THE CENTRAL FLORIDA DATA WAREHOUSE (CFDW), PHASE-2- THE CENTRAL ITS OFFICE FUNDING

FINAL REPORT

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University of Central Florida

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Submitted by

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The main goal of this project is to design and implement the Central Florida Data Warehouse (CFDW). This report documents the UCF management efforts of the TCSP project and steps towards completion of the first year of a three-year effort to deploy the traffic information data warehouse in Central Florida. Hardware and software components of the CFDW planned for the first year were procured under the TCSP contract and became functional online. This large scale TCSP project can be divided into a number of smaller projects that were completed with a thrilling success in this first year. These include the primary fiber connection on UCF campus project, the data grinding project, the web user interface (UI) design project, the video design project, and the Geographic Information Systems (GIS) integration project. The primary fiber connection was laid out from the entrance of UCF at Alafaya Trail along old Central Florida Blvd. to the Multilingual Multicultural Center, which connects through express fiber to the UCF Computer Science building, where the data warehouse servers resided. The primary fiber link was used to transmit live video from the I-4 cameras to UCF. The data grinding project cleaned the loop detector data and imputed missing data at the 5-minute aggregate level. A new algorithm for loop data imputation was developed and successfully implemented online. The web UI project produced the Central Florida Regional Transportation Operations Consortium's Traffic Information Web Site (or iFlorida web site www.iflorida.org which was maintained by UCF). This was based on a "Web Site User Requirements Document" written by UCF and approved by FDOT D-5 and the Consortium. The web front end was integrated with the GIS software to ensure functionalities of the above iFlorida web site. A video project was successfully implemented with video snapshots from selected cameras on I-4 showing live on the web site. Finally, the CFDW has provided web based real time and predictive travel time information to commuters and tourists in Central Florida and will be the "one stop shop" for traffic information in Central Florida.

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EXECUTIVE SUMMARY

The main goal of this project is to design and implement the Central Florida Data Warehouse (CFDW). The University of Central Florida (UCF) received funding through the Transportation and Community and System Preservation (TCSP) grant funded by the US Department of Transportation (USDOT) Federal Highway Administration with funding pass through the Florida Department of Transportation (FDOT) District-5, Deland, Florida. The funding was used to design and implement the CFDW. UCF has also received funding from the FDOT Research Center (with recommendation from the Central ITS Office) to have UCF manage the TCSP project. This report documents the UCF management effort and the steps taken towards completion of the first year of a three-year effort needed to deploy the traffic information data warehouse in Central Florida.

Hardware and software components of the CFDW planned for the first year have been procured under the TCSP project and were functional online for several months until funding of the TCSP project was depleted. The large scale TCSP project can be divided into a number of smaller projects that were completed with a thrilling success in this first year. These include the primary fiber connection on UCF campus project, the data grinding project, the web user interface (UI) design project, the video design project, and the Geographic Information Systems (GIS) integration project.

The primary fiber link connected the UCF data warehouse with the Regional Traffic Management Center (RTMC) through the Orange County and the Orlando-Orange County Expressway Authority (OOCEA) fiber network. The primary fiber was laid out from the entrance of UCF at Alafaya Trail along old Central Florida Blvd. to the Multilingual

Multicultural Center, which connects through express fiber to the UCF Computer Science building, where the data warehouse servers reside. The primary fiber link was used to transmit live video from the I-4 cameras to UCF through the RTMC. The UCF research team invented a new loop detector data cleaning and filtering algorithm that is capable of imputing the data to fill in the holes for missing or incomplete loop detector data. This first step is crucial before any loop data can be used for deriving useful traffic information, which could be disseminated to the traveling public. The data grinding project cleaned the loop detector data and imputed missing data at the 5-minute aggregate level. The new algorithm for loop data imputation was developed and successfully implemented online. The web UI project produced the Central Florida Regional Transportation Operations Consortium's Traffic Information Web Site (or iFlorida web site www.iflorida.org , which was maintained by UCF for several months after it was launched to the public towards the end of October 2003 and through the end of February 2004). The web site complied with a "Web Site User Requirements Document" written by UCF and approved by FDOT D-5 and the Consortium. The web front end was integrated with the GIS software (procured from ESRI or Environmental Systems Research Institute, Inc.) to ensure functionalities of the above iFlorida web site. A video project was successfully implemented with 16 selected cameras which show live video snapshots on the web site. Fifteen of these cameras are located along I-4 while the sixteenth camera is located at the interchange of I-95 and SR 528 in Brevard County. Finally, with great success, the CFDW is now providing web based real time and predictive travel time information to commuters and tourists in Central Florida and beyond. Once expanded and implemented at full scale, the above iFlorida web site will be the "one stop shop" for traffic information in Central Florida.

FDOT D5 requested to add the following statement in the report "The expansion of the Data Warehouse in years two and three to cover toll roads and other facilities will be determined as part of Phase 1 of the iFlorida Model Deployment Program."

ACRONYMS

ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management System
AVI	Automatic Vehicle Identification
C2C	Center-to-Center
TSI	Transportation Systems Institute
CATSS	Center for Advanced Transportation Systems Simulation
CCTV	Closed Circuit Television
CFDW	Central Florida Data Warehouse
DBMS	Database Management System
DDB	Distributed Database
DMS	Dynamic Message Signs
DOT	Department of Transportation
FDOT	Florida Department of Transportation
FHP	Florida Highway Patrol
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GUI	Graphical User Interface
IEEE	Institute of Electrical and Electronics Engineers
IMS	Internet Map Server
ISO	International Organization for Standards
ITE	The Institute of Transportation Engineers

ITS	Intelligent Transportation Systems
ITS-DR	ITS Data Registry
JDBC	Java Database Connectivity
NTCIP	National Transportation Communication for ITS Protocols
ODBC	Open Database Connectivity
OOCEA	Orlando-Orange County Expressway Authority
RTMC	Regional Traffic Management Center
RTMS	Remote Traffic Microwave Sensors
SDE	Spatial Database Engine
SQL	Structures Query Language
TBD	To Be Determined
TCSP	Transportation and Community and System Preservation Pilot Program
TMC	Traffic Management Center
TMDD	Traffic Management Data Dictionary
UCF	University of Central Florida

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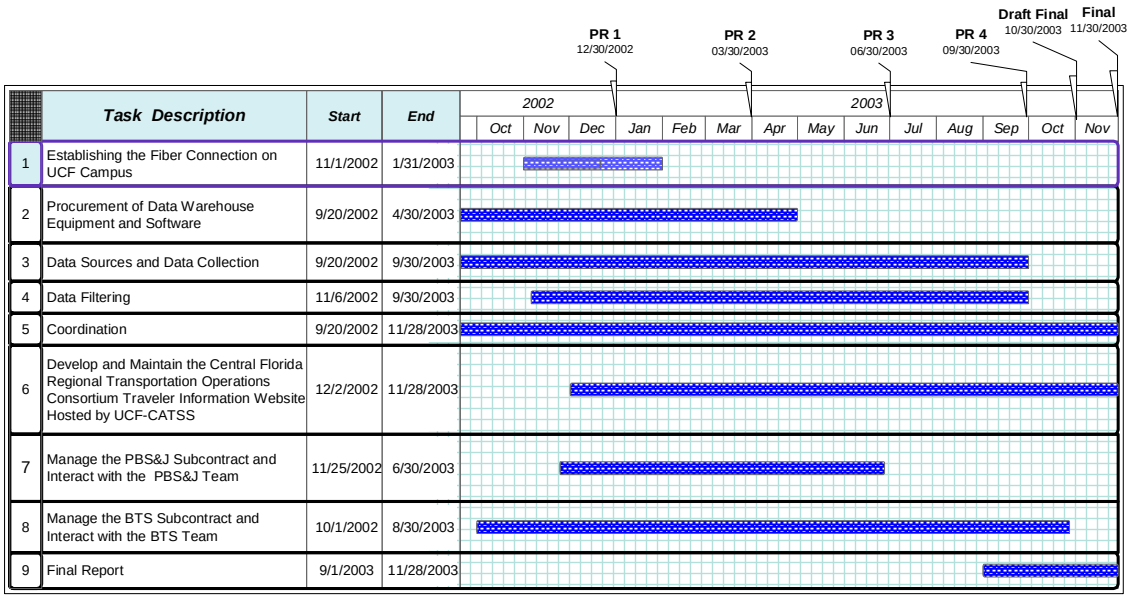
CHAPTER 1

INTRODUCTION

The University of Central Florida (UCF) was contracted by the Florida Department of Transportation (FDOT) to manage the TCSP project for designing and implementing the Central Florida Data Warehouse (CFDW) for traffic information. The TCSP funding was provided through the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA) Transportation and Community and System Preservation Pilot (TCSP) Program. The FDOT Research Center supported the UCF effort to manage the TCSP project in collaboration with the FDOT Central ITS Office in Tallahassee. As the title of this project suggests, the report herein is concerned with the second source of funding and hence is titled "The Central Florida Data Warehouse (CFDW), Phase-2-, The ITS Office Funding." This report is the final deliverable of this ITS Office project.

The intent of the FDOT Research Center funding (from now on referred to as the ITS Office project) is to cover the cost of labor by UCF in managing and executing the various tasks of the TCSP project. This ITS Office project has commenced on 09/20/2002. There are nine major tasks in this project, see Figure 1 below for project schedule. These tasks have been described in detail in the contract and in the first progress report.



	Task Description	Start	End
1	Establishing the Fiber Connection on UCF Campus	11/1/2002	1/31/2003
2	Procurement of Data Warehouse Equipment and Software	9/20/2002	4/30/2003
3	Data Sources and Data Collection	9/20/2002	9/30/2003
4	Data Filtering	11/6/2002	9/30/2003
5	Coordination	9/20/2002	11/28/2003
6	Develop and Maintain the Central Florida Regional Transportation Operations Consortium Traveler Information Website Hosted by UCF-CATSS	12/2/2002	11/28/2003
7	Manage the PBS&J Subcontract and Interact with the PBS&J Team	11/25/2002	6/30/2003
8	Manage the BTS Subcontract and Interact with the BTS Team	10/1/2002	8/30/2003
9	Final Report	9/1/2003	11/28/2003

Figure 1. List of Project Tasks and Schedule of the Central Florida Data Warehouse (CFDW) -PHASE-2-: The Central ITS Office Funding.

Study Objectives

The main objectives of the two CFDW projects are:

1. Design and implement the CFDW in this first year.

2. Develop and launch the Central Florida Regional Transportation Operations Consortium's Traffic Information Web Site known as iFlorida site (www.iflorida.org).

3. Maintain and host the web site once it is launched at UCF.

In this sense the present CFDW lays out the foundation for its expansion through the iFlorida research program.

Study Approach

This large scale project can be divided into the following smaller projects:

- The infrastructure (hardware and software needs) and primary fiber connection project.
- The network security project.
- The data grinding project.
- The Web User Interface (UI) design project.
- The video project
- The GIS integration project.

All of these projects were conducted and completed successfully through the course of this study under the TCSP project. A subcontractor was hired, under the TCSP project, to complete some of these tasks and projects. This is the Berkeley Transportation Systems, Inc. (BTS). BTS was instrumental in the data grinding, web UI design, and video design projects. Another subcontractor, PBS&J, was hired under the TCSP project to develop a business plan for the data warehouse to estimate the expenses and budget needs after CFDW deployment in the fourth and fifth years. The chapters to follow describe each project individually and in greater detail.

CHAPTER 2

DEVELOPMENT OF THE DATA WAREHOUSE INFRASTRUCTURE

The Primary Fiber Optic Installation

According to the Data Warehouse conceptual plan described in the final report for the Phase-1- of the Central Florida Data Warehouse authored by Al-Deek and Abd-Elrahman and titled "An Evaluation Plan for the Conceptual Design of the Florida Transportation Data Warehouse," March 2002, and according to the TCSP and ITS Central Office contracts, there were two fiber optic installations planned on UCF campus: primary and redundant connections.

The "primary fiber connection," was funded in the TCSP contract during the first year of the data warehouse project. This primary fiber link extended fiber from the UCF entrance at the intersection of Alafaya Trail and the old Central Florida Boulevard to the UCF Multilingual Multicultural Center, which connects to the express fiber optic cable going to the Computer Science building, where the CFDW servers reside. This layout is demonstrated in Figure 2. The primary fiber connection allows for UCF to receive video multicast of traffic cameras along the I-4 corridor which are then converted into JPEG snapshots and presented on the Internet. This connection will be used to retrieve traffic related road sensor data collected by FDOT.

Initially, the "redundant fiber connection" on UCF campus (also shown in Figure 2) was proposed in the "expansion of the data warehouse project" with funding anticipated from the iFlorida program, see page 54 of the iFlorida Final Work Plan. The redundant fiber was

proposed to extend from the UCF Intercollegiate Athletics Complex along the west side of Orion Boulevard to Orange/Seminole County Fire Station 65. This will serve as an alternative connection in case of accidental failure or damages to the primary fiber connection. Therefore, this redundancy is important for 24/7 operation of the CFDW and the regional iFlorida web site to provide increased protection from possible service outages.

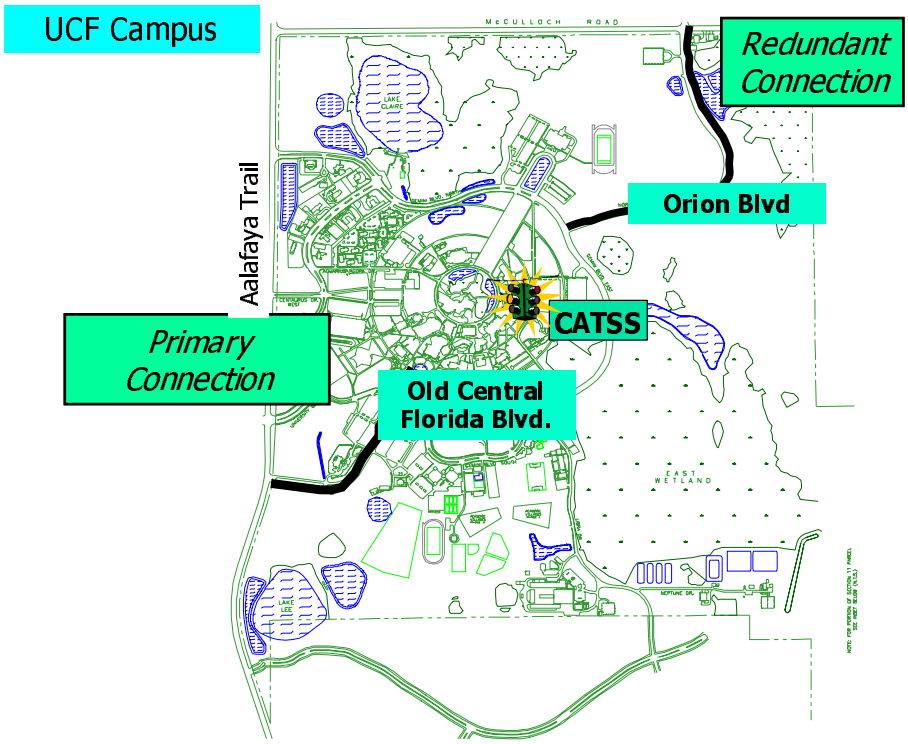


Figure 2. UCF On-Campus Links Needed to Connect the CFDW Web Servers with the FDOT Fiber Located at the Outskirts of the UCF Campus Perimeter

On December 20, 2002, the installation of a fiber optic connection between UCF and FDOT District 5 Regional Transportation Management Center (RTMC) was completed. In order to make the connection possible, it was necessary to install a concrete encased telecom duct bank (Figure 3) system on the campus of UCF. This installation is just a small portion of the connection between and UCF and the RTMC. To complete this connection, we have

collaborated with the Orlando Orange County Expressway Authority and the Orange County Traffic Engineering Department, both of which have allowed the use of their existing fiber network for this endeavor.

Figure 3. Concrete Encased Duct Bank

Acquisition of Hardware

In order to store, retrieve and present data through the CFDW, it was necessary to procure the hardware to support this endeavor. Listed below are the fundamental hardware components that were required and an explanation of each component.

a. 3 Production web servers (DELL) – these Windows 2000 servers host the web site in a round-robin cluster environment.

b. 1 Development web server (DELL) – any new development to the web site will occur on this machine. After the update has been tested on this machine, it will be ported to the production servers.

c. 5 Computer workstations (DELL Precision 530) – used for daily work in support of the CFDW.

d. 2 Laptop computers (DELL Latitude) – used for daily work in support of the CFDW as well as presentations off campus.

e. 2 Router/firewalls

    1. The first router/firewall (Cisco 2610) is located between the Internet and the computer network.
    2. The second router/firewall (Cisco 2611) is located between UCF and the RTMC.

f. 1 Firewall

    1. This firewall device (Cisco PIX 506E) is at the UCF end of the Point to Point T-1.

g. 3 Switches

    1. Cisco 2950G – used to terminate the fiber optic connection between the RTMC and UCF
    2. Cisco 2950 – used to define two VLANs. VLAN4090 represents the FDOT side of the network while VLAN903 represents UCF's side.

h. 1 Storage Area Network (DELL EMC^2) – a disk array that contains the storage for the database.

i. 1 Database Server (Sun Solaris) – Houses the database management system, Oracle 9i.

j. NetScreen- IDP 500 firewall as requested by FDOT D5 to be placed at the RTMC to secure FDOT's end of both the fiber optic and T-1 connections.

k. 2 GBICs – interface devices that convert the fiber optic light signals to electrical pulses. Allows the fiber optic connection to join the two Ethernet networks.

l. Video Server (Linux server) – receives the video signal from the RTMC and creates snapshot images.

Acquisition of Software

The following software was procured for this project:

a. Oracle License – monthly license model that was acquired through UCF. Provides access to technical support and any upgrades. This is the Database Management System.

b. DB Artisan – software tool that is used in conjunction with Oracle to maximize performance and ease management.

c. What's Up Gold – server management tool to assist in maintaining the web servers. Uses an alarm tool to notify administrators of outages in real time.

d. Hummingbird Exceed – tool to access and manage the Sun Solaris machine.

e. Winternals Administrators Pack – server based solution for managing the Windows web servers. Benefits include disk management and recovery.

f. Symantec Antivirus Corporate Edition (10 Licenses) – installed on all computers in the network running Windows OS. Prevents the computers from becoming infected by computer viruses.

The GIS software used in this project are products developed by the Environmental Systems Research Institute, Inc. (ESRI).

a. 4 ArcSDE 8.3 for Oracle 9i server license

b. 4 ArcIMS 4.01 per CPU license.

c. 2 ArcView 8.3 lab kit with concurrent use.

d. 50 ArcSDE Client Connects

ArcSDE 8.3 is a server side engine that enables management of geographic information in a database management system (DBMS). Oracle 9i is the DBMS used in this project.

ArcSDE allows serving spatial data to GIS client applications and through ArcIMS over the Internet.

ArcIMS 4.01 is an Internet Map server that allows distributing GIS applications over the Internet. It enables users to display, query and analyze GIS data source through an easy to use Web browser interface.

ArcView 8.3 is desktop GIS software that provides capabilities such as creating and editing of data, query, spatial analysis, and data visualization. In this project, it is predominantly used for creation and editing of GIS datasets.

ArcSDE Client, which is part of the ArcSDE server license, allows ArcGIS and ArcIMS to access GIS data stored on the DBMS server. It comes with its own API and libraries that allow users to develop stand alone applications.

Network Configuration and Security Plan

Figure 4 describes how the network is presently configured. The domain name *www.iflorida.org* has been registered for a three-year interval.

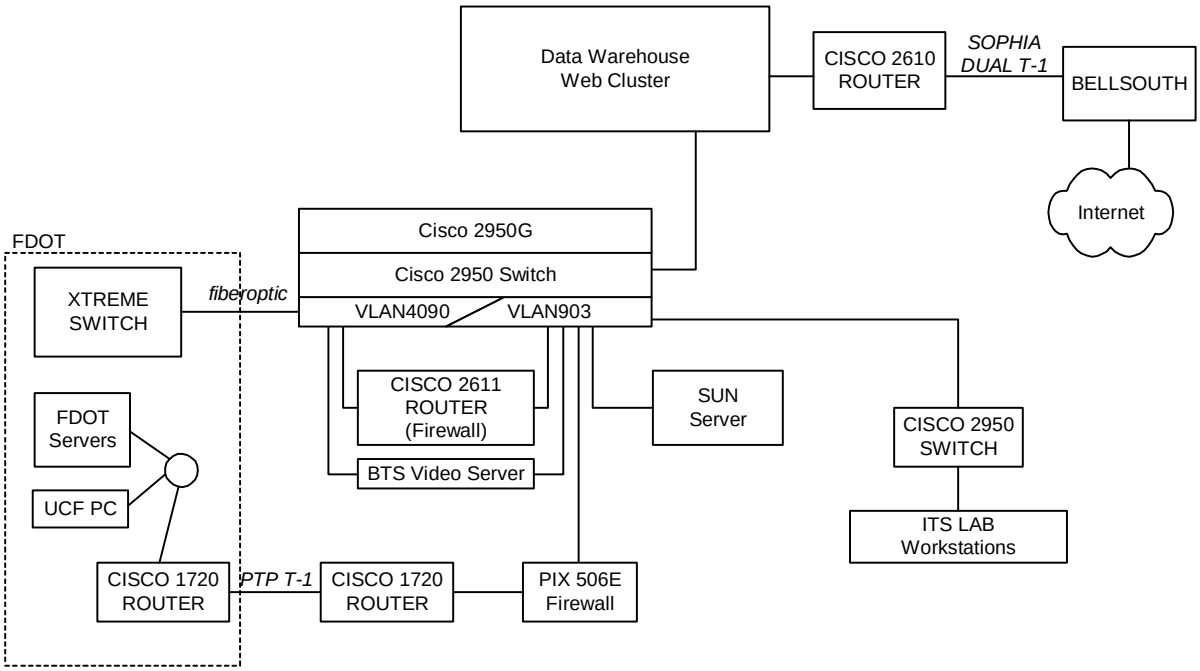


Figure 4. Current Network Configuration and Security.

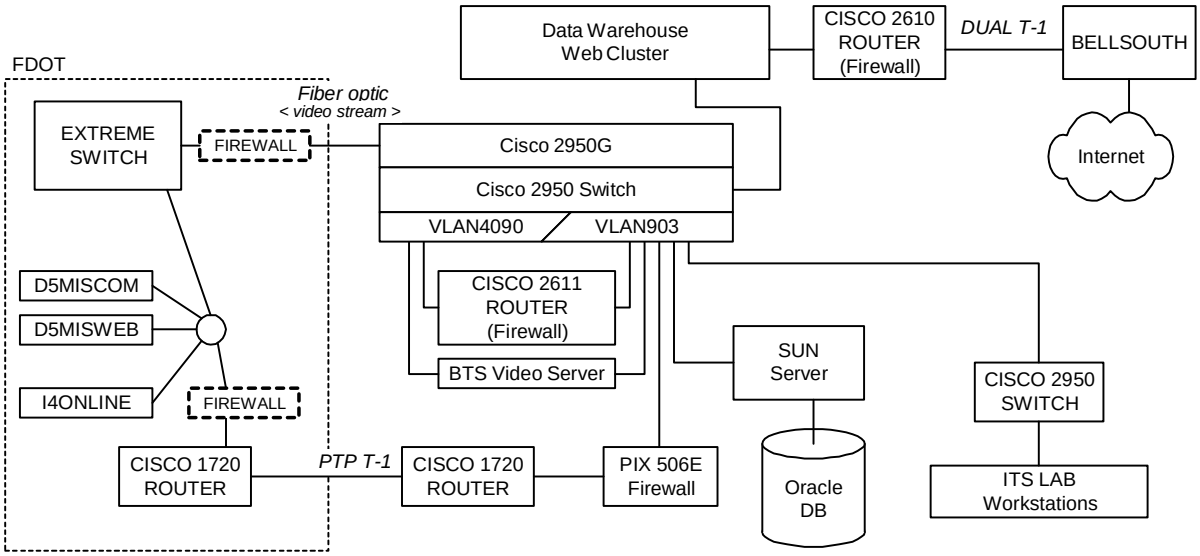


Figure 5. Proposed Network Configuration and Security Pending Availability of Future Funding

Security Agreement

A security agreement had been reached during a meeting between UCF Computer Services and FDTO D-5 RTMC in the UCF computer science building on January 27, 2003. Figure 4 describes the network configuration that was the outcome of that meeting. Later on, FDOT D5 decided that the RTMC needs hardware firewalls to be installed on-site and under control of the RTMC management. FDOT D-5 requested UCF to purchase a NetScreen- IDP 500 firewall to achieve loop detector data transmission from the RTMC to UCF. An additional firewall of the same type was proposed to protect UCF from FDOT's side if funding becomes available. Figure 5 describes the desired location for the new firewalls, again pending availability of future funding.

The firewall running on the Cisco 2611 router resides at and is managed by UCF's Network Operations Center (UCF contact person is Robert Scott, Associate Director of Computer Services for Network Operations, and FDOT D-5 contact person is Larry Rivera). The UCF personnel that have the password to this device are Mr. Scott and Jeff Pooley. This firewall protects network traffic in both directions. The only accepted traffic allowed through this firewall is:

- Terminal Services – allows for remote administration via the private network.
- Oracle Connection – access to Oracle database
- SQL Server connection – access to SQL Server 2000 database
- File folder access – able to access shared file folders over the private network

The firewall running on the Cisco 2610 router resides at and is managed by UCF. This firewall protects the network from breaches via the internet. The Cisco Pix 506E

firewall has the same restrictions as the Cisco 2611 firewall but is used to protect the point to point T1 line.

CHAPTER 3
DATA GRINDING

The objective of this sub-project is to develop and implement a new loop data filtering algorithms. This will be based on the BTS California experience but will be modified to fit the Central Florida and I-4 conditions.

Data Filtering

The motivation behind this task is to present loop detector data that make some "good" sense to the users of the system. Frequently, loop detectors do not report any data, or report erroneous data. The objective of this task is to identify these data errors and provide the users with reliable estimates to replace the "bad" data samples from the loops. The UCF research team has finalized the set of rules, conditions and tests to determine the goodness of each data sample from the loop. According to these rules, each 30 second sample will be checked for

1. 0 flow and non-zero speed
2. Non zero flow and 0 speed
3. Speeds > 100 mph
4. Occupancies > 100%
5. Flows > 25 vehicles / 30 seconds

Samples failing any of the above conditions are flagged as "bad" and are filtered. The remaining samples are treated as "good". These conditions are referred to as "impossible value" filters. The filters described above can be used to filter out egregiously bad data samples.

In addition to the checks on the raw samples at the 30 second level, the data samples are also checked after the 5 minute aggregation. The good 30 second raw samples are aggregated to 5 minutes. The aggregation scheme is to:

1. Sum up and normalize the "good" 30 second Volumes
2. Calculate the flow weighted average for the "good" 30 sec Speeds
3. Average the "good" 30 second Occupancies

Each aggregated 5 minute data sample is then checked for the average length of the vehicles in the flow. This can be calculated from the flow, speed and occupancy values. Also at the end of the day, all the data samples are checked together for the variation in occupancy. If the variation in occupancy is not high, it could indicate a stuck loop. These can be checked from two tests, which are:

1. If the average length of vehicles in the flow (calculated from the flow, speed and occupancy values) is outside reasonable limits – taken as 10 ft to 60 ft, then flag the 5 minute data sample as "bad".
2. If at the end of the day check the whole day data set from each loop the variation of occupancy is not significantly large, the loop is flagged as "bad". This is indicated by the entropy statistic of occupancy. If the entropy is less than 1, then the occupancy is constant for most part of the day, which might indicate loops that are stuck.

   Entropy of a variable x is defined by

$$E(x) = -\sum_{x,\, p(x)>0} p(x) \cdot \log(p(x))$$

   where $p(x)$ gives the probability at any x.

The basic use of entropy test is to identify those loops that give a constant occupancy all the time. It has been found that for about 90-95% of the time, if loops are stuck on a constant occupancy for a day, then they are stuck the next day too.

The aggregated data sample is flagged as "bad" if it complies with condition 1 (referred to as "length test"). The whole data set (or the loop) is flagged as "bad", if the dataset violates condition 2 (referred to as "entropy test").

In summary, the filtering is done in three stages- at the 30 second level, at the 5 minute aggregated level, and at the end of the day. Figure 6 shows the flow chart for data filtering. For each loop detector, at the start of the day, its status (good/bad) is checked from the previous day. In real-time, every 30 second sample is checked for the impossible values and flagged. The good raw data samples are then flagged as per the aggregation scheme once every 5 minutes. Each 5 minute sample is flagged as "bad" if it complies with the length test, and is marked for imputation. At the end of the day, all the available 5 minute data samples are checked for the entropy of occupancy. If it falls below 1, the loop is marked bad for tomorrow, and marked for imputation.

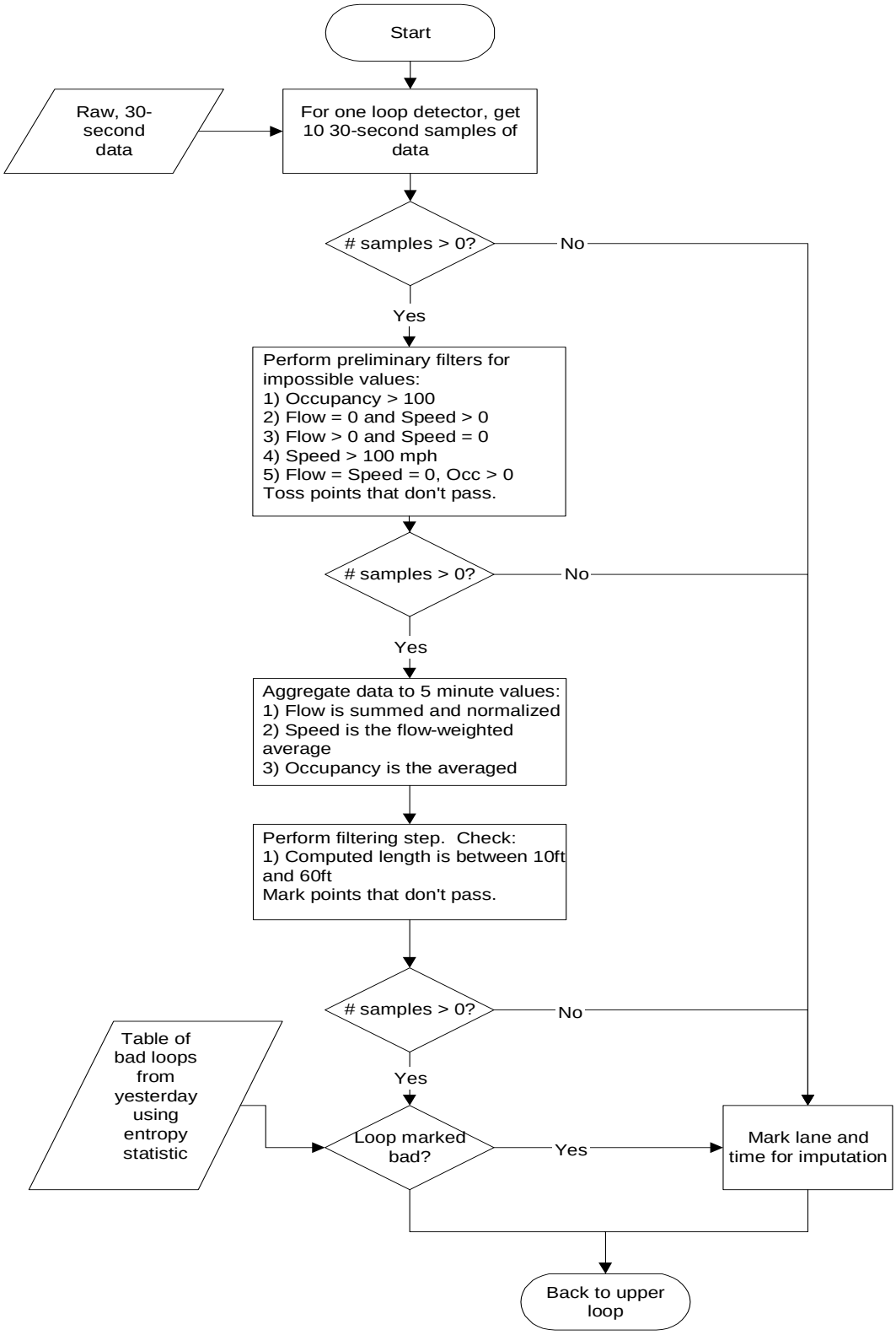


Figure 6: Flow Chart for Filtering

Figure 7 – Figure 16 illustrate the application of the relevant filters on two loops - a "good" loop and a "bad" loop. Few "bad" samples are identified at the 30 second level and therefore are not shown. At the 5 minute level though, a considerable number of samples from the "bad" loop show abnormally low lengths as well as entropy. The "bad" loop reports a majority of samples that report unreasonable lengths as well as very low entropy.

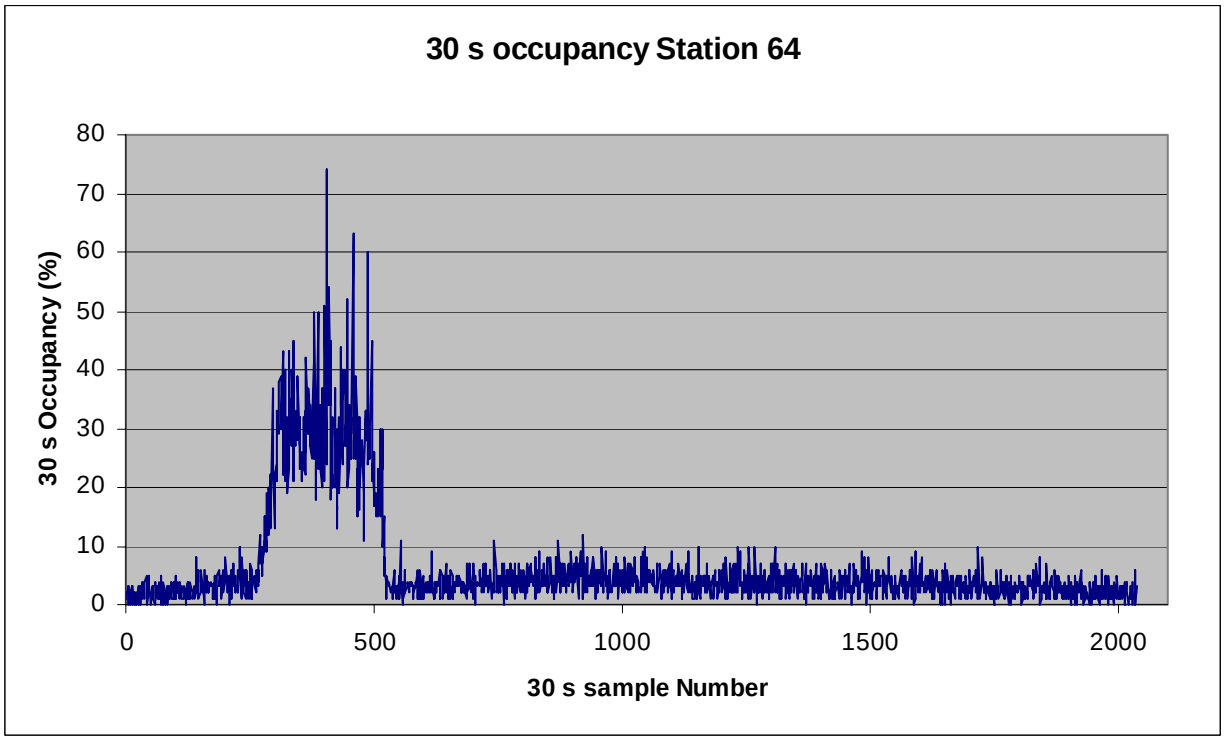


Figure 7. Raw 30 second Occupancy – Loop 1

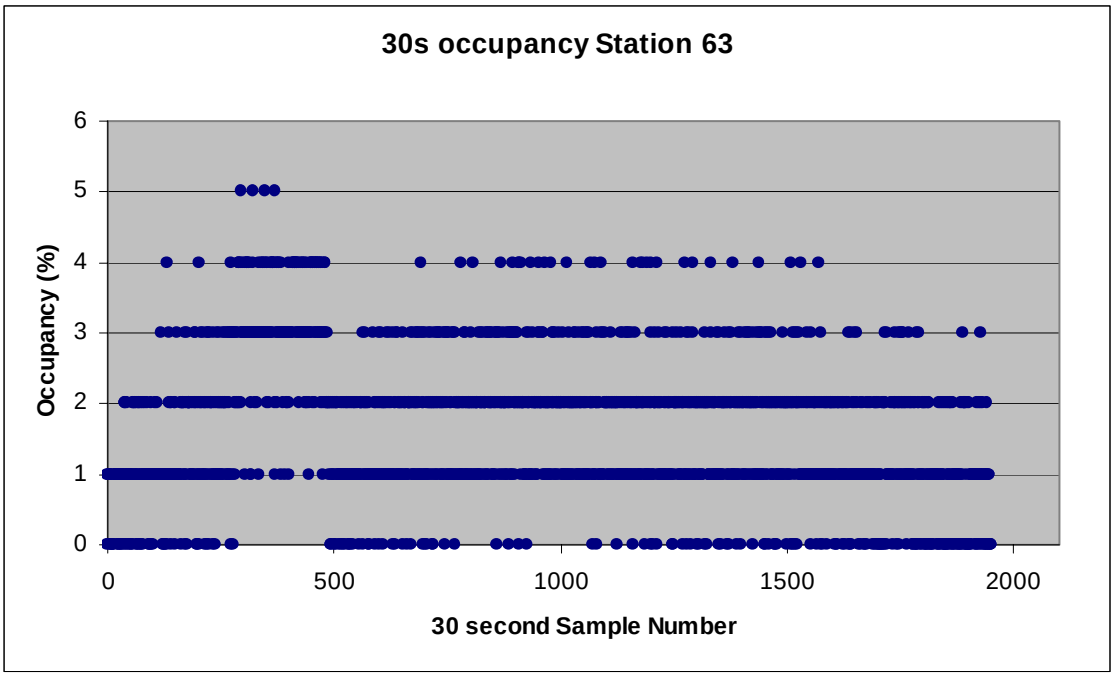


Figure 8. Raw 30 second Occupancy – Loop 2

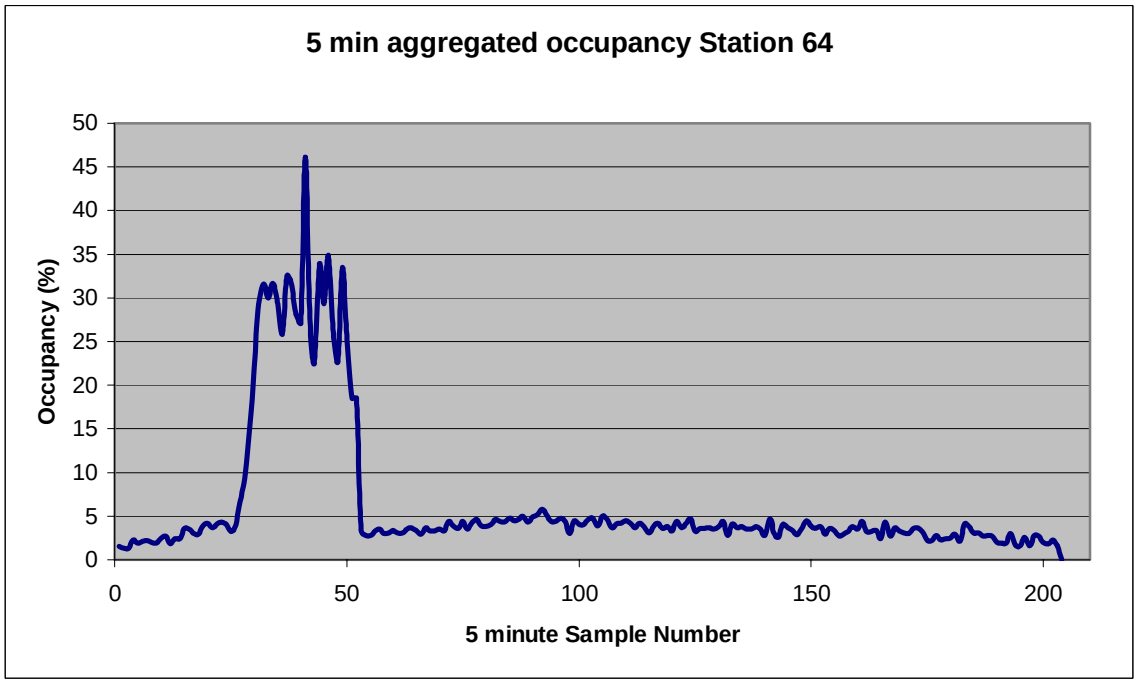


Figure 9. Aggregated 5 Minute Occupancy – Loop 1

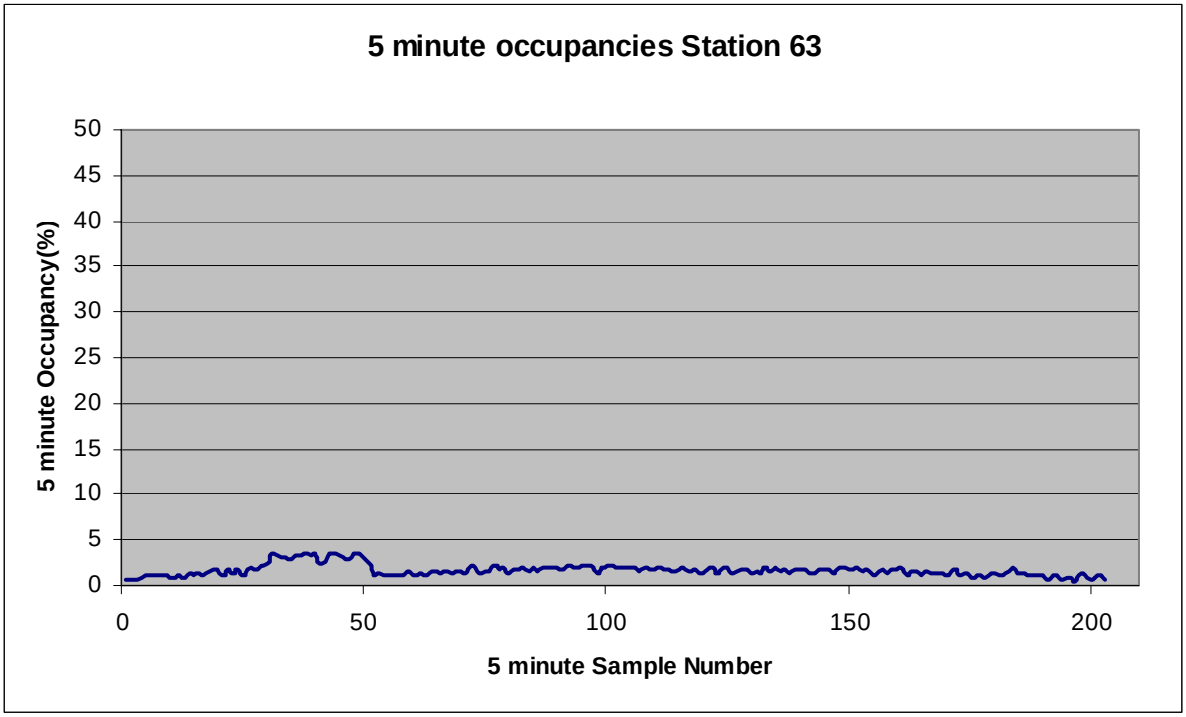


Figure 10. Aggregated 5 Minute Occupancy – Loop 1

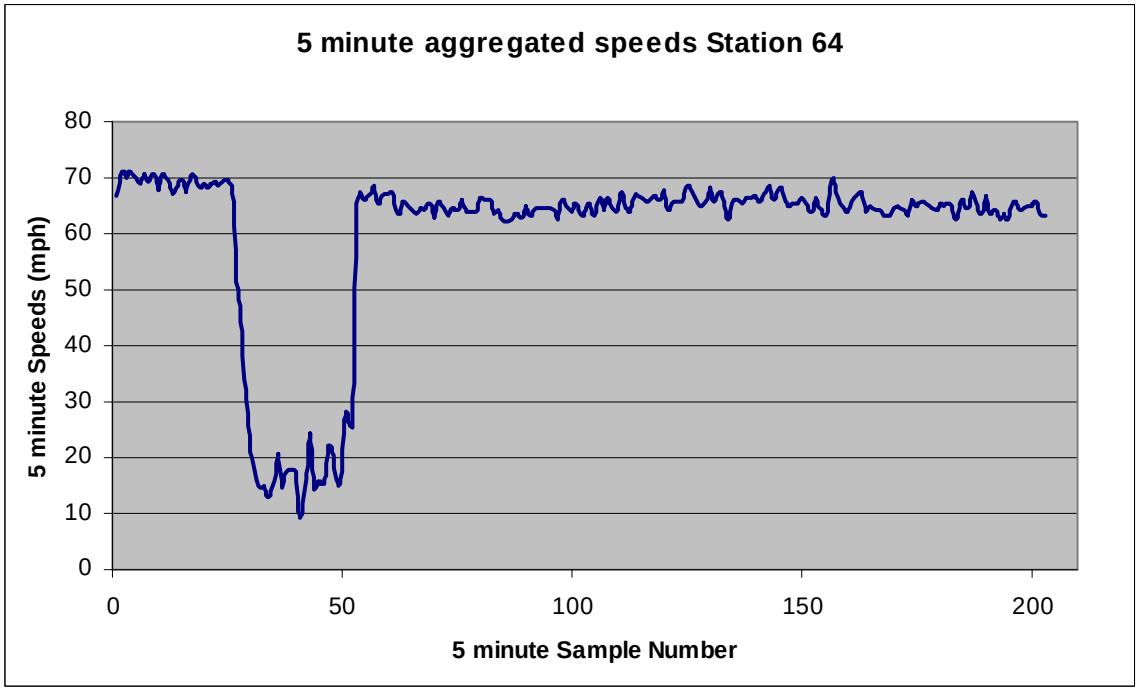


Figure 11. Aggregated 5 Minute Speeds – Loop 1

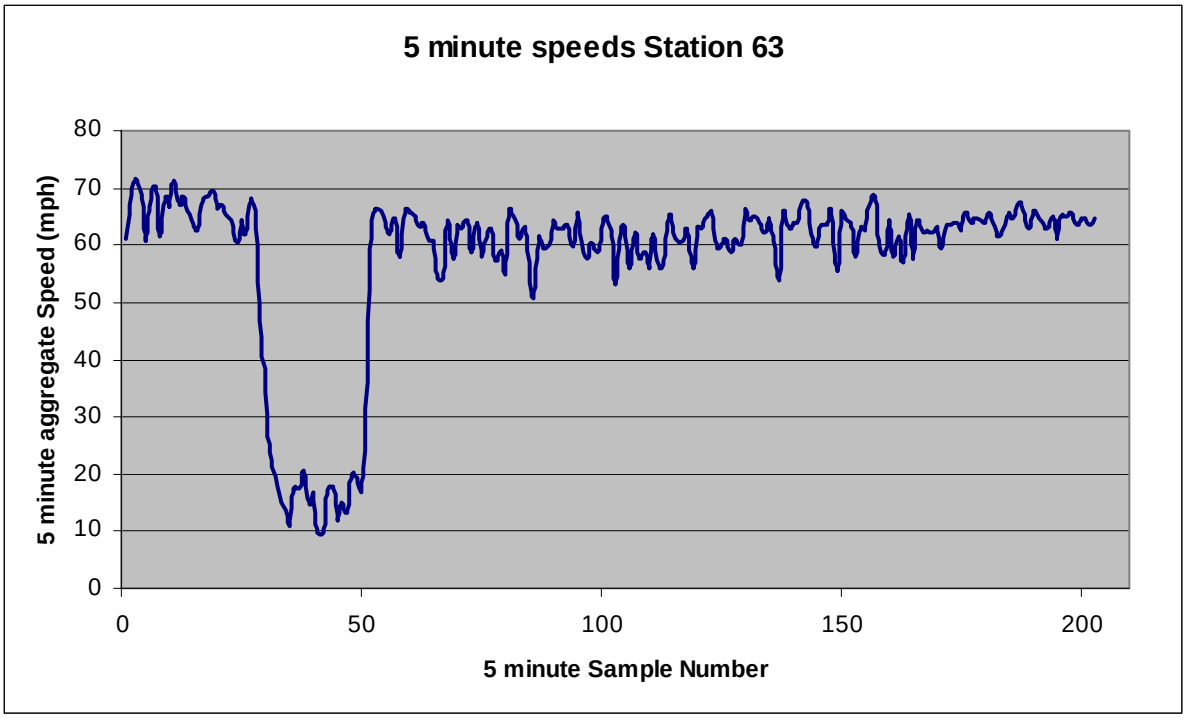


Figure 12. Aggregated 5 minute Speeds – Loop 2

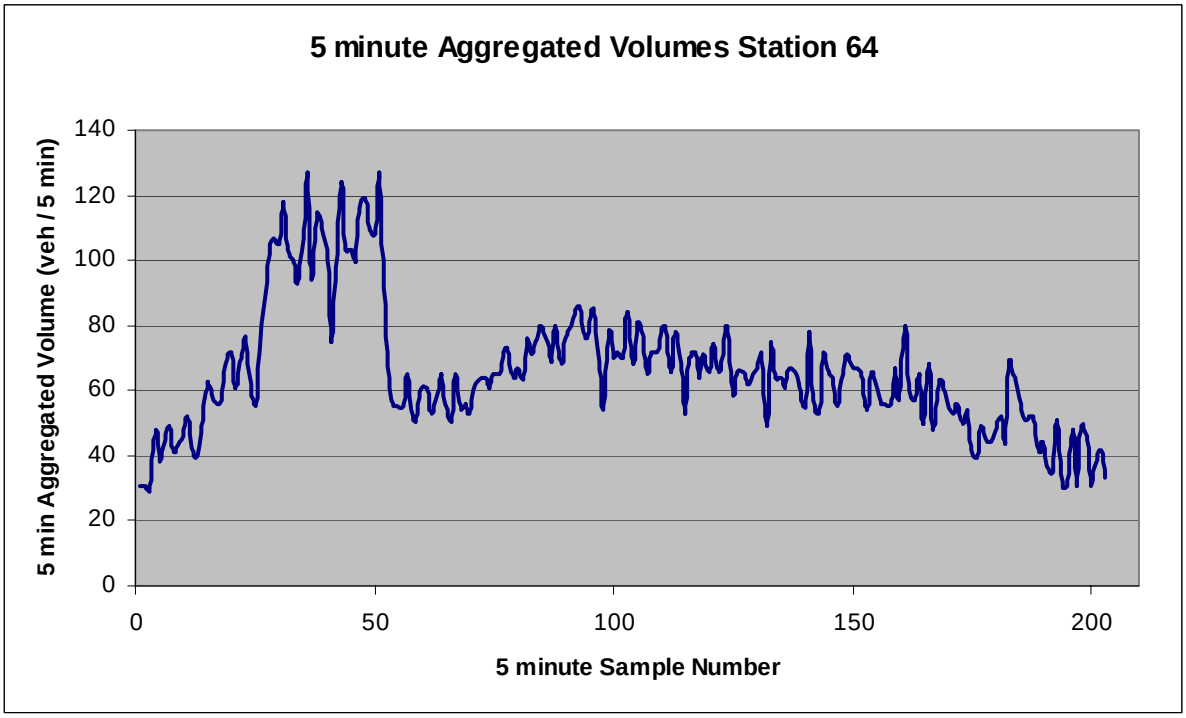


Figure 13. Aggregated 5 Minute Volumes – Loop 1

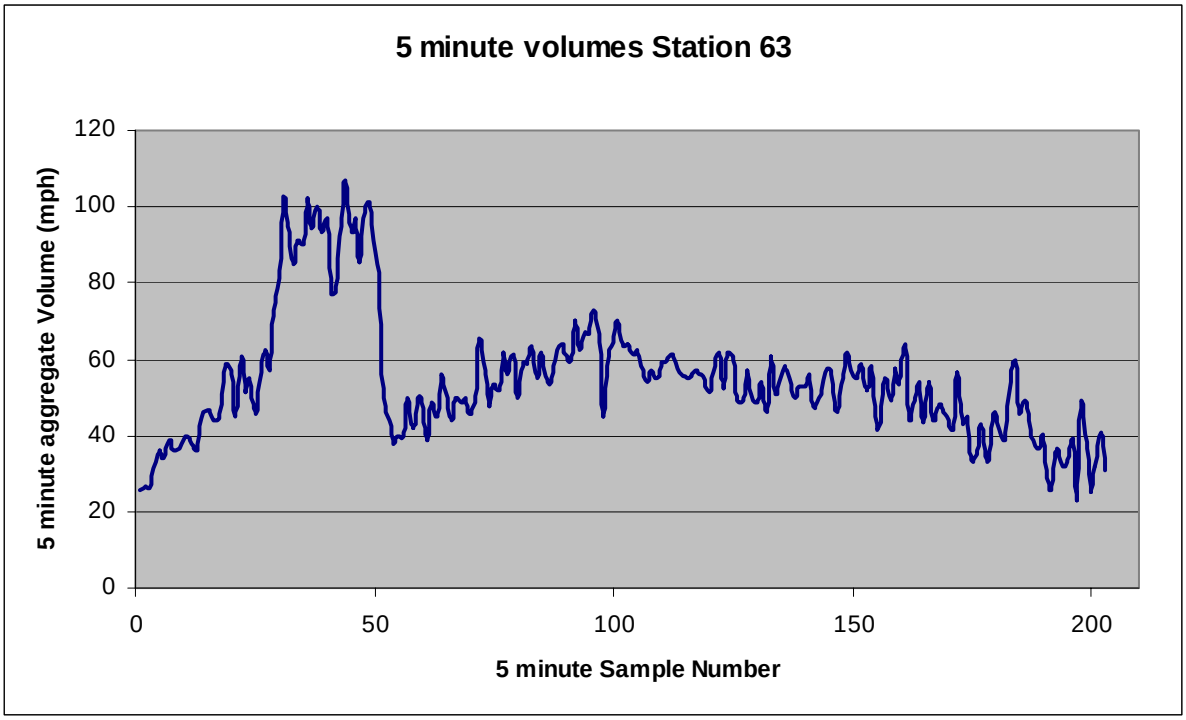


Figure 14. Aggregated 5 Minute Volumes – Loop 2

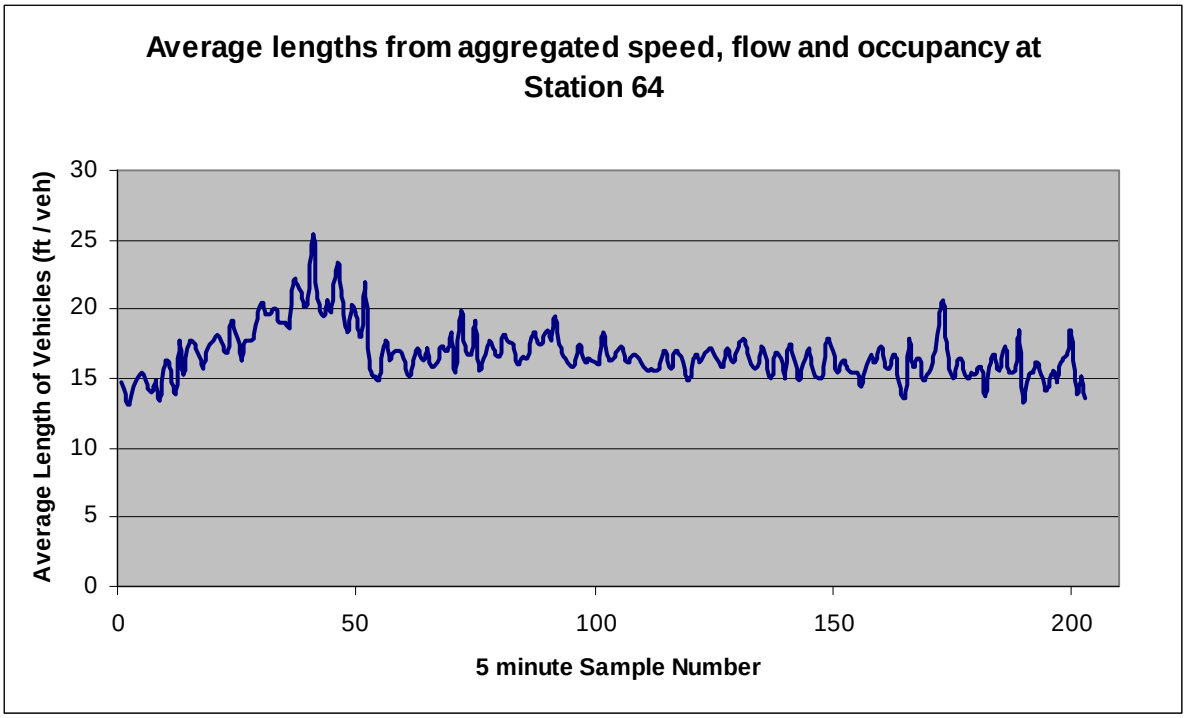


Figure 15. Lengths Calculated for all the 5 Minute Samples – Loop 1

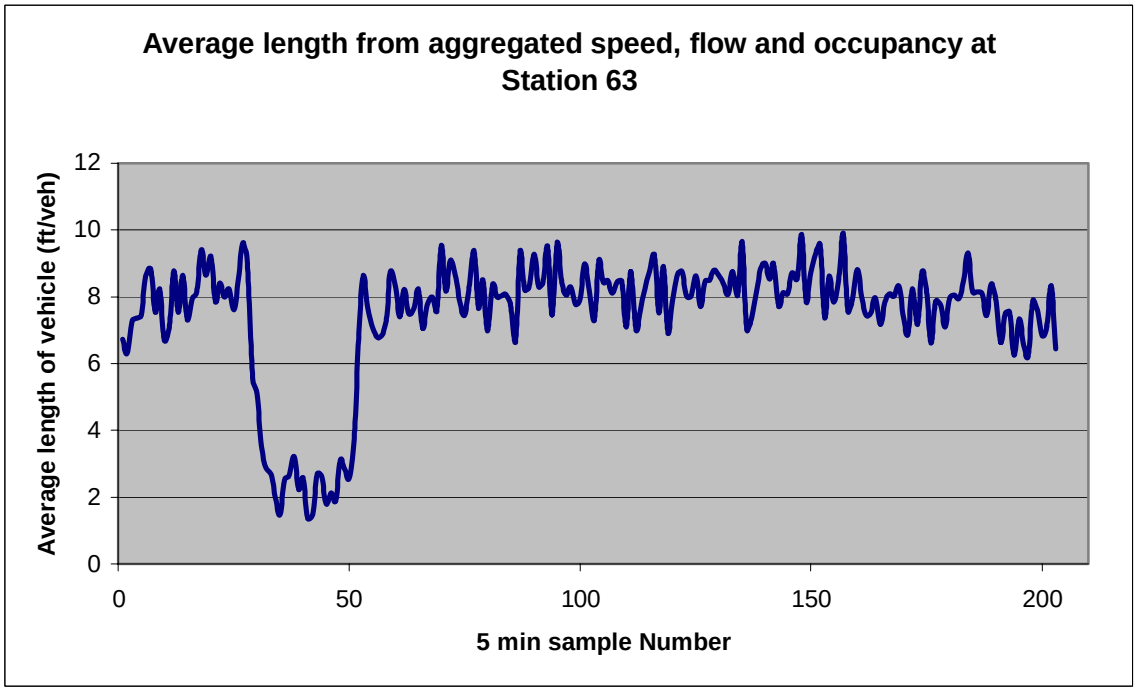


Figure 16. Lengths Calculated for all the 5 Minute Samples – Loop 2

For Figure 7 - Figure 16 the following notes in regards to the filtering need to be expressed:

- The data displayed in Figure 15 is taken from loop 1 at Station 64 in the eastbound direction. For this loop on this day there were no detected bad lengths.
- The data displayed in Figure 16 is taken from loop 1 at Station 63 in the eastbound direction. For this loop on this day every sample was determined to have bad lengths.
- Entropy of loop 1(Station 64, East left lane): 1.88
- Entropy of loop 2(Station 63, East left lane): 0.6

The series of plots show that the raw 30 second occupancy of station 63 (loop 2) shows abnormally low occupancies for comparable flows and speeds from station 64. The speeds and volumes seem to be fine for both loops. Therefore, one can conclude visually that there's something abnormal with the occupancies at station 63. This is also reflected in the length test and the entropy statistic for station 63. Therefore we can conclude that station 63 is bad while station 64 is good.

Imputation

The UCF research team investigated the viability of different regression models for imputation due to bad data in the data set. Different regression models (Multiple Regression Models, Pair wise Regression Models) were investigated

The literature provided insights into the applicability and feasibility of these two kinds of models for imputation in the traffic data scenario. Whenever there is traffic data missing at a lane, the parameters of the adjacent lanes would provide us with some data that can be used to estimate the missing parameters. But before this data can be used, it is required that this data be "good" too, so as to provide the right estimates for the missing

parameters. It is therefore required that the imputation be carried out after the filtering step is carried out over all the required lanes and stations. This will ensure that good data is available to fill the missing values.

Multiple regression models utilize the information from more than one independent variable to model a response (dependent variable). We could model the speed from a lane from say, speeds from all other lanes. They have been found cumbersome to deal with because the data requirements are huge. When we try to model a missing variable, say speed, from the neighboring lane speeds at the same station and from upstream and downstream stations, it is required by the multiple regression models to have all the neighbors as well as the upstream and downstream stations to be functional. Even if one of the lanes turns out a bad sample or is missing, the multiple regression models break down.

Pair wise models improve upon these shortcomings of the multiple regression models and are robust to the situations described above. In these models, we model the traffic variables from one lane (dependent variable) from the traffic parameters from its neighbor. In our context, neighbors have been defined as the adjacent lanes at the same station (location) and the lanes that are one station upstream and one station downstream. We therefore have target-neighbor pairs, each of which contributes individually to the response we are trying to model. In these models, the variable is modeled from a set of equations, rather than a single equation. Each equation in this set is a regression equation of the variable with the other variables in the neighboring lanes. Once we have estimates using these equations from the neighboring lanes, they are averaged using a robust averaging technique. We will be using the median of the estimated parameters to come up with the final estimate that will be used as the imputed value. Pair wise linear models have been

implemented in California, and they use the data from the adjacent lanes at the station, as well as upstream and downstream stations. For the Interstate 4 traffic data, a Pair wise quadratic model was developed that provided better results than the Pair wise linear models.

In the Pair wise quadratic models a variable, say flow, is expressed as a second degree model of all the traffic variables (flow, speed, and occupancy from each of the neighbors – adjacent and upstream / downstream).

If *i'* and *j'* represent the lane and station of the bad loop, Q_{ij}, S_{ij}, O_{ij} represent the flow, speed and occupancy respectively at lane *i* and station *j* (neighbors),

Then,

$$\hat{Q}_{ki'j'} = \beta_{0k} + \beta_{1k}Q_{ij} + \beta_{2k}S_{ij} + \beta_{3k}O_{ij} + \beta_{4k}Q_{ij}S_{ij} + \beta_{5k}S_{ij}O_{ij} + \beta_{6k}O_{ij}Q_{ij} + \beta_{7k}Q_{ij}^{2} + \beta_{8k}S_{ij}^{2} + \beta_{9k}O_{ij}^{2} \Big\}$$

$$\begin{aligned}
&where \quad j = j'-1(upstream)\\
&j = j' \quad (station \quad j')\\
&j = j'+1(downstream)\\
&when \quad j = j'-1, \quad i = 1,2,...n\\
&when \quad j = j', \quad i = 1,2,...n, i \neq i'\\
&when \quad j = j'+1, \quad i = 1,2,...n\\
&\hat{Q}_{i'j'} = Median(\hat{Q}_{ki'j'} \;/\; k = 1...(3*n)-1)
\end{aligned}$$

$\hat{Q}_{ki'j'}$ represents the estimate for $Q_{i'j'}$ from the kth predictor equation.

$\hat{Q}_{i'j'}$ represents the final estimate of the flow (imputed flow) that is the median of the estimates from the eight equations.

The first three equations are from upstream lanes, the next two equations are from the adjacent lanes at the same station, and the last three are from the downstream station of station *j'*.

When $j = j'$ (at the station j' itself,), we have i not equal to i' because it is the lane that we are trying to impute. Similar models would follow for speed and occupancy.

Since the upstream / downstream detectors were not as good "neighbors" in terms of predictions, especially in the incident scenarios, only the adjacent lane information is used when available. If adjacent lane data is unavailable, then the upstream and down stream data is used.

Therefore the medians are calculated from the estimates of adjacent lanes only if data from adjacent lanes are available, else all the neighboring lane data (including upstream and downstream lane data) is used to calculate the median. Figure 17 shows the data flow for imputation in real-time. In real-time implementation, for every 5 minutes, the imputed values are calculated for all the samples irrespective of their flagged status (good / bad). The imputed values are calculated based on the good neighbors available for each loop. If the adjacent lanes are good, only they are used for imputation. Else the upstream and downstream values are used. If none of the neighbors are reporting good samples, historical values are used to get the imputed value. Only if the sample is flagged as bad, the imputed value is used for further applications. Once each loop is filled with either good observed data or imputed data, a station aggregate is computed, and inserted into the database.

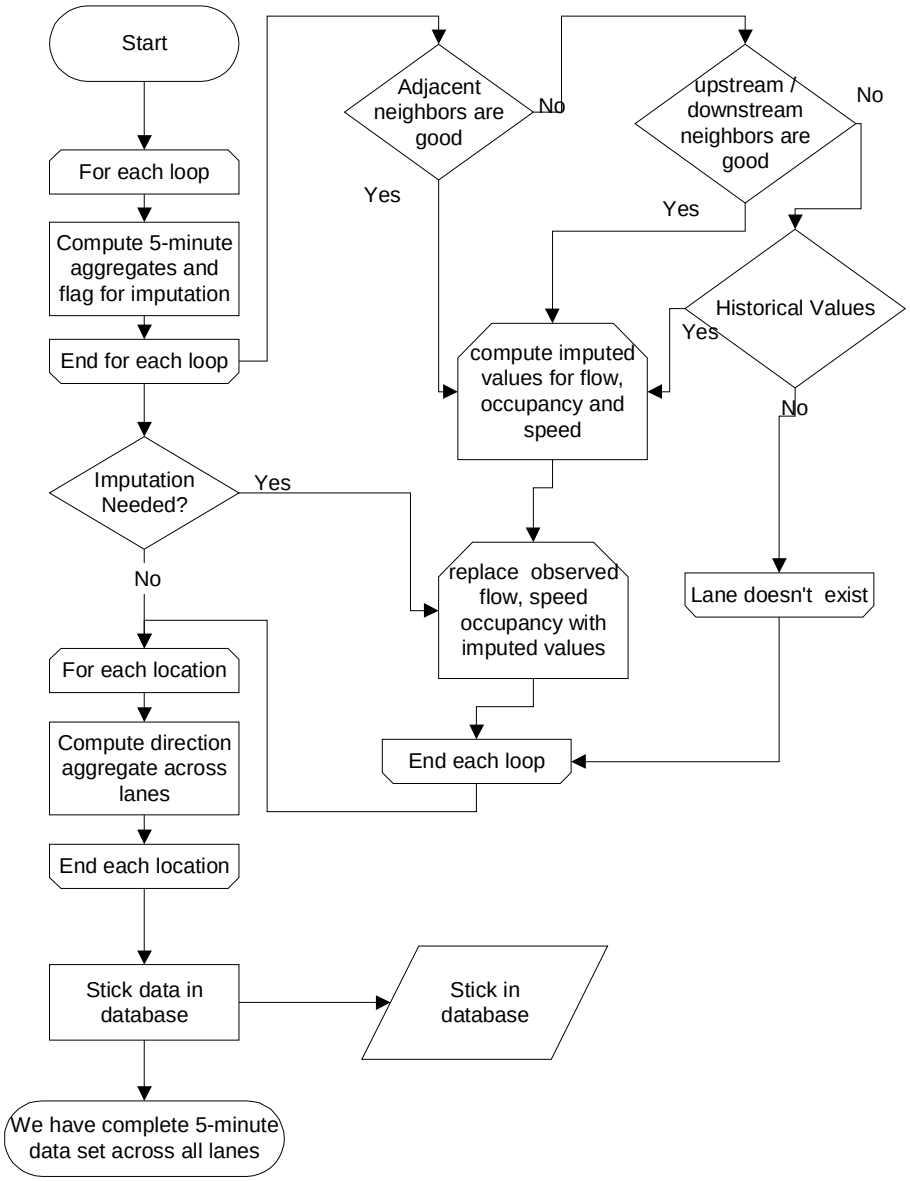


Figure 17: Data Flow for Filtering and Imputation

Figure 18 - Figure 20 provide a graphical comparison between the observed and imputed occupancy, speed and flow respectively for all samples in a typical day (since we calculate the imputed values for all samples irrespective of whether they are good or bad). The average error (average of the absolute difference between the imputed and observed

values) for speeds was 2.8 mph, the average error for volumes was 11 vehicles/5 minutes, and for occupancy it was 0.014. This is about 5% error in speeds, 11% error in volumes, and 15% error in occupancies at the peak hour.

While we are still studying the characteristics of the loop detection system, on a typical day the system reports that about 12% of the loops are bad, about 65% are good and about 23% of the loops do not report enough samples to judge their health status (out of 554 loops). Nevertheless, the imputation algorithms now in place provide us with a consistent way of dealing with these holes.

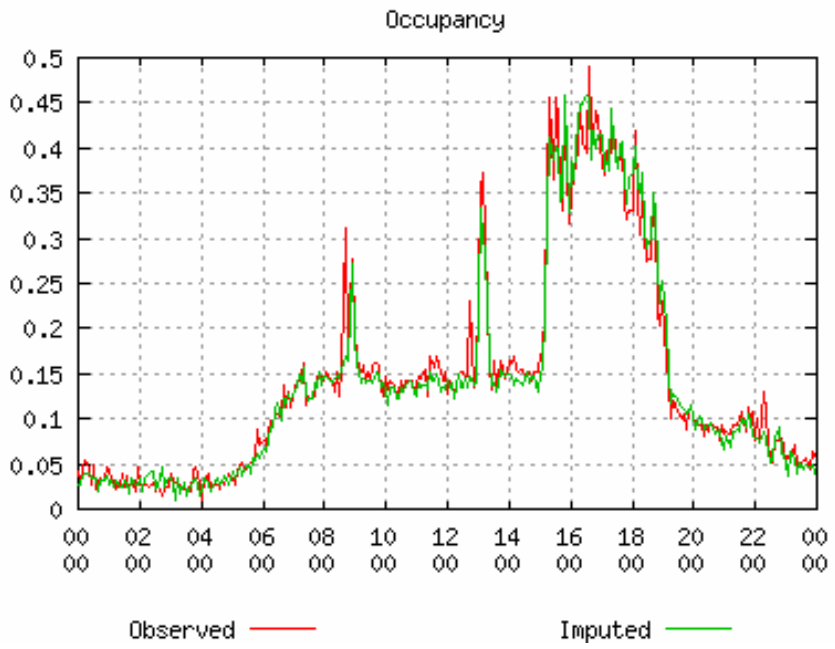


Figure 18: Imputation of Occupancy

Figure 19. Imputation of Speed

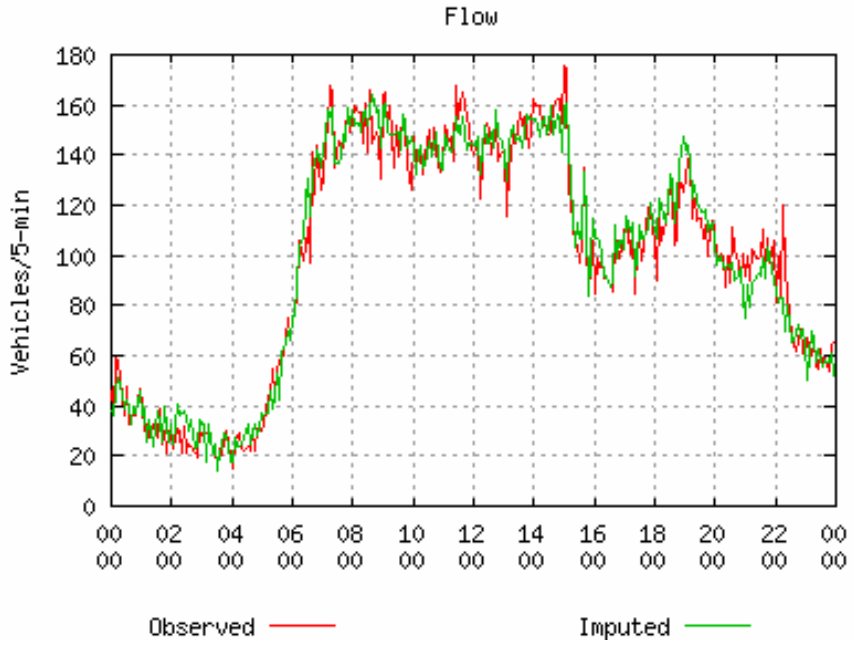


Figure 20: Imputation of Flow

Data Quality

An interesting question that came up is how to convey to an end user the fact that applications might use data that was possibly imputed. Since we are imputing data, we feel that we should relay this fact to the public. What we have decided is that we need to have a measure of data quality that is 1) easy to compute, 2) easy for end users to understand, and 3) is independent of the application using the data. We have developed a measure that fits these three criteria. This measure is based on the number of loop data samples which are used by the application which are observed versus imputed. We simply compute the percentage of loop data samples which are observed and then assign the measure of "low", "medium" or "high" to the data quality depending on the percentage. We currently use the thresholds of 30% and 60%. This means that if less than 30% of the data is observed (meaning that more than 70% of the data is imputed) then we assign the measure "low", if less than 60% of the loops are observed then we assign "medium", and if over 60% of the loops are observed then we assign "high". This quality measure is then presented to the end user with the results of the application. This computation is done for every invocation of the application by the end user. For example, each time the user invokes the travel time prediction application to get to a prediction, the application must collect the speed for all of the loops along the requested path for a minimum of the previous 30 minutes. When the application does this, it also determines the percentage of all of these samples (every loop, every lane, every 5-minutes) that are observed. It then applies our thresholds and presents to the user a data quality of either "low", "medium" or "high".

Conclusion

The data filtering and imputation procedures developed provide us with a consistent way of dealing with the holes created due to missing and bad data. The good data that comes out of these filtering procedures, acts as base data for further applications – like travel time calculation and prediction.

CHAPTER 4

DESIGN AND IMPLEMENTATION OF THE WEB USER INTERFACE OF THE IFLORIDA REGIONAL TRAFFIC INFORMATION WEB SITE

A Web UI requirements document was developed by UCF and approved by FDOT D-5 before this web design process started, see Appendix A.

The iFlorida Web site home page is the portal to all content on the site and is composed of four basic areas including the Navigation Bar, Features Section, Updates Section and Partners Section (Figure 21). The Navigation bar consists of a set of five hyperlinks that are used to navigate the non-functional content.

Figure 21. The iFlorida Home Page

The Help section (Figure 22) is used to instruct the end user on how to use the functional areas of the Web site. Help content includes, but is not limited to, how to use

'map-clicks' versus dropdown lists to make selections and how to use the pan and zoom features to manipulate the map. This portion of the Web site should be static and only be modified when any of the functional content is also modified.

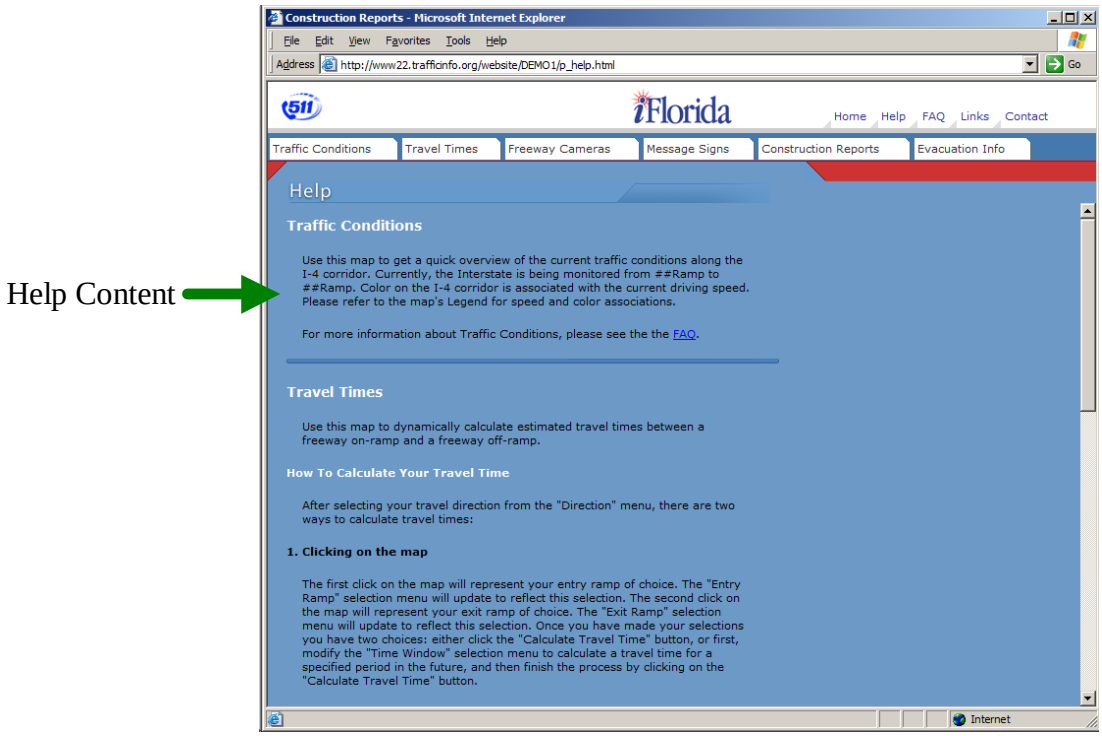


Figure 22. The iFlorida Help Page

The FAQ (Frequently Asked Questions) section (Figure 23) will allow the site developer/maintainer to address user based questions about the site. The FAQ is a simple way to respond once to a question that many users ask thus assisting in the minimization of site maintenance.

FAQ Content

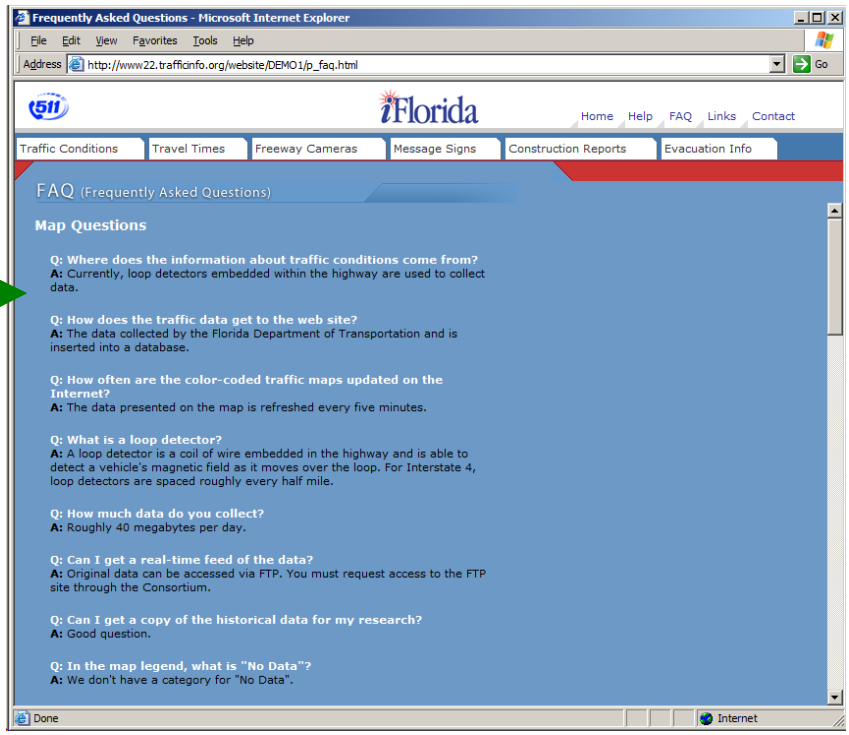


Figure 23. The iFlorida FAQ Page

The Link section (Figure 24) is used to forward the user to other similar content providers. These providers give transportation information at the local, state and national levels.

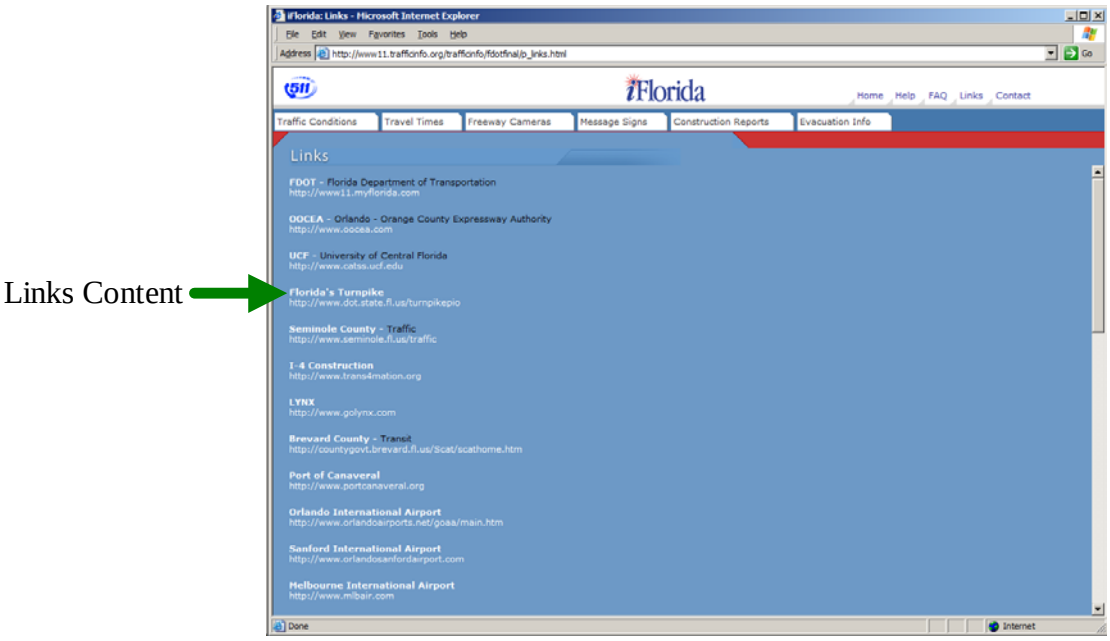


Figure 24. The iFlorida Links Page

The Contacts Section (Figure 25) will allow the end-user to contact the site administrator regarding questions associated with the site. This could be used to report broken links, service outages or any unexpected phenomena. The submitted information, when appropriate, will be used to update the FAQ and Help sections of the Web site.

The Features section of the home page directs the end-user directly to the functional content of the Web site. The functional content is composed of two types. The two types being map oriented and Web oriented.

The map oriented features are Traffic Conditions, Travel Times, Camera Images and Message Signs. All map oriented pages have a consistent look and feel composed of a map with pan tools to each side, a zoom selection tool above and a Region Selector Tool to the right. The Region Selector Tool provides the user with fast access to a specific area of interest within the region. The last selection on this tool is stored as an Internet Cookie on

the user's computer and will be the default map view the next time the user visits the Web site. Each map oriented page also has widgets specific to the content area to define the usage

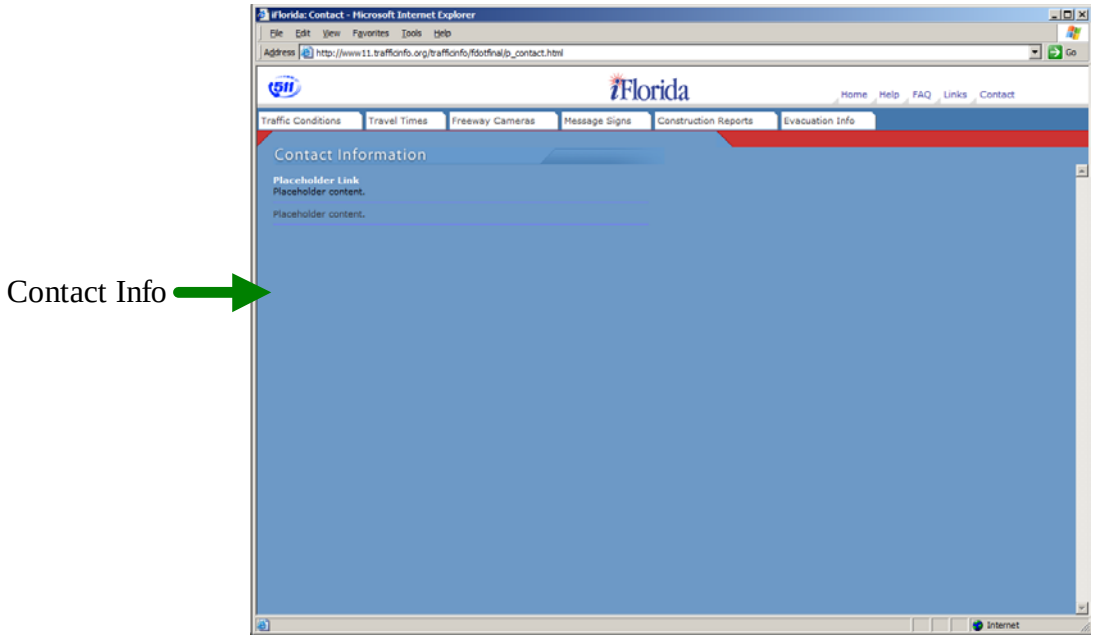


Figure 25. The iFlorida Contacts Page

of that page. The Traffic Conditions page (Figure 26) is the most basic of the map oriented pages. The only available information presented to the end user is current highway speeds. The available speed ranges are denoted below the map by the Speed Legend. Four colors are used to describe the speeds on the highway. Red represents speeds less than 30 mph, yellow represents speed in the range greater than 30 mph and less than 45 mph, green represents speed greater than 45 mph, black indicates data is not available, and grey indicates travel data under development. The speeds presented on the map are based on speeds aggregated over five minute intervals.

The Travel Times page (Figure 27) allows the user to receive a point to point travel time along the I-4 corridor from US 192 to Lake Mary Boulevard and all points in between. All possible combinations of entry to exit ramp are available.

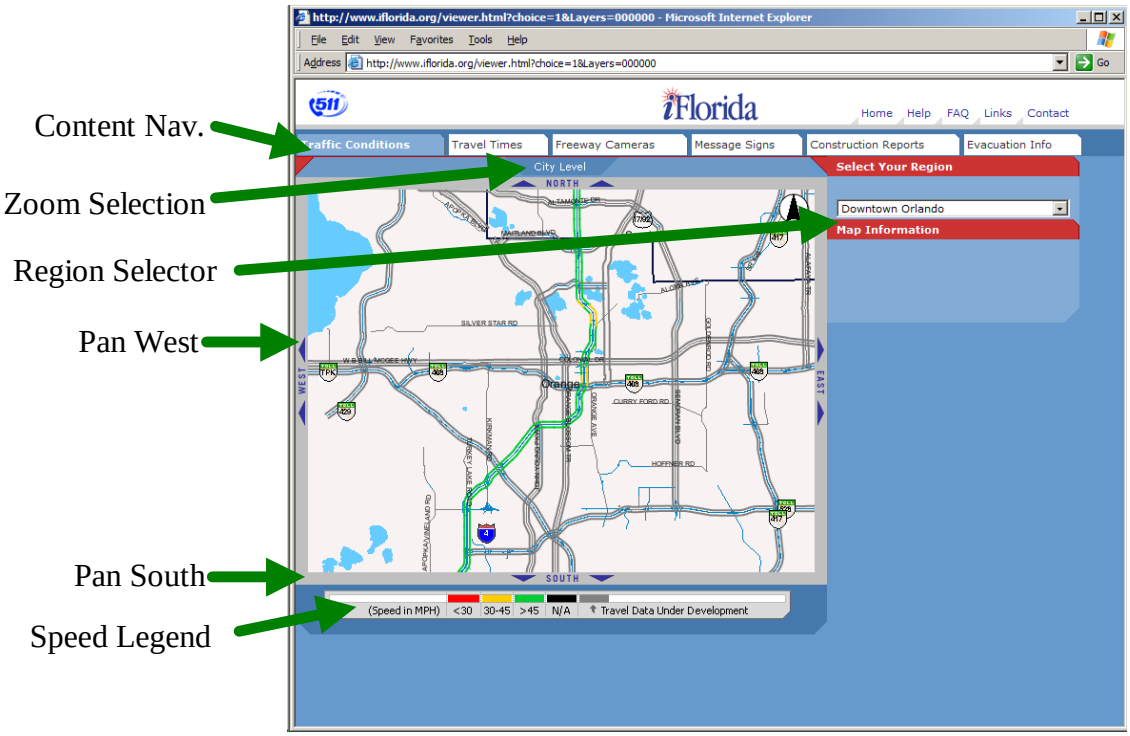


Figure 26. The iFlorida Traffic Conditions Page

The end user can choose the entry and exit points using the interactive map or drop down lists. The available predictions for travel time consist of either current or forecasted. In this context, forecasted indicates trips that start sometime in the future. The available options are 10, 20 or 30 minutes in the future and are selected in the Time Window selector. The results pane givers the user the predicted travel time, the delay (based on a free flow speed of 60 mph), the trip distance, the data quality, the trip origin and trip destination. The travel time prediction algorithm uses loop detector data that has been filtered for impossible

values as well as filled in missing values. The data quality is an indicator of how much of the data used for the prediction was based on actual, accepted data. The possible values for data quality are 'low', 'medium' and 'high' and correspond with less than 30% inclusive, 30 – 60% and greater than 60% inclusive, respectively.

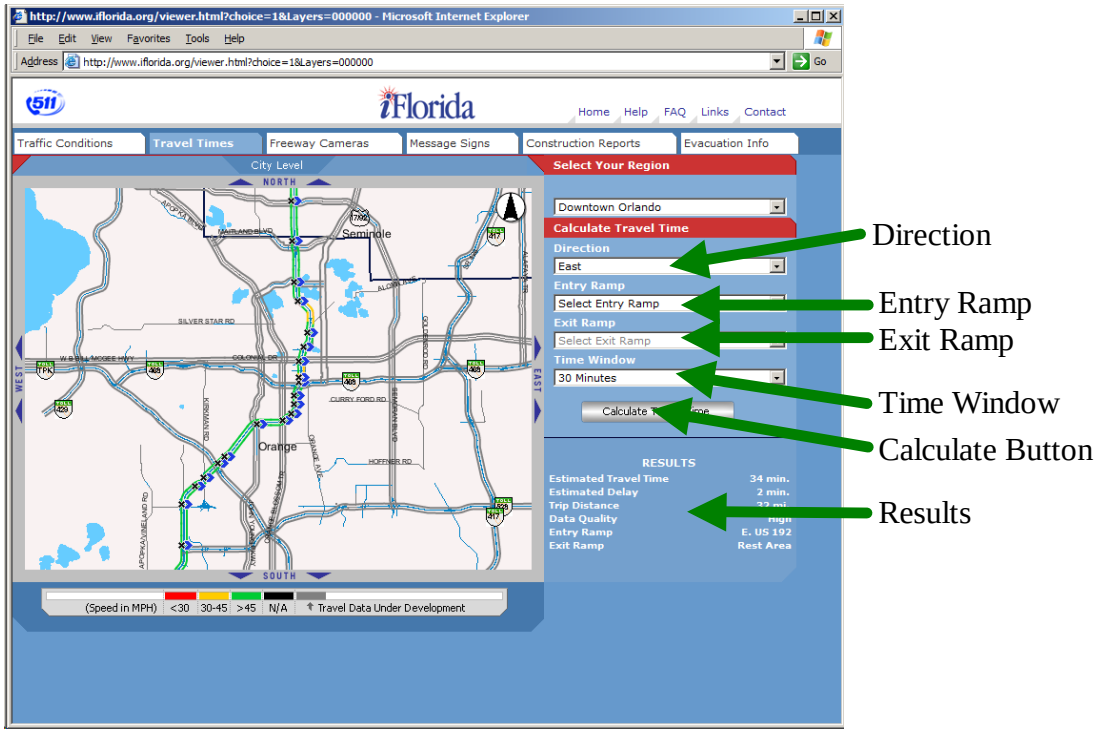


Figure 27. The iFlorida Travel Times Page

The Freeway Cameras Page (Figure 28) allows the user to view the 16 cameras along the I-4 corridor as well as one at the interchange of I-95 and SR 528 in Brevard County. The images displayed are made possible by a video stream that is piped over the fiber optic connection between the FDOT D-5 RTMC and UCF. Snaps are currently taken every 20 seconds and are updated on the page automatically. Because the cameras are maneuverable by an operator at the RTMC and can face any direction at any possible moment, it was imperative to present the user with two reference pictures of the highway. This way it is

possible to determine what direction the cameras are facing without any other feedback from the camera. The user selects which camera to watch by clicking on icons on the interactive map.

The Message Signs Page (Figure 29) allows the user to see the contents of the dynamic message signs along the highway. The user is able to click on icons on the interactive map to see the message in the sign display.

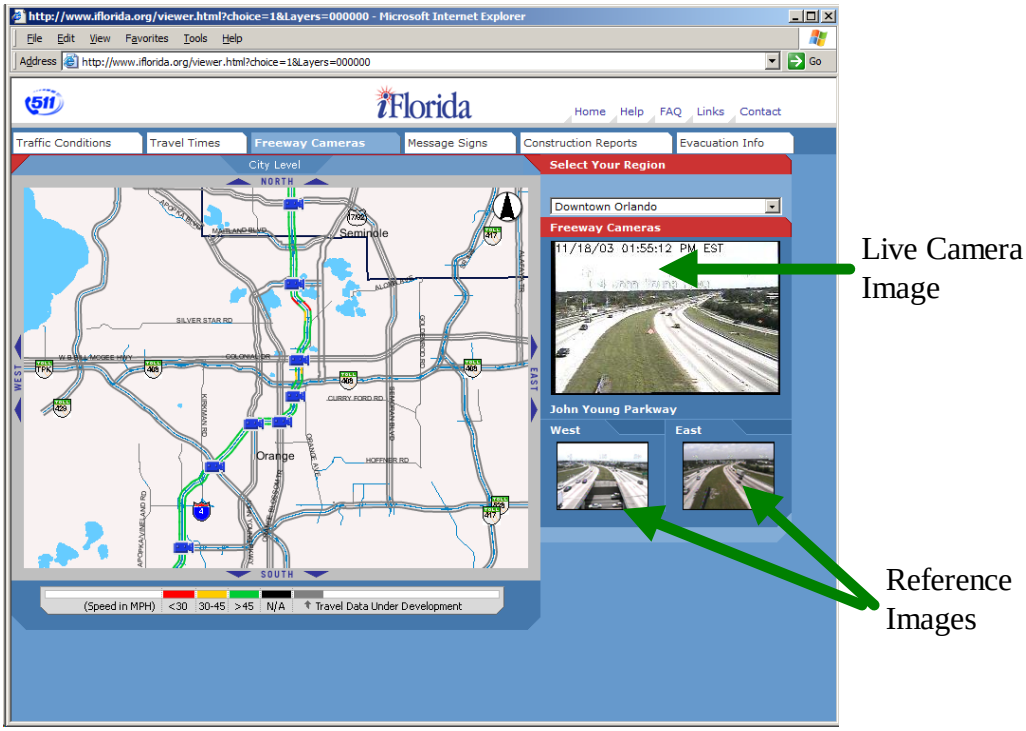


Figure 28. The iFlorida Freeway Cameras Page

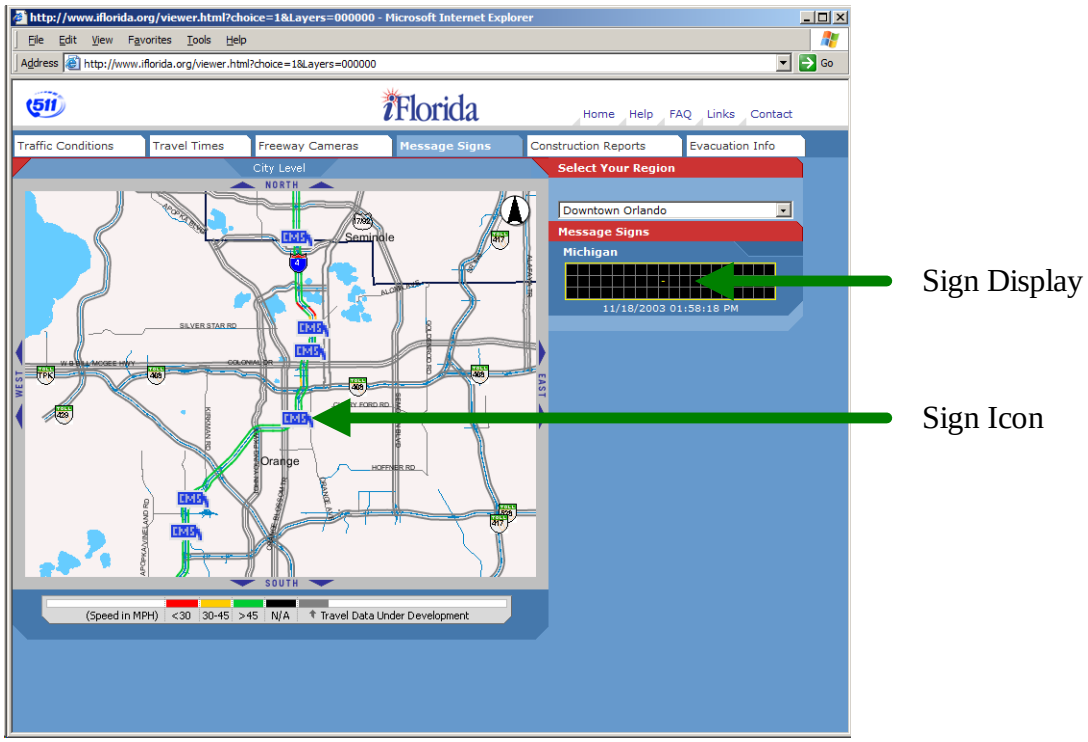


Figure 29. The iFlorida Message Signs Page

The Construction Reports Page (Figure 30) allows the user to see where current roadway construction projects are taking place within the region. All the participating member transportation engineering agencies within the region provide either links to their respective Web sites or provide content to this Web site.

Construction Info

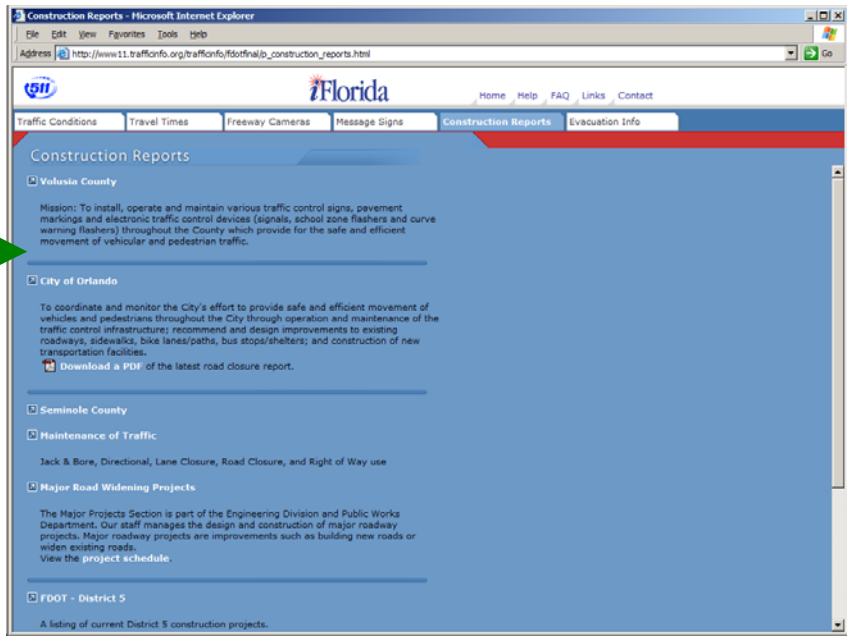


Figure 30. The iFlorida Construction Reports Page

The Evacuation Information Page (Figure 31) provides up to date information on how to prepare for and proceed during an evacuation. The goal is to educate the populace and help to prevent gridlock on the roadways in the event of an evacuation. Because the entire region is susceptible to hurricanes, the dominating information provided on this page is geared towards this topic. However, Homeland Security subject matter will be provided as well.

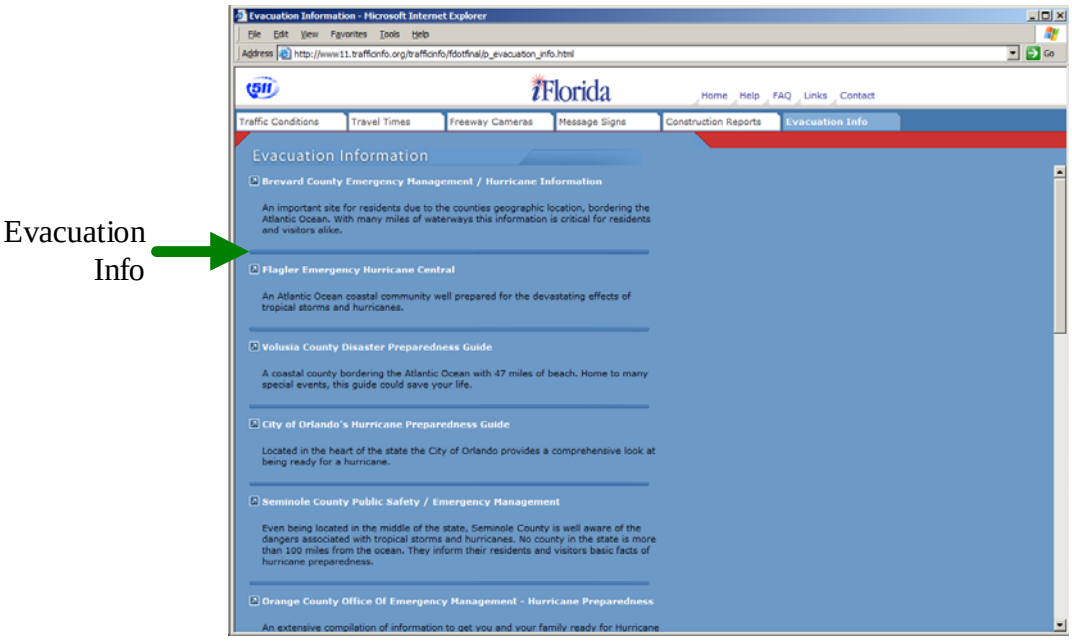


Figure 31. The iFlorida Evacuation Information Page

Additional evacuation information will be provided in regards to large venue events such as those that occur at Daytona International Speedway, the Orlando Citrus Bowl, the region's beaches, etc.

CHAPTER 5

GIS INTEGRATION

The objective of this section is to present the GIS integration project. GIS ensured the functionality of the web site front end that was described in Chapter 4.

System Architecture

A client / server architecture has been adopted in this project. This feature allows clients and servers to be placed independently on nodes in a network. It provides the opportunity for cross-platform access to the database. Figure 32 depicts the model employed

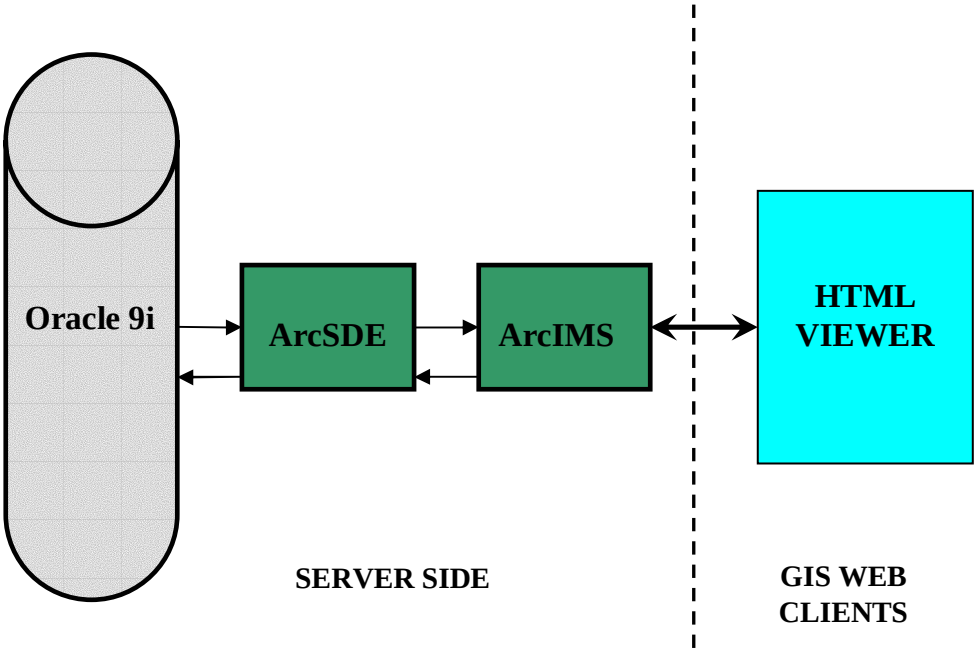


Figure 32. System Architecture

in this project. On the server side, Oracle Corporation's *Oracle 9i* Enterprise Edition database server for SUN Solaris and Environmental Systems Research Institute (ESRI) *ArcSDE 8.3* and *ArcIMS 4.01* are used. On the client side, GIS web clients are developed using HTML and scripting languages. A more in depth description of the server side implementation can be found in the network configuration section. Here, for brevity, only the major components on the server side are discussed.

Oracle 9i database acts as a central repository for both descriptive and spatial data collected and analyzed in the project. *ArcSDE* acts as a central gateway which spatially enables a Relational Database Management System (DBMS) such as *Oracle 9i*. *ArcIMS* is an Internet Map Server which facilitates development and distribution of GIS data, maps and tools over the Internet.

HTML is a standard non-proprietary format for publishing over the World Wide Web (WWW). *Javascript* is a compact, object oriented scripting language for developing client Internet applications. Most Internet browsers (Javascript enabled) interpret *Javascript* statements embedded in a HTML page. In the following sections, interactions between *ArcSDE*, *ArcIMS* and *Oracle 9i* are described.

ArcSDE

It is a middleware that allows storing and managing of spatial data in a DBMS. It adds location information to the existing descriptive data in an organization. It brings the benefits that are harnessed by a typical DBMS to GIS. It offers centralized management, distributed access, reduces data redundancy, improves data integrity and security; and cost effective application development. It supports most of the popular GIS data formats that are used in a typical organization. It is complaint with the Open GIS Consortium (OpenGIS)

simple feature standard. This facilitates interoperability of data across different platforms and DBMS.

The data is stored in the host DBMS as relational tables using the existing data types available in each one of them. The data types ranges from simple text, date, number to complex binary large objects (blobs). ArcSDE supplements the capabilities of a relational DBMS. Similar to a DBMS, ArcSDE supports a simple high-level language, known as structured query language (SQL). SQL allows users to develop the database by employing integrity rules. It allows querying the database to select a set of rows meeting certain criteria for an attribute both spatially and descriptively.

ArcSDE provides a means to deliver the stored data from a centralized DBMS to client applications. Figure 33 shows a three tiered ArcSDE architecture. The client, in our case ArcIMS service, makes a request to the server. The server in turn receives the request, generate results, and delivers to the client. This is eventually served as maps over the Internet.

In a typical configuration such as ours, the ArcSDE server performs spatial searches and sends data that meets the search criteria to the client. For example a classic search in our application is setting the extent to “Downtown Orlando” or “Space Coast” region. When the client makes the request, ArcSDE finds all the features falling within search envelope and sends the results back to ArcIMS and in turn is displayed in the map region window.

At any time, ArcSDE will have two process running on the server namely *giomgr* and *gsrvr* (Figure 33). The main task of *giomgr* is to check for availability of license for clients to connect and monitor the requests and responses for each one of them. It is a service to which all the clients connect. For each client connection request, a *gsrvr* process is spawned.

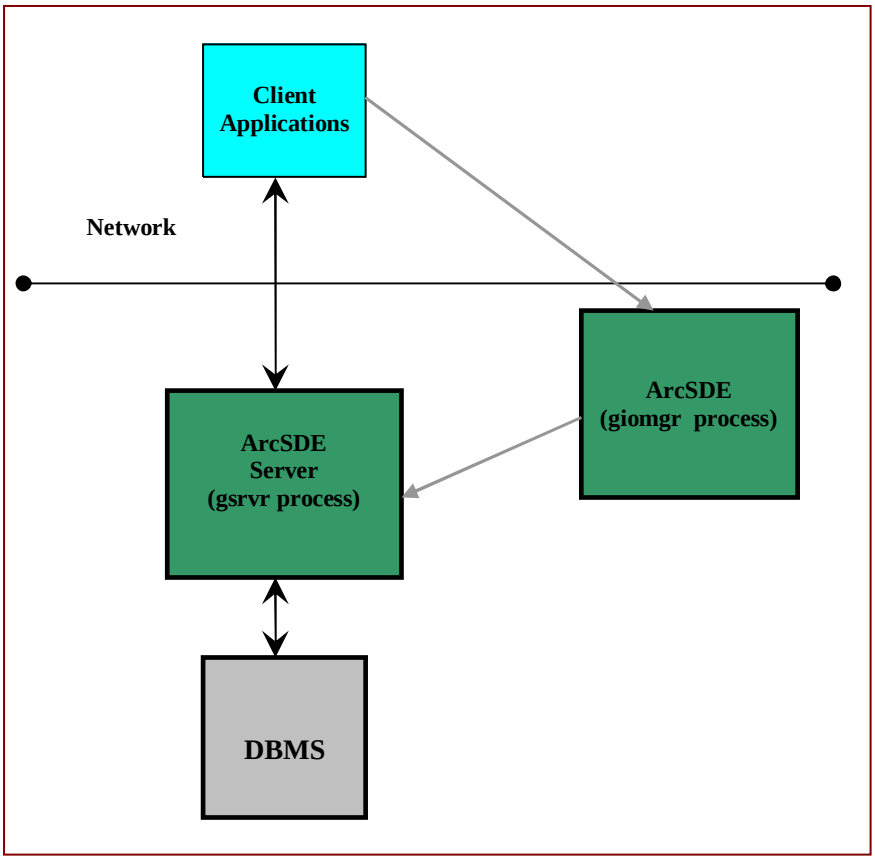


Figure 33. The ArcSDE Architecture (Source ESRI's Understanding ArcSDE)

This process does most of the geoprocessing on the DBMS server. The results are then tunneled back to the client through the *giomgr*.

ArcIMS

It helps to share data, information and technology over the Internet. In this project, the traveler's information is delivered in real time over the web using the above technologies. ArcIMS has both client and server side components. Figure 34 depicts the viewer (client) server communication process. All interaction between the viewer and the server components takes place through ArcXML. Figure 34 shows most of the server components related to ArcIMS architecture except the Web Server. The GIS web client is a HTML

viewer. It was chosen for its light weight and customization capabilities using HTML and *Javascript*.

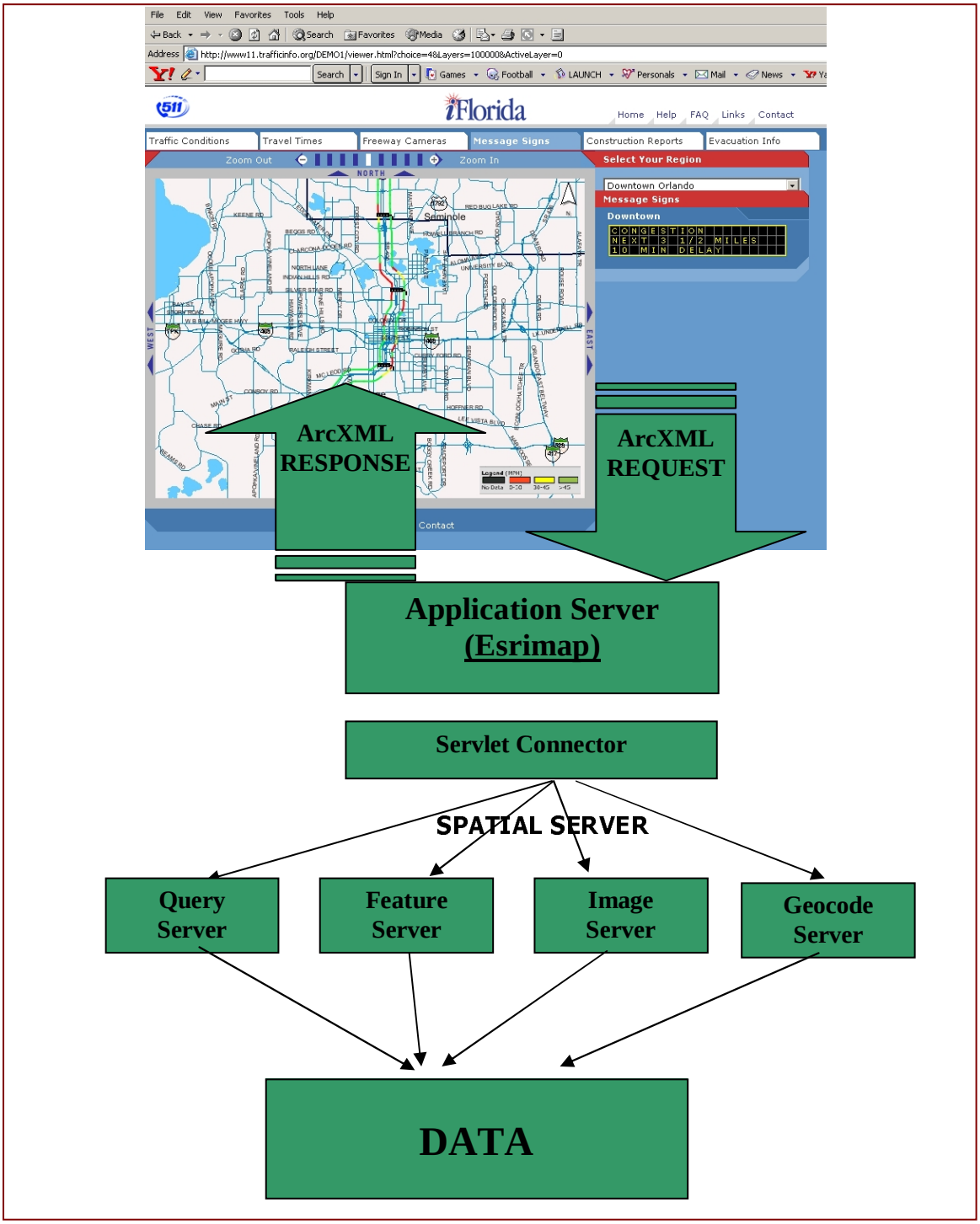


Figure 34. Server Viewer Communication (Source ESRI's Customizing ArcIMS: HTML Viewer)

When the web server receives a request for map related information, it transfers the incoming request to ArcIMS application server through the Servlet connector. The application server takes the incoming request and transfers to the appropriate service running on a spatial server. The spatial server can be of seven types namely Image, Feature, Query, Geocode, Route, Extract, and Metadata. In this project we are using only Image and Query servers. Each one of them gives different functionalities to the Spatial server. Image Server creates images of the map from the data. These images are served as map images to the clients. The Query server searches for features matching the search criteria. These two work in tandem to respond to the requests generated by the HTML viewer GIS clients.

There are two other background processes that support the spatial server namely tasker and monitor. The tasker removes the stale image files at a regular interval off of the server. The monitor helps the spatial server to restore and manage the services automatically when the system is brought down and brought up. In Figure 34 the DATA block refers to either ArcSDE data source or simple flat files such as a shapefile.

Figure 35 shows a typical series of execution that are triggered during a ArcXML request/response cycle invoked by a client. ArcXML is a set of XML tags generated by ESRI. XML, the Extensible Markup Language, is a W3C (World Wide Web Consortium) standard for document markup. It is similar to HTML but also allows creating custom tags to describe the data. The custom tags are defined in a document type definition (DTD) document. A similar DTD has been generated by ESRI for ArcXML tags. Documents that do not match the listing in these DTD are invalid.

For example in Figure 35, the client is making an ArcXML request for an image of an area for which it is sending the envelope information. The request is sent to the server which

redirects to the servlet connector and application server. It parses the request and sends to the appropriate spatial server, in this case Image server. The spatial server in response generates the image and sends it back to the application server. The response eventually reaches the client in the form an ArcXML tags giving the location of the generated image. The browser parses this information and shows the image in the map window.

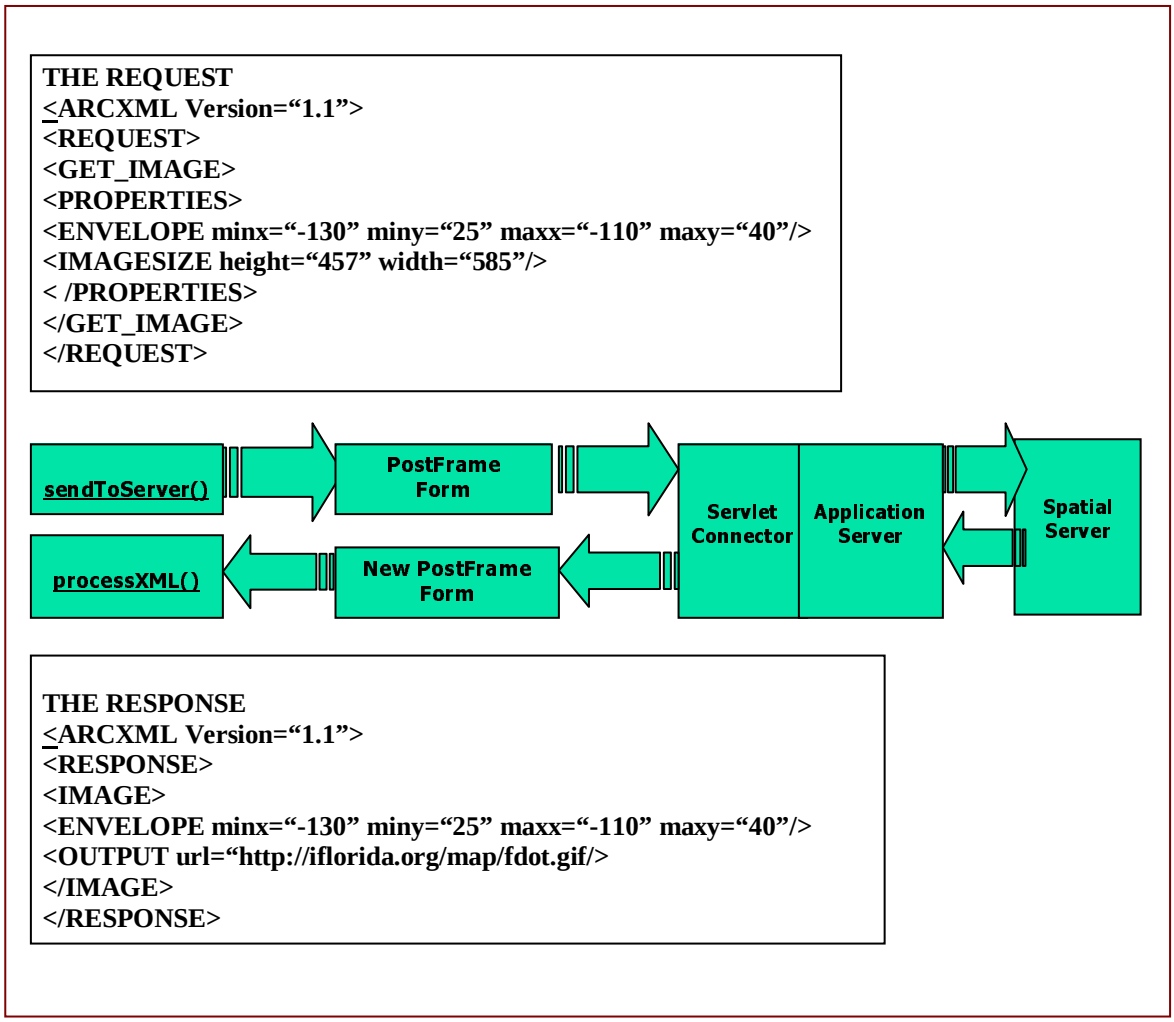


Figure 35. ArcXML Request/Response Cycle (Source ESRI's Customizing HTML Viewer)

Data Source and Data Collection

Data flow is shown in Figure 36. Raw data collected every 30 seconds from the reporting loop stations are populated in the CFDW database. Summarization algorithm written in perl program runs every five minutes as a cron job. It aggregates over five minute intervals and the imputation algorithm imputes the missing data in the datasets. Finally the program writes the results to a summary table. The processed data is ready to be presented on the web.

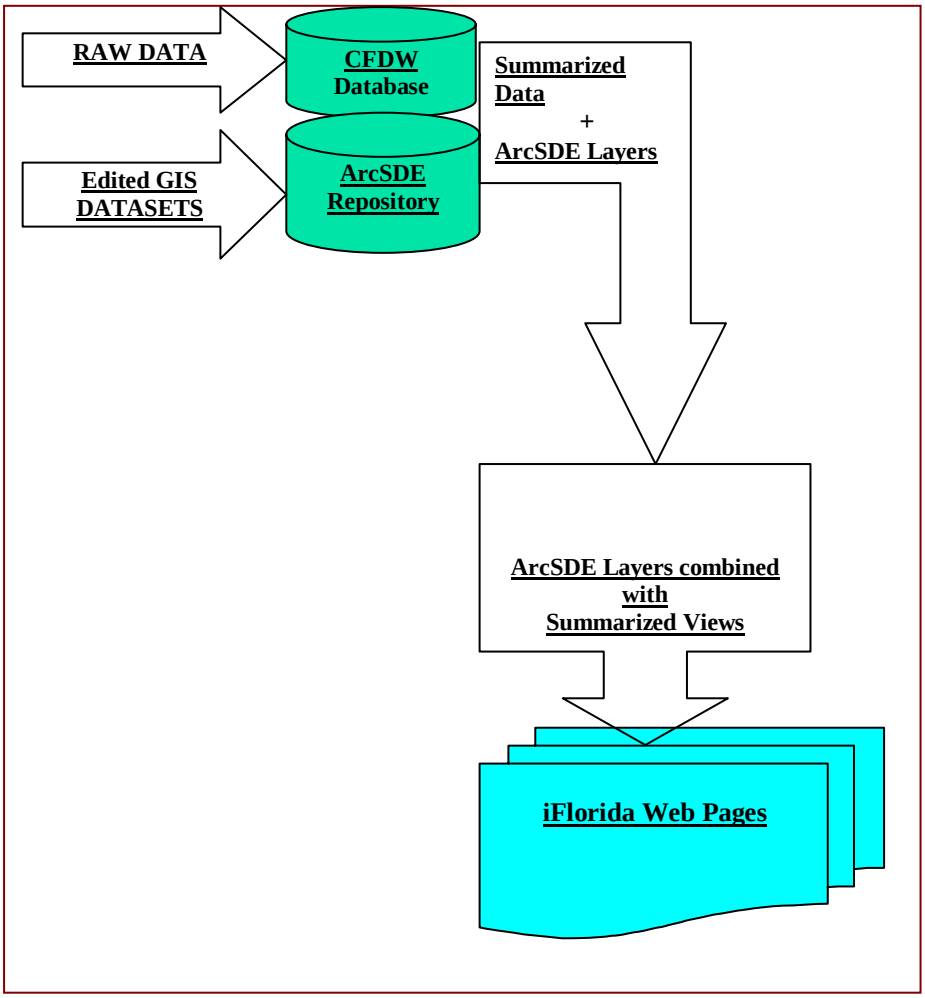


Figure 36. Data Flow

For this project both spatial (GIS datasets) and non-spatial (traffic data) are required. GIS datasets were obtained through different sources such as FDOT, FDOT D-5. The datasets include District 5 layout, cities, lakes, major highways, ramps and locations of detector, camera, and dynamic message signs (DMS). I-4 corridor as-built drawings were acquired through FDOT D-5. These GIS datasets were updated and QA/QC by the UCF data warehouse team. These datasets are generally prepared off-line using the ArcView GIS client software. Non-spatial data includes RTMC traffic data (e.g. loop detectors speed, volume, and occupancy, and dynamic message sign data). The spatial and non-spatial data elements are joined together via a common identifier to create a spatial view. These views present the latest data such as speeds and dynamic messages in real time over the web.

Conclusion

In the GIS integration project, it has been successfully demonstrated that integration of technologies such as Geographical Information System (GIS), Global Positioning System (GPS), Database Management System (DBMS) and Internet can provide real time traffic information to the traveler. Since the Orlando is a tourist destination, the location information will facilitate visitors to retrieve relevant travel information from the web site. By providing tourists and commuters with an easy way to access timely traffic and weather information, the iFlorida web site will serve as the “one stop shop” for traffic information in Central Florida.

Integration of the travel time prediction model with GIS gives the users the estimated delays in their travel times up to 30 minutes in the future. This is in addition to the current “calculated” travel time information. The travel time module has the capability to perform predictions to all of the entry and exit ramps along the highway.

CHAPTER 6

VIDEO CONVERSION SYSTEM COSTS

Addendum to the Video Discussion Document

Dr. Karl Petty
Berkeley Transportation Systems, Inc
17 March 2003

Executive Summary

In this chapter we discuss the tradeoffs inherent in any video conversion system. The general concept of a video conversion system which we are discussing is a machine(s) which takes in live video from a source and converts it to a format and bandwidth appropriate to serve to the public through a limited bandwidth connection. We apply these fundamental tradeoffs to the problem of providing video from the FDOT RTMC to the public through the UCF connection to the internet while converting the live video to static snapshots as well as live streaming video.

Introduction

The goal of this project is to take live traffic video from FDOT and place it on the UCF web site so that the traveling public can view the current conditions on the freeway. The video streams coming from the cameras in the field are MPEG-2 multicast streaming video streams encoded at 3 Mbps, producing a bit rate of 5Mbps on the wire. Currently, FDOT uses the VBrick 4200's to encode the video and to send it out via IP multicast. FDOT transports the video back to their RTMC where they decode it to analog video and display it on their monitors. They use these video streams for a variety of traffic management functions. Our goal is to take a number of these multicast video streams and place them on the UCF web site. This will allow the traveling public to view the road conditions and to make informed trip choices.

MPEG-2 is a video format which is commonly used in cable TV systems and/or systems which require high-fidelity video. It is not a format that regular computer users can view on their machines without a special decoder. In addition, most users access the internet via

dial-up lines, which are 56Kbps at the most, or through DSL or cable modems, which have a download speed of around 1-2Mbps. Hence the bit rate of the original video streams, 5Mbps, is much too high for most users to receive. Furthermore, there is a bandwidth limitation leaving UCF. This means that the connection from UCF to the internet is limited. Since each user receives their own copy of the video stream, there is a natural tradeoff between the bandwidth of the stream and the number of users that we can support. Therefore, for all of these reasons, the FDOT video streams need to be converted from their original format to something that the users can see that's at a much lower bandwidth.

When deploying a video conversion system there are many different options and tradeoffs. In a previous document we argued that in order to reach the largest number of users, the best choice for a video conversion system is to convert the streaming video into static images and to serve those out to the users. The static images are refreshed periodically to show a progression of the traffic. For this system, the relevant questions are: how many users can you serve? How many streams can you serve? What can be the bandwidth of each stream? The goal of this document is to describe the fundamental relationships constraining these choices for any video conversion system. In doing so, we hope to answer the questions for our video system.

Video Conversion Systems

A simple end-to-end networking diagram of a video conversion system is depicted in Figure 37.

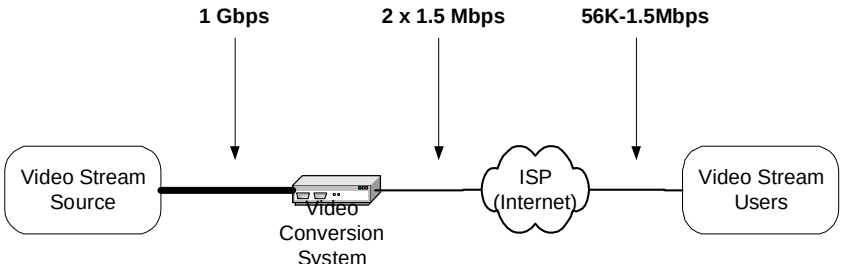


Figure 37: A Simple Video Conversion System.

On the left side of the figure we have the video source streams. For our configuration these are generated at the FDOT RTMC. In the middle we have the video conversion system itself. On the right side we have video stream users, who are trying to see the video streams. Connecting all of these boxes are the various network links. For our system, the

link from the video sources to the video conversion system is a 1Gbps link. This link is quite large and won't be a constraining factor in any of our discussions. Connecting the video conversion system to the end users are two different types of connections. First, there is the connection from UCF to the internet, which is currently a pair of T1 lines with a bandwidth of 1.5 Mbps each. Second, there is the connection from the internet to the end users, which ranges from 56Kbps, if they are using a dialup modem, to approximately 1.5Mbps, if they are using a DSL or cable modem connection. For this side of the system, we assume that there are going to be many users viewing the video streams. Each user pulls their own copy of the video (either the streaming video or the static images) across the link from UCF to the internet. This means that the limiting factor for all of our discussions is going to be the first connection, from UCF to the internet.

System Goals and Constraints

Given this setup, we frame the discussion as two sets of constraints. First there is the "supply" side, by which we mean the number of video streams that the conversion system can convert, or supply, to the end users. For all conversion systems, there is a finite amount of processing capacity available for each machine. Once you reach that limit then you have to add more machines if you want to convert more video streams. We make the explicit, and reasonable, assumption that the number of video streams that we can convert is independent of the number of people viewing the stream. Second, there is the "demand" side, which is the number of viewers that want to see the video streams. For this side the constraint is simply the bandwidth leaving UCF to the internet.

With these sides defined, we are interested in answering four inter-related questions:

1. How many video streams can we serve?
2. How many users can we support?
3. What bandwidth video streams can we serve?
4. How much does it cost?

The first question only deals with the supply side and the constraints are only due to the processing power of the conversion system. For our solution, where we convert the video streams to static snapshots, we can convert 2 frames per second independent of the number of video streams moving through the box. This imposes a tradeoff between the number of video streams and the minimum refresh rate as depicted in Figure 38.

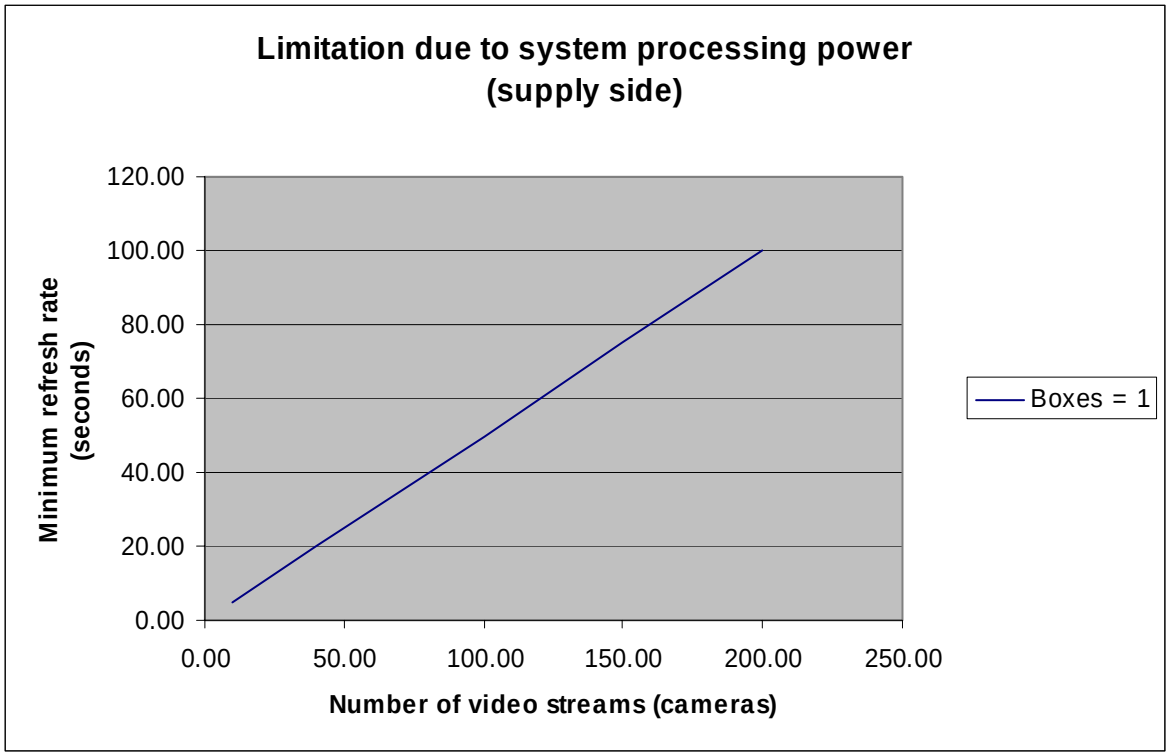


Figure 38: Tradeoff Between Refresh Rate and Number of Video Streams.

In this figure, for one box we sketch the relationship between the number of video streams and the minimum refresh rate. For example, if we have 100 different video streams flowing through the box, then the minimum refresh rate is 50 seconds, which would have us converting 2 frames per second. Note that you can operate at any point above the line. For example, with 100 cameras you can have the refresh rate be larger than 50 seconds. You just can't operate below the line.

The minimum refresh rate is proportional to the number of converting boxes. If you have 100 video streams and you would like to serve static images at a minimum refresh rate of 25 seconds, then you simply need to use two machines.

The next two questions, how many users and what bandwidth we can serve, are related and the answer is a function of the bandwidth leaving UCF. Each static image, or snapshot, that we generate is roughly the same size, around 16KB. As we mentioned above, if you choose the refresh rate then that dictates an average bandwidth served to each user. Since we assume that each user is only pulling one image at a time, the total number of users that

you can support is simply the bandwidth leaving UCF divided by the average bandwidth of each stream. That means that if we fix the bandwidth leaving UCF, then there is a natural tradeoff between the number of users that we can support and the minimum refresh rate. We have illustrated this tradeoff in Figure 39.

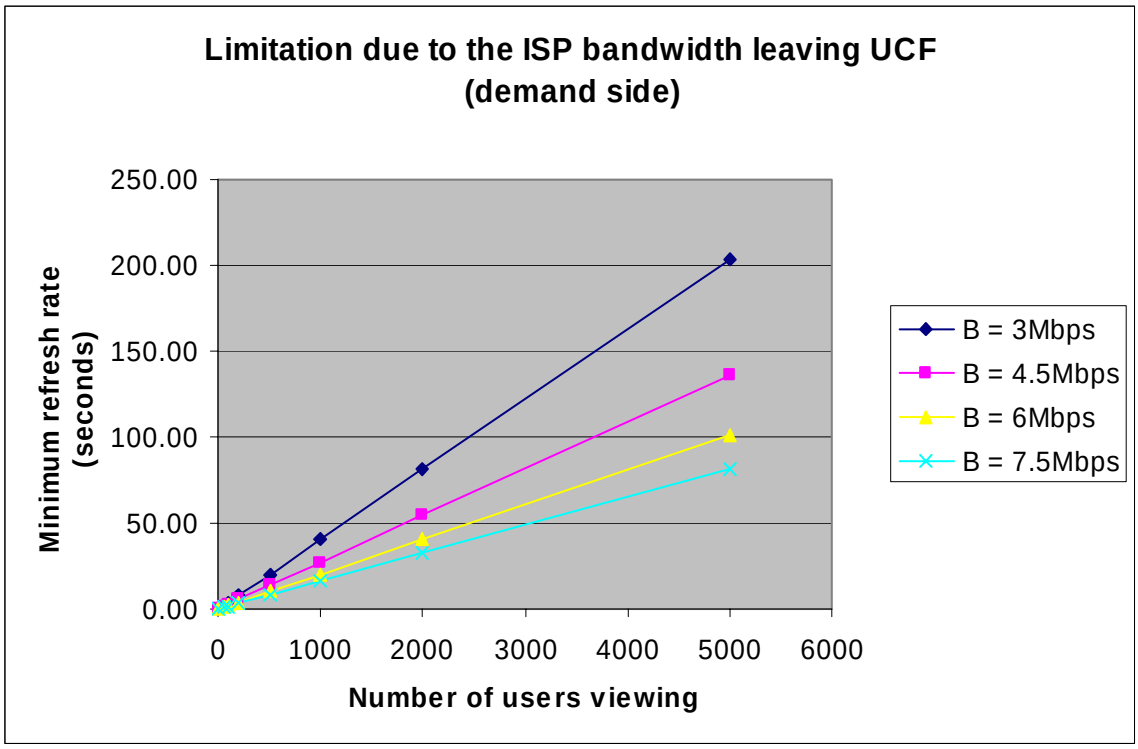


Figure 39: Relationship Between Refresh Rate and Number of Users.

In this figure, we are plotting the refresh rate versus the number of users (which is different from the previous figure where we are plotting the refresh rate versus the number of video streams). The different lines are the different bandwidth pipes. For example, the line where B = 3Mbps, which is the top line, shows that for 2000 viewers we can have a minimum refresh rate of approximately 70 seconds. If we increase the bandwidth leaving UCF to 4.5Mbps, which is the second line from the top, then for 2000 viewers we can have a minimum refresh rate of just over 50 seconds. Another way to think about this figure is to first fix the refresh rate at, say, 50 seconds. In that case, if the bandwidth is 3Mbps, then we can serve approximately 1100 people simultaneously. If we increase the bandwidth leaving the school to 4.5Mbps and keep the refresh rate the same, at 50 seconds, then we can now increase the number of simultaneous viewers to just under 2000. Intuitively this makes sense: if we add more bandwidth, then we can add more people.

In order to obtain our goal and answer the questions posed above, we need to combine the demand side with the supply side. In other words, we need to combine the constraints. In these relationships, we have five different variables: 1) the number of video streams, 2) the minimum refresh rate, 3) the number of viewers, 4) the bandwidth leaving UCF and 5) the number of video conversion machines. This makes it difficult to make a simple plot with all of the variables on it. Instead we choose to keep the number of video streams constant, at M = 100, and then plot the minimum refresh rate on the y-axis versus the number of users on the x-axis. We do this while letting the number of video conversion machines, which we denote by the variable C, and the bandwidth leaving UCF, which we denote by the variable B, vary over different values. The result is given in Figure 40.

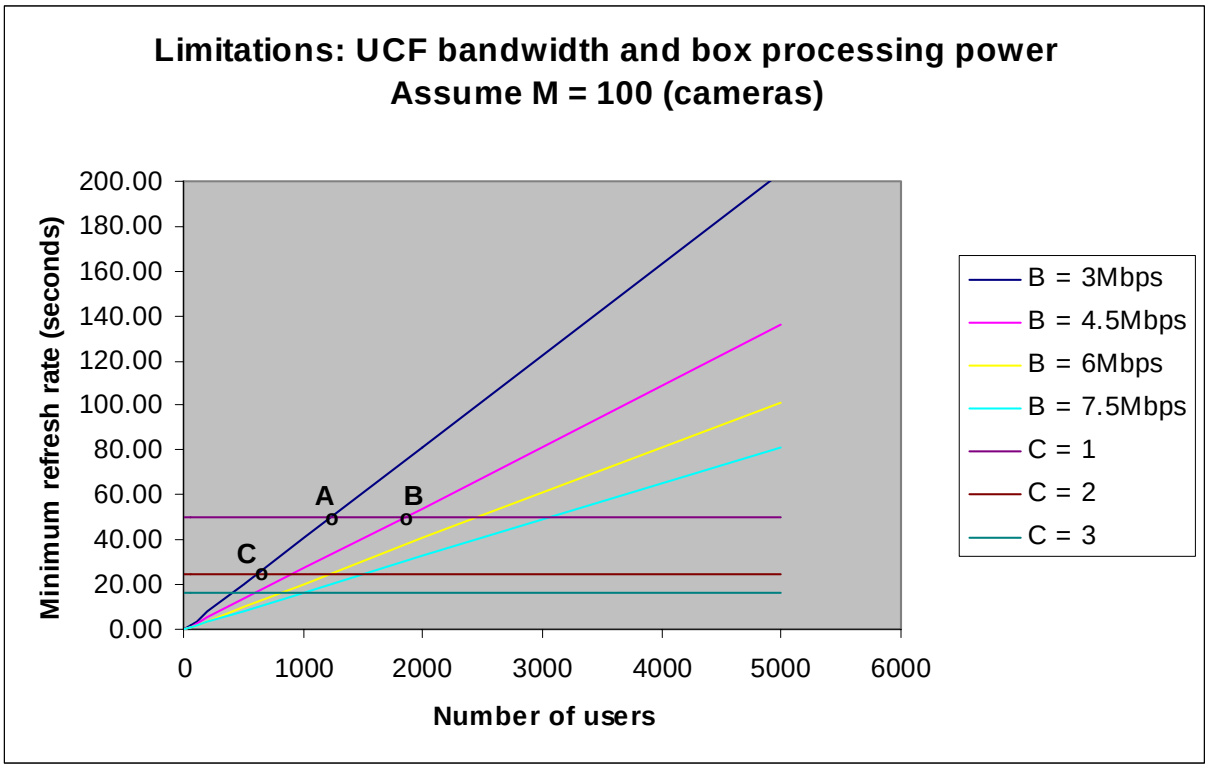


Figure 40: Combined Constraints and the Relationship Between Bandwidth, Number of Conversion Machines, Refresh Rate and the Number of Users.

In Figure 40, the horizontal lines represent the number of video conversion machines. C = 1 is the top line and C = 3 is the bottom line. As we mentioned above, the number of video conversion machines that we have effects the minimum refresh rate and is independent of

the number of users (which is why the lines are flat). The angled lines are the same ones as in Figure 39, and they represent different bandwidths leaving UCF. It is important to note that all of these lines are for the case where we have M = 100 video streams (cameras).

We can "operate" at any point on this plot. By this we mean that every point represents a certain refresh rate and a certain number of viewers that we can serve. Since it is generally accepted that serving more viewers and refreshing images faster is beneficial, we want to be as far to the right and as close to the bottom of the plot that we can. The lines on the plot delineate the constraints that we've discussed above. For example, with one machine, C = 1, the top horizontal line is the constraint that says that our minimum refresh rate is 50 seconds, independent of the number of users.

To explain the plot, we start with the hypothetical situation where we have a bandwidth of 3Mbps leaving UCF, and we only have one video conversion system. The bandwidth constraint means that we have to pick an operating point that's on or above the line B = 3Mbps, which is the top angled line. Since it's beneficial to always be lower and to the right, we assume that we would never operate above the line and that we would always operate exactly on the line. The machine constraint dictates that we have to operate on or above the line C = 1, which is the top horizontal line. If we combine these two constraints, and note that we want to be as far to the right and as close to the bottom of the plot as possible, then we see that we can operate at the point labeled "A". If we increase bandwidth on the UCF link to 4.5Mbps, then we can now operate at the point labeled "B", and we can serve just under 2000 users at the same refresh rate. If, instead of adding bandwidth we choose to add another video conversion machine, so C = 2, then we can move to the operating point labeled "C". In that case, we can now serve images faster, because the refresh rate has decreased to 25 seconds, but the number of users that we can serve has dropped from approximately 1200 to 600. This intuitively makes sense because we aren't increasing the total bandwidth leaving UCF but we are increasing the average bandwidth for each stream. Hence the number of streams that we can serve (which is the number of users) must decrease.

This figure allows you to examine the tradeoff between the different variables. For example, if we have a certain outgoing bandwidth, we have a single video conversion machine, and we know the number of video cameras, then we can use the plot to tell us how many users we can expect to support. Alternatively, you can turn the problem around and instead of

specifying the bandwidth and the number of machines constant, you can have those be the outputs of your study. You would normally do this when you are trying to determine the cost of the system given the number of users and the desired refresh rate.

Snapshot System Costs

The plot in Figure 4 almost gives us the ability to properly frame our last question: how much does this cost for different configurations? In order to completely answer this question, we need to know the costs for each unit of bandwidth and for each machine. The video conversion machines which we are using cost $5K each. The cost for bandwidth at UCF is given in Table 1 below.

Network Speed (Mbps)	Cost/month
3	$ 2,084
6	$ 2,798
9	$ 3,501
15	$ 4,904
21	$ 9,361
33	$ 11,867
45	$ 14,424

Table 1: Bandwidth costs at UCF.

The current networking connection at UCF is 3Mbps. There are additional installation costs for the networking of approximately $1.5K, but since those don't effect the marginal calculation I've left them off.

The straight lines sketched out in Figure 40 are iso-cost lines. This means that operating anywhere on that line costs the same amount of money. In order to get the total cost of the system you need to add the bandwidth cost and the machine costs. For example, in Figure 40, operating point "A" has a bandwidth cost of $2084/month and a fixed cost of $5K for one video conversion machine. So for the first year, the cost would be $5000 + 12 * $2084 = $30008.

With these costs, we can specify the two inputs, the desired number of users and the desired refresh rate, and then automatically calculate the number of machines needed, the

bandwidth needed, and the resulting fixed and recurring costs. I've done that for a number of different operating points in Table 2 below. Note that since we want to operate at the intersection of the two constraint lines, like at points "A", "B" and "C" in Figure 40, I've judiciously selected the number of users to be the maximum number that we can support given the bandwidth and the number of machines.

Inputs		Outputs		Costs		
Refresh Rate (sec)	# Users	# of Machines	Bandwidth (Mbps)	Fixed Costs	Yearly Cost	Total First Year Cost
50	1229	1	3	$ 5,000	$ 25,008	$ 30,008
50	3686	1	9	$ 5,000	$ 42,009	$ 47,009
50	8602	1	21	$ 5,000	$112,336	$117,336
50	18432	1	45	$ 5,000	$173,086	$178,086
25	614	2	3	$ 10,000	$ 25,008	$ 35,008
25	1843	2	9	$ 10,000	$ 42,009	$ 52,009
25	4301	2	21	$ 10,000	$112,336	$122,336
25	9216	2	45	$ 10,000	$173,086	$183,086
16.6	408	3	3	$ 15,000	$ 25,008	$ 40,008
16.6	1224	3	9	$ 15,000	$ 42,009	$ 57,009
16.6	2856	3	21	$ 15,000	$112,336	$127,336
16.6	6119	3	45	$ 15,000	$173,086	$188,086
12.5	307	4	3	$ 20,000	$ 25,008	$ 45,008
12.5	922	4	9	$ 20,000	$ 42,009	$ 62,009
12.5	2150	4	21	$ 20,000	$112,336	$132,336
12.5	4608	4	45	$ 20,000	$173,086	$193,086
10	246	5	3	$ 25,000	$ 25,008	$ 50,008
10	737	5	9	$ 25,000	$ 42,009	$ 67,009
10	1720	5	21	$ 25,000	$112,336	$137,336
10	3686	5	45	$ 25,000	$173,086	$198,086

Table 2: Total costs for different configurations for video snapshots

In Table 2 we can see that we can select a desired refresh rate, say 16.6 seconds, and we can select the desired number of simultaneous users, say just over 1200, and then read off the resulting equipment and bandwidth needed. For this particular combination the table indicates that we'll need three conversion machines and 9Mbps of bandwidth. This

translates to $15K of fixed costs and $42K per year of recurrent costs. Therefore the total first year cost is $57K.

As part of this work we performed a survey of the various live traffic cameras available on the web that were showing traffic video as snapshots. We surveyed a total of 15 sites which ranged in size from 5 to 300 cameras. We were interested in studying the relationship between the number of video cameras and the refresh rate used. The results are shown in Figure 41. In this survey the site with the largest number of cameras is Atlanta, with approximately 300. The site with the slowest refresh rate (so the longest time between refreshes) is Arizona DOT at 360 seconds, or 6 minutes. On average there were 78 cameras per web site with an average refresh rate of 130 seconds, or just over 2 minutes.

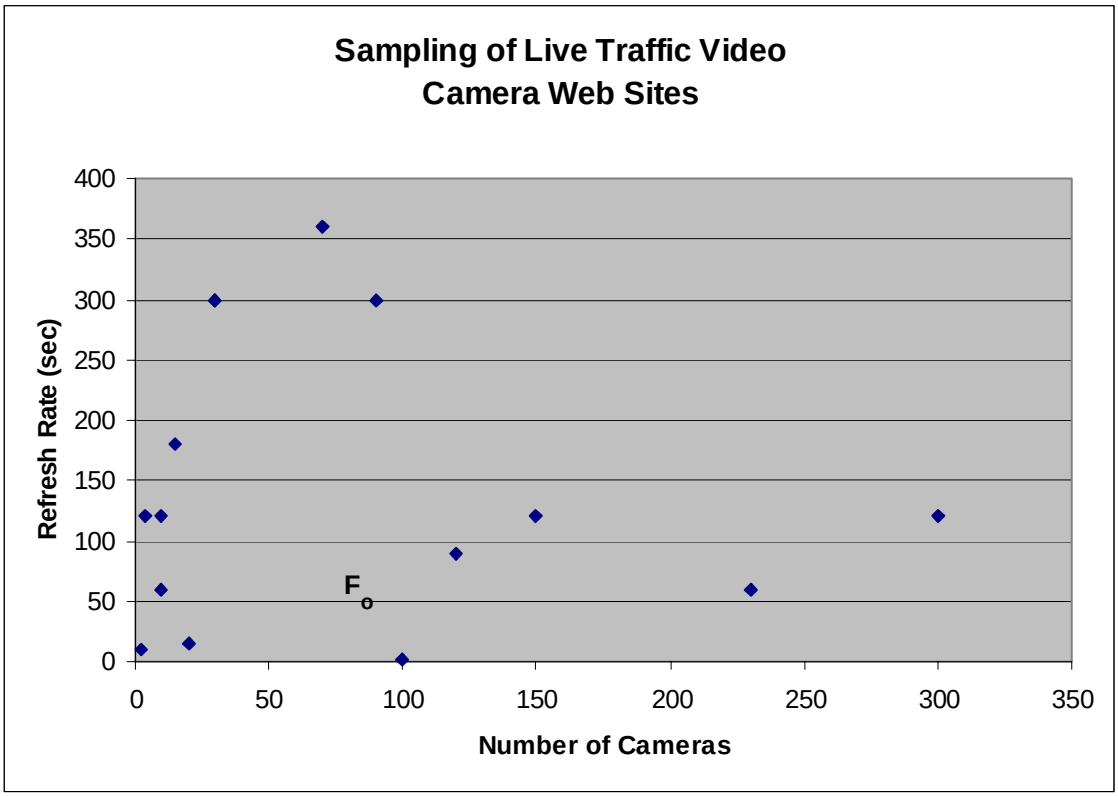


Figure 41: Survey of Refresh Rates of Other Traffic Video Sites.

With the goals spelled out above, and the results of the survey, we believe that a refresh rate of 40-60 seconds is quite reasonable and is generally expected by the public. At that rate, we would be twice as fast as the average camera sites in our survey. This would place

us roughly in the spot labeled “F” in Figure 41. In addition, we believe that supporting 1200 simultaneous users is an ambitious goal. By using Table 2, these two inputs tell us that we need a single conversion system and 3Mbps of bandwidth. Hence the total cost for the first year for a solution with only snapshots will be approximately $30K.

Live Streaming Video Costs

As technology marches on, new products will come onto the market. A brand new product by Vbrick which converts MPEG-2 video streams into MPEG-4 video streams is being released in April 2003. This product is an appliance that can plug into the network, receive a multicast MPEG-2 video stream and convert it to MPEG-4 and then serve it out to users on the internet. This presents us with a method for serving live video to users with only a single box. The characteristics of this box are as follows (note that these characteristics are reported by the Vbrick sales personnel and not independently verified): Each box can convert only one video stream. It can serve up to 120 users over unicast streams (which are required to serve out video across the Internet) with a maximum bandwidth of 38Mbps per box. It can step down the incoming bandwidth to 8Kbps. The boxes cost $8K each. With these characteristics for the live video appliance, we are interested in figuring out similar questions to those that were answered above: How many users can we serve? How much bandwidth do we need to do it? How many systems do we need to buy?

The characteristics of the video streaming appliance are a bit different than the video snapshot appliance. For example, the Vbrick video streaming appliance can only convert one stream per box. It is not possible to raise the refresh rate (or lower the bandwidth) in exchange for being able to convert more cameras per box as we did with the snapshot appliance and as we explained in Figure 38 above. If we want the public to see more cameras, then we simply have to buy more Vbrick boxes. In addition, the major knob to tweak with the Vbrick box is the outgoing bandwidth that it serves to each user. With the video snapshot box the major knob was the snapshot refresh rate. In that example, a lower refresh rate meant that a higher bandwidth was required and it provided the user with a better viewing experience. In a similar manner, with the Vbrick box a higher bandwidth output stream also provides end users with a better view experience. The difference is that with the video snapshots we were tweaking the refresh rate and with the Vbrick boxes we'll tweak the bandwidth (which is inversely proportional to the refresh rate). Nevertheless, we can still explore the relationships between the various variables.

As we mentioned above, the main knob to tweak is the outgoing bandwidth to serve to each user. Possible values range from 8Kbps to 2Mbps. The higher the bandwidth the better the quality. When choosing the bandwidth for the video streams we usually take into consideration the target audience we're trying to reach. If our target audience is users at home behind 56Kbps dial-up modems then we should serve out streams at a rate less than 56Kbps, so something like 28Kbps. Alternatively, we could reason that users behind dial-up modems won't be able to receive video and that the target audience is really home users behind broadband connections and users at work. In that case, we can serve out video streams at 150Kbps which have a much higher quality but home users wouldn't be able to see them. A quick survey of 10 different live traffic streaming video web sites shows that the typical bandwidth is between 20Kbps and 34Kbps, with most of them at 28Kbps. The total amount of bandwidth, B, needed leaving UCF is simply the number of simultaneous users, N, multiplied by the bandwidth of the encoded stream, E.

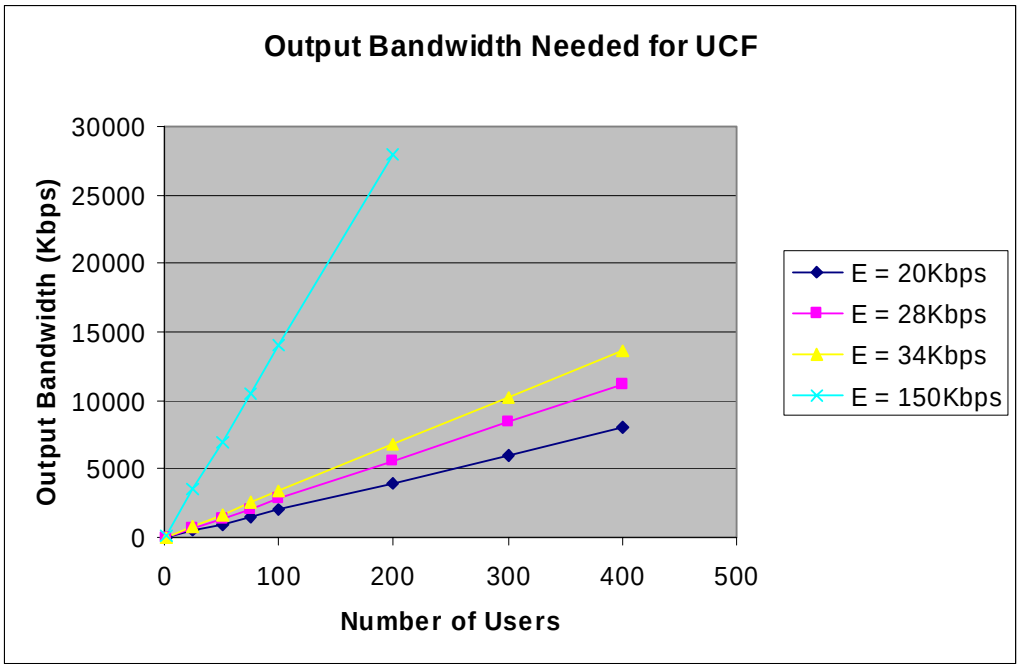


Figure 42. Bandwidth Needed at UCF as a Function of the Number of Users and Encoding Rates.

We can clearly see this relationship in Figure 42 above. In that figure, we plot the output bandwidth needed by UCF in order to support a given number of users for different encoding rates. The bottom line has E = 20Kbps. In that case we can see that for 200

users that we need approximately 4.5Mbps of outgoing bandwidth at UCF to support that. As we increase the bandwidth of the encoded stream, then the required bandwidth increases, which intuitively makes sense.

It's clear that Figure 42 doesn't allow us to explore the relationship between the number of video cameras and the required bandwidth. To do that, we realize that the total bandwidth needed by UCF is simply the number of users per camera, N_c, multiplied by the encoded bandwidth per stream, E, multiplied by the number of cameras being shown (which is the number of Vbrick boxes in operation). So we have the formula $B = E * C * N_c$. As we noted above, this is subject to the limitation that a single Vbrick box can not serve more than 120 users. We can illustrate this relationship by fixing a value for E, and then choosing different values for B and seeing how many cameras and how many users we can support.

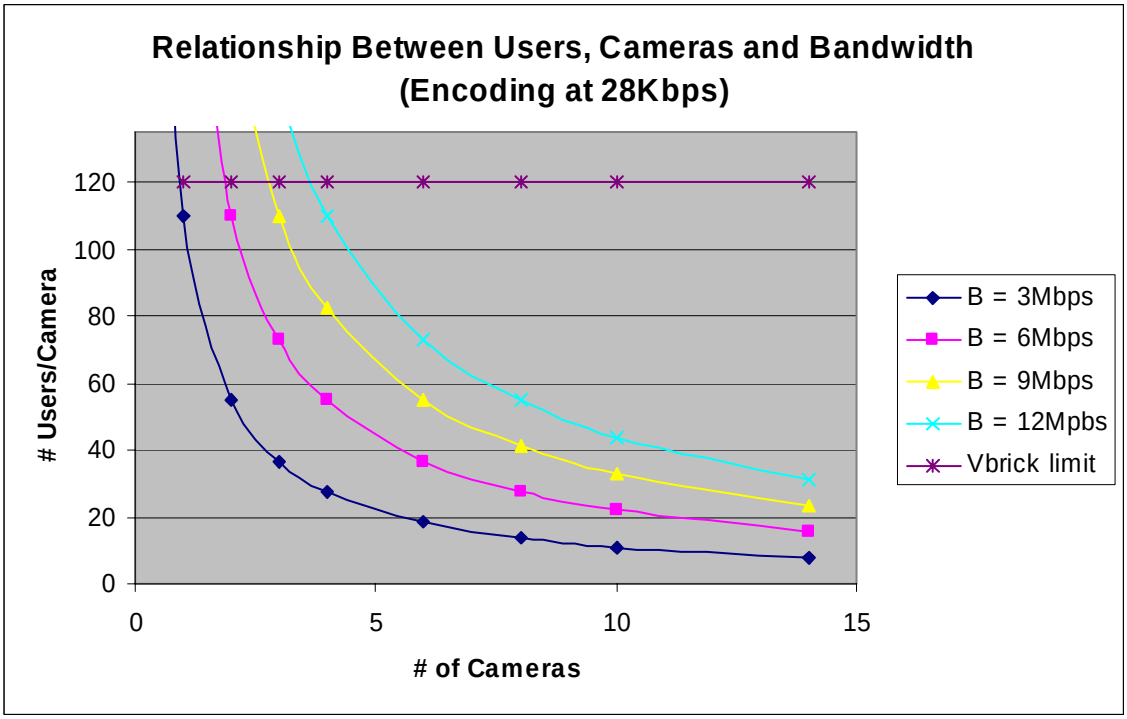


Figure 43. Relationship Between Users, Cameras and Bandwidth (encoding at 28kbps)

In Figure 43 we have a plot of the number of users per camera versus the number of cameras. We have chosen a number of different outgoing UCF bandwidths at which to plot these points. In addition, we have drawn the Vbrick limitation of 120 users per camera. For

this plot, we have chosen a fixed value of the encoding bandwidth at 28Kbps. To take an example, for four cameras, with a UCF bandwidth of B = 3Mbps, we can serve out approximately 27 users per camera. This means that we'll be able to serve 27 * 4 = 140 total users (although they aren't all looking at the same camera). A given UCF bandwidth, B, sketches out a line of the maximum number of users per camera that we can support for a given number of cameras. In terms of bandwidth, that line is an iso-cost line. So anywhere on that line we have the same cost for bandwidth. We can operate anywhere under that line without upgrading the UCF bandwidth. To verify that these curves make sense, take the example of four cameras again. At B = 3Mbps we can serve around 27 users. At B = 6Mbps we can serve around 54 users. So as the outgoing bandwidth goes up, the number of users that we can serve goes up, which intuitively makes sense.

In Figure 43 we kept the bandwidth of the individual streams being served to the users, the encode rate, constant at E = 28Kbps. In a manner similar to Figure 43 we can, of course, explore the relationship between the number of users per camera and the number of cameras as a function of the encode rate. We do this in Figure 44 below.

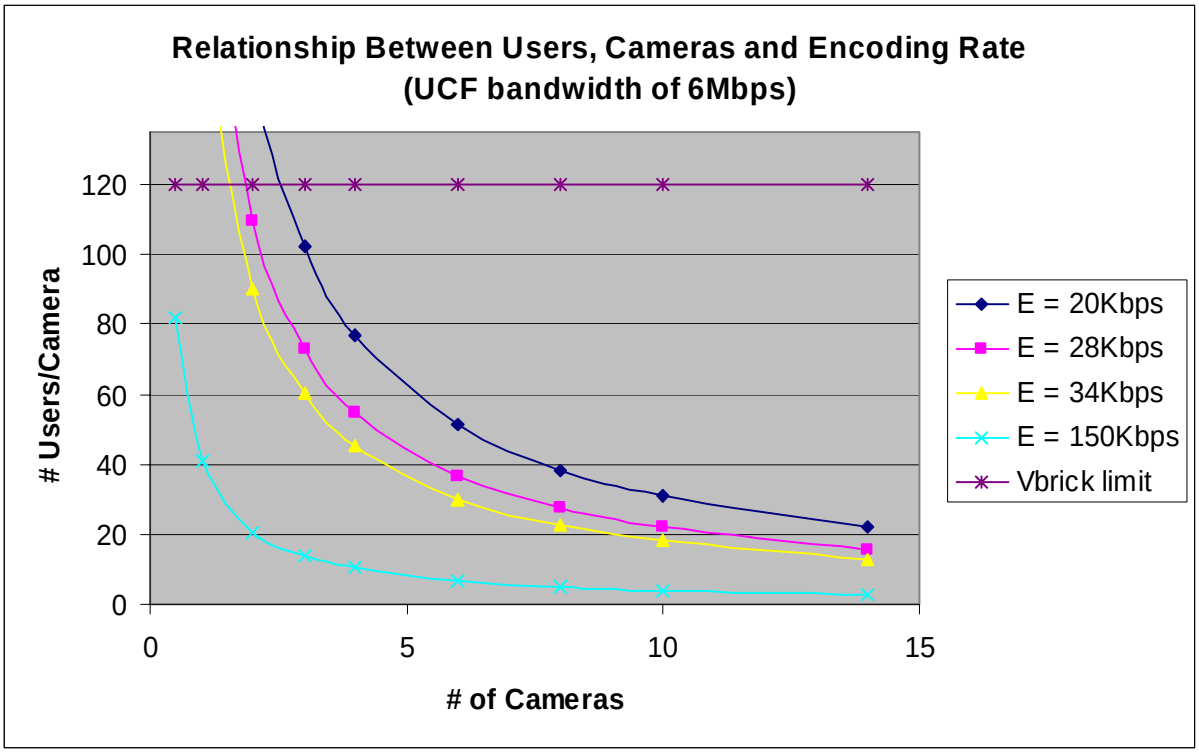


Figure 44. Relationship Between Users, Cameras and Encoding Rate

In this figure, we have held the outgoing UCF bandwidth constant at 6Mbps. We then allow the encode rate to vary from 20Kbps to 150Kbps. We can see that as the encode rate increases, each user is getting a higher bandwidth stream and we can serve less users simultaneously.

Just as we did in Figure 38 above for the video snapshot case, we can now use these relationships to determine what kind of system we'd like to build and how much it will cost. In the streaming video case, we have three main input variables: 1) the number of cameras that we'd like to show, 2) the number of users that we'd like to be able to support, and 3) the encode rate for the video streams. The output that we are looking for is the amount of bandwidth required by UCF. We're going to recommend that we encode at 28Kbps. This is a common rate for traffic video cameras and is reasonable for our application. With this fixed, we can now vary just two parameters and see the effect on the outgoing UCF bandwidth and hence the effect on the total cost. This is given in the table below.

Inputs		Outputs		Costs		
# of Cameras	Total # of Users	# Users per Camera	Bandwidth (Mbps)	Fixed Costs	Yearly Costs	Total First Year Cost
1	109	109	3	$ 8,000	$ 25,008	$ 33,008
1	120	120	6	$ 8,000	$ 33,572	$ 41,572
1	120	120	9	$ 8,000	$ 42,009	$ 50,009
1	120	120	15	$ 8,000	$ 58,846	$ 66,846
1	120	120	21	$ 8,000	$112,336	$120,336
3	108	36	3	$ 24,000	$ 25,008	$ 49,008
3	219	73	6	$ 24,000	$ 33,572	$ 57,572
3	327	109	9	$ 24,000	$ 42,009	$ 66,009
3	360	120	15	$ 24,000	$ 58,846	$ 82,846
3	360	120	21	$ 24,000	$112,336	$136,336
5	105	21	3	$ 40,000	$ 25,008	$ 65,008
5	215	43	6	$ 40,000	$ 33,572	$ 73,572
5	325	65	9	$ 40,000	$ 42,009	$ 82,009
5	545	109	15	$ 40,000	$ 58,846	$ 98,846
5	600	120	21	$ 40,000	$112,336	$152,336
10	100	10	3	$ 80,000	$ 25,008	$105,008
10	210	21	6	$ 80,000	$ 33,572	$113,572
10	320	32	9	$ 80,000	$ 42,009	$122,009
10	540	54	15	$ 80,000	$ 58,846	$138,846
10	760	76	21	$ 80,000	$112,336	$192,336
10	1200	120	45	$ 80,000	$173,086	$253,086

Table 3: Total Costs for Different Configurations for Streaming Video. We assume that the encode rate for the outgoing streams in E = 28Kbps.

As an example, in Table 3 if we chose to show three video cameras and we'd like to be able to support just over 200 users then we'd need to have 6Mbps of outgoing bandwidth at UCF. This would cost us $24K for the three Vbrick converter boxes and just over $33K/year for the bandwidth costs. Hence the total first year cost would be just over $57K.

Recommendations and Conclusions

The inputs to the above equations are difficult to agree upon and all arguments ultimately end up back at the same point: what are the goals of the project? The goals which we used to design the video snapshot system are discussed in more depth in the video discussion document. As a short recap, the goals were: 1) to allow users to see the conditions on the freeway, 2) to cover as many cameras as possible, 3) to serve as many users as possible, and 4) to have very low technical requirements for the users.

We believe that the best way to achieve the above goals is through a combination of video snapshots and streaming video. We feel that it's not feasible to buy one Vbrick box for every camera in the system. Therefore to get the widest possible coverage, we should supply a limited number of live video streams in combination with all of the other video cameras being converted and displayed with snapshots. This would allow us to serve both the home user behind a slow dial-up connection as well as the users that are using a broadband service. In this scenario, we can still use one video snapshot box, but then we can purchase a limited number of Vbrick converter boxes depending on how many streams we want to present to users. If the live video streams are popular then we can incrementally add more Vbrick boxes and add more outgoing bandwidth at UCF to meet the demand.
Hence our final recommendation is to have:

1. A single video snapshot converter box that has a refresh rate of 50 seconds and serves out all traffic camera images. This will cost $5K.
2. Three Vbrick live video converters that are converting at 28Kbps. This will cost $24K. The cameras should obviously be selected to view the most important regions and/or interchanges.
3. The bandwidth leaving UCF should stay at 3Mbps. At this rate, if we're sharing the bandwidth equally between the video snapshot system and the streaming video system, then we can expect to be able to serve at the maximum around 600 users with snapshots and around 50 users with live video simultaneously. This keeps the

yearly cost at $25K for the bandwidth alone. Of course it should be pointed out that both the video snapshots and the live video need to share the bandwidth with the web pages themselves. So the maximum practical rates for both of these services are lower.

Hence the final costs for the first year are right around $54K. If we wanted to enhance the system, we feel that we'd get the most bang for the buck by first adding a second video snapshot converter so that we can decrease the refresh rate to 25 seconds for all of the images, and second by adding additional live video converter boxes. We do not recommend increasing the bandwidth leaving UCF until we start seeing limitations in practice.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

In this one year study, the UCF research team designed, developed, and implemented the Central Florida Data Warehouse (CFDW) using funding from the TCSP project and the FDOT Research Center (Central ITS Office funding) project. Funding from the FDOT Research Center was used by UCF to manage the TCSP project. Hardware and software components planned for the first year were procured under the TCSP project and have been functional online. The large scale TCSP project can be divided into a number of smaller projects, each were executed successfully while maintaining smooth integration at the system's level.

A number of lessons were learned in this one year productive study. The following is a summary of the conclusions and recommendations in this study. In the data grinding project, we found that the data filtering and imputation procedures developed provide us with a consistent way of dealing with the holes created due to missing and bad data. The good data that comes out of these filtering procedures acts as base data for further applications – like travel time calculation and prediction.

In the GIS integration project, it has been successfully demonstrated that integration of technologies such as Geographical Information System (GIS), Database Management System (DBMS) and Internet can provide real time traffic information to the traveler. Since Orlando is a tourist destination, the location information will facilitate visitors to retrieve relevant travel information from the website. By providing tourists and commuters with an easy way to access timely traffic and weather information, the iFlorida web site, once

expanded and implemented at full scale, will serve as a "one stop shop" for traffic information in Central Florida.

Integration of the travel time prediction model with GIS gives the users the estimated delays in their travel times up to 30 minutes in the future. This is in addition to the current "calculated" travel time information. The travel time module has the capability to perform predictions to all of the entry and exit ramps from US-192 to Lake Mary Blvd. along Interstate 4.

The snapshots from the video server give the users an opportunity to correlate the real time speed information shown on the map with the existing conditions on the ground. A video conversion cost document was prepared by the UCF subcontractor (BTS) and presented in Chapter 5 of this report. BTS concluded that a single video snapshot converter box that has a refresh rate of 50 seconds and serves out all traffic camera images will cost $5K. This is the cheapest solution and was implemented for the first year of the data warehouse and web site. It is not recommended to go with video streaming, because this will provide very limited coverage in terms of the number of cameras and number of users. Presently, the main constraint is budget. The cost of video streaming is very high. For example, three Vbrick live video converters that are converting at 28Kbps will cost $24K. This will only provide three cameras and these should obviously be selected to view the most important regions and/or interchanges. Another constraint is the bandwidth leaving UCF. Through the implementation of the CFDW this was set at 3Mbps for funding reasons. At this rate, if we are sharing the bandwidth equally between the video snapshot system and the streaming video system, then we can expect to be able to serve at the maximum around 600 users with snapshots and around 50 users with live video simultaneously. This keeps the

yearly cost at $25K for the bandwidth alone. Given that the Consortium is interested in showing hundreds of cameras on the iFlorida web site this video streaming option is infeasible. Of course it should be pointed out that both the video snapshots and the live video need to share the bandwidth with the web pages themselves. So the maximum practical rates for both of these services are lower. Also, a clear decision needs to be made by the FDOT D-5 and the Consortium members as to how many cameras will be displayed on the web site with video streaming, which in turn translates to the number of converter boxes and huge cost escalation. The cost of the bandwidth is another important consideration as well as the number of end users. In any case, video streaming cannot be implemented due to these limitations and its extremely high cost.

Future Research

Currently, construction reports and evacuation information are static modules. In the future, the decision support system capabilities of GIS should be harnessed in these modules. When the FHP (Florida Highway Patrol) CAD (Computer Aided Dispatch) web site is upgraded to include geo-referenced (latitude and longitude) traffic incidents at every crash scene they investigate, then it will be possible to transmit this information to the data warehouse so that it can be incorporated in real time with the iFlorida web site.

The related construction activities and their impact on the traffic should be included in the analysis to re-route the traveler through alternate routes. Similarly, in case of evacuation management such a decision support system will be invaluable. Weather may be a key factor in traffic prediction. This issue needs to be investigated. Integrating weather information such as visibility, rainfall, and temperature with the current UCF traffic

prediction algorithm is a challenge that is worth pursuing due to the significant benefits expected from this integration. Travel time prediction on toll roads and arterials will be different and much more difficult than prediction of travel times on I-4. As such, we leave these research issues to conduct in the future iFlorida CFDW expansion project.

UCF has gained significant experience in collecting, filtering, mining, and warehousing more than ten years of the I-4 data. Most importantly, UCF has designed, developed, and implemented online the CFDW and iFlorida web site in a timely fashion. Also, UCF was able to maintain the operation of the CFDW for several months after it was officially launched in late October 2003.

FDOT D5 requested to add the following statement to this report: "The expansion of the Data Warehouse in years two and three to cover toll roads and other facilities will be determined as part of Phase 1 of the iFlorida Model Deployment Program." Previously, and as stated in the iFlorida Final Work Plan, UCF was listed as the lead agency on the expansion of the data warehouse project in years two and three to cover toll roads and other facilities. The iFlorida Final Work Plan was submitted by the Florida Department of Transportation, District-5 to the Federal Highway Administration and approved by FHWA on or around June 13, 2003, see page 54 of the iFlorida Final Work Plan, section "Central Florida Data Warehouse." The iFlorida Final Work Plan is a public document, which was posted on the iFlorida project web site (http://www.iflorida.net/documents.htm) on or about June 9, 2003. This document continued to show on this public web site for several months thereafter and was removed in January 2004. It was replaced by the iFlorida Final Deployment Plan document, which was posted on the above web site and dated January 29, 2004.

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APPENDIX A

APPROVED WEB SITE REQUIREMENTS DOCUMENT REVISION#6

Approved Revision 6.0

DESIGN AND IMPLEMENTATION OF THE CENTRAL FLORIDA DATA WAREHOUSE (CFDW)

YEAR1: THE TCSP FUNDING

Central Florida Regional Transportation Operations Consortium's Web Site Requirements Document

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INTRODUCTION

The Central Florida Data Warehouse project will be invaluable for disseminating real time traveler information in the I-4 corridor. This data will be available through the result of dedicated efforts by FDOT and other entities to develop a framework for ITS deployment in the Central Florida region. These entities include government agencies throughout the area that have a commitment to work together to achieve a common goal. The agencies have formed the Central Florida Regional Traffic Operations Consortium (CFRTOC).

Developing a regional traffic information Web site that serves the public is one of the major objectives of the regional agencies current effort. This document describes the requirements of this Web site emphasizing high-level functional requirements and their associated technical or non-functional requirements.

GOAL

The main goal is to design and implement a regional traveler information website that provides Central Florida travelers with real time traffic information. The traffic information that will be available will include speed maps, dynamic message sign information, current and forecasted point-to-point travel times, incident locations, work zones and construction information, hurricane evacuation map, and video snapshots.

The first step is to utilize existing data provided by FDOT on I-4. The second step would be to bring on-line additional data from FDOT D-5, Florida's Turnpike Enterprise, OOCEA, and other regional partner's arterial network as it becomes available.

DELIVERABLES:

Published Web site: A functionally tested and approved Web site will be the first and major deliverable.

Functional description

The design of the Web site will be going through an eight step incremental process. The major steps are outlined in the BTS subcontract and include Site Map Design, Wire Frames, Consortium Trip, Prototype in HTML, Visual Design, Production HTML, Trip to UCF, and Wrap-up. During this process, the CFRTOC and more specifically Team 1, will have the opportunity to provide feedback at the major milestones.

Because the Visual Design of the Web site occurs later in the process, it is impossible to show how they User Interface will be laid out.

The Web site will include an interface for the following:

- Interactive speed maps
- Point to point travel times (current and predictive) for instrumented roadways
- Dynamic message sign data
- Incident locations
- Work zone and construction information
- Camera still images
- Hurricane evacuation map

Source code

Hardcopies and softcopies of the developed Web site code will be provided. This includes HTML and developed script code.

OVERVIEW:

At the time of the launch of the Web site, the only data that will be available will be that from FDOT including I-4 speed, incidents and DMS data. The Traffic Map will break the speeds into three categories: free-flow condition (speeds in excess of 45 mph) will be shown as green, slow-down condition (speeds in the range of 30 to 45 mph) will be shown as yellow and heavy congestion (speeds less than 30 mph) will be shown as red. Black will represent no data available at time of query.

Work zone and construction information will be provided by FDOT and other local agencies.

LIST OF FUNCTIONAL REQUIREMENTS:

High Level Functional Requirements

1. Traffic Map will show near real time data with the loop detector links color-coded based on averaged speed values. The averaged speed is the average of all loop detectors at a particular station in a single direction over a five minute interval.
2. Traffic Map will show icons for traffic cameras, if camera images are implemented in the initial release.
3. Traffic Map will show icons for DMS locations on I-4.
4. Hovering the mouse over a segment for approximately three seconds will cause a tool-tip window to appear displaying the station number, speed value for the current interval and time stamp.

5. To display current DMS (Dynamic Message Sign) info, a user will need to click on an overview tab on top of the Conditions page which will display a separate page with DMS and Incident info.
6. The Traffic Map will have pan and zoom capabilities. Under a certain range of zoom, side streets will be visible with their names visible. Specific levels of zoom will be need to be defined and agreed upon.
7. Overview (key) map will be used to select area of interest. Predefined views will be outlined within the overview map. This overview map will provide quick navigation to predefined areas.
8. Origin to destination travel time will be provided for I-4.
9. Origin and destination can be selected via ramp names listed in drop-down boxes.
10. Origin and destination can be selected using the mouse to click ramp locations on the Traffic Map. Once selected, the name of the ramp/exit will be displayed within the corresponding drop-down boxes visible on screen.
11. Because the functionalities functionality of current and predicted travel times are so similar, both will be made available on the same page.
12. When available, information on Florida Highway Patrol (FHP) incidents will be provided. The source of this information will be the FHP Web site which updates their data every six minutes. The information will be filtered to display only incidents within the area of interest. How this information is displayed will be addressed during the development of the UI.

13. Incident information provided by FDOT and other agencies will be listed in tabular format on the web site when it is launched. Incident information will be presented on the regional web site as received from the agencies. Future consideration will be given to placing them on the map as interactive icons.
14. The Traffic Map will have a default refresh rate of five minutes.
15. The iFlorida logo will be present on every page on the web site.
16. Work zone and construction information is dependent on the level of cooperation received by other local agencies. Initially, only hyperlinks to agency web sites will be provided so the public can get this construction information. The recommended solution (which may occur in later stages and after the web site is launched) is for agencies to formulate their construction information as one of the standard Institute of Transportation Engineers message sets (which uses elements from the Traffic Management Data Dictionary (TMDD), another ITE standard) and to then encode it as XML. This file should be periodically updated by the entity and placed underneath a web server that they control. This will allow for the simple retrieval of the information by UCF via HTTP and automatic parsing of the information for display on the Web site. Should a certain agency not be able to provide data using this method, then a link will be provided to that agency's Web site if available."
17. Snap shots that are taken from the FDOT video streams will be made available on the Web site. These camera images will be selected by clicking on an icon on a map. This map will show speed data but the functionality will be limited to camera image

information. The live camera feed will be accompanied by two images that depict the directions available for that camera.

18. An Adobe Acrobat file displaying evacuation routes will be available for download and printing. A GIS layer will be available to display on the interactive map as well.
19. The maps will contain a layer that provides county lines. This layer will be colored gray (249, 242, 242 or #F9F2F2). The background color of the map will have a default color of blue (153, 255, 255 or #99FFFF), which in effect will give color to the Atlantic Ocean.
20. Site navigation will be assisted by a quick navigation bar on the bottom and top of each page. This navigation utility is for quick access to non-traffic related information such as FAQ, Help, Links and Contact information.

Low Level Functional Requirements

1. The Web site will be developed to be best viewed on a PC using Internet Explorer (IE) version 5.5+ and Netscape version 6.2+ at screen resolution of 800x600.
2. The target download time for most of the Web site content for a user with a 56k dial-up modem should take 30 – 40 seconds. The primary content will be the navigation and GUI components. The secondary content will be the traffic map. During the loading of the map data, the user will be presented with a dynamic banner showing that more content is downloading.
3. Accessibility requirements as dictated by Section 508 of the Rehabilitation Act will be followed through the use of Style Sheets and appropriate HTML coding.

USE CASES:

Use Case 1 – Browse Traffic Map

Title	Browse Traffic Map
User(s)	a. User who wants a quick overview of current traffic conditions on I-4
Description	A user who just wants to see the Traffic Map of the region and the corresponding speeds on the links. The links are color-coded to represent current speed values.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality. c. The user is presented with a map that has the I-4 road segments corresponding to the loop detector stations color-coded according to the current speed values.
Additional Actions	a. To magnify the current view, the user clicks on the Zoom selection tool to get the desired level of magnification. b. The map refreshes showing the area of interest magnified.
Exceptions	a. Should the map server be unavailable, the map area will indicate the service is unavailable and request that the user check again later. b. If the database is not available to provide speed values for I-4, the map area will indicate the service is unavailable and request that the user check again later c. In the instance that a single station or several stations are not available, this will be displayed on the map, and in the legend, as black.

Use Case 2 – Estimate Current or Predictive Travel Times Using Clickable Map

Title	Estimate current or predictive travel times using clickable map.
User(s)	User who wants to see travel time from on-ramp to off-ramp based on current traffic conditions.
Description	The user wants to get point-to-point travel time using the interactive map. This result is based on the most recently updated speed data in the database. The user also gets his input information such as the date, time, selected entry ramp and selected exit ramp names.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality. c. The user selects an on-ramp from the map (the associated drop-down menu is update to reflect the user's choice). d. The user selects an off-ramp from the map (the associated drop-down menu is update to reflect the user's choice). e. The user selects the predicted horizon (current, 10, 20 and 30 minutes). The default will be current travel time. f. The user clicks to 'Calculate Travel Time'. g. The calculated travel time along with estimated delay is presented to the user.
Additional Actions	The user may choose a forecasted travel time by modifying the 'Time Window'.

Use Case 3 – Estimate Current Travel Time Using Drop-Down Boxes

Title	Estimate current travel time using drop-down menus
User(s)	User who wants to see travel time from on-ramp to off-ramp based on current traffic conditions.
Description	The site provides point-to-point travel times using drop-down boxes for selecting entry ramps and exit ramps. This result is based on the most recently updated speed data in the database. The user also gets his input information such as the date, time, selected entry ramp and selected exit ramp names.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality. c. The user selects an on-ramp from the drop-down menu. d. The user selects an off-ramp from the drop-down menu. e. The user selects the predicted horizon (current, 10, 15, 20, 25 and 30 minutes). The default will be current travel time. f. The user clicks to 'Calculate Travel Time'. g. The calculated travel time along with estimated delay is presented to the user.
Additional Actions	The user may choose a forecasted travel time by modifying the 'Time Window'.

Use Case 4 – View Dynamic Message Sign Data

Title	View Dynamic Message Sign Data
User(s)	Casual user who is not familiar with the details of the site.
Description	A user just wants to see the messages displayed in the I-4 DMS on his route.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality. c. The current date, time and DMS status (active or non-active) are displayed to the user. If the DMS is active the current DMS message will also be displayed.

Use Case 5 – View Incident Data

Title	View Incident Data.
User(s)	User who wants to see if an incident is the cause of current congestion.
Description	One of the data sources from FDOT will include incidents that are detected by the MIST system. Another source of incident data will be the Florida Highway Patrol Web site. With the FDOT data, we will be able to show locations on the Traffic Map based on nearest loop station. The FDOT Web site currently uses descriptions of locations that are too variable to accurately define on the map.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality c. User can find incident information either as icons on the map or listed as text on a separate page. d. The user is able to read the location of the incident.

Use Case 6 – View Video Snapshots

Title	View Video Snapshots.
User(s)	User who wants to view camera images of traffic.
Description	FDOT will provide a video stream of the cameras along Interstate 4. These streams will be used to provide snapshots of traffic.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality c. User can click on an icon on the map that represents a specific camera. The corresponding image along with two images representing possible angles is displayed.

Use Case 7 – Work Zone and Construction Information

Title	Work Zone and Construction Information
User(s)	User who wants to determine where there are lane closures or work zones.
Description	FDOT and the other Consortium agencies will provide detailed work zone and lane closure information following the TMDD.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality c. User can read from a list the reported lane closures.

Use Case 8 – Hurricane Evacuation Map

Title	Hurricane Evacuation Map
User(s)	User who wants to view a map of hurricane evacuation routes.
Description	FDOT provided a map in Adobe Acrobat format.
Actions	a. The user browses to the home page. b. The user selects the link on the home page that point to this functionality c. User downloads or views in the browser the hurricane evacuation map.

TECHNOLOGIES:

Serving Maps:

Maps will be generated using the Arc Internet Map Server (ArcIMS) commercial software package. ArcIMS is one of the Environmental Systems Research Institute Inc. (ESRI) products that is capable of serving maps and providing navigation capabilities in addition to different GIS functionalities over the Internet. The method followed in developing the CFRTOC regional Web site will make use of the basic functionalities provided by the ArcIMS HTML viewer. More functionality will be developed and integrated to facilitate the requirements of the Web site.

Generally, when a user submits a request through the Web site, it is first handled by the Web server, passed through a servlet engine connector, and then forwarded to the ArcIMS Application Server. The Application Server, in turn, dispatches the request to ArcIMS Spatial Server for processing. The communication between components in this tier is handled through ArcXML, which is an implementation of XML used with ArcIMS. The ArcIMS HTML viewer uses a minimum of two Web frames to serve the map image.

Spatial Database

Spatial data will be integrated with non-spatial traffic data such as detectors speed, volume, and occupancy using the Arc Spatial Database Engine (SDE). SDE is a tool that allows to store and manage spatial data in many commercial DBMS such as Oracle, SQL server, DB2, …etc. It provides the gateway between the GIS and the DBMS to share and manage spatial data as tables. Spatial data stored in Oracle database and managed by ESRI

SDE can be integrated with non-spatial data. This data can be served as images directly to the Internet through ArcIMS.

Scripting Languages:

Java script will be used as the client side scripting language. Java scripts are used to provide most of the basic functionalities in the ArcIMS HTML viewer. It will also be used to provide some of the proposed Dynamic HTML (DHTML) features for the Web site user interface such as pull-down or sliding menus. Active Server Pages (ASP) will be used as the server side scripting language. All the features of the current I-4 Web site are provided via ASP programming. The objective here is to reuse as much as possible of this code in the CFRTOC Web site.

DHTML may be used in addition to client side programming to provide dynamic menus capabilities. DHTML is also used by ArcIMS to provide and assist some of the GIS and navigation features.

Supported Browsers:

Although ArcIMS supports both Netscape 4.0+ and IE 4.0+, it is proposed that the developed Web site supports only Netscape 6.2+ and IE 5.5+ due to some DHTML compliance issues related to the Document Object Model (DOM) standards released by the World Wide Web Consortium (W3C). Users of these browser versions constitute about 90% of the total web surfers.

MANAGEMENT CONSTRAINTS:

The official Web site due date is October 30th, 2003. Earlier versions of the Web site will be released for review and testing. The following items need further investigation:

1. Web site loading speed on 56k modems (not tested yet). Different optimization steps may be needed to speed up the Web site loading time.
2. User interface design for travel time computations using map-clicked origin and destination has not been decided yet. Experimenting with different designs may be needed to reach the most feasible design from both the ease of use and the development sides. The selected UI design may require some changes due to technical limitations or optimization needs during the development and testing stages.
3. FHP incidents are not geo-coded. The Web site may only provide a list of FHP incidents on the I-4 without plotting them on the map if no accurate method for geo-coding the incidents is developed in time to deliver this CFRTOC Web site.

DATA SOURCE CONSTRAINTS

At the present time there are three data sources available from FDOT D-5 for use on the Web site. These data sources reside as files on two servers located at the RTMC. Applications have been developed by the UCF research team to read the available information and insert it into the database. The contents of the files are described below to detail exactly what data is available.

1. Loop detector data provided by FDOT D-5 is written to a text file line by line. Each line is representative of a loop-pair and contains the following information:
    a. Time stamp at the server at the time that the data is written to the file
    b. Station number

c. Lane
d. Direction
e. Speed (mph)
f. Volume (vph)
g. Occupancy (%)
h. Pair or single loop detector
i. Flag for bad speed data
j. Flag for bad volume/occupancy data

2. Incident data provided by FDOT D-5 is written to an HTML file at regular intervals. It has been witnessed that there are two different versions of this file, one with basic information and a second with more extended information.

   k. The 'basic' file contains the following information

      i. The time at which the file was written
      ii. Incident ID
      iii. State - three different states witnessed are 'Active', 'Confirmed' and 'Terminated'.
      iv. Associated Link – location. For stations 2 -72 the Associated Link is listed by station number. Newly instrumented lanes are listed by descriptive text.

   l. The 'extended' file contains the same information as the basic file with the following additions:

      i. Start time – Date and time
      ii. Estimated duration – in minutes
      iii. Type
      iv. Last Modified
      v. Modified by
      vi. Control Station

There seems to be no pattern to when each of the files are present so the application that collects this data has been written so as to be able to identify which type of file is present and be able to accept input from either source.

3. The DMS data provided by FDOT D-5 is written to an HTML file at regular intervals and contains the following information

    m. ID
    n. VMS Name – provides location information
    o. Comm Mode
    p. Time Commanded – date and time
    q. Cmd Mode
    r. Display Mode – will act as our flag for information to present to the user. The mode 'Sequence' ties to Current Message with useful traffic condition information such warning of congestion ahead and approximate delay
    s. Current Message.