

Implementing And Simulating Dynamic Traffic Assignment With Intelligent Transportation Systems In Cube Avenue

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Abstract. As urban populations and traffic congestion levels increase, effective use of information and communication tools and intelligent transportation systems as becoming increasingly important in order to maximize the efficiency of transportation networks. The appropriate placement and employment of these tools within a network is critical to their effectiveness. This presentation proposes and demonstrates the use of a commercial transportation simulation tool to simulate dynamic traffic assignment and rerouting to model route modifications as a result of traffic information.

1. INTRODUCTION

Modeling and Simulation (M&S) of transportation is critical to developing and assessing proposed ideas and technologies. Simulations of past transportation events allow planners to better understand what really happened. By simulating future changes, decision makers can greatly improve the roadways of tomorrow.

Alternatives are frequently proposed in different locations of cities for the future development of city and federal roadways. Proper testing of proposed plans must be done to assure best solution. One area of transportation system improvements that has largely not benefited from M&S testing is the installation or improvement of Intelligent Transportation Systems (ITS).

IEEE's Intelligent Transportation Systems Society defines ITS as systems that utilize synergistic technologies and systems engineering concepts to develop and improve transportation systems of all kinds. ITS refers to efforts to add information and communications technology to transport infrastructure. It strives to apply advanced technology to resolve the problems of surface transportation by improving efficiency, safety, and mobility. Other objectives include reducing energy, economic costs, and damage to the environment [2]. To better improve the planning of a large area such as the region of southeastern Virginia, ITS should be tested over the entire network to assess the improvements in traffic flows and congestion levels. This document will describe efforts and research to implement ITS and vehicle driver effects from ITS in a mesoscopic model using Avenue from the Cube family of transportation software.

2. TECHNICAL BREAKDOWN OF CUBE

2.1 Cube A Transportation Tool

Cube family of transportation tools developed by Citilabs is chosen for this projects as the tool of choice because it is already selected as the planning standard by the Virginia Department of Transportation (VDOT). Cube provides a macroscopic transportation modeling tool, a microscopic modeling tool and a mesoscopic modeling tool, each of these tools can integrate together by sharing loaded networks. It also allows the modeler additional control with its scripting language allowing the ability to program in vehicle reactions that the software tool was not developed or intended to do through the default user interface. The scripting language is proprietary, and offers flexibility to make changes to road networks and Origin Destination matrices (OD).

2.1.1 Microscopic Dynasim

The Cube microscopic tool Dynasim is like other transportation micro simulation in that the user can simulate individual vehicle behavior creating a very accurate simulation. The problem with a micro simulation is the amount of time required to develop and run a scenario [4]. This problem usually requires the simulated area to be reduced to a more manageable size so that the simulation can run in a reasonable amount of time. Therefore, if the interest of the study is to see the effects of ITS on an intersection, a microsimulation would work quite well. This type of simulation will show you the local effects in a very small area very well, but what if the planners need to see effects in a larger scale in multiple locations at the same time? A microscopic simulation could accomplish this but require much more time to set up and to run.

2.1.2 Macroscopic Voyager

The macroscopic tool within Cube, Voyager, is probably the most used and well known tool within the suite. Voyager can calculate volumes of traffic over large networks. It offers a number of modules that users can use to simulate transportation demand macroscopically. Each module requires its own input files, and using either a script file generated by the module to perform a default task, or a script created by the user to do a unique task can produce many outputs. Once the script runs the task the module can generate a number of outputs files of various formats that can be used as inputs to other modules or as strict outputs that visualize data.

Voyager runs the highway module which produces the calculated values on each segment of the network for a period of time chosen by the user using a gravity model [1]. The highway module takes as in input a daily demand matrix, then uses the command pathload to run the volume over the network and using a gravity model to find an equilibrium over the network. The pathload command within highway takes a few inputs, one being the path variable. The path variable is used to set impedence over the roadways that are being simulated with pathload. The model developer can select different roadways to run with different pathload statements allowing multiple impedances over the entire road network. A typical example would be to see the average congestion for the Hampton Roads area for an entire day. In this case, the user could color code the road segments to display a range of colors representing the value of congestion. This type of output is useful for showing daily traffic and is able to highlight the roadways that are being overused. Using Voyager to model ITS is very possible and can show the change in volume on roads due to ITS in a static sense. However if the planner wants to simulate over time how vehicles are changing direction and routes, then the macroscopic model will not completely accomplish that.

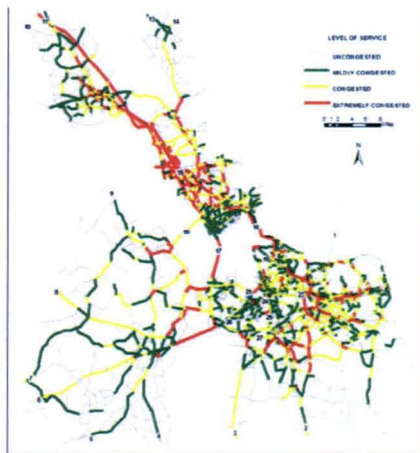


Figure 1: Shows an image of a Voyager output network with links color by level of service.

2.1.3 Mesoscopic Avenue

Mesoscopic models are in between a micro and a macroscopic model, allowing traffic volume to change over time through a large scale system [4]. While some mesoscopic simulation tools have more micro than macro features, Cube has more macro than micro features in that it simulates volume over the road network. Visualization of the output animation appears as a microscopic simulation where but it visualizes packets of vehicles based off of the volume calculations instead of individual vehicles. The mesoscopic tool in Cube is very closely related to the macroscopic tool, so close that it is actually just another module added to Voyager.

Avenue is capable of reading in a list of OD matrices, one for each time segment and a network file. Time segments are defined time steps that the simulation advances and also are the defined moments when new volume can be added to the system by a new OD matrix. At each time segment the simulation will run the volume over the network as a discrete event simulation finding equilibrium then doing the same thing for the next time segment. All of this is done through Avenue's Dynamicload statement. Much like the highway module's pathload, Dynamicload uses a gravity model to calculate equilibrium, but instead of for one OD Matrix for one time period Dynamicload will calculate equilibrium for each time segment using the calculated equilibrium from the previous time segment. The output files that Avenue produces are matrix files, network files, data/text files, path files, packet log files and a few other types of outputs. The most important output file is the network file which contains values on all of the road segments from the last simulation run. Most of the values that are outputted on the road segments have a value for each time segment that the simulation ran. For example, volume, queue length, speed, and time are default outputs that Avenue provides, with each segment representing each variable as *variable_t* where *t* equals the time segment it represents and variable representing the name of the variable. This allows the user to color code the road segments over time using the Bandwidth chart display. A bandwidth chart is a display that gives the user controls to advance time and to see how that particular value changes.

SPEEDS_2	60	60
SPEEDS7_2	60	60
VS1_2	474	43
VS2_2	529	66
VS3_2	36	26
VS4_2	56	14
VS5_2	39	19
VS6_2	52	17
VS7_2	46	12
QUEUEVS1_2	0	0
QUEUEVS2_2	0	0

Figure 2: Shows an output from one of the road segments in a simulation run providing values of Volume at each time segment.

Packet log output is a text file containing a record of locations where the packets have traveled for each time segment. The user can load this file over the network and view animations of the transportation that was simulated. The animation is a view of packets represented as rectangles over the loaded network. Users can control time to advance at different speeds and as time progresses the animation displays packets traveling the routes they were simulated to take towards their destinations. Since the packet log file is a text file, script files can be written with a matrix module to parse the log file and determine data that can be presented in a user created output file. An example of a parsing task would be to locate the amount of time segments it took each packet to arrive at its destination, and then average that value to obtain the average travel time for the simulation.

Avenue's dynamic assignment and flexibility along with its informative outputs and helpful visualizations make it a great choice for modeling vehicle behavior from ITS. Large areas can be simulated in a reasonable amount of time and in a time stepped simulation. Mesoscopic simulation benefits the non technical planners who need to understand how the simulated system is affected by driver behaviors.

3. IMPLEMENTING A DAILY MESOSCOPIC MODEL

3.1 A Hampton Roads Mesoscopic Model

Implementing a daily mesoscopic model for a major metropolitan and especially in the Hampton Roads can be challenging. Demand must be generated for all origins and destinations at each time segment. This is typically done by taking percentages of the daily demand over each time segment. The problem with this technique in a Hampton Roads model is that the traffic patterns here resemble two peak load curve for most routes. One peak represents vehicles going one direction in the morning, and another representing the same traffic returning in the evening. The best solution will have demand values for the morning, lunch and evening traveling in the appropriate direction. Because the tests being done now are prototype tests, smaller percentages of the daily demand will work.

3.2 Mesoscopic Model For Testing

Specific tests require manually injecting traffic in a test area and applying congestion to one of the roadways in the way of this injected demand. This process is much like the process of doing a microscopic test in that only a small test area is being worked on. The demand is also set up much like the microscopic simulation where an origin destination matrix needs to be defined for each time segment. Once the test area is performing as expected the same type of driver intelligence can be applied in multiple areas for

the entire Hampton Roads network, or in one spot with demand over the entire network to cause different reactions to the test area.

4. CAUSING CONGESTION

4.1 Implementing Incidents

In order to realistically model driver behaviors and the influence of ITS, congestion must also be simulated. There are two ways that congestion can be accurately portrayed in Avenue. The easiest method is to overload the system with large amounts of vehicle traffic volume, a more realistic method involves injecting a simulated incident by reducing road capacity. The most precise way to create congestion where needed is to create an incident. Overloading the system with traffic volume is effective but can be unpredictable as traffic could overly congest areas that are not of interest.

In Cube there is not a default function to apply incidents, so to implement incidents the modeler has to be able to use the Cube scripting language. The incidents modeled in Avenue require that the incident last as long as the time segment. A modeler cannot request Avenue to reduce the capacity of a roadway for one half of the time segment because all dynamic changes and calculations are done by time segment. Therefore to model fifteen minute incidents Avenue would require fifteen minute time segments or a different capacity reduction would need to be calculated. This new capacity would equal the capacity effects of a fifteen minute incident but at a one hour value [5]. The locations and severity of the incidents can be selected from historic data of road segments in Hampton Roads that are more likely to have an incident [5], or can be assigned to specific areas that a planner would like to study.

The command Avenue uses to reduce capacity on road segments is Dynamic. The Dynamic command only works with the variable C. In Avenue to change the capacity of the road segment the C variable has to be changed which represents the capacity on the road segment over the entire simulated time. When the Dynamic command is used with C, a value of C is calculated for each time segment. The modeler can then alter the C value for any road segment at any defined time by using Dynamic and C. The script line needs to contain the A node (which refers to the starting point of a segment) and B node (which represents the end point of a segment) of the link segment, this is to assure that the incident occurs in the right direction and on the right road segment. The capacity is usually reduced by multiplying the current C variable by a reducing factor. When the time segment of the incident is over, the C variable is calculated by its normal calculation, capacity multiplied by lanes multiplied by simulation length.

$IF(li.A = 66537 \text{ and } li.B = 66791)$

$DYNAMIC C[28] = li.C \times 0.5$

The equation above shows a conditional statement that locates the link with an A node equal to 66537 and a B node equal to 66791 then sets its C variable to half of its normal value at time segment 28.

5. SIMULATING DYNAMIC BEHAVIOR

5.1 Road Impedance To Control Behavior

Currently in Avenue dynamic behavior is already being simulated. The idea of this study is to better control that behavior and accurately simulate what is really happening. As stated in the documentation of Avenue, impedance for all road segments can be defined by the user. This impedance can be altered based on the road cost value, time to traverse link values, and user defined values. Smarter traffic can also be simulated by running multiple iterations of Avenue allowing the gravity model better equalize the network reducing congestion by having vehicles choose different routes based on the knowledge of the previous run simulation. This is accurate to a point, if an incident is being simulated then a multi iteration run is not going to be realistic. Therefore Avenue needs to be manipulated to allow the impedance of some specific roads to change at different times.

When the evacuation model of the Hampton Roads was developed a compliance variable was implemented to control the behavior of vehicles sticking to the evacuation routes [5]. This same principal can be applied to this study. Early implementations involved using compliance variables over the network for each time segment. These compliance variables could then route vehicles around incident areas as if there were information alerting vehicles of these areas.

The problem is that vehicles need to approach the accident segments as if knowledge of the accident doesn't exist. Then once the accident knowledge can be distributed the vehicles need to make an attempt to divert. This clearly shows that the impedance needs to change dynamically. The only way to change the impedance is to change the path variable within Dynamicload.

Dynamicload is Cube's dynamic analog of the static PATHLOAD which is the heart of the macroscopic simulation, and takes as an input a list of volumes for each time segment as well as a path impedance (1). The path variable can be set to COST, TIME, or a list of working link variables (LW). LW variables can contain values of link impedance or impedance equations and can be set, then altered after each time segment in the ADJUST phase of Avenue. This provides a nice dynamic adjustment to the link impedance providing a more controlled environment to produce dynamic behavior in a simulated ITS event.

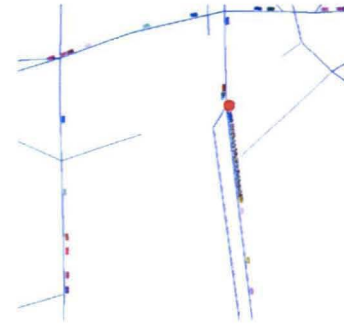


Figure 3: Shows an Avenue output network with an incident occurring on a road segment indicated by the large red dot.

5.1.1 Impedance set to Cost and Time

By using a mixture of Cost and Time a simple and deterministic ITS system can be simulated. By using two Dynamicload statements ITS behavior can be achieved by using one statement for the time segments where ITS is being simulated and the other statement for normal times when ITS is not active or needed. This is accomplished by using Cost as the impedance for the Dynamicload simulating the ITS time segments and using Time as the impedance for the other Dynamicload statement to simulate impedance without ITS. This method also requires that your demand cooperates with the Dynamicload statements. For example during normal road impedance the regular demand matrices will be applied to the Dynamicload that has its path equal to Time, and during those time segments the other Dynamicload's demand matrices should equal zero. When ITS effects need to be simulated then the Dynamicload with path equal to Cost takes the regular demand matrices and the Dynamicload with path equal to Time takes the zero demand matrices. This method keeps the regular volume flowing onto the network at all times and seamlessly simulates deterministic behavior due to ITS.

5.1.2 Impedance set to LW variables

Deterministic behavior really isn't enough to simulate the true behavior of ITS effects so instead of using just Cost and Time as impedance, LW variables are used. LW variables for each time segment give the ability to simulate different behavior to the entire system. To simulate certain dynamic behaviors caused by ITS, specification of road segments to road impedance needs to take place. New variables can be assigned to the road network to give weighted values that can specify which roadways will be effected and which roadways will stay the same. By setting all normal roadways to a weight of 1 and the effected roadways to a value greater than one, a multiplicative operation to the impedance equation will result in a greater value for the effected road segments and a normal value for the non effected segment.

6. FUTURE WORK AND CONCLUSION

Development and testing of these scenarios have a ways to go, but current tests show control over the traffic in a way that can be made more realistic to mimic real driver behaviors. Using driver survey's to obtain data that can produce frequencies of when drivers decide to abandon a normal route because of information or congestion and to reroute either to a known or an unknown route. These frequencies can then be applied to the LW variable equations to create realistic simulations. Then using the data from the surveys the model can be validated to the number of vehicles that potentially would reroute. More tests of manipulating the LW values to be altered by time values per segment as well as congestion values are being done. Currently Avenue allows time to dynamically alter impedance variables but the results are inconsistent and need to be verified.

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