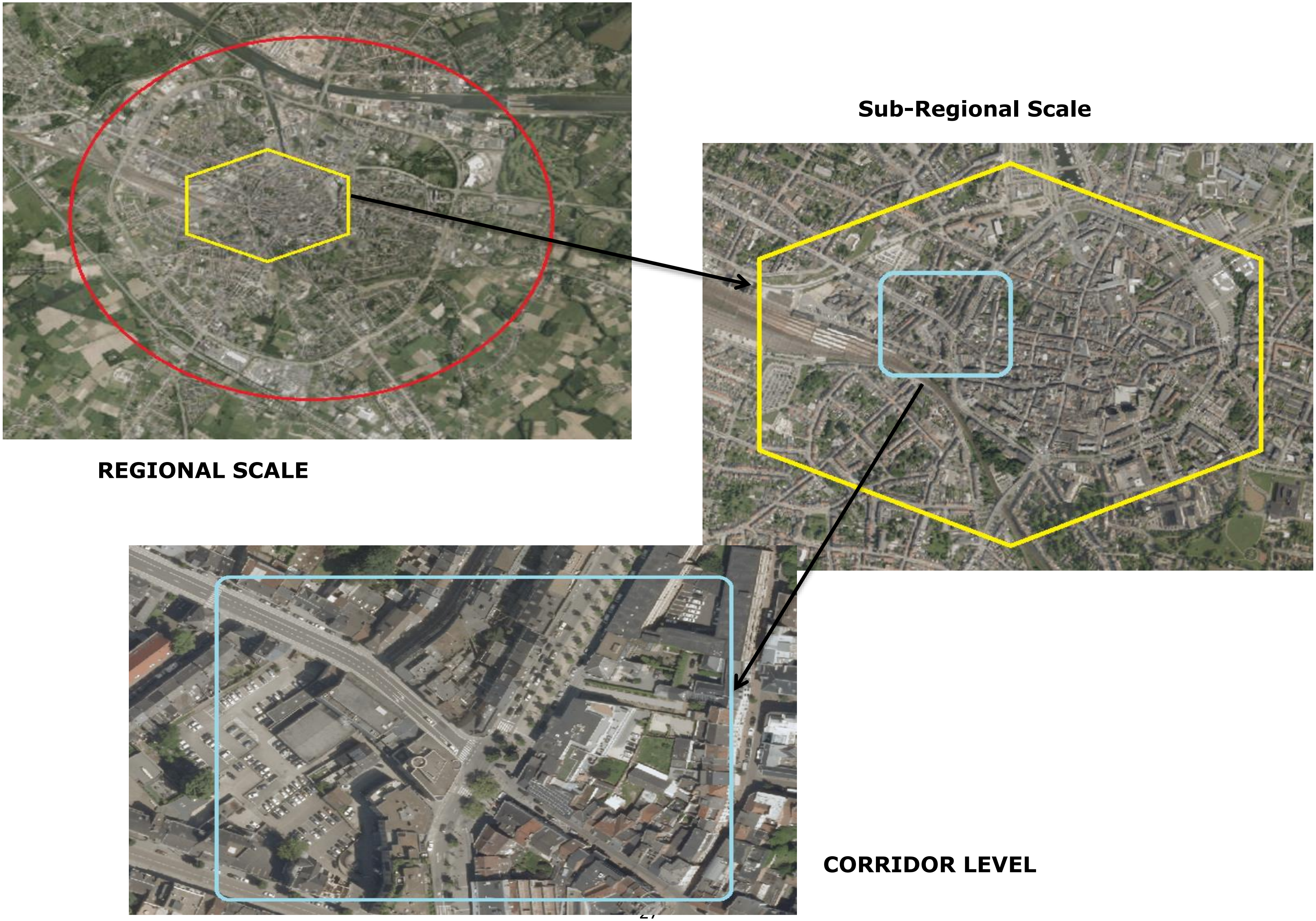

Figure 12: Model scale (source own work, Hasselt image from geopunt.be)

CHAPTER 4: INTRODUCTION TO SOFTWARE

4.1 General:

To perform the task of dynamic traffic assignment modeling, DTALite and NEXTA softwares were selected. This chapter deals with the introduction of the softwares with their features and also the data requirements for developing the model.

These softwares are open source softwares distributed under general public license (GPL). This is an extension of DYNASMART-P which is also a dynamic traffic assignment tool. This extension project was majorly founded by FHWA agency to enhance DTA simulation. The extension was made to make it more simple, understandable and light in working. Extension was also done to make it capable to deal with road pricing, emission control, safety and crash strategies, comparison of various alternatives, use the performance measures in implementing and planning decision. These modifications in the software were not done at once. The development process has been going on since 2009 and the last modification came with the name of NEXTA version 3 in 2014. In this project of dynamic traffic assignment development, the NEXTA version 3 was used. These softwares are open source, therefore information regarding the modeling process is not properly stated. The last proper guideline was developed for an earlier version in 2011. The version 3 came up with some different features and easy options to use and access various tools available within the software. It came up with more rigorous theoretical background in queuing analysis and QEM quick estimation method. This report do not cover the modification and in depth theoretical background of these softwares.

4.2 NEXTA:

DTALite/NEXTA software are open source and easily available. NEXTA is an acronym of Network Explorer for Traffic Analysis. NEXTA provides user the access to open source graphical user interface (GUI) for analysis of traffic assignment and it also supports in alteration as per requirement. The purpose of NEXTA is to assist the preparation, analysis of transportation assignment, data scheduling, post-processing and simulation. NEXTA works with association of DTALite. For analysis, it uses the output generated from DTALite and also assist in further modification and adjustment in the network. It also gives the visual compression (if needed). The user interface of NEXTA is shown in (Figure 13).

4.3 DTALite:

DTALite is the DTA tool to perform dynamic traffic assignment. The acronym of DTALite is Light Weight Dynamic Traffic Assignment Engine. The software is a simple and highly efficient tool to perform the DTA task with less timing as compared to others. It takes approximately an hour to run the half million vehicles with 10 iterations (NEXTA, 2015). It requires multi-core and multi-processors to run the simulation and perform the whole task. DTALite uses the simple input file and that must meet certain requirements to run the software. The input file is in the form of csv. It also needs to meet some necessary data requirement just to start the process. The DTALite window is shown in (Figure 14).

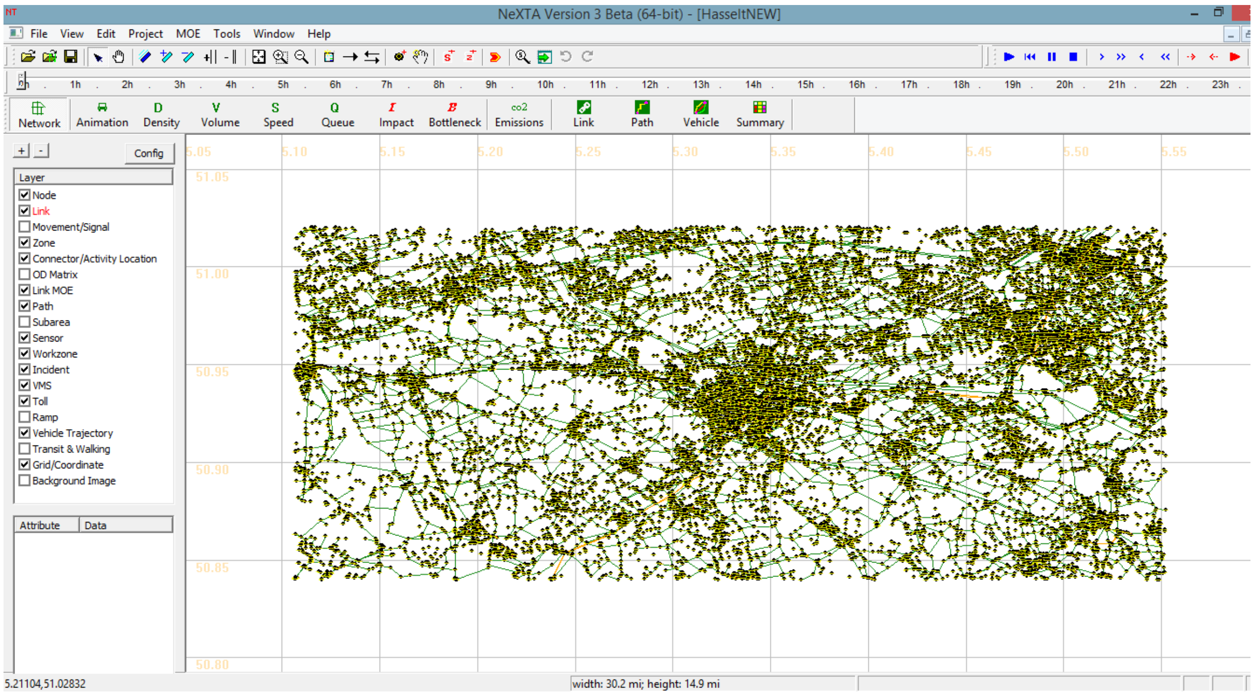

Figure 13: NEXTA GUI showing the network of Hasselt

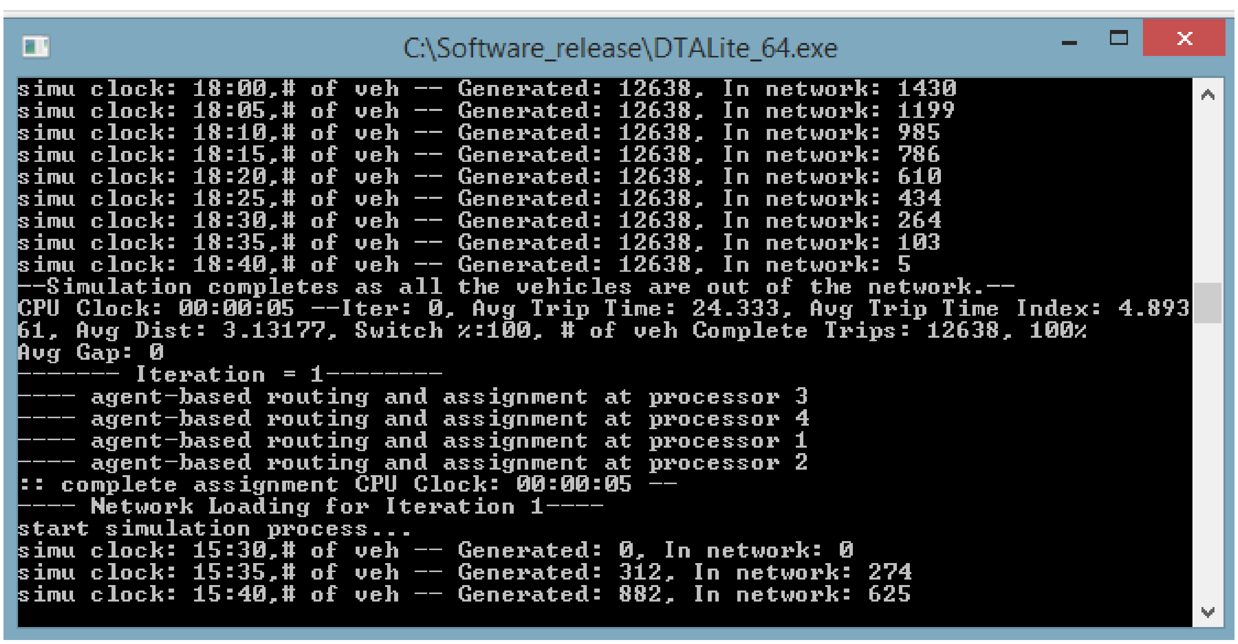

Figure 14: DTALite exe showing running simulation

4.4 System Design:

Dynamic traffic assignment software tool need to understand the temporal demand for origin and destination (O-D matrices) and assign individual vehicle to the various paths in between origin and destination according to dynamic travel time. (Figure 15) shows the physical procedure that the individual vehicle follow during the modeling. First, vehicle moves through a link by link transversal model. This involves speed-density relationship and outflow capacity constraints. The next stage is the node transfer function that involves specific left-turn or through movement and other attributes for signalized node. Travel time updates are sent to the time dependent shortest path model to help in the selection of a specific route through route choice utility function or traffic assignment rules (NEXTA, 2015). The new updates of routes are then fed back to traffic simulation section for new iteration.

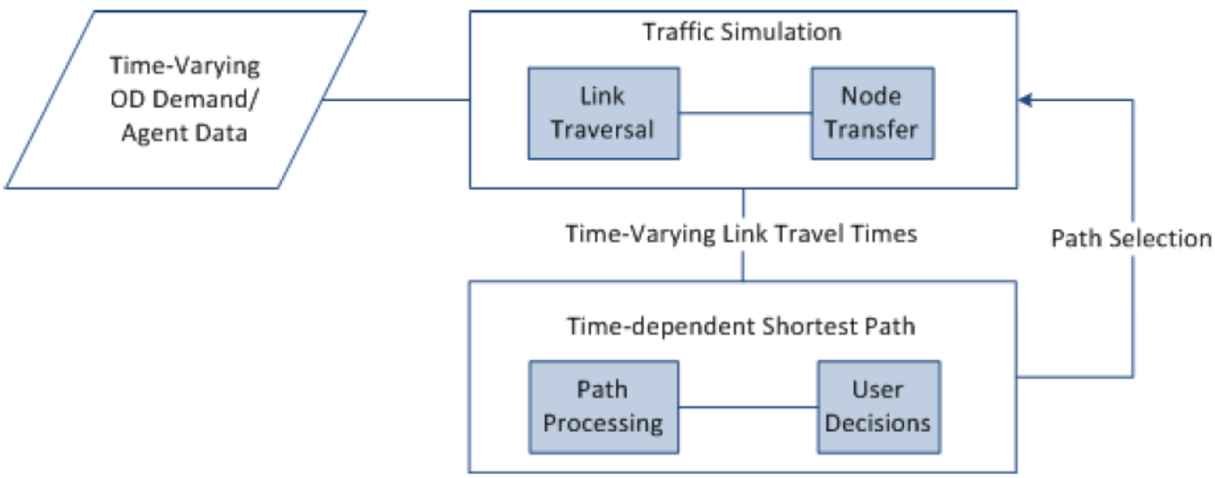

Figure 15: Modeling framework in simulation based dynamic traffic assignment

4.5 Data Flow Process for Dynamic Traffic Analysis:

The whole process is designed based on the practical challenges faced by multi-level dynamic traffic analysis. The system needs to facilitate the data importing, exporting and analysis.

The data types are generally divided into network data, demand data and control. Network data deal with the nodes and link specification, demand data usually depend on the traffic and vehicle data in between origin and destination while control data deals with the signal timing and phasing data. The flow chart of processing the data from initial data input level till exporting level is shown in (figure 16).

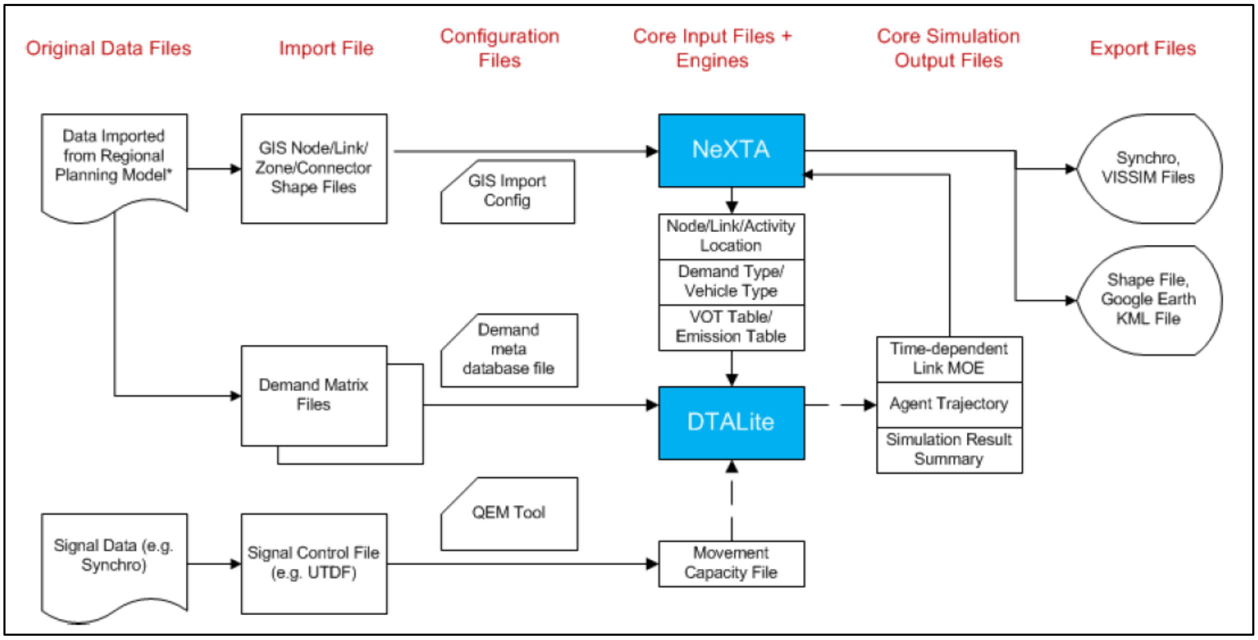

Figure 16: Work flow analysis in NEXTA and DTALite

The working process in these software are involve on different step which depends on the required output need. This software package has ability to work flexibly with different input file and in corresponding provide different file which enable the user to openly choose this DTA tool for project. The process of working is generally divide into input part processing and output part. As shown in Figure 16 the network input that is obtain from geographical tool need for NEXTA for developing the desired network further the demand data with movement file facilitated the DTA tool to perform the dynamic traffic assignment. The core simulation output file obtained from DTALite which then analysis through NEXTA or by the Excel as the output file .csv in nature.

4.6 Data structure:

Further in this chapter is the description about the data structure used in NEXTA and DTALite. Input data files are important requirements for developing a DTA model. Output data are the DTA model results that are obtained after running the simulation (Dongmei Lin, 2015). As shown in Figure 16, the input data comes from three different sets. One is used for networking which is called as network input file (the most important sets of data), second data set belong to traffic flow that is called as demand input file. Both these types of input files are discussed in next section. The third set of input data files are traffic signal, movement and scenario based data. These type of data sets are not covered in this project but is discussed briefly in the coming section.

4.6.1 Input Data:

i. Network Input file:

The network input file contains the main component for developing the traffic model visualization network. Node, link and zone are major representation of network. These are the basic component to visualize the network in many microsimulation softwares. This software is also used to certain flow of file to take input for processing. Each of these elements needs to be defined with certain attributes which must have assigned values in their respective file. In DTALite and NEXTA, the network input files define the basic node-link structure, along with attributes for each link and node. The Table 1 shown below describes the input file in the essential data file column needed for network development along with their definition. The table also labels the necessary attribute column that present the column name or attribute that must be present in that input file.

Table 1: Essential input file for network establishment

Essential Data Files	**Definition**	**Necessary attributes**	**Corresponding Information Layer**
input_node.csv	Provide input of nodes in the network	node_id, x, y	For Node Layer
input_link.csv	Provide input for the link type of the nodes	input_node_type, input_node_type_name etc.	For Node Layer
input_node_ control_type.csv	Provide info to input link file about control type of the nodes	input_node_type, input_node_type_name	For Node Layer
input_zone.csv	Provide info about number of zone, with unique ID	zone_id	For Zone Layer
input_link_type. csv	Types of link type present	Input_link_type	Link Type Definition: default file is available
input_activity_ location.csv	Provide activity location or activity node with respect to zone	zone_id, activity location	-

ii. Demand input file:

The most important type of input data is demand file to describe the number of trip among different zones in the network. There are a variety of formats available to input demand input file. These file are not giving input directly to the system but the main file of meta_data manages all demand files to finally make it ready for the process as shown in Figure 17. The table 2 shown below describe the input file that comes under demand data type with their definition. In which input_demand_meta_data.csv and input_demand_type.csv are most essential files.

Table 2: Essential input file for demand data feeding

Essential Data Files	Definition
input_demand_meta_data.csv	Provide the characteristics of demand data to be loaded for DTALite
input_demand_type.csv	Provide different demand types and patterns for the trips in the input demand files
input_vehicle_type.csv	Provide emissions analysis for different vehicle types.
input_VOT.csv	Provide VOT (value of time) distributions for different demand types
input_vehicle_emission_rate.csv	Provide quick look on emissions analysis and rate.

In the demand input file the most important file is input_demand_meta_data.csv. This file defines the necessary characteristics of the demand data and sequentially take input from the other input file and upload to DTALite for further processing. The relationship and the flow of demand input file are shown in Figure 17.

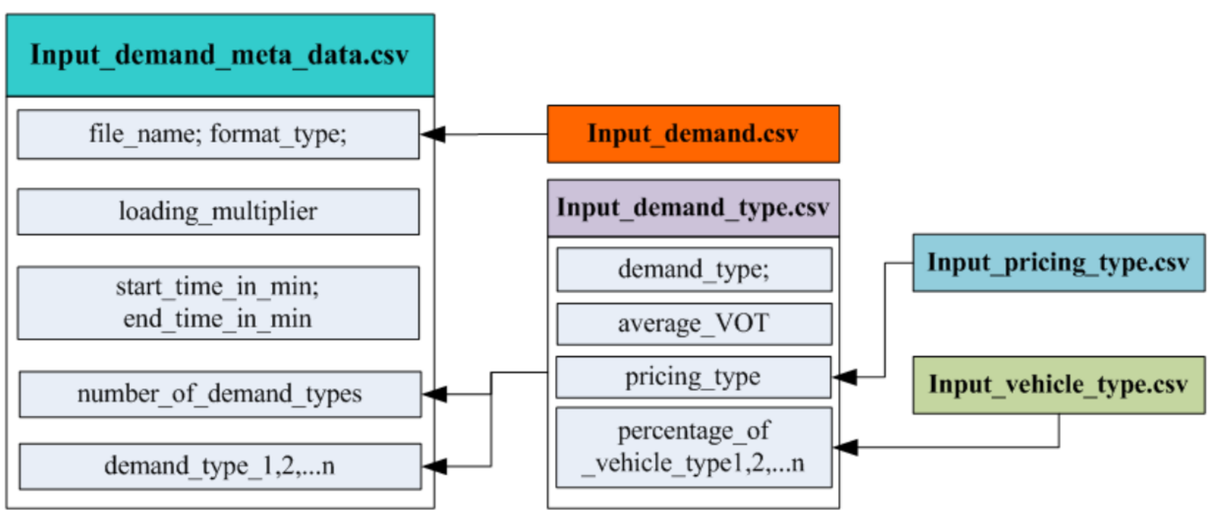

Figure 17: Work-Flow of demand input data file (Dongmei Lin, 2015)

iii. Other input files:

There are other numerous number of input files that automatically generate once the project is saved. It depends upon the data availability and need of output to complete input files. These input files are not necessarily needed to edit only the specific output required. These input files were not used in this project.

Table 3: Other input file required for different task

Input file name	Definition
input_movement.csv	Provide turning movements at all nodes in the present in the network
input_phase.csv	Define the traffic control signal phase at all nodes present in the network.
input_sensor.csv	Not necessarily use need to use sensor data if needed in the study
input_subarea.csv	Provide understanding of a subarea polygon, based on its vertices, for subarea cut.
scenario_link_based_toll.csv	Gives the understanding about the tool with respect to location and characteristics for simulation use.
scenario_work_zone.csv	Use to define the work zone area in the simulation in different scenario

iv. <u>Output files:</u>

The wide range of output files were generated when the simulation was run. All output files are auto generated after the simulation but only some of them have results in accordance with the input data and the method of simulation used. These file are very large in size and depend on the network use and also the number of input used in it. List of output files are shown below in Table 4. Detailed discussion of each agent in the simulation is presented in the result chapter.

Table 4: List of output file generated after simulation

File Name	Description
output_summary.csv	Contains detailed information about traffic assignment iteration results
output_multi_scenario_results.csv	Contains the simulation results for multiscenario results
output_agent.csv	Shows the specific information of each agent in the simulation network
agent.bin	A binary version of output_agent.csv file
output_ODMOE.csv	Contains ODMOE simulation results
output_pathMOE.csv	Contains the specific information of path MOE
output_linkMOE.csv	Contains detailed results from the simulation aggregated at each link

output_linkTDMOE.csv	Contains less detailed results from the simulation, aggregated at each link
output_linkTDMOE.bin	A binary version of output_linkTDMOE.csv
output_MovementMOE.csv	Describes the MOE information of movement
output_NetworkTDMOE.csv	Contains time-dependent, network-level information about assignment iteration results over the modeling horizon
output_vehicle_emission_MOE_ summary.csv	Describes all results from emissions post processing

4.7 Way Forward:

This chapter deals with the discussion about the software and the input/output data files. Next chapter contains the procedural working of the software and the development of the model. The problems faced during the preparation of different files within software are also discussed in the following chapter.

CHAPTER 5: MODEL DEVELOPMENT WORKING

5.1 Introduction:

This chapter contains an in-depth explanation of the procedure for the traffic model development using DTALite and NEXTA. The focus of this research is to prepare the model for Flanders region. The data used in this project is provided by IMOB. This chapter describes the preparation of each input file that is necessary to run the software (see Table 1 and 2). Moreover, it also discusses the problems faced in the preparation of various input files and model processing stages. Initially, it was decided to develop the model for whole Flanders region but due to certain limitations such as the requirement for a high processing machine, the study area for the project was restricted only to the city of Hasselt.

As discussed earlier as well, the softwares used for the project i.e. DTALite and NEXTA require some basic essential input files in order to operate. (Tables 1 and 2) above describe the essential files required by the software. Also it is important to note that each data file must have an attribute data column present in it.

Dynamic traffic assignment usually requires a large amount of data. Moreover, the data requirement for the model mostly depends on the level of output needed. However, a minimal set of data was used for this project in order to make the model operational in the given softwares. Following is the description of the most important input files that are needed for the model development:

5.2 Input Files:

Once a new project is created, all the input files are automatically created in the project file which can be saved anywhere in the computer. A number of files are generated but only those files are needed to be filled which are required for the output.

Note: All the input files should be in the .csv format that can easily be edited by using excel. However, make sure that the MS-Excel is properly installed and is legal, otherwise saving and editing the file in the same format can become difficult.

Before the formation of essential input file, the Open Street Map (OSM) was used for selecting the area of Hasselt city which was then processed through QGIS to obtain the essential input data.

- **input_node.csv:**

This input file, as the name suggests, describes the nodes to the network. The nodes are points that either connect the two links or indicate the end or starting point of the link. The generated file must contain the node id and their respective x and y coordinates. For more advanced and professional level working, one can also define the name of the node, for instance the node can be a tree, a signal, an intersection, a pass through point or a signboard.

The auto generated input_node.csv file contains a number of columns as shown below:

- Name
- Node_id
- QEM_reference_node_id
- Control_type
- Control_type_name
- x
- y
- Geometry

The node_id, x and y coordinates columns are mandatory fields. The Geometry column is filled by software after successful simulation, however this particular simulation option was not explored in this project. The Control type column is for signalized intersections and other types whereas the Control type name is used to further refine the network. This file is simple to prepare if the node id and their x and y coordinates are already known. This given data just needs to be entered into the respective columns of the input file generated automatically.

Note: This input file comprises of the most basic as well as the most critical fields. Hence, it needs to be prepared carefully. This file acts as a node bank with each and every node along with its attributes present in the link file. If the file is not properly prepared, the following error as shown in Figure 13 may pop-up while processing and visualizing the network.

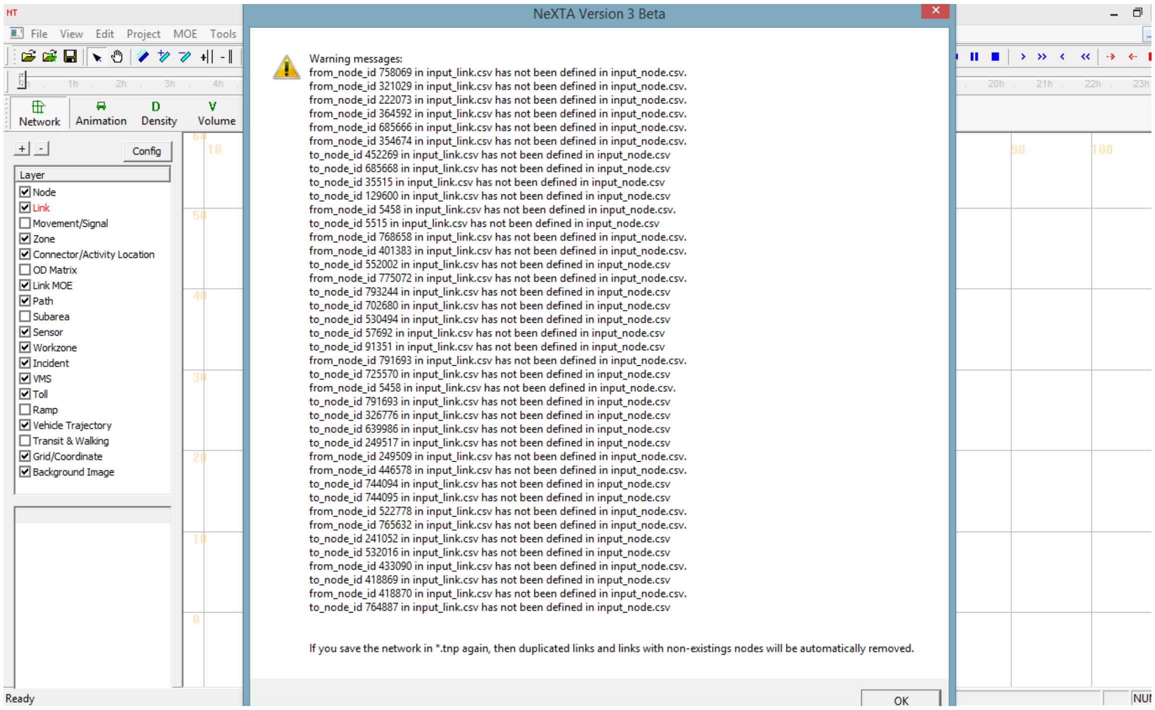

Figure 18: Shows the possible error if the node file not accurately prepared.

- **input_link.csv:**

The input_link file is also one of the most important input files required to define the network. This auto generated file takes a long time to prepare as it consists of 26 columns in software package version 3. Following are some of the fields included in the file:

  - Name
  - Link_Id
  - Speed_Sensor_Id
  - Count_Sensor_Id
  - From_Node_Id
  - To_Node_Id
  - Link_Type_Name
  - Length
  - Number_Of_Lanes
  - Speed_Limit
  - Lane_Capacity_In_Vhc_Per_Hour
  - Link_Type
  - BPR_Alpha_Term
  - BPR_Beta_Term
  - Jam_Density

Note: The number of input column varies with the change in version so keep in view which version is being used. The system of interconnection of input files vary in different versions but the essential input files remain the same.

The major columns that need to be filled are link_id, from_node and to_node. Apart from these three fields, some fields are also significant to enhance the network specification such as the number of lanes, link type, length of link, speed limit, BPR beta and BPR Alpha (Bureau of public roads-type). There are some columns that require to be converted into the respective case like the type of road definition in different region. This can be done with the help of simple Excel functions. Besides, there is also a need to homogenize the link_type_name with link_type in connection with the other input file fields. This work can be easily done by excel commands like 'if' and 'vlookup'. Other data like sensor and left turn data can also be used if the required data is available. However, only the minimal set of data has been used in this project. Annex 3 shows the portion of prepared input_link.csv file.

Note: When the study area is selected from the map, there are some links that start in the study area but end somewhere outside. Keep in view that the presence of such extra nodes and links creates trouble in processing the network diagram. For simple solution, NEXTA automatically deletes the to and fro nodes with links. Also, it can be perfectly done by using excel formula like 'vlookup' to manage the missing nodes in the network or to remove that link from the link list, preferably removing link is an easier task.

- **Input_Node_Control_Type.Csv:**

The Input_Node_Control_Type.Csv file can also be used depending upon the data availability for the particular node type. The following are the columns present in this auto generated file:

  - control_type_name
  - unknown_control
  - no_control
  - 2way_stop_sign
  - Roundabout

Some columns present in the file need to be symbolized with a specified number such as number 3 is assigned to a no- control intersection whereas number 2 is assigned to a 2-way-stop-sign. This coding is used in the node.csv file to represent the particular node types. The control type data can be employed depending upon the project scope and requirements. However, this type of data was not available for this project, therefore this file did not require to be edited for this particular project.

- **input_zone.csv:**

The Zone file is also an important input file that is required for the traffic assignment modelling process. The following are the columns included in this file:

  - Zone_ID
  - Production
  - Attraction

Initially, only the zone ID column is needed to be filled. The zone IDs can be filled randomly with no consideration to a particular descending or ascending order, however it must be made sure that all the zones as in the input_activity_location file (discussed in the later part of the section) are present in this particular file.

- **input_link_type.csv:**

This input file is used as a support file for input_link.csv file. This file helps to decode the link specifications that are used in the input_link file. The initial two columns in the file i.e. link type and link type name also appear in the link.csv file to represent the belonging of an individual link to a specific category.

The Table 5 below represents the link categories present in this project. It is also possible to change the default type as shown in Table 6, but it takes a long time and effort to change the programming behind this. In this project, however, we change the characteristics of the default links according to our requirements and make their representation by using the formula as shown in Table 7. After the successful preparation of this file, the network diagram with its property is completed.

Table 5: Given road type in the network

Cycle_way	Secondary
living_street	secondary_link
Motorway	Service
motorway_link	Tertiary
primary	tertiary_linik
primary_link	Trunk
residential	trunk_link
road	Unclassified

Table 6: Auto generated link type file

link_type	link_type_name	type_code	default_lane_capacity	default_speed_limit	default_number_of_lanes
1	Freeway	F	1000	50	2
2	Highway	H	1000	50	2
3	Principal arterial	A	1000	50	2
4	Major arterial	A	1000	50	2
5	Minor arterial	A	1000	50	2
6	Collector	A	1000	50	2
7	Local	A	1000	50	2
8	Frontage road	A	1000	50	2
9	Ramp	R	1000	50	2
10	Zonal connector	C	1000	50	2
100	Transit link	T	1000	50	2
200	Walking link	W	1000	50	2

Table 7: Formula use for link type interchange

```
=IF(E15="cycleway",7,IF(E15="living_street",7,IF(E15="motorway",2,IF(E15=motorway_link,2,IF(E15="primary",5,IF(E15="primary_link",5,IF(E15="residential",6,IF(E15="road",6,IF(E15="secondary",7,IF(E15="secondary_link",7,IF(E15="service",7,IF(E15="tertiary_link",8,IF(E15="tertiary",8,IF(E15="trunk",10,IF(E15="trunk_link",10,IF(E15="unclassified",7,))))))))))))))))
```

- **input_activity_ location.csv:**

This input file is simple as it consists of only 2 columns. This file only requires the zone_id column to be filled with respect to the activity location present in the zone. In this file, all the zones and nodes should be present as in the input_zone.csv and input_node.csv files respectively.

Following are the column present in this file.

  - zone_id
  - node_id

Note: If any zone and node ID that was used in this file and not present in the basic file, as mentioned above, then there will be a problem during the simulation step.

- **input_demand_meta_data.csv:**

As shown in Figure 17, the input_demand_meta_data.csv file is the most superior file among all demand input files as it takes input from all the demand representing files and eventually prepares the files for the simulation. Following are the columns that are present in the file and need to be filled in: Annex 1 and 2 shows the prepared file of input_demand_meta_data.

  - Scenario_no: Scenario number is used in connection with other input scenario files, in this project no scenario was used
  - File_sequence_no: In this project, only one basic situation was developed, therefore the file_sequence_no = 1 was used for all input files.
  - File_name: This represents the file input demand file names. The file name should be correct as it is case sensitive and should be present in the specified project folder.
  - Format_type: The file can read various formats like 3-column, matrix etc. In this project, matrix format was used.
  - Number_of_lines_to_be_skipped: It indicates the number of lines to be skipped while reading the specific demand file.
  - Loading_multiplier: Defines the multipliers of demand used.
  - Start_time_in_min: Defines the start time of simulation. In this project, the hourly data was given like 14:00.
  - End_time_in_min: Defines the end time of simulation. In this project, the hourly data was given like 15:00.

- **input_demand_type.csv:**

This file demand type describes the type of demand modes that are present in the simulation area such as SOV, HOV, truck and others. In this project, however, only 2 modes i.e. SOV and trucks were used with high percentage of SOV and less percentage of trucks. The default data on VOT and pricing was used as there were no particular related data available. Following are the column present in this file:

  - demand_type
  - demand_type_name
  - average_VOT
  - pricing_type
  - percentage_of_pretrip_info
  - percentage_of_enroute_info
  - percentage_of_vehicle_type1
  - percentage_of_vehicle_type2

After the preparation of all the above mentioned important files, the project file .tnp was created. This file was then opened through NEXTA software. The time taken for this process to be completed depends upon the machine and the network size. For the map of the study area of this project i.e. Hasselt, it took about 30 minutes to just load the network on a dual core processor machine.

5.3 Way forward:

This chapter covers the file preparation and discuss the basic understanding of input file. There many input file that were not use in this project but can be use full if needed. The next chapter explains in detail the output obtained from the simulation, followed by the description of the output files and the data obtained from them.

CHAPTER 6: RESULT AND DISCUSSION

This chapter covers the discussion and analysis on the output obtained. After running the simulation, the result obtained was in the form of different output files. This chapter also discusses the output that was visualize through the NEXTA GUI. The output of the simulation can easily be divided into two parts, the first part being the visualization from the NEXTA explorer while the other part constitutes of the analysis through the output file generated. To visualize the results in NEXTA as discussed earlier requires a higher processing machine that can easily open and load the output result.

First of all, the output results that are generated through NEXTA explorer are discussed. NEXTA provides the option to quickly view and analyze the results and also makes it possible to compare two different scenarios. The following figures were made using the data obtained from the output summary option from the NEXTA explorer by exporting the data into excel sheet.

Figure 19 represents the average travel distance in miles for all the vehicles travelling with in the study area. The results are shown with respect to different travel distance intervals ranging from zero to ten miles, the intervals use are of two miles each. It is obvious that the average travel distance is directly proportional to travel distance interval. It shows from the figure that the least average travel distance of the vehicle within least travel distance interval i.e. 0-2 mile is 1.28 miles. In addition, the highest average travel distance of the vehicle within highest travel distance interval i.e. 8-10 mile is 8.95 miles.

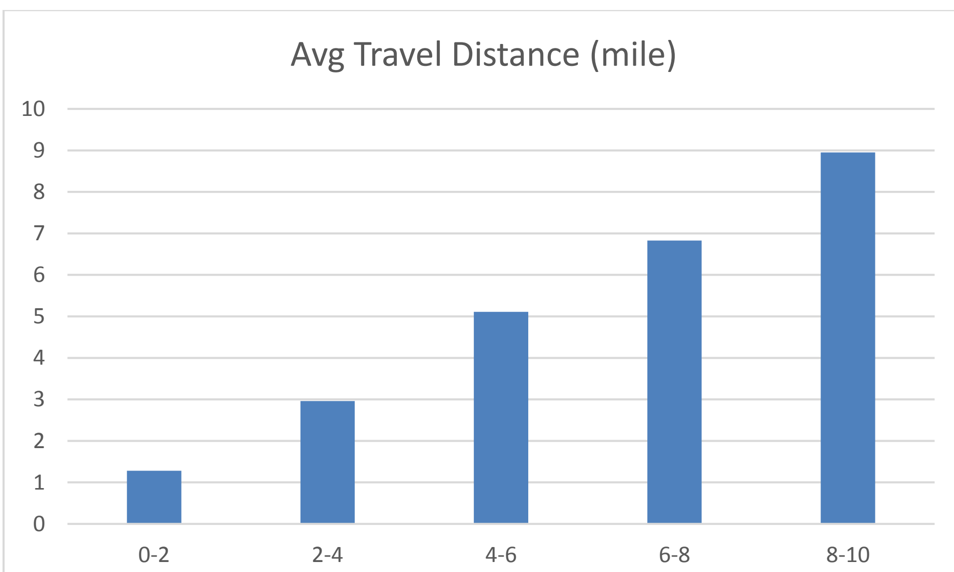

Figure 19: Average travel distance on 2 mile interval

The software package measures the speed in miles. The average speed in miles per hours is shown in Figure 20. The average speed is measured in two mile travel distance interval ranging from zero mile to ten miles with the interval of two miles each. As shown in figure below, the average speed in different time intervals increase directly with the travel distance interval. The average lowest speed is 26.45 miles/hours in the least travel distance interval and the highest speed is 31.9 in the highest interval of travel distance.

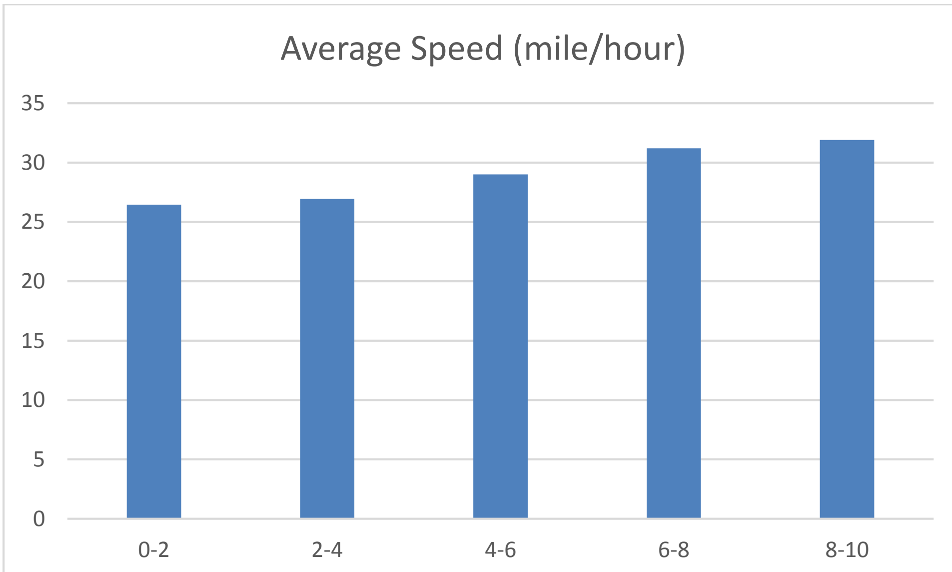

Figure 20: Average speed on 2 mile interval

The Figure 21 shows the total number of vehicles for each two miles travel distance interval. It is evident that the maximum number of vehicle lies under 2 to 4 miles interval. Secondly, the large number of vehicles lie in 0 to 2 miles interval. This figure shows that the major movement in the study area is under 4 miles distance. There are some vehicles present in upper travel distance but the percentage is very low.

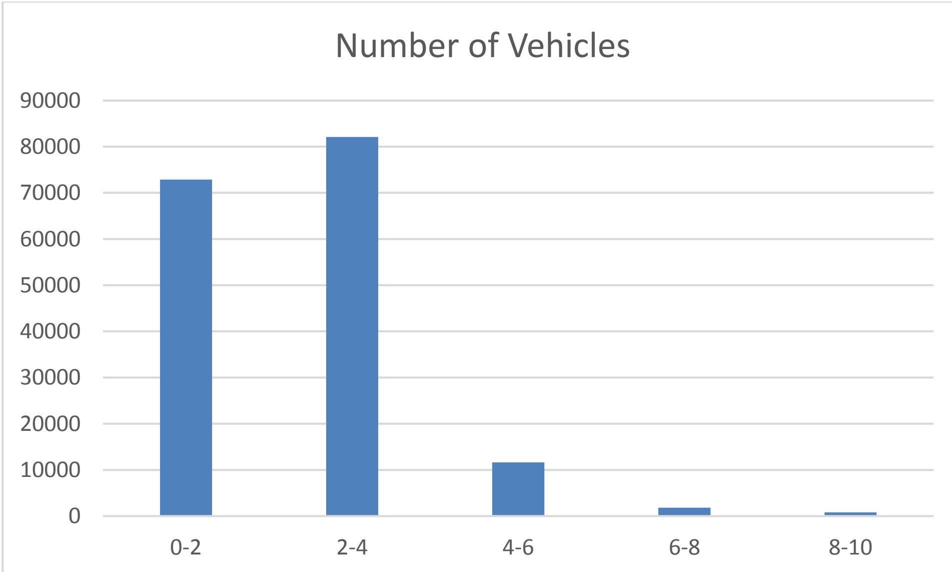

Figure 21: Number of vehicle travel on 2 mile interval

The average speed in four hours interval of time from 0 hours to 24 hours is shown in Figure 22. The maximum speed shown in the 0 hour to 4 hour interval of time is 34.2 miles/hours whereas the lowest speed i.e. 29.5 is found in 8 hour to 12 hour interval. It can easily be concluded that due to high traffic volume in 8 to 12 time interval, the traffic stream experiences the lowest average speed.

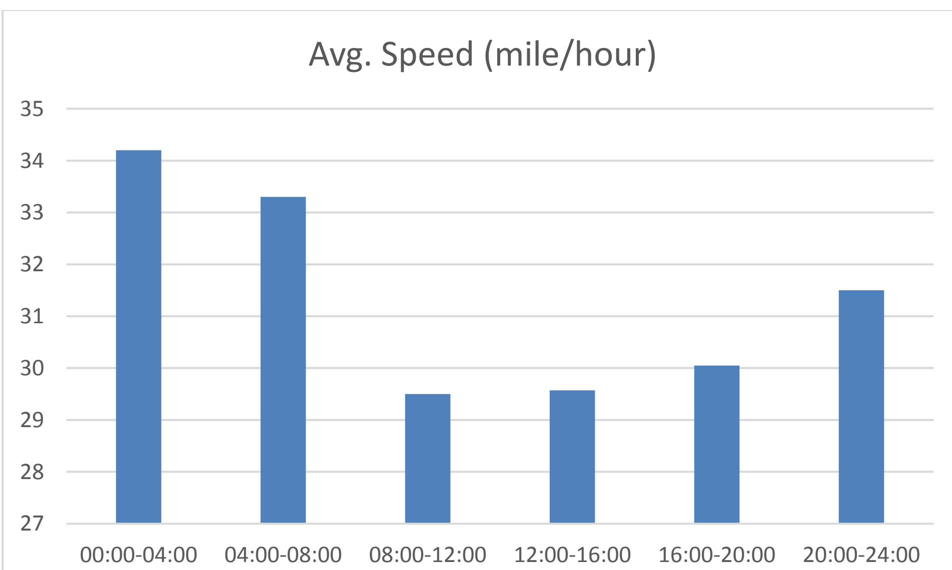

Figure 22: Average speed of all vehicle in 4 hour time interval

The Figure 23 shows the traffic movement during the simulation. The black line shows the links with in the study area. The visualization of traffic movement is a more convenient way for analysis while using a simulation software. Many softwares provide visualization only when the new result is needed like Paramics.

NEXTA provides the flexible visualization of the simulated results produced from DTALite. The software provides the option to easily see the visualization as many times as needed with no restriction to time. It is also possible to just picture the peak hour period in the simulation study time.

It is evident from Figure 23 that the major vehicular movement of the traffic is shown in a specific part of the study area. The black line in the figure shows the presence of link in the network and the green connecting dots show the vehicles present on the link. The major movements are observed around the Hasselt and Genk station and near Diest. In figure, the Hasselt station lies in the middle and the major movement is in and out of the station. The other busy place is Genk Station, not completely appearing in our study area, lies on right top corner in the figure. The vehicular movements are same as for Hasselt station. Apart from it, Diest inner circle also comes in the study area and shows the large movement on Staat Baan road and on E314 highway near Diest. The area of Diest lies in the middle of left of the picture. The large area under the given study shows less and small traffic movement which depicts that the major individual trips are small in time and distance. It is also evident from the Figure 21 that the most number of trips are present in 2-4 travel distance interval. It may also be concluded that the study area is an example of Mix Land use where the basic facilities like work, recreational and other locations are nearby the households.

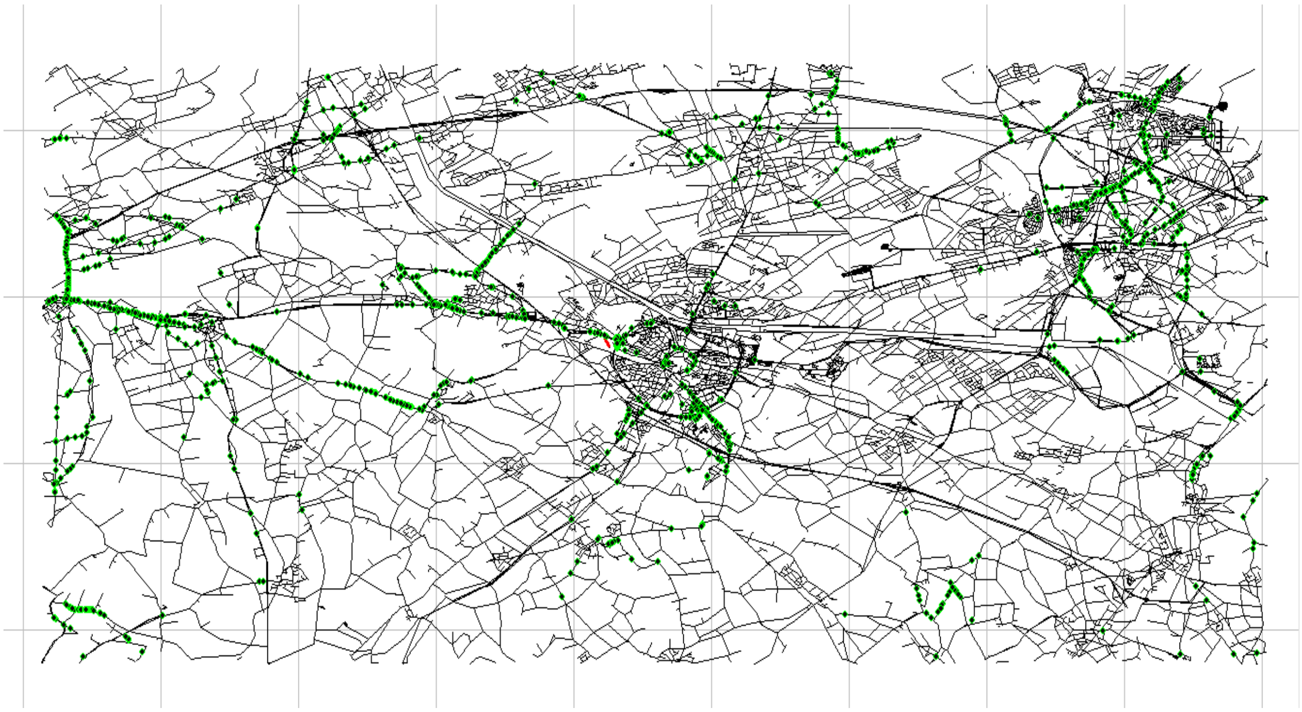

Figure 23: Simulation of the study area

NEXTA also allows the user to observe the network with different characteristics related to links, nodes etc. The pictorial representation enables to see the network attributes all at once. Figure 24 shows the free flow travel time of the network displayed on each link. The picture was taken when the node layer was off and the FFTT attribute was on.

Output generated in the form of a file are listed in Table 4, in which the output file “output_agent” is the most important file that describes the detail of each individual agent with respect to the trip e.g. start time of trip and type of trip, vehicle type use (if specified earlier), number of nodes passed through, name of node, travel time, travel time in between each node pair and other emission and cost related data that is not covered in this report. The total number of agents produced was around 250k on the simulation with loading factor of 1. It is also observed from the data that the majority of the links used by the agent were less in number as shown in Figure 21. Majorly, the number of trips with in the area were less with short time interval.

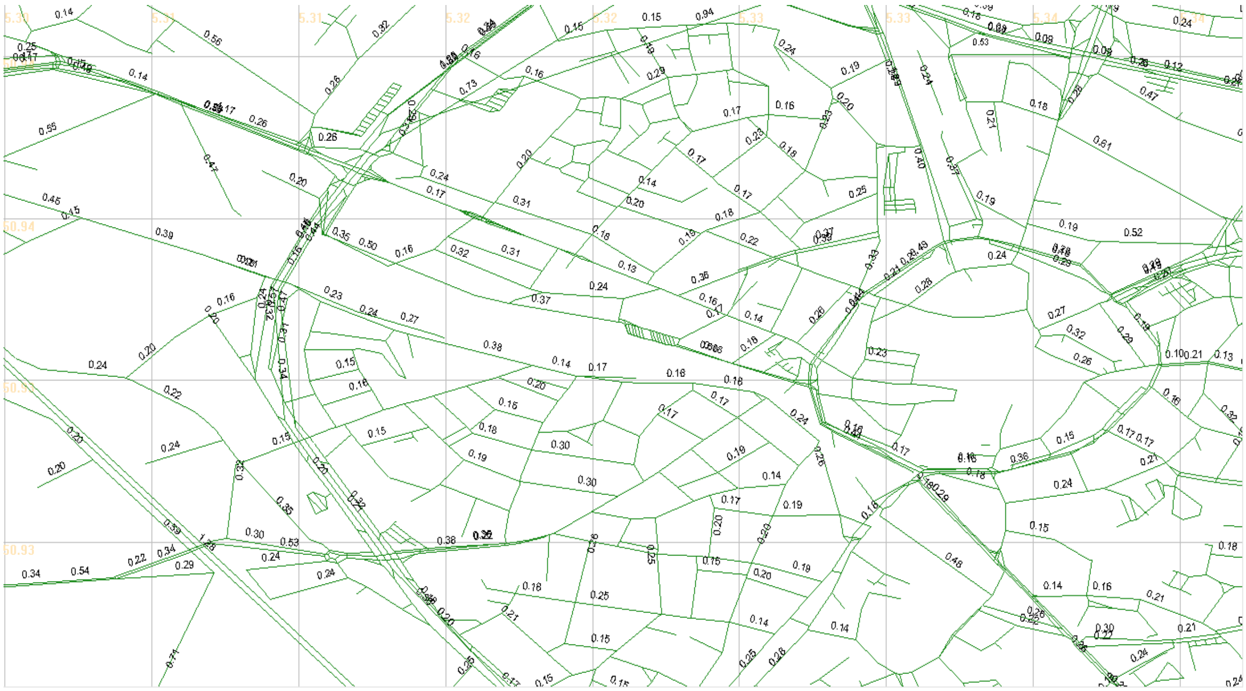

Figure 24: Shows the FFTT of the given study area

The Figure 25 shows the study area with the bandwidth of volume in the links. It appears that the large area under the given network is having traffic less than 1500 vehicle per hour while the major road in the network shows a high volume of up to 3000 vehicle per hour. The representation is based on the thin and thick lines in the network. The network can also be visualized with respect to queuing model which is not covered in this project.

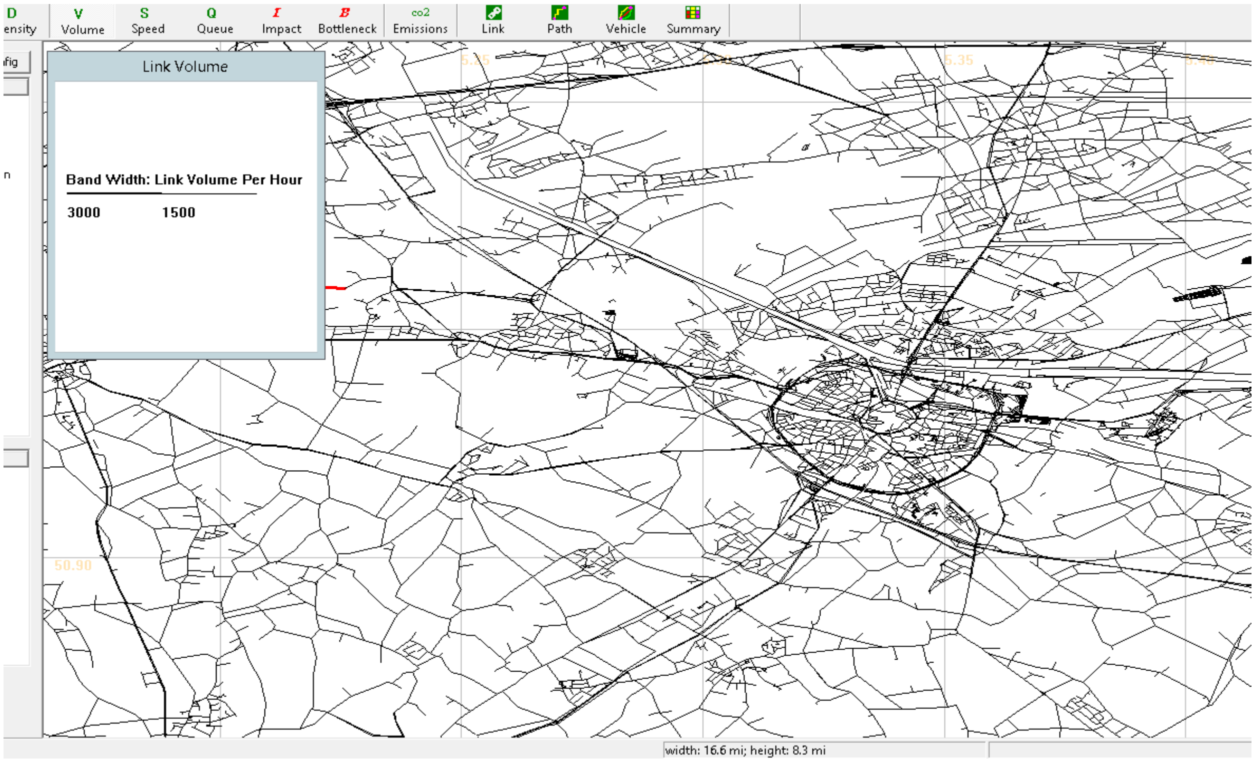

Figure 25: Link volume of study area

CHAPTER 7: RECOMMENDATION:

In this project, DTA model of Hasselt was developed using DTA light and NEXTA. The model was developed using already developed data. The data requirement and preparation for the software was discussed in detailed in this report. The project was developed based on the least data requirement for preparing the model with respect to network and least output. The focus of the project was to run the model by completing the least data requirement for Flanders area i.e. Hasselt. Earlier the study area of this project was whole Flanders area but due to large machine requirement and time, the work was first restricted to Leuven city and then only to Hasselt city. To develop the large network with the help of DTALite and NEXTA, a high processing machine is required. The network based on 10 k nodes with 10 k links can easily be simulated by using ordinary PC machine. However, for the network having above 80000 links and 90000 nodes i.e. Leuven can be hardly developed on an ordinary machine. The network data preparation for Leuven was performed in the project. Figures 26 and 27 show the network of Leuven, however because of high machine requirement further processing was stopped and focus was narrowed down only to the city of Hasselt. It is also recommended to further enhance input data in Leuven network to perform assignment using same software.

The simulation run on the ordinary machine is nearly impossible for the network having more than 10,000 nodes and links. It was observed in the project that the simulation of Hasselt city with more than 30000 nodes and links was very difficult to be completed on an ordinary PC. The simulation took more than 30 hours but still it ended with an error because of low PC processing memory. The project was conducted on a DELL CORE i3 laptop for establishing and preparing the network model in all steps whereas the simulation of Hasselt was run on the University server. The result was observed through NEXTA visualizer.

For the future work, it is highly recommended to extend the work of this project. The possible recommendation is to use more detailed and vigorous data for the model. The extraction of data should be accurate and no node and link should be missing. As it was noticed in the project that some links and nodes were missing in different aspects as already discussed above in this report. The software also provides the facility to perform analysis of different scenario to check the changes in environment and infrastructure like round about and left turn checking. As discussed in data structure, simulation can also estimate the emission and VOT for the individuals. By providing the estimation of fuel consumption and different attributes regarding mode use, emission estimation can also be performed.

DTALite can also perform the estimation for signal timing, however data availability of control node data with their characteristics and the phase timing of the signal data is essential.

Signal estimation function by Quick Estimation Method (QEM) in NeXTA provides an easy to use tool that uses HCM's estimation method for initial signal phasing and timing for a signalized intersection. The availability of signal data within the network can also improve the results leading towards a more realistic outcome.

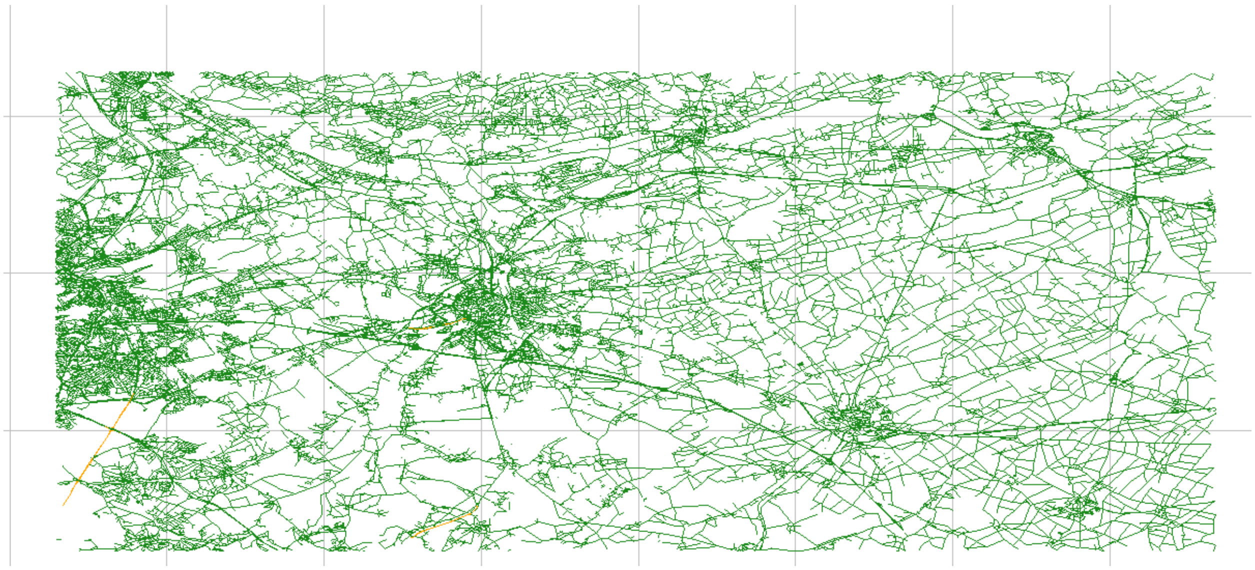

Figure 26: Link Network of Leuven.

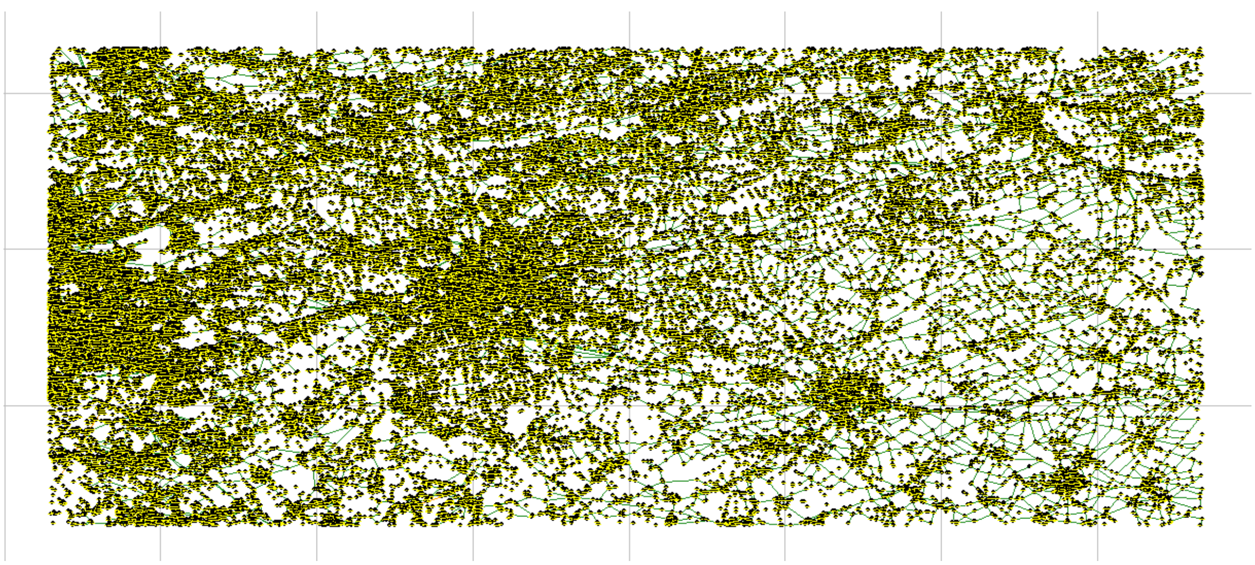

Figure 27: Network of Leuven with nodes and link

It is highly recommended to use server having more than 5 processors to run this simulation and run with more iterations and number of simulation days for more realistic results.

As the project is in initial stage, therefore a lot of difficulties were encountered such as long running time, data preparation etc. Different problems were also observed during the analysis of the result. The travel time of the links was not realistic as a large value was determined as compared to the actual value given by google maps. In one of the link that is specified in the Figure 29, Google map shows the travel time for car which is 1min, but the simulation result found it be 17.4 min. The calculation of travel time came out wrong in this simulation run according to this comparison. Keep in view that the calculation of travel time of google is based on average values and is also dependent on the time of the day when the journey is planned (Russell, 2015). It is also notable that the model did not incorporate the control and uncontrolled intersection data for the sake of simplicity. This may also lead towards the wrong estimation of the results. For further work, this can also be the main exploring point to understand the error.

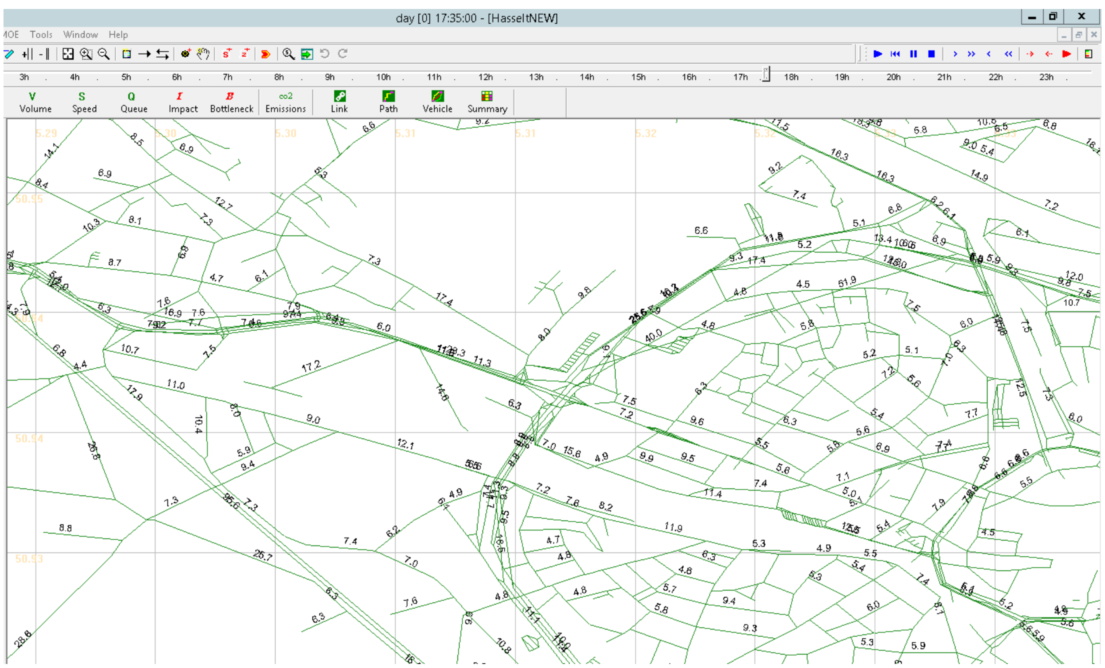

Figure 28: Simulated travel time

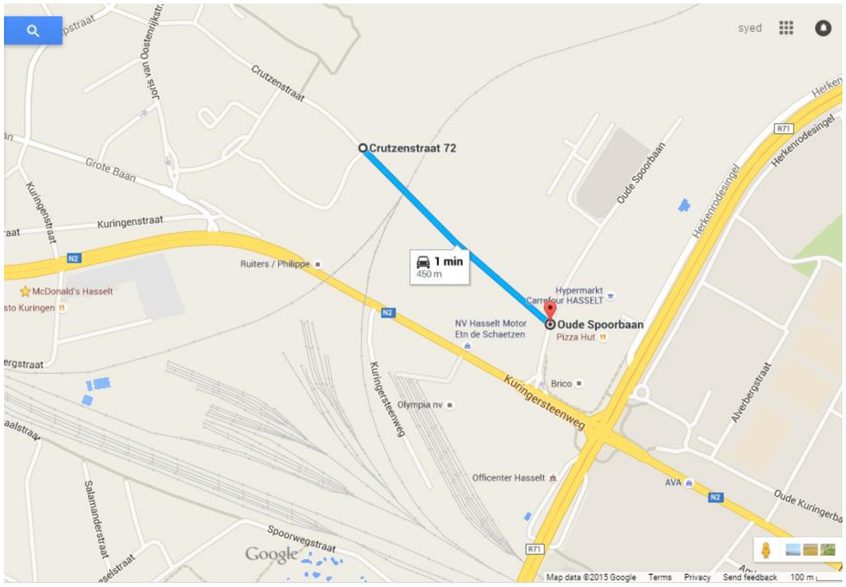

Figure 29: Google maps view for specific link travel time measurement

CHAPTER 8: CONCLUSION:

The basic objective of this research project was to develop a dynamic assignment model for Flanders region by using DTALite and NEXTA softwares. However, this objective was narrowed down later only to the city of Hasselt due to lack of a higher processing machine.

DTALite is a widely used open source dynamic traffic assignment software that is famous for its fast processing and easy to use interface. The software also provides a platform for the estimation of different parameters like VOT, CO_2 emission levels, signal time estimation etc. Apart from it, DTALite also provides the option of flexible demand input system like 3-column, matrix system etc. which allows it to incorporate with other softwares like GIS, Synchro, VISSIM and Trans CAD. While on the other hand, NEXTA provides an easy access to the results of the simulation by visualizing it in different ways. This software package is an open source software that can directly run through exe or cmd without any installation. In this project, NEXTA version 3 was used that was released in early 2014.

The reported cases of using the NEXTA software specifically the version 3 are very limited and are not well-documented. Even the official website and guides do not state clearly the small technicalities that are critical for using the software. Therefore, the report of this research project can serve not only as the first basic document that describes the process in detail but also as a first-hand experience guide that discusses the problems faced during the process. Besides this project, a detail step by step tutorial will also be produced that will support in further use of this software at IMOB.

Beside the use of this software package, there are many other softwares available in the market that can also perform the same task efficiently. The literature review in this report gives an overview of these available softwares but an in-depth study is required if a large scale work is planned.

This modelling project started with the software familiarization through the input files preparation followed by a simulation run and eventually ended with the data analysis. A lot of difficulties were encountered during the project. One of the major problem faced was the running of the software on an ordinary PC. This problem started with the preparation of .csv file when dealing with huge data in it, as 12 GB .csv file takes a long time for analysis. The problem was partly encountered through limiting the network use and by performing majority of the preparation work on university student PC.

The preparation of input files is based on filling of desired data in the required fields of different .csv file that were auto generated by the software. Input file preparation also needs the use of excel formulae in order to shape the available data as required. The software is suitable for small scale projects on an ordinary computer whereas for large scale projects, powerful processing machines are required. In input data preparation, most of the data like vehicle emission, VOT, mode characteristics were used as default and in some cases general values were used to make this software workable for Hasselt Area. The simulation was performed once on the university server so the result analysis is based on a single result with 10 iterations for 5 simulation days.

Results output of the simulation are based on .csv file that were auto filled after the simulation run. These files were then analyzed and visualized through NEXTA that makes the process easier and provides a unique accessible option.

The major analysis of the simulation results was done on the NEXTA software. The results were visualized in the software based on different ways. The output shows the results of average travel distance, average travel time and other parameters based on the travel distance interval and time interval for the selected study area. The network-wide visualizing results are discussed in detail in the results and discussion chapter of the report. The minimum average travel time came out to be 2.9 min for the travel distance interval of zero to two miles and the highest value was found out to be 15.3 min in the travel distance interval of 8 to 10 miles. The average travel distance for least travel distance interval i.e. 0 to 2 miles was 1.28 miles whereas for the highest distance interval i.e. 8 to 10, it was 8.95miles. Average travel speed for all vehicle travel in the network came out to be 26.4 mile per hour for the travel distance interval of 0 to 2 miles while for 8-10 miles, the value was highest which was around 31.9 miles per hours.

It is also evident through visualizing the simulation that the major movement in the given study area was near busy places like Hasselt and Genk station. It can also be concluded that mostly there was much less traffic observed in the study area or the trip distances were very short. The result also verify this conclusion as the most number of vehicles lies under the travel distance of 2 to 4 miles and similar number of vehicle lies under category of 0 to 2 mile interval. In conclusion, it can be said that the large number of vehicle come under 0 to 4 miles travel distance interval.

The way forward of this project is to proceed it for other cities in Flanders such as Leuven and then eventually for the whole of Flanders. The input network files of Leuven were also developed but due to high processing machine requirement, it became impossible to run simulation. That is why, the work was narrowed down to Hasselt City. So it is highly recommended to proceed the work on the university server where more than 5 processors can be dedicated simultaneously to the process. It is also recommended to explore other significant input data set that might help in predicting the emission levels and other characteristics. The software is also famous in quick estimation of signal and phase timing so this feature can also be used for the network. The software is highly efficient and easy understandable for working so it is also recommended to use it for future work but keep the in view the need of a higher processing machine.

Bibliography:

aimsun. (2015, July 30). *TSS-Transport Simulation Systems*. Retrieved from TSS-Transport Simulation Systems website : http://www.aimsun.com/

Bar Gera H. (1999). *Origion based Algorithum for Transportation Network Modeling,.* North Carolina: Technical report #103 NISS Research park.

Bergomi, M. (2009). *Traffic Assignment Problem: The Stochastic User Equilibrium.* ETH Zurich: Department of Mathematics.

Corporation, C. (2014, May 20). *Caliper Corporation*. Retrieved from Caliper Corporation: http://www.caliper.com/

Corporation, Caliper. (2007). *Travel Demand Modelling with TransCAD.* Caliper Corporation.

Daganzo C., S. Y. (1977). Stochastic Models of Traffic Assignment. *Transportation Science 16*, 332-360.

Dail R, .. (2006). *A Path-based user-equilibrium traffic Assignment Algorithum .* 2006: Transportation Research B.

developer, S. (2012). *User guide .*

Dial, H. (1971). *A Probabilistic Multi Traffic Assignment Algorithum.* Transportation Research 5.

Dongmei Lin, Z. T. (2015). *Travel Demand Modeling with Micro Simulation.* Nevada: CATER, University of Nevada, Reno.

Dr Ziad Sabra, D. C.-b. (2000). *TRAFFIC ANALYSIS SOFTWARE TOOLS.* Florida: TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL.

FHA, R. a. (2015). *Federal Highway Administration Research and Technology*. Retrieved from Federal Highway Administration Research and Technology website: https://www.fhwa.dot.gov/publications/transporter/04sep/index.cfm

G.Willumsen, J. d. (2011). *Modelling Transport.* WILEY.

Jaimison Sloboden, J. L. (2012). *Guidebook on the Utilization of Dynamic Traffic Assignment in Modeling.* Washington, DC: Cambridge Systematics, Inc.

Jones, S. L. (2004). *TRAFFIC SIMULATION SOFTWARE COMPARISON STUDY.* Birmingham: University Transportation Center for Alabama.

Jordi Casas, J. L. (2010). Traffic Simulation with Aimsun. In J. Barceds, *Fundamental of traffic simulation* (pp. 173-232). Springer link.

Mactrans. (2007). *McTransTM Home*. Retrieved from McTransTM website : http://mctrans.ce.ufl.edu/

Mathew, D. T. (2008). *Transportation Network Design.* India.

Mathew, K. V. (2007). *Introduction to Transportation Engineering.* NPTEL.

Merchant D.k and G L, N. (1978). Optimal condition for dynamic traffic assignment model. *Transportation science 12(3)*, 200-207.

NCHRP. (2012). *Travel Demand Forecasting: Parameters and Techniques.* WASHINGTON, D.C.: National Academy of Sciences.

NEXTA. (2015, July 7). *NEXTA (Network EXplorer for Traffic Analysis (NEXTA) and DTALite)*. Retrieved from NEXTA (Network EXplorer for Traffic Analysis (NEXTA) and DTALite) website : https://code.google.com/p/nexta/

PTV, g. (2015, july 25). *PTV Group*. Retrieved from PTV Group website: http://vision-traffic.ptvgroup.com/

Russell, R. (2015, August 10). *Quora* . Retrieved from Quora website: http://www.quora.com/

Salvin H. (1996). An Integrated, Dynamic Approach to Travel Demand Forcasting. *Transportation 23*, 313-350.

Sheffi, Y. (1985). *Urban transportation network with Mathematical Progrmming Methods.* Englewood Cliffs.

Wardrop, J. G. (1952). Some Theoretical Aspects of Road Traffic Research. *Proceedings of the Institution of Civil Engineers.*, Part II, 1(36):352–378.

YI-CHANG CHIU, J. B. (2011). *Dynamic Traffic Assignment.* Washington, DC: Trannsportation Research Board.

Zilialaskopoulos, S. P. (2001). Foundation of Dynamic Traffic Assignment:mThe Past, the present and the future. *Network and spatial economics*, 233-25.

Appendix:

Annex 1: Prepared file of input_demand_meta_data file

scenario_no	file_sequence_no	file_name	format_type	number_of_lines_to_be_skipped	loading_multiplier	subtotal_in_last_column	start_time_in_min	end_time_in_min
0	1	OD_03_0400_TransportMode_1_noZeroes.csv	column	1	1	0	180	300
0	1	OD_0500_TransportMode_1_noZeroes.csv	column	1	1	0	300	360
0	1	OD_0600_TransportMode_1_noZeroes.csv	column	1	1	0	360	420
0	1	OD_0700_TransportMode_1_noZeroes.csv	column	1	1	0	420	480
0	1	OD_0800_TransportMode_1_noZeroes.csv	column	1	1	0	480	540
0	1	OD_0900_TransportMode_1_noZeroes.csv	column	1	1	0	540	600
0	1	OD_1000_TransportMode_1_noZeroes.csv	column	1	1	0	600	660
0	1	OD_1100_TransportMode_1_noZeroes.csv	column	1	1	0	660	720
0	1	OD_1200_TransportMode_1_noZeroes.csv	column	1	1	0	720	780
0	1	OD_1300_TransportMode_1_noZeroes.csv	column	1	1	0	780	840
0	1	OD_1400_TransportMode_1_noZeroes.csv	column	1	1	0	840	900
0	1	OD_1500_TransportMode_1_noZeroes.csv	column	1	1	0	900	960
0	1	OD_1600_TransportMode_1_noZeroes.csv	column	1	1	0	960	1020
0	1	OD_1700_TransportMode_1_noZeroes.csv	column	1	1	0	1020	1080

0	1	OD_1800_TransportMode_1_noZeroes.csv	column	1	1	0	1080	1140
0	1	OD_1900_TransportMode_1_noZeroes.csv	column	1	1	0	1140	1200
0	1	OD_2000_TransportMode_1_noZeroes.csv	column	1	1	0	1200	1260
0	1	OD_2100_TransportMode_1_noZeroes.csv	column	1	1	0	1260	1320
0	1	OD_2200_TransportMode_1_noZeroes.csv	column	1	1	0	1320	1380
0	1	OD_2300_TransportMode_1_noZeroes.csv	column	1	1	0	1380	1440
0	1	OD_2400_TransportMode_1_noZeroes.csv	column	1	1	0	0	60
0	1	OD_2500_TransportMode_1_noZeroes.csv	column	1	1	0	60	120
0	1	OD_2600_TransportMode_1_noZeroes.csv	column	1	1	0	120	180

Annex 2: Prepared file of input_demand_meta_data showing distribution of traffic with in hour (cont.)

demand_type_1	'00:00	'00:15	'00:30	'00:45	'01:00	'01:15	'01:30	'01:45	'02:00	'02:15	'02:30	'02:45	'03:00	'03:15	'03:30	'03:45	'04:00	'04:15	'04:30	'04:45
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0.25
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0

Annexure 3: Prepared file of input_link.csv file showing necessary column

name	link_id	link_key	speed_sensor_id	count_sensor_id	from_node_id	to_node_id	link_type_name	direction	length	numbe
764621	764621	764621	0	0	124086	124080	Local	1	0.05134	
764622	764622	764622	0	0	124089	124088	Collector	1	0.04877	
764623	764623	764623	0	0	124078	124088	Collector	1	0.08558	
764624	764624	764624	0	0	124088	124136	Collector	1	0.08283	
764694	764694	764694	0	0	755939	755938	Collector	1	0.0674	
764695	764695	764695	0	0	755938	755925	Collector	1	0.15295	
764696	764696	764696	0	0	755925	755924	Collector	1	0.02227	
764697	764697	764697	0	0	755924	755930	Collector	1	0.17338	
764698	764698	764698	0	0	755926	755925	Local	1	0.04229	
766412	766412	766412	0	0	231941	7194	Collector	1	0.01178	
766413	766413	766413	0	0	7194	625772	Collector	1	0.07892	
766414	766414	766414	0	0	625772	7195	Collector	1	0.00274	
766415	766415	766415	0	0	84277	103610	Collector	1	0.21143	
766416	766416	766416	0	0	103610	7210	Collector	1	0.3406	

766828	766828	766828	0	0	478680	398183	Collector	1	0.0785	
766845	766845	766845	0	0	572841	571800	Collector	1	0.08554	
767018	767018	767018	0	0	700215	200676	Local	1	0.00779	
767019	767019	767019	0	0	548682	700215	Local	1	0.05904	
767020	767020	767020	0	0	725633	380402	Local	1	0.03251	
767021	767021	767021	0	0	380402	380407	Local	1	0.00636	
767022	767022	767022	0	0	380407	552954	Local	1	0.02337	
767023	767023	767023	0	0	548709	548708	Collector	1	0.01053	
767024	767024	767024	0	0	552954	548709	Collector	1	0.02058	
767025	767025	767025	0	0	548709	700217	Collector	1	0.01859	
767026	767026	767026	0	0	548682	548681	Local	1	0.0109	
767027	767027	767027	0	0	552954	700217	Local	1	0.00855	

Auteursrechtelijke overeenkomst

Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
Traffic assignment using DTALite : model setup for Flanders

Richting: **Master of Transportation Sciences-Mobility Management**
Jaar: **2015**

in alle mogelijke mediaformaten, - bestaande en in de toekomst te ontwikkelen - , aan de Universiteit Hasselt.

Niet tegenstaand deze toekenning van het auteursrecht aan de Universiteit Hasselt behoud ik als auteur het recht om de eindverhandeling, - in zijn geheel of gedeeltelijk -, vrij te reproduceren, (her)publiceren of distribueren zonder de toelating te moeten verkrijgen van de Universiteit Hasselt.

Ik bevestig dat de eindverhandeling mijn origineel werk is, en dat ik het recht heb om de rechten te verlenen die in deze overeenkomst worden beschreven. Ik verklaar tevens dat de eindverhandeling, naar mijn weten, het auteursrecht van anderen niet overtreedt.

Ik verklaar tevens dat ik voor het materiaal in de eindverhandeling dat beschermd wordt door het auteursrecht, de nodige toelatingen heb verkregen zodat ik deze ook aan de Universiteit Hasselt kan overdragen en dat dit duidelijk in de tekst en inhoud van de eindverhandeling werd genotificeerd.

Universiteit Hasselt zal mij als auteur(s) van de eindverhandeling identificeren en zal geen wijzigingen aanbrengen aan de eindverhandeling, uitgezonderd deze toegelaten door deze overeenkomst.

Voor akkoord,

Noman, Syed Muhammad

Datum: **24/08/2015**