I-4 Corridor Traffic Simulation and Visualization

Contract No. BD548, RPWO #7

Phase 2- Final Report

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16. Abstract

The primary objective of this research project is to develop a procedure for integrating a simulation package (WATSIM) with high fidelity visualization of traffic flow along the 1-4 corridor in Orlando, Florida. The objective of Phase 1 of this project is to code the I-4 corridor from Kaley Avenue to Lee Road using UNITES and 3D gaming engine tool. In Phase 2, this research project attempts to evaluate the utility of the developed tool for decision-making and public hearings. Other benefits include the study of congestion/choke points and determine the effectiveness of incorporating new technologies for highway improvements such as high speed rails and other ITS deployments.

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ABSTRACT

The U.S. Department of Transportation and Environmental Protection Agency have invested over $25,000,000 in developing a traffic simulation that provides data and statistics meeting the reporting requirements of the Intermodal Surface Transportation Efficiency Act, the Transportation Equity Act for the 21st Century, and Clean Air Act Amendments. The computer gaming industry has developed advanced algorithms for rendering complex scenes in 3-D virtual reality using readily available personal computers. This study attempted to integrate the data derived from the WATSIM software with the visualization capability of current game engine technology to enhance the analysis of congestion /choke points and determine the effectiveness of incorporating new technologies for highway improvements such as high speed rails and other ITS deployments in the future studies.

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1. INTRODUCTION AND OBJECTIVE

Traffic simulation tools are becoming more attractive in studying traffic issues. With the advances in computers and simulation techniques, it is now possible to model any roadway network and simulate traffic flow on these roads in a very realistic fashion. This enables traffic engineers and transportation planners to investigate the effect of hypothetical changes in the network geometry and traffic control strategies on traffic performance.

1.1. Problem Statement

Tremendous advancements in simulation technology have brought about new capabilities in modeling transportation systems. Current simulations are able to model individual vehicles and pedestrians in a large area. However, their data is generally available as large tables that must be analyzed statistically. For example, the data can predict a twenty-minute wait at a toll plaza or a two-mile backup at a congested on-ramp. However, it is difficult to interpret the impacts of these phenomena upon the rest of the transportation system.

A parallel advance in visualization systems, capable of operating on ubiquitous personal computers, makes possible the rendering of the transportation system in 3-D, virtual reality. This technology has been developed for high-performance gaming engines, and can be applied to other simulations. By utilizing this technology, researchers, analysts, and planners can view the transportation system through virtual traffic cameras, traffic-monitoring helicopters, or first-person from an individual driver or pedestrian viewpoint. For example, this would enable the planner to see the impact of bailout traffic. Thus impacts of traffic changes could be visually demonstrated. Other potential applications include simulation and visualization of work zones on freeways, the addition of a rail system in the median of a freeway, the inclusion of stations and pedestrian overpasses into the right-of-way, and the status of the network due to some natural disasters like hurricanes and floods.

1.2. Objective

The primary objective of this research project is to develop a procedure for integrating a simulation package (WATSIM- Wide Area Traffic SIMulation) with high fidelity visualization of traffic flow along the 1-4 corridor in Orlando, Florida. And extend the current simulation (Phase 1) of the I-4 corridor, which runs between Kaley and Lee Road to the 528 interchange (west) and Maitland interchange (east). Furthermore, this research project attempts to evaluate the utility of the developed tool for decision-making and public hearings. Other benefits include the study of congestion/choke points and determine the effectiveness of incorporating new technologies for highway improvements such as high speed rails and other ITS deployments in the future studies.

1.3. Tasks Completed in Phase 1

Four tasks were completed in Phase 1 and they are as following:

1. Reviewed and adopted the source data for the section between Kaley and Lee Road of the I-4 corridor.
2. Coded the geometries of I-4 corridor network from Kaley Avenue to Lee Road using UNITES.
3. Simulated the coded network using simulation tool WATSIM and analyzed the results.
4. Developed a 3-D visualization of the modeled section of the I-4 corridor using gaming engine technology.

1.4. Task Descriptions

There are three tasks to this Phase 2 study and they are as following:

Task 1. Extend current simulation of the I-4 corridor.

Phase 1 of this study simulated the I-4 corridor between Kaley and Lee Road. We extended the simulation to the 528 (Beeline) interchange (west) and to the Maitland interchange (east). Specific subtasks accomplished include:

1. Acquired source data for the extended portions of the I-4 corridor.
2. Conducted a source data review.
3. Developed an initial 3-D database of the extended areas of the I-4 corridor.
4. Conducted a review of the initial 3-D database.

5. Finalized the development of the 3-D database (incorporated comments from the initial review).
6. Conducted a final demonstration of the entire 3-D database (September 22, 2004).

Task 2. Adding Truck Lane on the I-4 Corridor.

Truck-only lanes, commonly called "truck lanes," are lanes designated for the exclusive use of trucks. Passenger cars may not use truck-only lanes. The purpose of truck lanes is to separate trucks from other mixed-flow traffic to enhance safety and/or stabilize traffic flow. Specific subtasks included adding a truck lane along the I-4 corridor and study the benefits of adding a truck lane. Scenarios included the simulation of I-4 corridor with and without the truck lane and to study the utility of adding a truck lane.

Task 3. Integrate traffic simulation with the 3-D visualization.

This task extended the initial integration of the underlying simulation (e.g. WATSIM) with the 3-D visualization that was accomplished in Phase 1 of the project. Output file from WATSIM was converted as XML file and fed into 3-D visualization engine as an input. The middleware that performs the integration of the transportation simulation will support vehicular models.

2. TRAFFIC SIMULATION SOFTWARE

2.1. Traffic Simulation Tool

There are a large number of traffic simulators on the market. Some of these are developed in the United States like CORSIM and WATSIM. And others are marketed by European software developers like VISSIM and PARAMICS. CATSS researchers have assessed all four software. WATSIM model is easy to code, no need for origin and destination data, takes turning volumes at the intersection and has good customer support. And therefore, we came to the conclusion that WATSIM is the best simulation model to use for research and development of traffic studies.

WATSIM Traffic Simulation Model developed by KLD Associates, Inc. is designed to perform a microscopic, stochastic simulation of traffic operations on highway networks comprised of freeways, ramps and surface streets. The software provides a wide spectrum of measures describing traffic operations in statistical, graphical and animation formats. With FHWA support, KLD Associates, Inc. has developed a new software product named, UNITES: Unified Integrator for Transportation Engineering Software. This product is designed to integrate the suite of network coding to WATSIM.

2.2. Commercial Gaming Engines

In 2002, the Nvidia GeForce 4 Titanium 4800 graphics card was released. This card is the most advanced graphics processor available on the market today. Containing over

136 million transistors, this card executes over 1.23 trillion operations a second. It also brings an unprecedented amount of cinematic realism to gaming, and injects life into the previously artificial world of computer-generated graphics.

The realistic qualities of video games today make them an increasingly valuable tool for visualization. They are accessible, since they operate on PCs. The technology is reliable and inexpensive, having been refined in the entertainment field for more than a decade. They are intuitive and allow users to interact and view the simulation simultaneously via a network or the Internet. Game engines make use of the latest advances in computer graphics technology. By reusing a game engine's original programming for rendering, networking controls, Internet connectivity, and user interface, we can effectively lower the development costs of the total visual environment while increasing the quality of the final product. Today's computer games use graphical worlds that surpass the quality of legacy computer systems costing many thousands of dollars, yet run on PCs that are commonly available for less than two thousand dollars.

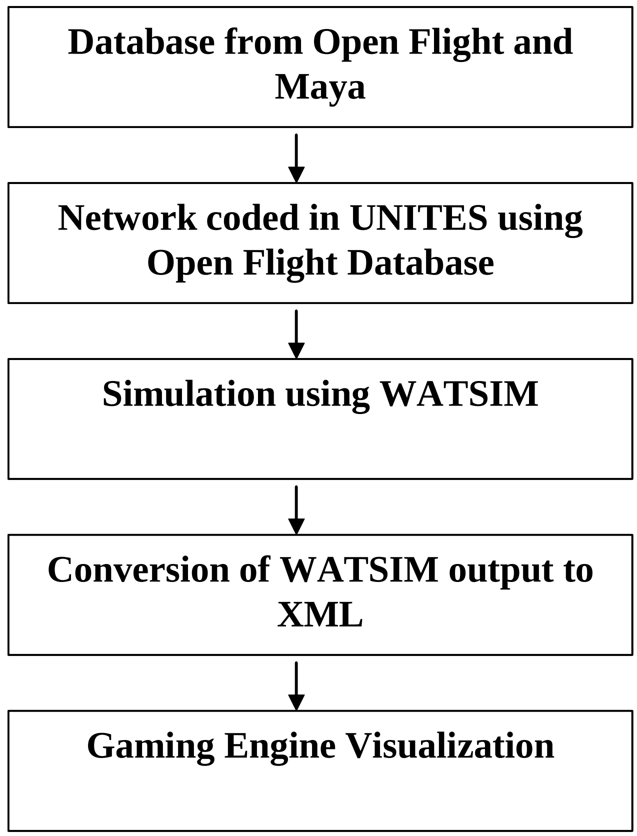
CAD drawings and Digital photography were utilized to develop the I-4 database in Open Flight and Maya. The underlying simulation engine was developed in SmallTalk, which is responsible for manipulating the vehicular models through out the simulation database.

3. METHODOLOGY

The methodology consists of the following four steps:

1. Database creation using Open Flight and Maya: CAD drawings and Digital photography were utilized to develop the I-4 database in Open Flight and Maya. It can realistically represent the true surroundings of the area being viewed.
2. Network coding using UNITES: I-4 corridor network links and nodes were coded in UNITES using the Open Flight database file. This was done to match the x and y coordinates of WATSIM file to the 3D visualization file. The entire relevant geometric and traffic features (traffic composition and signal timing) were coded in UNITES.
3. Model simulation: The coded network was simulated using WATSIM. The output was then converted in to eXtensible Markup Language (XML) format to be fed into gaming engine tool.
4. 3-D visualization of traffic flow: The XML file was fed into gaming engine tool (MAYA) for realistic viewing of the simulated traffic in a very rich virtual environment that contains high-fidelity terrain and structures representative of the metropolitan area of Orlando, Florida.

Flowchart 1 shows the flowchart of the methodology for the integration of WATSIM and MAYA.



Flowchart 1: Methodology for the Integration

4. I-4 CORRIDOR VISUALIZATION

The Phase 1 of this 'The I-4 Corridor 3-D Visualization and Simulation' project developed a 3D visualization of a 3 mile segment of I-4 from Kaley Ave to Lee Rd. Engineering and Computer Simulations, the subcontractor for this project, acquired source data for the sections between Kaley and 528 (Beeline) interchange of the I-4 corridor and between Lee Road and Maitland Interchange. Using the source data we developed the 3D database of the section. Figure 1 shows the snapshot of 3-D visualization of John Young Parkway overpass.

Figure 1: Snapshot of 3-D Visualization of John Young Parkway overpass

CAD drawings and Digital photography were utilized to develop the I-4 database in Open Flight and Maya. The underlying simulation engine was developed in SmallTalk, which was responsible for manipulating the vehicular models through out the simulation database. The simulation engine is the mechanism that allows the user to move freely within the database. The user has the ability to attach or detach from a vehicle and fly around the database and zoom in and zoom out, freeze the simulation and resume. The intent of this effort was to demonstrate the capability of simulation and how it can provide a high fidelity tool using the latest visualization technologies integrated with an approved DOT simulation for analyzing traffic flow and congestion along the I-4 corridor; Immerses the analyst/user into the simulation to provide a realistic look and feel. By utilizing this technology, researchers, analysts, and planners can view the transportation system through virtual traffic cameras, traffic-monitoring helicopters, or first person from an individual driver or pedestrian viewpoint. For example, this would enable the planner to see the impact of bailout traffic.

4.1. Source Data Collection

Data was collected for this project from a variety of sources. There was data available for the area near Kaley St. from the previous effort. Additionally, survey data was acquired from PBSJ for the majority of the remaining highway and bridges. Finally, GIS and aerial imagery was used for the stretch of the highway from below Kirkman to the exit for SR528.

4.2. Development of I-4 3D Database

The database was modeled from source data in Maya and exported to Open Flight format. The major highway area from Kaley St. down to the Beeline interchange was modeled. This included all the bridge overpasses and underpasses, major signs and limited jersey barriers on the bridges. The area on either side of the highway was then extended from the base of the burm to about 100 ft on most areas and a tree wall was placed along the edge. In many cases, the roads going under or over the main highway were modeled out to tree wall and the highway on and off ramps were added. No new buildings were added for this part of the simulation. Although the initial section of the database was high-detail with the majority of the Downtown Orlando area buildings modeled, the Phase II area was less detailed in order to concentrate on vehicle throughput.

The cars used were the same ones in the original database and new roads paths will be added to run the simulation with the additional highway.

Figure 2 shows the snapshot of 3-D visualization of I-4 corridor.

Figure 2: Snapshot of 3-D Visualization of I-4 Corridor

5. TRAFFIC SIMULATION TOOL – OVERVIEW

5.1. UNITES Overview

UNITES is comprised of the following components:

1. A *generic* graphical user interface (GUI), named the "UNITES Network Editor" (UNET) supports the data needs of the models in the UNITES "toolkit".
2. A database management system (DBMS) that performs the storage, formatting and manipulation of data that resides in a central database that is application independent.
3. A separate Model Interface Program (MIP) designed for each Legacy Traffic model supported by UNITES. The MIP performs the following functions:

- "Marshall" the data stored within the database that are needed by the model to form the input file, then "launches" the execution of the model.
- Retrieve the data that are output by the model and stores them into the central database.

4. Support the available models.
5. Interface with MS Office and with other "third-party" software products through widely accepted database standards.

5.2. WATSIM Overview

WATSIM is designed to perform a microscopic, stochastic simulation of traffic operations on highway networks comprised of freeways, ramps and surface streets. This model applies an *interval-scanning discrete* simulation approach to describe traffic operations. The traffic stream is modeled explicitly; each vehicle on the network is treated as an identifiable *entity*. Furthermore, each vehicle is identified by *category* (auto, car pool, truck, transit) and by *type*. Up to 16 different types of vehicles with different operating and performance characteristics may be specified defining the four categories of the vehicle fleet. In addition, a driver behavioral characteristic (ranging from *cautious to aggressive*) is assigned to each vehicle. The *state* of each driver/vehicle entity is defined in terms of its location and its kinematic properties (speed, acceleration), as well as its local environment (leader and follower vehicles, its intended turn maneuver, etc.). Turn movements are assigned stochastically to each driver/vehicle entity as it enters each link, as are its free-flow speed, queue discharge headway and other behavioral attributes. Consequently, each vehicle's behavior may be simulated in a stochastic manner, reflecting real-world processes.

During each time-step, a vehicle is moved by the program logic. Its updated position (both lateral and longitudinal) on a network link is determined, as well as it's other *state* variables. This approach allows the program to simulate detailed vehicle-specific traffic processes so that actuated signal control and dynamic routing may be simulated, and vehicle-vehicle and vehicle-control device interactions may be explicitly modeled. In general, most conditions experienced in an urban traffic environment can be realistically described. In this interval-scanning traffic simulation model, each driver/vehicle entity is moved each second according to car-following and lane-changing logic in response to any traffic control devices and other conditions which influence vehicle behavior.

6. I-4 CORRIDOR CODING AND SIMULATION

I-4 corridor from Kaley Avenue to Lee Road was coded in UNITES. The spatial or geometric description of the traffic environment is represented, as a network comprised of *links* and *nodes.* And the network is simulated using WATSIM.

6.1. Representing Traffic Environment

The physical traffic environment, which must be specified as input data by the user when applying the model, consists of the following features:

- Topology of the roadway system.
- Geometries of each roadway component.
- Channelization of traffic on each roadway component.
- Circulation pattern of traffic on the roadway system.
- Motorist behavior, which, in aggregate, determines the operational performance of vehicles in the system.
- Specification of the traffic control devices and their operational characteristics.
- Traffic volumes entering and leaving the roadway system.
- Traffic composition.
- Specification of all transit systems: routes, stations and frequency of service.

6.2. Traffic Volumes

In UNITES, traffic demand and turning movements on the approaches to the intersection can be specified. Traffic volumes were specified as vehicle per hour by turn movement. The traffic counts were taken from Traffic Engineer's Annual Report (2003). The throughput volumes for I-4 East Bound and I-4 West Bound were estimated as 5500 vehicles per hour. Table 1 and 2 shows the on and off ramp volumes for I-4 East and West Bound respectively.

ON RAMP:I-4 East Bound	AADT	K	PEAK HOUR VOLUME
From SR-528	14,300	8.06	1153
From SANDLAKE RD	10,700	8.06	862
From INTERNATIONAL DRIVE	8,400	8.06	677
From KIRKMAN RD	7,300	8.06	588
From FL TURNPIKE	12,900	8.06	1040
From CONROY RD SOUTH	6,400	8.06	516
From CONROY RD NORTH	3,200	8.06	258
From JOHN YOUNG PKWY	13,600	8.06	1096
From US-441	15,000	8.06	1209
From MICHIGAN ST	7800	8.06	629
From KALEY ST	5,200	8.06	419
From SR-408(E/W EXPWY)	12,800	8.06	1032
From ANDERSON ST	4,700	8.06	379
From SOUTH ST	4,700	8.06	379
From SR-50	9,000	8.06	725
From IVANHOE BLVD	8,400	8.06	677
From PRINCETON ST	7,200	8.06	580
From FAIRBANKS AVE	8,400	8.06	677
From LEE RD	11,300	8.06	911
From MAITLAND BLVD	11,900	8.06	959
OFF RAMP:I-4 East Bound	**AADT**	**K**	**PEAK HOUR VOLUME**
To SR-528	15,600	8.06	1257
To SANDLAKE RD	10,700	8.06	862
To UNIVERSAL BLVD	8,000	8.06	645
To KIRKMAN RD	7,300	8.06	588
To FL TURNPIKE	9,900	8.06	798
To CONROY RD	9,300	8.06	750
To JOHN YOUNG PKWY	6,600	8.06	532
To US-441	6,800	8.06	548
To KALEY AV.	8,700	8.06	701
To SR-408(E\W EXPWY)	13,600	8.06	1096
To ANDERSON ST.	5,500	8.06	443
To ROBINSON ST.	6,300	8.06	508
To AMELIA ST.	5,800	8.06	467
To INVANHOE BLVD.	3,300	8.06	266
To PRINCETON ST.	8,500	8.06	685
To PAR ST.	4,900	8.06	395
To FAIRBANKS AVE	8,700	8.06	701
To LEE RD	10,500	8.06	846
To MAITLAND BLVD SOUTH	10,600	8.06	854

Table 1: Ramp Volume for I-4 East Bound

ON RAMP:I-4 West Bound	AADT	K	PEAK HOUR VOLUME
FromSR-528	16,400	8.06	1322
From SANDLAKE RD SOUTH	6,100	8.06	492
From SANDLAKE RD NORTH	6,000	8.06	484
From UNIVERSAL BLVD	5,500	8.06	443
From KIRKMAN RD	9,100	8.06	733
From FL TURNPIKE	8,300	8.06	669
From CONROY ROAD	9,400	8.06	758
From JOHN YOUNG PKWY	7,800	8.06	629
From US-441	7,900	8.06	637
From KALEY ST	5,700	8.06	459
From SR-408(E\W EXPWY)	21,200	8.06	1709
From SOUTH STREET	5,900	8.06	476
From ROBINSON STREET	8,600	8.06	693
From SR-50	5,500	8.06	443
From INVANHOE BLVD.	4,200	8.06	339
From PRINCETON ST.	6,200	8.06	500
From PAR ST.	3,700	8.06	298
From FAIRBANKS AVE	8,600	8.06	693
From LEE RD	11,100	8.06	895
From MAITLAND BLVD	9,600	8.06	774
	14,700	8.06	1185

OFF RAMP:I-4 West Bound	AADT	K	PEAK HOUR VOLUME
To SR-528	15,400	8.06	1241
To SANDLAKE RD	8,800	8.06	709
To UNIVERSAL BLVD	4,200	8.06	339
To KIRKMAN ROAD NORTH	4,300	8.06	347
To KIRKMAN ROAD SOUTH	8,600	8.06	693
To FL TURNPIKE	12,800	8.06	1032
To CONROY RD	9,500	8.06	766
To JOHN YOUNG PKWY	14,000	8.06	1128
To US-441	13,900	8.06	1120
To MICHIGAN ST	6,300	8.06	508
To KALEY ST	5,400	8.06	435
To SR-408(E\W EXPWY)	13,300	8.06	1072
To GORE ST.	3,800	8.06	306
To ANDERSON ST.	3,800	8.06	306
To SOUTH ST.	2,600	8.06	210
To INVANHOE BLVD.	2,600	8.06	210
To PRINCETON ST.	6,600	8.06	532
To FAIRBANKS AVE	6,400	8.06	516
To LEE RD	11,400	8.06	919
To MAITLAND BLVD	10,000	8.06	806

Table 2: Ramp Volume for I-4 West Bound

6.3. Data eXchange Format or Bitmap Files

UNITES uses the DXF drawing image or bitmap files as a background overlay for entering a traffic network. Nodes and links were coded on the background DXF file. The DXF file used before had the section from Kaley Avenue to Maitland Interchange. To extend the simulation further down till SR528, a new DXF file needs to be created to cover the sections from Kaley Avenue to SR528. Using ArcGIS, a new DXF file was created as an overlay. Figure 3 shows the DXF file as a background in the UNITES editing window.

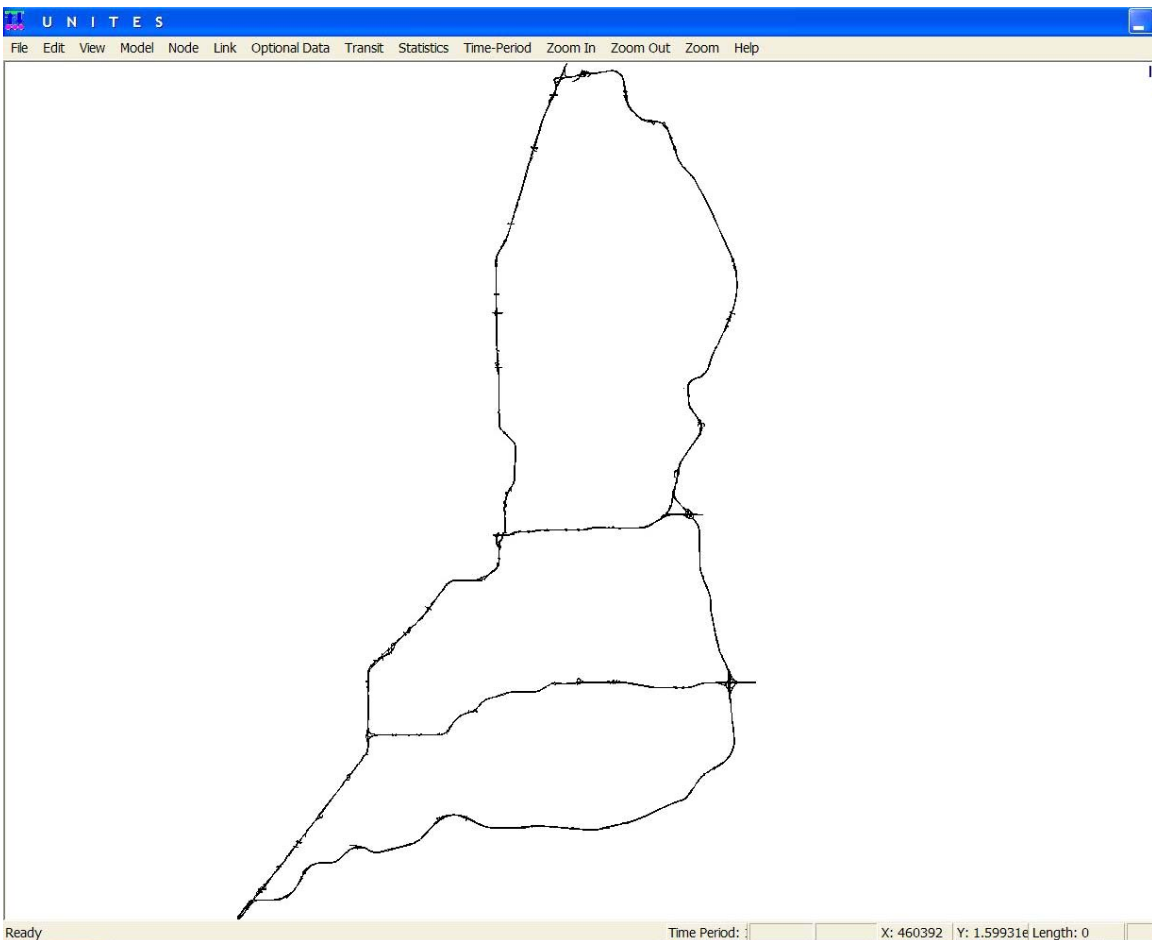


Figure 3: Background DXF File in the UNITES Editing Window

After embedding the template road geometry file (AutoCAD dxf file), a road network is built by adding nodes, links and zones and coding detailed lane and junction descriptions. The car following model is based on the fact that drivers desire to follow the car in front of them at a given value of the time headway. This time headway differs from driver to driver which is randomly assigned to a vehicle drawn from the distribution of time headways. Most of the model default values were left unchanged. Figure 4 shows the coded I-4 network using UNITES.

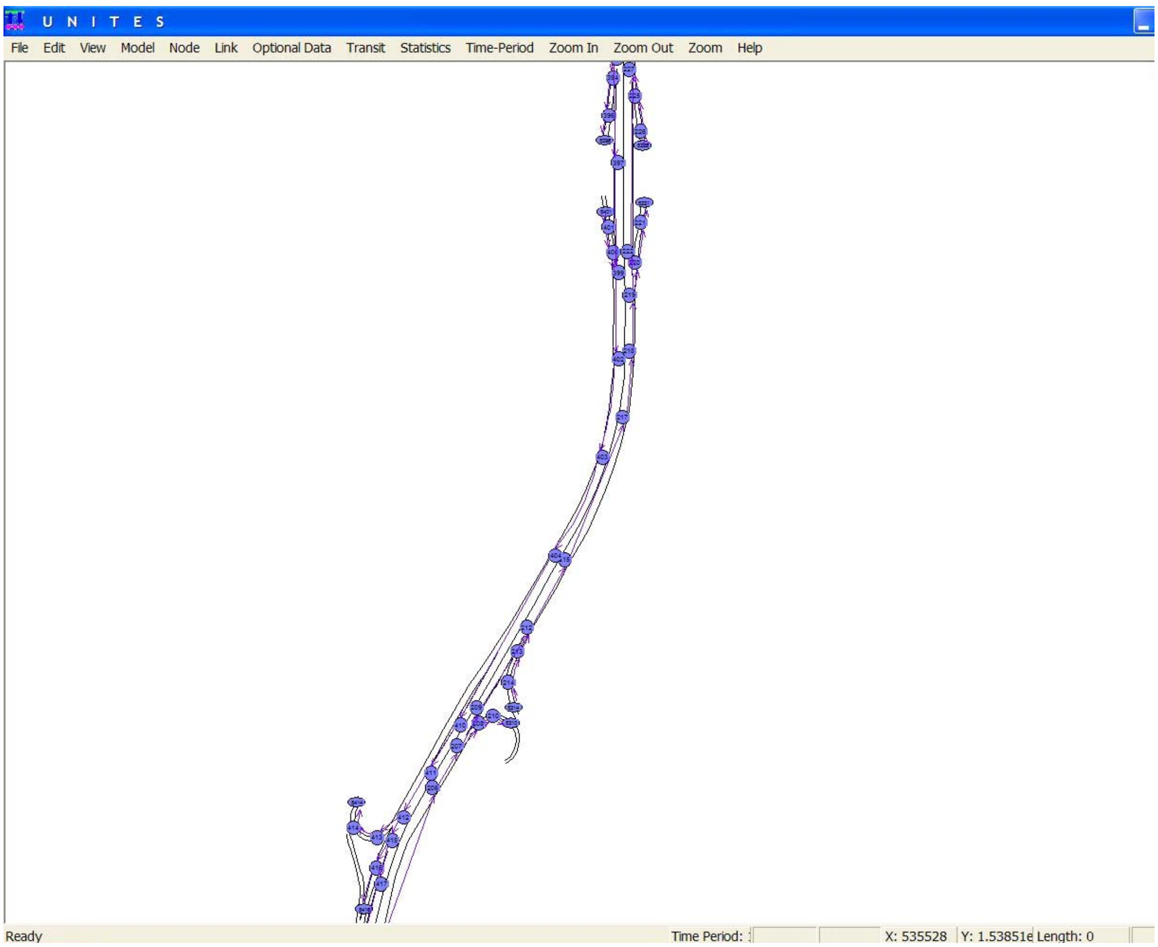


Figure 4: Coded Network Showing Nodes and Links on the I-4 Corridor

6.4. Model Calibration

Calibration is the process by which the individual components of the simulation model are refined and adjusted so that the simulation model accurately represents field measured and observed traffic conditions. The major parameters of a simulation model that require calibration include the following:

- Traffic control operations;
- Traffic flow characteristics; and
- Driver behavior.

With regards to calibration, traffic simulation models contain numerous variables to define and replicate traffic control operations, traffic flow characteristics, and driver behavior. Simulation models contain default values for each variable, but also allow a range of user-applied values for each variable. In some cases, the variables affect the entire network while others are specific to individual roadway segments or nodes. Changes to these variables during calibration should be based on field-measured or observed conditions.

Under ideal conditions, the calibration of individual components of a simulation model will improve the model’s ability to replicate traffic flow results that match field conditions within an acceptable range of error. The model can be calibrated by comparing simulated vehicle release counts to observed field data. The release counts can be varied using seed value.

The seed value is a starting value for the random number generator. From this starting value, a set of random numbers is produced. These random numbers are called by the program and used in processes that calculate many different parameters within the simulation. The parameters which use random numbers include car following, lane changing, vehicle behavior, route choice, release of demand and many more processes. Each process will call a random number from the list of random numbers as and when it is required and each calculation will be carried out in order. This means that if the same seed value is used, then the selected run will reproduce the same simulation results every time the network is simulated (provided the network is not modified). Using different seed values on the same network will then produce different simulation results.

The release counts can be calibrated by repeatedly running the simulation with different seed values and comparing the results to the field data. Then the best fit seed value is selected that is close to the field data and used for further scenario simulation results.

In WATSIM, the network is simulated using seed values 33,583, 1021, 2979, 3333, 4843, 5479, 6001 and 7237 for the peak hour traffic and the release counts are compared to the observed field data. These seed values are chosen randomly for calibration. Tables 3 and 4 shows the release counts at the ramps (West and East Bound) for observed field data and the different seed values.

I-4 West Bound	Field Data	Seed 33	Seed 583	Seed 1021	Seed 2979	Seed 3333	Seed 4843	Seed 5479	Seed 6001	Seed 7237
SR-528	1322	1314	1314	1314	1314	1314	1314	1314	1314	1314
SANDLAKE RD SOUTH	492	489	489	489	489	489	489	489	489	489
SANDLAKE RD NORTH	484	480	480	480	480	480	480	480	480	480
KIRKMAN RD	1176	1169	1169	1169	1169	1169	1169	1169	1169	1169
FL TURNPIKE	669	665	665	665	665	665	665	665	665	665
CONROY ROAD	758	753	753	753	753	753	753	753	753	753
JOHN YOUNG PKWY	629	625	625	625	625	625	625	625	625	625
US-441	637	633	633	633	633	633	633	633	633	633
KALEY ST	459	457	457	457	457	457	457	457	457	457
SR-408(E\W EXPWY)	1709	1479	1576	1509	1538	1517	1516	1477	1556	1519
SOUTH STREET	476	473	473	473	473	473	473	473	473	473
ROBINSON STREET	693	689	689	689	689	689	689	689	689	689
SR-50	443	440	440	440	440	440	440	440	440	440
INVANHOE BLVD.	339	337	337	337	337	337	337	337	337	337
PRINCETON ST.	500	497	497	497	497	497	497	497	497	497
PAR ST.	298	296	296	296	296	296	296	296	296	296
FAIRBANKS AVE	693	689	689	689	689	689	689	689	689	689
LEE RD	895	889	889	889	889	889	889	889	889	889
MAITLAND BLVD	774	753	753	753	753	753	753	753	753	753
MAITLAND BLVD	1185	1177	1175	1177	1173	1175	1177	1172	1176	1177

Table 3: Release Counts at West Bound Ramps for Observed Field Data and Seed Values

I-4 East Bound	Field Data	Seed 33	Seed 583	Seed 1021	Seed 2979	Seed 3333	Seed 4843	Seed 5479	Seed 6001	Seed 7237
SR-528	1153	1192	1192	1192	1192	1192	1192	1192	1192	1192
SANDLAKE RD	862	866	866	866	866	866	866	866	866	866
KIRKMAN RD	1265	1259	1259	1259	1259	1259	1259	1259	1259	1259
FL TURNPIKE	1040	1041	1041	1041	1041	1041	1041	1041	1041	1041
CONROY RD SOUTH	516	517	517	517	517	517	517	517	517	517
CONROY RD NORTH	258	258	258	258	258	258	258	258	258	258
JOHN YOUNG PKWY	1096	1098	1098	1098	1098	1098	1098	1098	1098	1098
US-441	1209	1212	1212	1212	1212	1212	1212	1212	1212	1212
MICHIGAN ST	629	630	630	630	630	630	630	630	630	630
KALEY ST	419	419	419	419	419	419	419	419	419	419
SR-408(E/W EXPWY)	1032	1007	905	996	1004	985	1003	1011	1004	980
ANDERSON ST	379	377	377	377	377	377	377	377	377	377
SOUTH ST	379	377	377	377	377	377	377	377	377	377
SR-50	725	720	720	720	720	720	720	720	720	720
IVANHOE BLVD	677	673	673	673	673	673	673	673	673	673
PRINCETON ST	580	576	576	576	576	576	576	576	576	576
FAIRBANKS AVE	677	673	673	673	673	673	673	673	673	673
LEE RD	911	905	905	905	905	905	905	905	905	905
MAITLAND BLVD	959	953	953	953	953	953	953	953	953	953

Table 4: Release Counts at East Bound Ramps for Observed Field Data and Seed Values

Chart 1 and 2 shows the comparison of observed field data release counts and different seed values release counts. It can be seen that the seed value 6001 matches closely to the observed field data. The simulated ramp volumes were almost the same as the actual ramp volume except at the East-West expressway on-ramp. It can also be seen that the seed value 6001 matches closely to the observed field data.

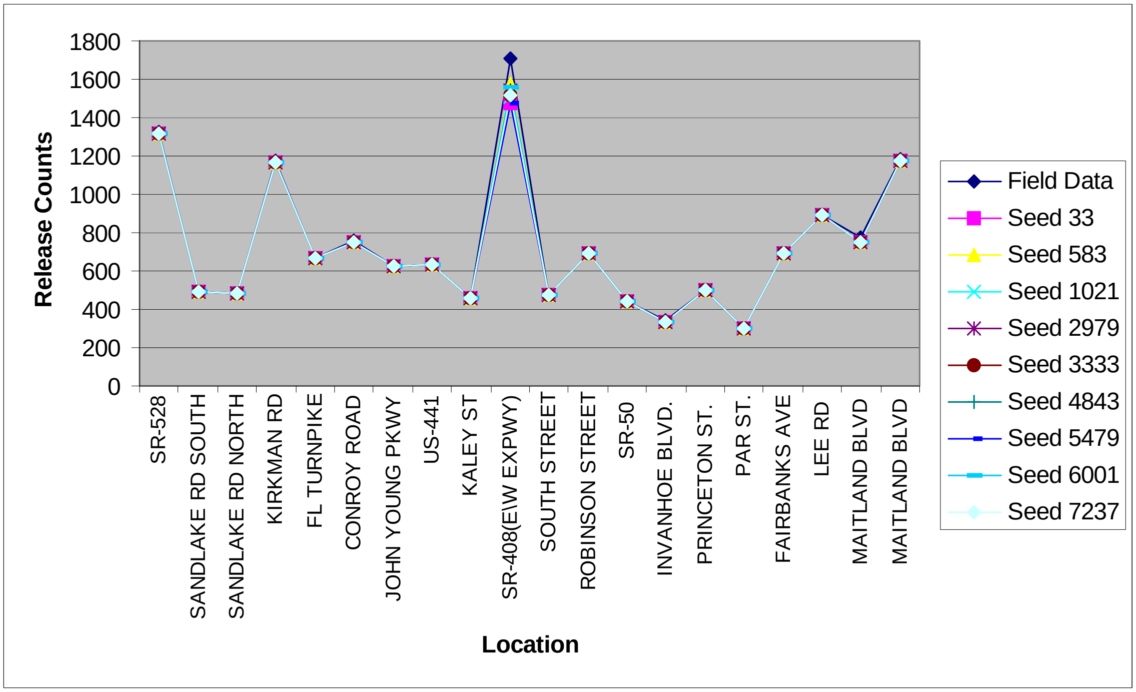


Chart 1: Chart showing the WB release counts comparison for observed and seed values

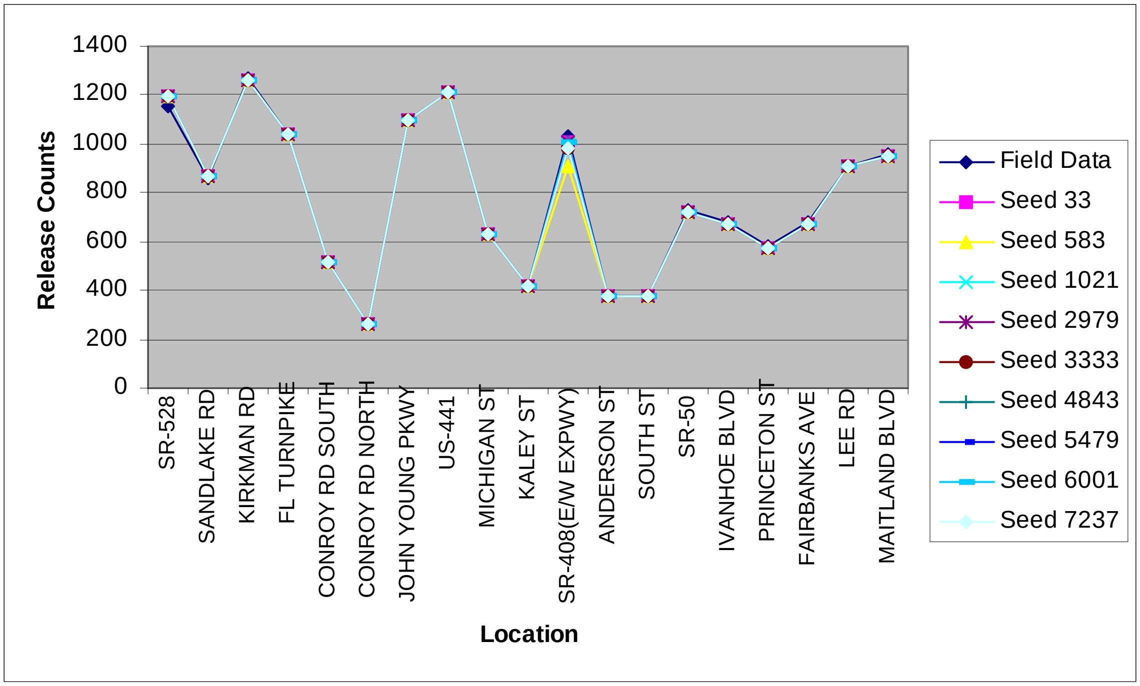


Chart 2: Chart showing the EB release counts comparison for observed and seed values

Freeway capacity can be directly specified in WATSim; it can vary between 1,000 vphpl and 2,500 vphpl. Table 3 shows that increasing the lane capacity from 2,200 vphpl to 2,500 vphpl near the SR408 had no effect on the ramp throughputs. Default lane-changing parameters were also modified to examine their effect on the ramp throughputs, but no significant improvements were obtained. The WATSim model developer suggested that different acceleration lane lengths be tried to obtain the observed mainline and ramp throughputs. By increasing the acceleration lane length and using the 2,400 vphpl capacity, the simulated throughputs became close to the actual volume. Tables 5 and 6 show the release counts at the ramps (West and East Bound) for observed field data and the seed value 6001.

I-4 West Bound	Field Data	Seed 6001
SR-528	1322	1314
SANDLAKE RD SOUTH	492	489
SANDLAKE RD NORTH	484	480
KIRKMAN RD	1176	1169
FL TURNPIKE	669	665
CONROY ROAD	758	753
JOHN YOUNG PKWY	629	625
US-441	637	633
KALEY ST	459	457
SR-408(E\W EXPWY)	1709	1689
SOUTH STREET	476	473
ROBINSON STREET	693	689
SR-50	443	440
INVANHOE BLVD.	339	337
PRINCETON ST.	500	497
PAR ST.	298	296
FAIRBANKS AVE	693	689
LEE RD	895	889
MAITLAND BLVD	774	753
MAITLAND BLVD	1185	1176

Table 5: Release Counts at WB Ramps for Observed Field Data and Seed Value 6001

I-4 East Bound	Field Data	Seed 6001
SR-528	1153	1192
SANDLAKE RD	862	866
KIRKMAN RD	1265	1259
FL TURNPIKE	1040	1041
CONROY RD SOUTH	516	517
CONROY RD NORTH	258	258
JOHN YOUNG PKWY	1096	1098
US-441	1209	1212
MICHIGAN ST	629	630
KALEY ST	419	419
SR-408(E/W EXPWY)	1032	1004
ANDERSON ST	379	377
SOUTH ST	379	377
SR-50	725	720
IVANHOE BLVD	677	673
PRINCETON ST	580	576
FAIRBANKS AVE	677	673
LEE RD	911	905

Table 6: Release Counts at EB Ramps for Observed Field Data and Seed Value 6001

The t-test of paired two samples for means of release counts from observed field data and seed value 6001 is done to show that there is no significant difference between the two sets. The paired t-test results using confidence level 95% is shown in Table 7 and 8 for West Bound and East Bound respectively. Since the P(t<=T) value is smaller than t critical, it is proven that there is no significant difference between the two release count sets.

Paired Two Sample for Means	*Variable 1*	*Variable 2*
Mean	731.55	725.65
Variance	131575.9447	128879.4
Observations	20	20
Pearson Correlation	0.999943704	
Hypothesized Mean Difference	0	
df	19	
t Stat	4.932012951	
P(T<=t) one-tail	4.62758E-05	
t Critical one-tail	1.729131327	
P(T<=t) two-tail	9.25515E-05	
t Critical two-tail	2.093024705	

Table 7: T-test of Field Data and Seed Valve 6001 for WB release Counts

Paired Two Sample for Means	*Variable 1*	*Variable 2*
Mean	777.1578947	776.31579
Variance	95904.14035	96962.673
Observations	19	19
Pearson Correlation	0.999291314	
Hypothesized Mean Difference	0	
df	18	
t Stat	0.310687747	
P(T<=t) one-tail	0.379803465	
t Critical one-tail	1.734063062	
P(T<=t) two-tail	0.75960693	
t Critical two-tail	2.100923666	

Table 8: T-test of Field Data and Seed Valve 6001 for EB release Counts

The calibrated network is simulated using WATSIM and the animation can be generated. This software imports data from the central UNITES database and creates a WATSim (.trf) input stream representing the selected network. The Model Interface Processor (MIP) then executes WATSim, which reads that input stream. After WATSim completes its calculations, the MIP software stores the MoE results generated by WATSim, into the UNITES database. The output from this WATSim execution is also stored in the UNITES/Projects directory. The user may examine the results by running the animation or viewing the output file. Figure 5 shows the snapshot of the animated I-4 corridor.

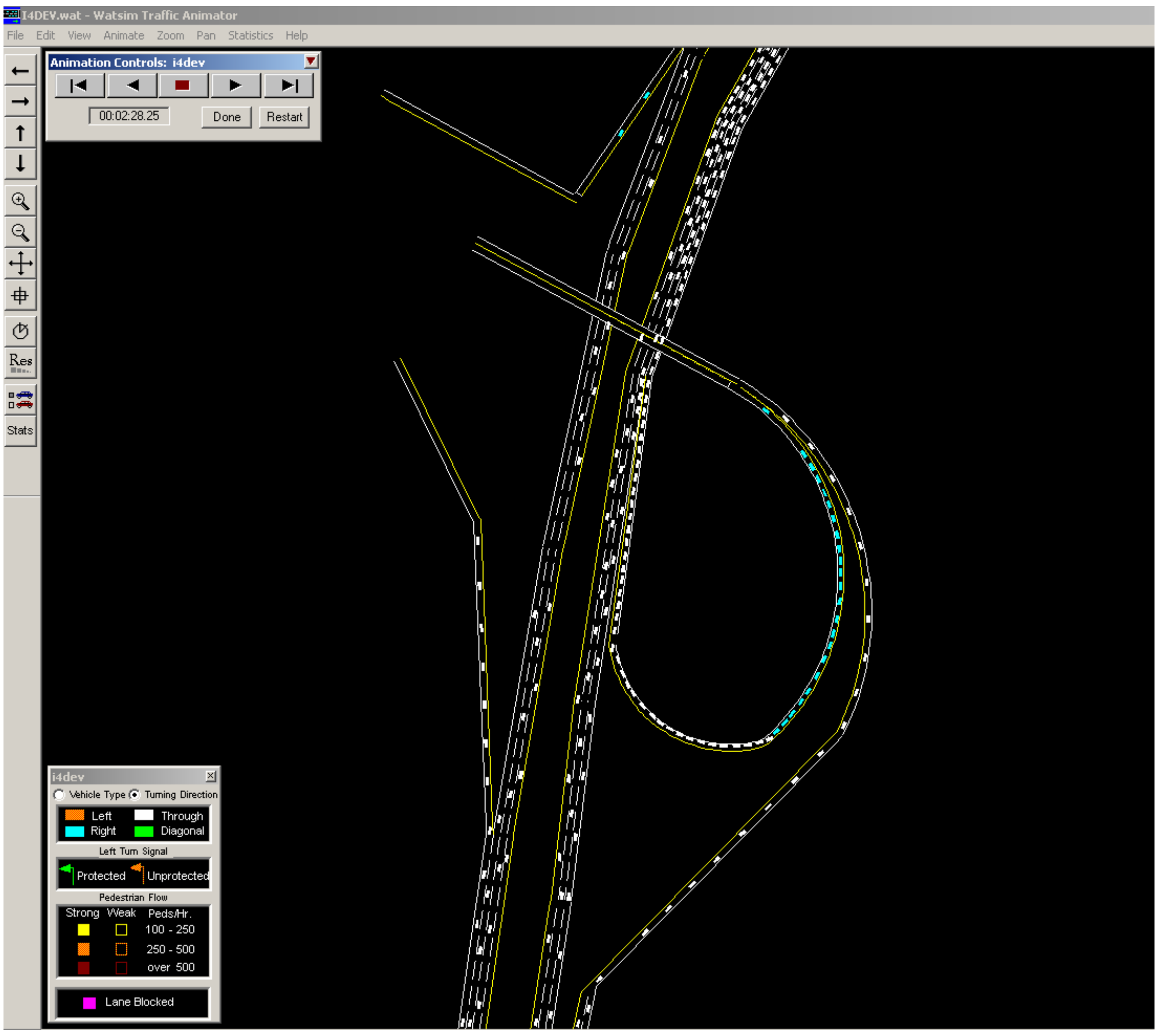


Figure 5: Snapshot of Animated I-4 and SR 408 Interchange in WATSIM

6.5. WATSIM Model Results and Analysis

The results of the existing peak hour traffic conditions for I-4 corridor from Kaley Av. to Lee Rd. are summarized as follows:

6.5.1. Freeway Analysis

During the peak hour, the I-4 segment from SR 528 to Lee Road is operating at congested conditions. WATSIM generates Density for the freeway segment links. Highway Capacity Manual 2000 provides the LOS criteria for freeways (Chapter 23, page 4, Exhibit 23-2) for the simulated density. Table 9 and 10 show the level of service (LOS) for I-4 West and East Bound Mainline respectively

I-4 WEST BOUND	DENSITY (veh/mi/la)	LOS
West of SR-528	52.9	F
West of SANDLAKE RD	39.1	E
West of KIRKMAN RD	90	F
West of TURNPIKE	30.8	D
West of CONROY RD	31.8	D
West of JOHN YOUNG PKY	44.2	E
West of OBT	32.6	D
West of FL-408	35.8	E
West of SR-50	35.3	E
West of LEE RD	26.4	D

Table 9: Level of Service for I-4 West Bound Mainline

I-4 EAST BOUND	DENSITY (veh/mi/la)	LOS
East of SR-528	56.3	F
East of SANDLAKE RD	59.1	F
East of KIRKMAN RD	34.5	D
East of TURNPIKE	43	E
East of CONROY RD	57.1	F
East of JOHN YOUNG PKY	51.2	F
East of OBT	53.8	F
East of FL-408	87.2	F
East of SR-50	60	F
East of LEE RD	31.2	D

Table 10: Level of Service for I-4 East Bound Mainline

6.5.2. Ramp Analysis

WATSIM generates average vehicle per hour (VPH) and speed for the network links. The density was then calculated for the network links. Highway Capacity Manual 2000 provides the LOS criteria for merge and diverge areas for lane density (Chapter 25, page 5, Exhibit 25-4). The LOS for on and off ramps is found using the HCM 2000 for the calculated density. Table 11 and 12 show the level of service (LOS) for I-4 West and East Bound ramps respectively.

WEST BOUND OFF RAMP	VPH	SPEED	DENSITY (veh/mi/la)	LOS
To SR-528	1130	30	37.7	E
To SANDLAKE RD	662	28.3	23.4	C
To KIRKMAN RD	909	28.3	32.1	D
To TURNPIKE	988	27.4	36.1	E
To CONROY RD	683	27.3	25.0	C
To JOHN YOUNG PKY	1090	27.8	39.2	E
To OBT	1065	30	35.5	E
To 408	1002	28.3	35.4	E
To SOUTH ST	181	27.1	6.7	A
To LEE	849	30	28.3	C
WEST BOUND ON RAMP	**VPH**	**SPEED**	**DENSITY (veh/mi/la)**	**LOS**
From SR-528	1314	28.9	45.5	F
From SANDLAKE RD	969	20.6	47.0	F
From KIRKMAN RD	1169	12.6	92.8	F
From TURNPIKE	665	29.2	22.8	C
From CONROY RD	753	28.9	26.1	C
From JOHN YOUNG PKY	625	28.3	22.1	C
From OBT	633	27.7	22.9	C
From 408	1689	27.1	62.3	F
From SR-50	440	28.8	15.3	B
From LEE	889	29.8	29.8	D

Table 11: Level of Service for I-4 West Bound On and Off Ramps

EAST BOUND OFF RAMP	VPH	SPEED	DENSITY (veh/mi/la)	LOS
To SR-528	1230	24.8	49.6	F
To SANDLAKE RD	804	27	29.8	D
To KIRKMAN RD	527	27.5	19.2	B
To TURNPIKE	758	27.7	27.4	C
To CONROY RD	738	30	24.6	C
To JOHN YOUNG PKY	485	27.8	17.4	B
To OBT	512	29.2	17.5	B
To 408	1037	25.4	40.8	E
To AMELIA AVE	445	28.2	15.8	B
To LEE	780	27.9	28.0	C
EAST BOUND ON RAMP	**VPH**	**SPEED**	**DENSITY (veh/mi/la)**	**LOS**
From SR-528	1192	25.9	46.0	F
From SANDLAKE RD	866	28.7	30.2	D
From KIRKMAN RD	1259	28.3	22.2	C
From TURNPIKE	1041	28.3	36.8	D
From CONROY RD S	517	28.2	18.3	B
From CONROY RD N	258	29.4	8.8	A
From JOHN YOUNG PKY	1098	28.2	38.9	E
From OBT	1212	28.5	42.5	E
From 408	1004	12.4	81.0	F
From AMELIA AVE	720	25.7	14.0	B
From LEE	905	28	32.3	D

Table 12: Level of Service for I-4 East Bound On and Off Ramps

6.6. Scenario- Addition of Truck lane

Truck-only lanes, commonly called "truck lanes," are lanes designated for the exclusive use of trucks. The purpose of truck lanes is to separate trucks from other mixed-flow traffic to enhance safety and/or stabilize traffic flow.

An exclusive truck lane (left lane) was coded on the I4 network. Passenger cars are not allowed to use truck-only lanes. The truck percentage was taken from the Florida Traffic Count, 2001. Simulation was done with and without the truck lane to study the utility of adding a truck lane. The default value of 1.3 and 1 was used as the occupancy for passenger cars and trucks respectively. Figure 6 shows the animation of the simulated I-4 corridor with trucks.

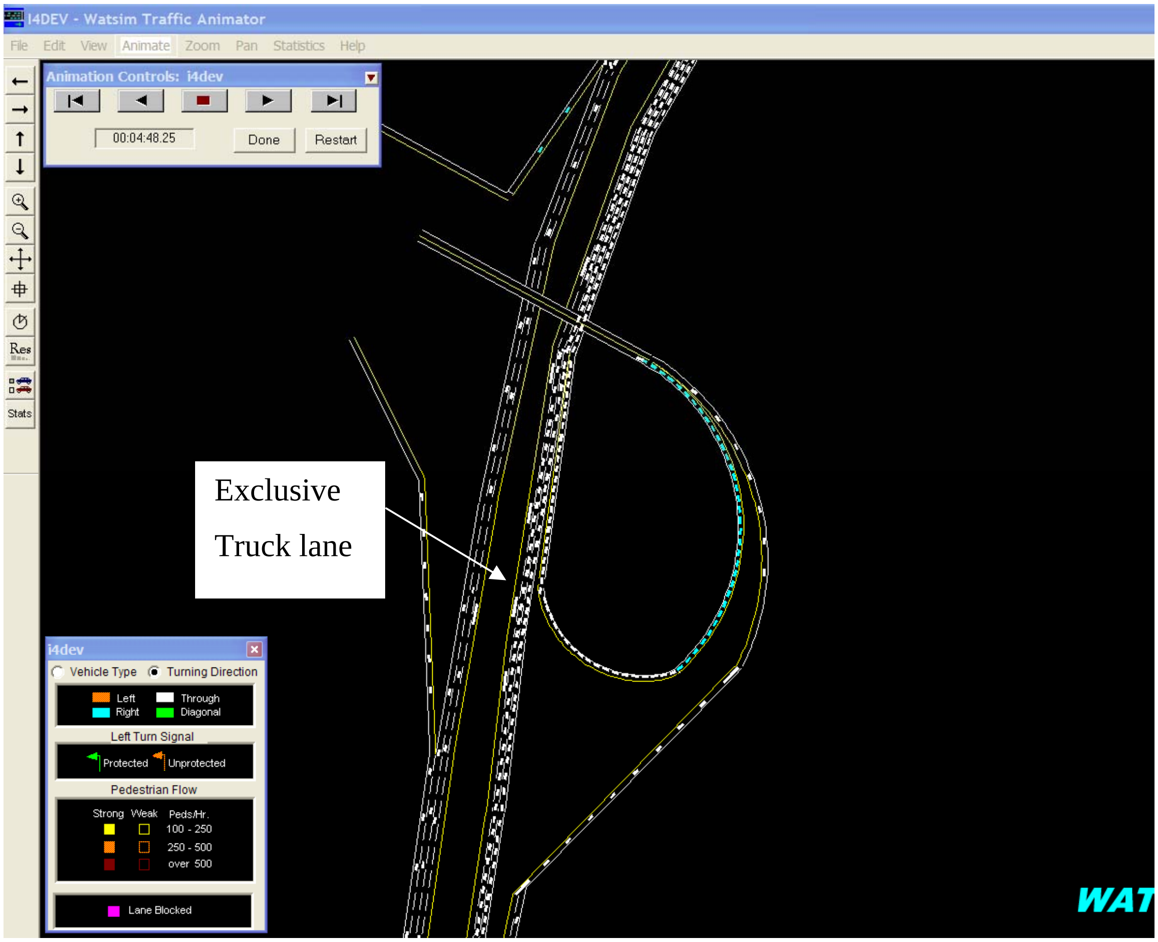


Figure 6: Snapshot of Simulated I-4 and SR 408 Interchange in WATSIM

Analysis

The WATSIM program provides a wide range of Measures of Effectiveness (MOE) on a link specific basis or aggregated over each subnetwork. It produces cumulative output which provides data accumulated since the beginning of simulation. Some of the MOE's generated are as follows:

Travel: Vehicle miles and Person miles traversed on the link.

Vehicle Delay Time: Total time vehicles were delayed on the link (veh. hrs.)

Person Delay Time: Total time people were delayed on the link (person hrs).

Table 13 shows the simulation results (cumulative) of I-4 corridor with and without truck lane. The WATSIM analysis indicate that vehicle delay time and person delay time are more for corridor with exclusive truck lane than without exclusive truck lane. And the vehicle miles and person trips were reduced significantly with the exclusive truck lane. This indicates that the capacity of the corridor reduces if you have an exclusive truck lane.

Simulation Type	Vehicle Miles	Person Trips	Vehicle Delay (Vehicle-hours)	Person Delay (Person-hours)
Without Truck Lane	182380	38624	3362	4361
With Truck Lane	143336	32020	4477	5802

Table 13: MOE Comparison of I-4 Corridor With and Without Truck Lane

7. INTEGRATION OF WATSIM WITH GAMING ENGINE

The integration of simulation software (WATSIM) and gaming engine was an imperative element of this project. The handshake between these two was achieved by converting output file from WATSIM as eXtensible Markup Language (XML) file and fed into 3-D visualization engine as an input.

XML is a generalized markup metalanguage that allows people to create their own tags to describe their own data.

In WATSIM simulation model, the coordinates (and azimuths) of vehicles (with ID numbers) at one second time-steps were generated. The animation code remembers where the vehicle was in the previous time-step, determines an offset time, and interpolates a position for the vehicle and renders it repeatedly until the time-step is accomplished. At the end of each time-step, the new positions were remembered, and the next position time-step was read, and interpolation begins again. Code that maps the simulation software to gaming engine will be files of waypoints along with the arrival time for each vehicle. Each of these files, which contain a vector of waypoints that the vehicle models using each file traverse, will be called by the main structure.

The waypoint file for a test vehicle titled VEH1.xml looks as follows:

<waypoint>
<x>16830.3</x>
<y>23322.9</y>
<z>0</z>
<time>1</time>
</waypoint>
<waypoint>

```
<x>16883.9</x>
<y>23322.8</y>
<z>0</z>
<time>1</time>
</waypoint>
```


And the main structure for VEH1 was coded as following,


```
<?xml version="1.0"?>
<models>
<model>
<name>VEH1</name>
<sensorRadius>800</sensorRadius>
<status>healthy</status>
<type>automobile</type>
<startTime>2</startTime>
<speed>49</speed>
<positionNorth>23322.9</positionNorth>
<positionWest>16883.9</positionWest>
<route>VEH1.xml</route>
</model>
</models>
```


The main structure contains the vehicle's details such as vehicle name, vehicle type, start time from the beginning of simulation, speed of the vehicle, x and y coordinates of the vehicle and the reference to the route of that vehicle (i.e. waypoint file of the vehicle). These XML files were fed into gaming engine to generate the vehicular movements thus allowing the users to view the I-4 corridor through various perspectives in a very rich virtual environment that contains high-fidelity terrain and structures.

7.1. Challenges Faced in Integration

After much iteration we successfully parsed xml files to build internal route representations in the gaming tool. After the first iteration, when we ran the 3D visualization, most of the vehicles stayed in the lane as simulated by the WATSIM. But, few vehicles flew in the air. The vehicles flew in the air because it couldn't locate the road texture in the gaming tool. The road texture coordinates of the gaming tool didn't exactly match the WATSIM coordinates. This was because the node-link diagram was not exactly matched with the background DXF diagram. We started matching the WATSIM coordinates to the 3D Gaming Tool coordinates. It was a painstaking process and the work was completed in a month.

The aligned network was simulated and then the output was converted to XML for matching. Still the vehicle coordinates weren't matching with the 3D gaming tool visualization. After reexamining the algorithm, we found that the WATSIM XML handler adds median width to the pavement width and this shifted the vehicle coordinates by 6 ft. This made the right lane vehicles move off 6 ft and not stay on the road texture. After fixing the algorithm by removing the median width, the network was again simulated. The XML file generated matched with the roadway texture of the 3D gaming tool. The vehicles stayed within the pavement and it followed the car following theory and lane change behavior.

In the previous iterations, we generated XML files of 250 vehicles. We now increased the number of vehicles to 10000. We were able to generate more number of vehicles by increasing the XML file handling capability of WATSIM. And it could handle more vehicles if the simulation runs on a PC with a good memory space (> 2GB).

8. SUMMARY AND NEXT STEPS

Based on the traffic operations analysis of the select I-4 corridor using WATSIM model, the summary is as follows:

1. I-4 Mainline: I-4 operates at congested conditions in both the direction during peak period.
2. Ramp: The LOS for on and off ramps is found using the HCM 2000 for the calculated density from simulation. Table 9 and 10 of this report show the level of service (LOS) for I-4 West and East Bound ramps respectively
3. The WATSIM analysis indicate that vehicle delay time and person delay time are more for the corridor with exclusive truck lane than without exclusive truck lane. And the vehicle miles and person trips were reduced significantly with the exclusive truck lane.

Other challenges were related to the integration of WATSIM with Gaming Engine tool. In Phase 1 we were limited to number of cars and processing speed. Right now we can simulate up to 10000 cars in the gaming engine tool with processor memory of 2GB. WATSIM algorithm was fixed to match the simulated vehicle coordinates to the road texture of the gaming tool. This allowed the vehicles stayed within the pavement and it followed the car following theory and lane change behavior.

9. REFERENCES

1. KLD Associates. "UNITES Draft User Manual"
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3. Highway Capacity Manual 2000
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5. Florida Traffic Information, 2001, Florida Department of Transportation
6. Quadstone Ltd. "PARAMICS ModellerV3.0 User Guide and Reference Manual" Edinburgh, February 2000