FINAL REPORT

to

THE FLORIDA DEPARTMENT OF TRANSPORTATION

STATISTICS OFFICE

on Project

"FDOT Central Data Warehouse Enhancements, Part 2"

FDOT Contract BDK77-TWO934-11 (UF Project 00092671)

January 2012

University of Florida

Transportation Research Center

Department of Civil and Coastal Engineering

Disclaimer

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FDOT Central Data Warehouse Enhancements, Part 2		5. Report Date January 2012 6. Performing Organization Code UF-TRC
7. Author(s) Scott S. Washburn and Vipul Modi		8. Performing Organization Report No. TRC-FDOT-92671-2012
9. Performing Organization Name and Address Transportation Research Center University of Florida 512 Weil Hall / P.O. Box 116580 Gainesville, FL 32611-6580		10. Work Unit No. (TRAIS) 11. Contract or Grant No. FDOT Contract BDK77-934-11
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee St. MS 30 Tallahassee, Florida 32399 (850) 414 – 4615		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Statewide Transportation Engineering Warehouse Archived Regional Data (STEWARD) database was developed to organize the raw traffic data collected by the traffic management centers (TMC's) in the metropolitan areas of Florida with the help of the SunGuide system. The database processes the raw data and converts it into useful reports for various users of the system. While the software and hardware aspects of the STEWARD system, data availability, and increased system's performance were achieved in a previous enhancement project, other recurring issues pertained to the STEWARD system were addressed in this project. With the increase in the number of users of the STEWARD system, other FDOT districts' data were added to the STEWARD system, and the changes in the facility information from the FDOT districts were updated in a timely manner. The usability features of the interactive maps and STEWARD website were improved. The scripts associated with the STEWARD website were reviewed, and all the possible bottlenecks were removed. With these improvements, significant improvements in the STEWARD system were achieved.

17. Key Words	18. Distribution Statement
STEWARD, Traffic database, Central Data Warehouse	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA, 22161

19 Security Classif. (of this report)	20.Security Classif. (of this page)	21.No. of Pages	22 Price
Unclassified	Unclassified	21	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgments

The authors would like to express their sincere appreciation to Mr. Richard Reel of the Florida Department of Transportation (Central Office) for the support and guidance he provided on this project.

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1 Introduction

1.1 Background

The traffic management centers (TMCs) in the metropolitan areas of Florida utilize SunGuide system, a combination of both software and hardware developed for the Florida Department of Transportation (FDOT) for their daily operations. The SunGuide system creates a daily text file containing the basic data produced by each of its sensors at a specific time interval. In one of the FDOT-sponsored projects(BD545-37, "Development of a Central Data Warehouse for Statewide ITS and Transportation Data Phase II: Proof of Concept"), the Statewide Transportation Engineering Warehouse for Archived Regional Data (STEWARD) was developed, which processes the raw data obtained from the TMC's, organizes the processed data in an Oracle database system, creates a number of useful traffic information and traffic data diagnostic (based on traffic flow principles) reports, and provides web interface for data users to access and retrieve the traffic data and reports.

While the hardware and software implementation of STEWARD was generally sufficient for a prototype application, it became clear that the prototype configuration imposed too many limitations on the system for it to be completely useful in a production mode. Some of the issues included: the storage capacity of the system reaching its limit due to the increasing amount of data being supplied by the FDOT TMC's; the data processing and uploading of the data to the STEWARD database taking a very long time, requiring the web-server to be taken off-line for unacceptable lengths of time; and a considerable lag between the current date and the date of the most recently available data on the STEWARD system.

Thus, the FDOT funded the "FDOT Central Data Warehouse Enhancements" project (BDK-75-934-05) to make software enhancements to the system to improve STEWARD's performance and usefulness, among other tasks. At the same time, the University of Florida's Center for Multimodal Solutions for Congestion Mitigation (CMS) upgraded all of the hardware for STEWARD, which resulted in the realization of significant performance gains for the system. The following section provides an overview of the STEWARD enhancements made in the last enhancements project.

1.2 STEWARD Enhancements

As part of FDOT project BDK-75-934-05 and the CMS-funded hardware improvements, the software and hardware aspects of STEWARD were enhanced in order to improve the system availability, data availability, and the system performance. The FTP (File Transfer Protocol) server of the STEWARD system was upgraded to a faster computer and additional storage capacity (4TB) was included. This storage capacity is in the form of internal SATA drives,

replacing what was a daisy-chain of several USB-interfaced external hard drives, resulting in significant performance gains. A professional-grade server computer was also bought to replace the desktop-based computer that hosted the database and web-interface. The database server of the STEWARD system was upgraded with Windows Server 2008 (previously Windows Server 2003) as the operating system and Microsoft Internet Information Services as the web server.
A utility application was developed that reads the daily incoming data feeds from the FTP server, then processes the raw data using the ETL (Extraction, Transfer and Loading) utility, and uploads the data directly to the database server. The application is run on the FTP server during the day time after all the raw data is received and the data is uploaded during the late-night hours. The creation of this automatic utility application allowed the system to take better advantage of the improved hardware performance, as well as make the entire process of getting processed data onto the server and available to the user much more efficient. The end result was that the lag time for the data availability from TMC's to the users was reduced to two days. To further enhance the system performance, the customized reports are also now updated automatically.

While this enhancements project was a good start to making the STEWARD system more useful in a production mode, there are still several improvements that can be made to the system. Furthermore, there is the ongoing need for system maintenance. The following section describes the objectives and tasks of this follow-on project (BDK77-TWO934-11) that provided additional improvements and continued maintenance.

1.3 Further Development of STEWARD System

With the implementation of the automatic utility application on the STEWARD system, STEWARD has reached a self-sustainable stage and is up-to-date with every district's detector network (except the Turnpike district). However, the system is not yet self-expandable and there could be other issues and concerns that may arise while operating and maintaining the system in the long-term. These issues, briefly, are:

- It is anticipated that STEWARD user activity levels will increase as more data become available and awareness of STEWARD increases as it transitions from the research and development phase to the operational phase. With the increase in the number of users of the STEWARD system, other FDOT districts' data should be included in the future since it is not self-expandable. And as the districts currently included in the system continue to update their facility information and expand their network on a regular basis, it is necessary that these changes are incorporated accordingly in a timely manner.

- The STEWARD system receives approximately 1 GB of data every day. As the TMC's continue to expand their network detector coverage, the amount of data that must be transferred to STEWARD and then processed and loaded into the database will continue to increase. It is necessary that this operation is regularly monitored with proper maintenance of the hardware and timely review of the database and web-scripts.

- As STEWARD gains increased user activity, there will be increased demand for additional pre-configured reports to be provided on the STEWARD website. It is also necessary that other updates, such as data availability and tools/resources availability should be provided in a more user-friendly manner.

1.4 Research Approach

The objective of this project was to enhance the current STEWARD system configurations and to improve the system performance. The tasks that were undertaken to accomplish this objective are described briefly as follows:

- Adding data from new facilities from Districts 1, 3, 4 and Turnpike
- Adding arterial data to the STEWARD database
- Improve the interactive maps on STEWARD
- Calibrate detectors by comparing counts from ITS detectors with permanent station counts
- Critical review of STEWARD webpages
- Monitor the progress of the system in a timely manner

1.5 Organization of Report

Chapter 1 provides an overview of the last enhancements to the STEWARD system, the emerging issues in the STEWARD system and the research approach from the STEWARD operators. Chapter 2 provides a detailed description of the various activities that were undertaken during this project. Chapter 3 provides a summary of the activities performed, and the potential activities to be undertaken in future.

2 ACTIVITIES PERFORMED

This chapter describes the activities that were performed during this project. The objective of this project is to expand the number of data sources available on STEWARD, implement improved usability features, and continue the maintenance activities as needed.

2.1 Adding additional districts

The current STEWARD system included the ITS (Intelligent Transportation System) detectors from five districts across Florida covering the regional areas of Jacksonville (District 2), Ft. Lauderdale (District 4), Orlando (District 5), Miami (District 6) and Tampa (District 7). With the increasing ITS detector network across other regional areas and districts within Florida, it was proposed that new districts would be added to STEWARD. The new districts that were proposed to be added to the STEWARD database included detectors from regional areas of Ft. Myers/Naples (District 1), Pensacola (District 3), the counties covering Palm Beach, Martin, St. Lucie and Indian River (referred thereafter as 'new territories') from District 4 and Florida Turnpike (if available).

In the current system settings, the TMCs at each respective district transfer the archived raw data files daily to the FTP (File Transfer Protocol) server at the University of Florida. To receive the raw data from new districts, the research team contacted the respective TMCs to obtain the necessary facility information, such as detectors' geographical location, lane-mapping configurations, description, mileposts, freeway segment speed limits, etc., for the detectors installed on the roadways within the area limits of the respective TMCs. After exchanging the files, the research team obtained the necessary information for the detectors in Districts 1, 3, and 4. The facility files pertaining to these districts were then prepared by the research team in a format compatible with the STEWARD system. During the preparation of these files, several edits and modifications were made to the detector details. These edits, upon approval from the respective TMCs, were included to the facility files and were added to the STEWARD database system. The details on the preparation of the facility files, and the steps undertaken to add them to the database are provided in the resource section of the STEWARD website. With the help of these facility files, the detectors from the districts 1, 3, and 4 were added to the STEWARD database system.

While the addition of detectors from Districts 1 and 3 turned out to be a standard procedure, additional efforts were required to include the new detectors from District 4. It came to the attention of the research team that the raw data for the new territories were archived separately and were not included in the existing archived data for District 4. Moreover, the SunGuide system settings restricted the transfer of the data from new territories to the existing District 4 settings, and as a result, the data were sent to a different location at the FTP server. It meant that the inclusion of the data from new territories would require new district numerology within the current STEWARD database architecture. This situation was obviously not desirable, as it would have created complexity in the database, and would have confused the users.

To avoid this complexity, the research team decided to merge the raw data files from both the existing District 4 network and the new territories of District 4, and to create a single raw data file from District 4 before the ETL (Extraction Transformation Loading) process. Therefore, a separate utility, 'MergeUtility.exe' was written in the C# programming language that merges the two raw data files. This utility selects the raw data files from their respective locations on the FTP server, and adds the data from one raw data file into the other raw data file on a row by row basis. This led to the creation of an entirely new raw data file that contained the information from all the counties in District 4. The new raw data file is then used in the ETL process. The facility files from both the existing District 4 and new territories were also merged with each other. The new facility file and their respective new raw data file were then integrated with the automated utility. As a result, the data from the new territories were added to the STEWARD database. It should be noted that the 'MergeUtility.exe' utility is also scheduled to run every day via the FTP server system settings, once the raw data files from both the old territory and new territories from District 4 are received.

The new facility files from Districts 1, 3, and 4 are currently integrated with the automated utility of the STEWARD system for daily data transformation, and uploading. For Florida Turnpike, the research team contacted the respective TMC, but due to the Turnpike District not having time to set up the file transfer process, this task was not completed within the current project timeline. It is expected that if the Turnpike District is able to set up the file transfer process in the future, the detectors from the Turnpike will be added to the STEWARD database.

2.2 Inclusion of arterial data

In the same manner that freeway data are included in the STEWARD system, it was proposed that the arterial data from District 5 would also be included in the STEWARD system. As the raw data for the arterials were already included in the existing District 5 archived data, there were no additions/changes made to the FTP server system settings. While the arterial raw data were reviewed, it was realized that the format in which the arterial data are archived is different from the format in which the freeway data were archived. To understand the nature of this format, the research team contacted the District 5 personnel, and were informed that the arterial data are collected for vehicles with SunPass tags only. This meant that the data would not include the traffic information for all vehicle types that pass through the detector location. This also meant that only little information can be collected from these detectors, and it may not be of great value to FDOT. Therefore, after further discussions with the project manager, it was decided that the arterial data would not be included in the STEWARD database at this time. The possibility of including traffic data for vehicles with only SunPass tags may be undertaken in a future project provided the information is useful to FDOT.

2.3 Customized Interactive Maps for each district

To improve the usability features of the interactive maps, the research team modified and edited the scripts for all district maps. The previous interactive maps allowed the users to view the detector details via a scroll-mouse-over feature. Through this feature, the users were able to view the detector details like geographic location, description, etc., when the systems' cursor was rolled over the detectors' place mark on the map. Although useful, this feature only allowed the users to view this information for a limited period of time, which was not enough to gather all necessary information in a single attempt. This motivated the research team to improve this usability feature, and other features as well in this project.

After investigating, and testing several other features, the research team decided to implement the 'balloon blip' feature on the interactive maps. This feature, provided by Google Maps, allows the users to view the detector details in a separate window, and view the detector details for an indefinite time until the user chooses to close the window. The motivation was to ensure that the detector details are available on screen for a longer time, which otherwise was available for only a limited time in the previous interactive maps. This feature also gave an opportunity to the research team in providing the detector details in a more user-friendly format. Apart from the detector-id, description, and geographic location of each respective detector, the lane-type details were also provided in this balloon blip feature.

To include the lane-type details, i.e., whether a lane is a general purpose lane or an auxiliary lane or managed lanes, the lane-by-lane information at each detector location was added to all district maps. The research team prepared the lane type details for each detector in a district with the help of Google Earth. To ensure accuracy, a detailed review/investigation at all detector locations was performed manually. The possibility of automating this process was ruled out as these details were not provided by the respective TMCs. As a result, the research team reviewed all the detector locations across Florida visually through Google Earth, and prepared the respective files. To implement this feature, the scripts associated with the interactive maps were modified by updating the API (Application Programming Interface) key used in the Google maps, and subsequently, the lane-type details were also added to the respective interactive maps. The old scripts were replaced with the modified scripts, and currently the balloon blip feature is implemented in all the interactive maps on the STEWARD website. This feature now allows the users to differentiate the lane types at each detector location, and helps the users in identifying the lane details without the need to refer to any other source. A snapshot of the balloon blip feature is provided in Figure 1.

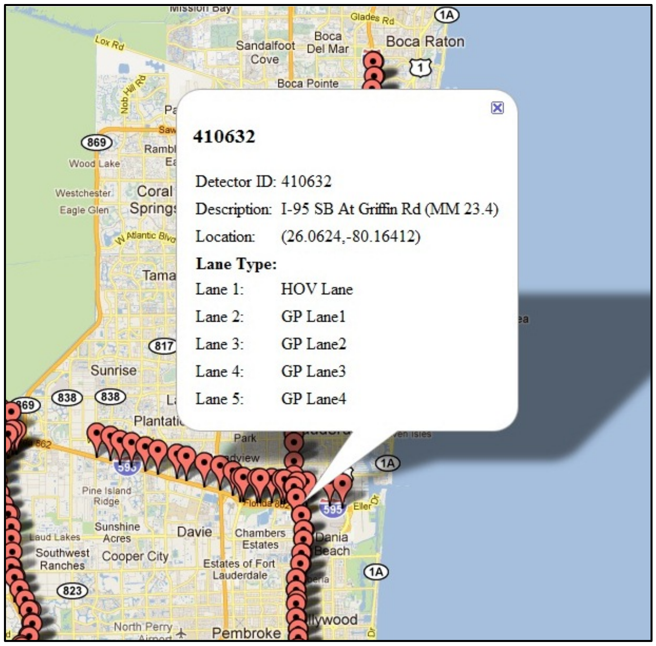

Figure 1: Snapshot of the detector location in District 4 depicting the lane-by-lane details in the interactive map

Along with the balloon blip feature, efforts were made to improve the other usability features of the interactive maps. The research team added a 'search' feature in all interactive maps that allows users to search for a particular detector within that district. With the help of this feature, the detectors can be identified via a keyword. The keywords could be anything from STEWARD's detector ID, roadway name, or the geographic location. Upon entering the keyword, the system returns a list of all possible matches, and asks the user to select the respective detector. Once the user selects the detector of interest from the list of returned matches, the user can view the detector location and the balloon blip window with the detector details. This feature has proved to decrease users' time to search/look for a particular detector location while navigating the maps. This feature has been tested for various cases, and appears to be working well. A snapshot of this feature (as designed on the interactive map webpage) is shown in Figure 2. These two features appear to have improved the usability features of the interactive maps, and it is expected that more features could be added to the interactive maps depending upon FDOTs' requirements.

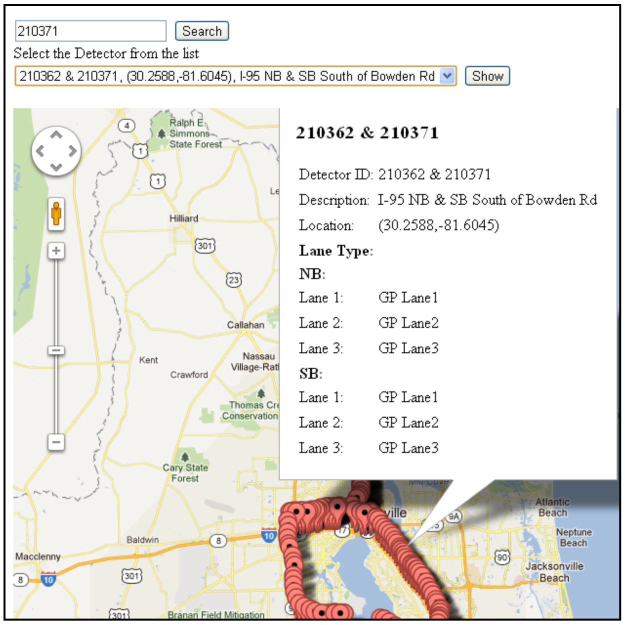

Figure 2: Snapshot of the detector location in District 2 showing the search feature in the interactive maps

2.4 Improvements to the STEWARD website

The scripts associated with the STEWARD website were critically reviewed to identify possible performance bottlenecks. While the database review was completed in the last enhancement project, several other issues associated with the web server were identified that decreased the system's performance: 1) the delay in the system's response when the homepage was accessed; 2) the delay when users tried to access the reports webpage; 3) the delay while selecting the dates in the calendar, and 4), the delay in the system's response during data retrieval. All these issues were found to be associated with the webpage scripts written in .ASP (Active Server Pages) programming environment. Therefore, in an attempt to improve the system's performance, a detailed review of these scripts was performed. After the completion of review procedures, two critical bottlenecks were identified that accounted for significant delays in the website's response time. It appeared that these two bottlenecks caused a significant amount of delay during the loading and navigation of the website. The nature of these bottlenecks and the solutions to remove them are briefly described next in the report.

STEWARD Homepage bottleneck

The first bottleneck that appeared to have significantly affected the system's performance was when the system's homepage was accessed, or whenever the homepage of the STEWARD website was loaded. More specifically, the left column of the homepage that enables the user to select districts and the reports page, took a significant amount of time to load up. As a result, the overall performance of the system was decreased. To remove this bottleneck, the research team reviewed the scripts associated with the homepage. During the review process, it was observed that a query involving the two largest database tables of the STEWARD system was executed, which requires full scanning of these tables. To improve this bottleneck, the research team decided to modify and edit the scripts in such a manner that it avoids the full scanning of the database tables.

To avoid the full scanning of the database tables, the research team created a new temporary table that contained all the necessary information used repeatedly during the webpage loading. This new table, 'TSS_1HR_STATION', keeps all the necessary information from the largest database tables that are used during the full scanning. As a result, whenever the left column of the homepage is accessed, the data from this temporary table are fetched and the full scanning of the largest database tables is avoided. However, it also becomes necessary to update the information in the temporary table. To update this, a PL/SQL (Procedural Language/Structured Query Language) script is scheduled to run on the first day of every month. With this query, the temporary table is loaded with new information, and gets updated automatically. The creation of the new temporary table is found to have significantly improved the website's performance, and the homepage gets loaded without the need of full scanning of the database tables. The details of the modified scripts, and the components added to the scripts are beyond the scope of this report.

Calendar Dates Selection bottleneck

The second bottleneck that appeared to have significantly affected the website's performance was when the dates were selected from the to-and-from calendars displayed on the reports homepage. The selection of dates from these calendars is one of the most important things during the data retrieval process, and hence it is necessary to improve this selection process. These calendars are displayed such that it indicates the dates with available data to the users. The dates with available data generally appeared in 'bold style', and the dates with no data were generally grayed out. To differentiate the availability of data within the dates, a data validation query was written in the scripts associated with the reports homepage. The scripts were written in such a manner that they accessed the system's database tables, and indicated the presence of data for that date by the color scheming. These scripts, written in .ASP programming language, appeared to execute every time the reports homepage was accessed. Although useful, as this step informs the user on data availability, this step was found to delay the system's response time, and resulted in significant delays during the data retrieval process.

The research team reviewed the scripts in an attempt to avoid or skip the validation step during the data retrieval process. After further investigation, it appeared that this validation step could be avoided. However, removing this validation step meant that the information on available data dates will no longer be present in the calendar section of the reports homepage. This also means that all the dates in the calendar will be displayed in 'bold font' even if data were not available for those dates. This approach removed a useful feature of the data availability on the reports homepage, but the performance of the system's response to any user query was found to be significantly better. Therefore, it was decided to remove the validation step from the calendar scripts. During the data retrieval process, if the user selects dates with no data, a message appears at the end of the process about the non-availability of data. Also, to maintain the information on the data availability, a separate section is created in the STEWARD website that indicates the dates with no data.

All other queries of the STEWARD website were analyzed for possible bottlenecks or optimizations. The execution plan of several queries was verified in order to avoid any unnecessary full-table scans. At the end of this project, no further scope of enhancing the website was identified. However, once the system expands, and the scope of including other reports is possible, further reviewing of the scripts may be performed.

2.5 Maintenance of the current STEWARD system

As the activities related to the STEWARD system increases, it becomes necessary to closely monitor the progress of the system from the hardware and software point of view. For a proper functioning of the system, the research team made continuous efforts to maintain and update the system on a regular basis. The maintenance activities that were covered during this project are described briefly as follows:

Regular system maintenance

The computers that host the FTP server, database server, and web server were maintained and monitored on a daily basis. The monitoring becomes necessary to avoid any kind of unnecessary system breakdowns, for maintaining the security features of the system, and to ensure that all the components/utilities of the STEWARD system are running fine. The task, but not limited to, that was performed most frequently was to restart the servers during an event of power loss, mandatory shut down of servers during automatic updates and any other unavoidable events. While some of the utilities associated directly with the operating system are restarted automatically, there are other features within the Oracle environment that need to be started manually. This includes starting the data uploading processes in the Control Center of the Oracle database design center. During any other event, all necessary steps were taken to ensure the smooth functioning of the system.

Daily transmission of data

The raw data transmissions from the TMC's onto the FTP server were monitored on a daily basis. This includes monitoring the incoming data to their respective location on the FTP server.

In an event of any missing data, the research team contacted the respective TMC to obtain the missing data files, and upload the missing data onto the STEWARD database at a later time. Since the SunGuide system is also updated on a regular basis, it is necessary to monitor the daily transmission of the raw data files to the FTP server.

Updating facility information

The facility information that includes the details of the detectors, and their respective lane-mappings, were regularly reviewed and updated during this project. As more roadways and detectors are added to each district, it is necessary to monitor the addition of these new detectors and update the facility files accordingly. The research team made efforts to update all the facility files with new detectors in the SunGuide system, including any changes in the lane-mapping, during this project. The raw data were reviewed every fortnight evening for any information on additional detectors/lanes data. The modified facility information was sent to the respective TMC for approval, and only then, the new facility files replaced the previous files in the STEWARD system.

Enterprise Manager

As briefly mentioned in the last enhancement project, the STEWARD system is not yet self-sustainable because the table spaces, the virtual tables where the daily traffic data are stored, requires regular size increments. With additional districts in the STEWARD system, the amount of incoming data has increased, and therefore, it is necessary that the size of these table spaces also increases in a timely manner. Incrementing the sizes of these table spaces are performed via the Oracle Enterprise Manager (EM). The EM helps in maintaining these table spaces, the database operations, and creating backups of the existing database. The research team made efforts to automate the increment of these table space sizes, but due to unexpected system configurations, this issue is not yet resolved. However, an alternate and easier solution to this issue was found. This alternate solution increases the sizes of the table spaces by running a PL/SQL query on the command prompt of the machine that hosts the STEWARD database. The research team is still investigating the limitations of the system configurations that do not allow the size increment via the EM. It is expected that, in the future, the system configurations and the EM settings will be modified to automate the table space sizes.

2.6 Calibration of the detectors

After the new detectors from Districts 1, 3, and 4 were added to the STEWARD database, the research team decided to go ahead with this task. The motivation behind this task was to check and improve the accuracy of the volume counts measured by the TMC microwave/loop detectors by comparing the volume counts available from the FDOT installed permanent count stations.

Only the detectors in close proximity to the permanent count stations were considered for this task. The project manager narrowed the list of permanent count stations, and obtained the volumes for these locations. To extract the volumes from the TMC detectors, the 'ITSCounts.exe' utility was used. During the initial extraction process, it was realized by the project manager that the utility did not function properly. Therefore, the research team investigated the associated scripts, and realized that the scripts used for this utility were not properly written as desired. Due to time constraints and unavailable resources, the scripts were not rewritten within the project timeline, and hence, this task was not completed. It is expected that in a future enhancement project, this utility will be reviewed in detail and updated as desired for detector calibration.

3 SUMMARY AND FUTURE WORK

3.1 Summary

The various tasks that were performed during this project are summarized in this section. One; as a part of this enhancement project, the detectors from Districts 1, 3, and new detectors from District 4 were added to the STEWARD database. A new utility was created and implemented to add the new detectors from District 4. All the utilities were integrated with the automated data uploading application of the STEWARD system for daily processes. Two, the research team investigated if arterial data from District 5 could be included in the STEWARD database, and since the available information was not found to be in the necessary format and is of currently limited value, the arterial detectors were not added to the system. Three, the interactive maps on the STEWARD webpages were improved, and lane-by-lane details of all detectors were added. A search feature was also added to the interactive maps that allow users to select detectors upon entering keywords. Four, the homepage of the STEWARD website and other webpages of the website were reviewed in detail. The bottlenecks that reduced the system's performance were removed and significant improvements in the system's performance were observed. Five, several tasks were performed in order to maintain the system configurations and for smooth functioning of the STEWARD system. Last, the research team made efforts to calibrate detectors by comparing ITS detector volume counts with counts from FDOT permanent count stations. The limitations in the 'ITSCounts.exe' utility did not allow the comparisons, and as a result, this task was not completed. The following section describes some important tasks that could be undertaken in a future enhancement project.

3.2 Future Work

With the success of these enhancement projects, it is felt that there are other potential aspects of traffic data that STEWARD can successfully cover, given the high performance server machines. Furthermore, as the data are added to the STEWARD system on a regular basis, there is obviously the need for system maintenance. However, there are other areas that STEWARD can address before it is moved fully into a production mode. These areas, briefly, are:

- Inclusion of Florida Turnpike data in the STEWARD system, and other available roadways across the state.
- The quality assurance procedures (as per FDOT's guidelines) embedded in the ETL (Extraction, Transformation, Loading) utility should be reviewed thoroughly to identify any missing components from these QA procedures.
- With increasing data in the STEWARD system, it is necessary to monitor the daily operations of this system along with periodic maintenance of the hardware and timely review of the database and web-scripts.

- STEWARD at present does not contain incident data, weather data, toll-rates data, etc. The inclusion of these datasets could prove to be of great value to the transportation community.
- Since STEWARD forms a repository for huge datasets, additional outputs could be created from these datasets for users. One example is to provide users with the capacity value for a given freeway segment.
- As STEWARD gains increased user activity, there will be increased demand for additional pre-configured reports to be provided on the STEWARD website. It is also necessary that other updates, such as data availability and tools/resources availability should be provided in a more user-friendly manner.
- The calibration of detectors could be assisted by comparing the counts obtained from FDOT's permanent count stations with volume counts from TMC detectors.