REGIONAL TRANSPORTATION DATA WAREHOUSE – Phase I, II, III

TECHNICAL REPORT

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EXECUTIVE SUMMARY

The Paso Del Norte Region includes El Paso County (Texas), Dona Ana County (New Mexico), and Ciudad Juarez (Mexico) along the southwest border region between U.S. and Mexico. With a combined population of more than two million, City of El Paso and Ciudad Juarez have an intertwined transportation system with one of the nation’s busiest international borders. In response to growing transportation needs in this bi-national region, Texas Transportation Institute (TTI) established a new transportation research center in the City of El Paso. One of many research initiatives identified at early stages of the center’s inception was to develop a mobility information system for the Paso Del Norte Region.

The goals of regional mobility information system were to demonstrate significance and benefits of archiving Intelligent Transportation System (ITS) data, build a centralized repository of transportation data, provide ability to monitor regional and cross-border mobility, and provide a platform to adopt newer ITS technologies. Objectives of the regional mobility information system are to provide archived transportation data user service and advanced traveler information system in the region.
The regional mobility information system is first of its kind in the region and has been well received by stakeholder agencies. The system is designed using extremely flexible and scalable database framework and built using the concept of data warehouse and data-centric architecture. In terms of providing advanced traveler information system, the system provides access to users information related to everyday travel through a single window website.
1. **BACKGROUND**

1.1 **El Paso Region**

The Paso Del Norte Region includes El Paso County (Texas), Dona Ana County (New Mexico), and the Municipality of Ciudad Juarez (Mexico) along the western portion of the U.S.-Mexico border (as shown in Figure 1-1). Along with its sister city of Ciudad Juarez across the border in Mexico, the entire region has a combined total population of more than two million, which makes this region world’s largest bi-national metropolitan area, including the nation’s busiest international border crossings (1).

![Map of the El Paso region](http://maps.live.com)

**Figure 1-1 Map of the El Paso region.**

*Source: [http://maps.live.com](http://maps.live.com)*
The City of El Paso and the Texas Department of Transportation (TxDOT) have deployed several ITS technologies including traffic management centers, centralized traffic signal control systems, dynamic message signs, closed-circuit television cameras, vehicle detectors, electronic toll collection at international bridges, and transit vehicle tracking. The Ciudad Juarez transportation planning body, the Instituto Metropolitano de Investigacion y Planeacion (IMIP), has deployed a number of closed-circuit television cameras on the approaches to the three international bridges within its urban area. ITS deployment in this region is primarily used for day-to-day transportation operation, and archiving data generated by ITS systems has been ignored.

In response to the growing transportation needs in this bi-national region, and through a grant from the 79th Texas State Legislature, the Texas Transportation Institute (TTI) established the Center for International Intelligent Transportation Research (CIITR) in El Paso, with the mandate of performing research in the areas of transportation operations, air quality, and border crossings. One of many initiatives identified at early stages of the center’s inception was to develop a regional mobility information system (referred hereafter as Paso Del Norte Regional Mobility Information System or PDN-RMIS).

1.2 Stakeholder Needs in the Region

The stakeholders in the region include agencies that provide day-to-day transportation services and agencies that plan and develop policies to address current and future mobility needs of the region. These stakeholders will directly benefit from the archived transportation data that will be provided by the PDN-RMIS. The stakeholders also include general public, daily commuters, local media, and international border crossers that will benefit from the advanced traveler information. The stakeholders in the region comprise of local and state transportation agencies from El Paso, Ciudad Juarez, and New Mexico and are the following:

- Texas Department of Transportation;
- Sun Metro;
- El Paso Metropolitan Planning Organization;
- City of El Paso;
- County of El Paso;
- Customs and Border Protection;
- Ciudad Juarez;
- New Mexico Department of Transportation;
- Environmental Protection Agency – Region 6;
- Instituto Municipal de Investigacion y Planeacion; and
- General public, local media, daily commuters, and international border crossers.

TTI organized several meetings with the stakeholders in the region to identify their mobility information needs. The stakeholders emphasized on the following needs in terms of archived transportation data and advanced traveler information:

- Create a regional data warehouse and allow data from disparate applications and agencies to be managed;
- Archive real-time transportation data for planning, design, operation, management, and research purposes;
- Promote the use of archived transportation data;
- Maximize cost-effectiveness of data collection by reducing data acquisition costs;
- Provide advanced traveler information to motorists and commercial vehicle operators; and
- Provide a platform to research new technology for advanced traveler information gathering and dissemination.
2. GOALS AND OBJECTIVES

2.1 Goals of the Paso Del Norte Regional Mobility Information System

A comprehensive set of goals were outlined prior to conceptualization of the mobility information system in accordance with stakeholder needs. This was followed by defining a specific set of objectives that would guide development and implementation of the system.

Demonstrate Significance and Benefits of Archiving ITS Data - ITS deployment in this region is primarily used to manage transportation system and to provide advanced warning to motorists. However, the “secondary” use of archived ITS data has been ignored. The ITS infrastructure deployed by TxDOT and the City of El Paso generates large amount of data mostly as a continuous stream of data collection processes. However, neither agency has a formal business process and physical infrastructure to archive ITS data. Hence, one of the goals of PDN-RMIS was to demonstrate significance and benefits of archiving ITS data.

Provide Ability to Monitor Regional and Cross-Border Mobility - The Safe, Accountable, Flexible, and Efficient Transportation Equity Act for the 21st Century – A Legacy for Users (SAFETEA-LU) continued the emphasis on performance monitoring of transportation systems (3). As the region continue to deploy ITS to meet its growing mobility needs, the ability to quantify mobility to determine performance of transportation infrastructure will become highly desirable. Hence, PDN-RMIS will assist transportation agencies to engage in formal performance measurement and reporting processes.

Build a Centralized Repository of Transportation Data and Information - ITS data, if properly archived, is a valuable resource for planning, research, and policy development. In large urban areas, transportation systems are managed by agencies covering multiple jurisdictions and hence, sharing archived data by agencies is crucial for planning and decision making process. Hence, PDN-RMIS was designed to develop a centralized repository to archive “raw” ITS data and convert into valuable information to make sure that the system would facilitate unambiguous interchange and reuse of data and information
throughout all functional areas (4) (5). PDN-RMIS will also promote the use of archived data in the region and maximize cost-effectiveness of collecting ITS data by reducing acquisition costs (6).

*Provide a Platform to Adopt Newer ITS Technologies* - The growing mobility needs of Paso Del Norte Region have prompted agencies to deploy newer ITS technologies to operate transportation system more efficiently. While ITS technology evolves constantly, mechanisms to archive data should be able to adopt newer data collection technologies. PDN-RMIS was designed with data warehouse concept and database-centric architecture, which easily integrates future implementation of ITS data collection mechanisms and technology.

### 2.2 Objectives of the Paso Del Norte Regional Mobility Information System

The US National ITS Architecture and the El Paso Regional ITS Architecture define Archived Data User Service (ADUS) as a data warehouse distribution function, which integrates planning, safety, operations, and research communities into ITS and processes data products for these communities (4) (5). Archived data in ITS also refers to the systematic retention and re-use of transportation data generated for various purposes (7). Transportation agencies in the Paso Del Norte Region are aware of the value of archiving ITS data. However, the agencies have allocated resources mostly for the deployment of ITS field devices for day-to-day transportation operation only. Hence, the first objective of PDN-RMIS was to demonstrate significance and benefits of archiving ITS data by creating and providing the service for the region.

The El Paso District of TxDOT provides “limited” en-route driver information and incident management services on state highways. Similarly, the City of El Paso provides the only pre-trip information, which is the incident information. Commuters entering U.S. on a daily basis use wait times at the border, which are relayed by the Customs and Border Protection. Hence, to get a comprehensive view of traffic conditions, a traveler has to access multiple agency websites, which is clearly not an efficient method of obtaining the pre-trip information. Hence, the second objective of the PDN-RMIS was to provide a single-window to access travel information only inside El Paso, but also to commuters and freight operators entering U.S. from Mexico. Further sections describe in detail how the PDN-RMIS
Regional Transportation Data Warehouse

system was designed and implemented to achieve above mentioned goals and objectives. Figure 2-1 illustrates both objectives of the regional mobility information system.

Figure 2-1 Objectives of the Regional Mobility Information System.
3. **SYSTEM DESIGN AND DEVELOPMENT**

3.1 **High-Level System Requirements**

The National ITS Architecture defines Archived Data User Service (ADUS) as “Data Warehouse Distribution function, which integrates the planning, safety, operations, and research communities into ITS and processes data products for these communities” (4). ADUS promotes “the unambiguous interchange and reuse of data and information throughout all functional areas.” ADUS requires that data from ITS systems be collected and archived for historical, secondary, and non real-time uses, and that these data be made readily available to users.

Archived data in Intelligent Transportation System (ITS) applications refers to the systematic retention and re-use of transportation data generated for various purposes (7). Though the primary purpose of generating these data is for management and operation of transportation infrastructure, archived data can be a valuable resource of information for various entities and agencies with a need to plan and evaluate system performance and characteristics on a constant basis. The centralized data warehouse should not only integrate various types of transportation data, but also convert raw data to meaningful information for planners, designers and researchers. The archived traffic data is used by transportation agencies for planning, design, operation, management, and research purposes.

The National ITS Architecture also defines advanced traveler information service as a decision support system that enables traveling public to make informed decisions about their trip. Advanced traveler information service includes pre-trip information, en-route driver information, route guidance, traveler services information etc.

The most important requirements of the system was to provide a single window for information retrieval and access for both archived transportation data and advanced traveler information, as illustrated in Figure 3-1. The single window will facilitate users at levels to access the information from a single source, instead of multiple agency websites.
Regional Transportation Data Warehouse

3.2 Concept of Data Warehouse

A data warehouse is defined as a subject-oriented, integrated, nonvolatile, and time-variant collection of granular data (8). The archived data user service of PDN-RMIS was designed following a concept of data warehouse, of which one of the main features is to integrate data from multiple and disparate sources. A data warehouse is built mostly as a series of orderly and iterative processes and the concept is built upon the need to provide granular as well as single view or image of the data (9). The data stored in the warehouse is time variant, which implies that every record represents a moment in time.

Data warehouse is normally used to store large and voluminous data that is queried less frequently and should not be used to store high frequency transactional data (9). Hence, archiving voluminous ITS data fits perfectly into data warehouse model, since archived ITS has a much smaller user base that accesses the archived data less frequently than real-time transaction users.
3.3 Database-Centric Architecture

Database-centric architecture was used to design the PDN-RMIS, in which database is a core component. The characterization of an architecture as "database-centric" refers to the fact that relational database management system, as opposed to customized flat file-based data structures, were used to archive data using dynamic table-driven logic. The primary benefit of database-centric architecture is that the development of application user interface is independent of the core database, which allows seamless migration from one user interface platform to another.

3.4 Multi-Tier Architecture

Multi-Tier Architecture (commonly known as Three-Tier Architecture) is a client-server architecture in which the user interface ("PRESENTATION TIER"), functional processes ("BUSINESS LOGIC"), and data storage ("DATA STORAGE TIER") are implemented as independent modules, most often on separate platforms. The architecture is intended to allow any of the tiers to be upgraded or replaced independently when required (10). The Three-Tier architecture used in development of PDN-RMIS is illustrated in Figure 3-2. Each tier in the architecture is described briefly as following:

- The DATA STORAGE TIER consists of a series of data tables (represented by smaller cylinders in the figure below), which stores archived ITS data in a relational database model. It also consists of temporary tables to hold real-time data, which is used to display advanced traveler information.
- The BUSINESS LOGIC TIER consists of series of stored procedures and server agents, which extract data from multiple sources, parse, filter, aggregate, and estimate performance indices.
- The PRESENTATION TIER consists of mechanisms to disseminate archived ITS data and advanced traveler information to users through intranet, internet, and standalone applications.
3.5 High-Level Architecture

The high level system architecture for the regional mobility information system is based on a concept of database-centric architecture. Figure 3-3 illustrates the high-level interface diagram for transportation data exchange and relay. The physical architecture of RMIS consists of communication infrastructure between data providers and RMIS. Various communication options were explored, including mediums of information dissemination. The regional mobility information system will be connected either physically or virtually to various transportation data providers. At present, only Transvista is physically connected to the RMIS to receive real-time traffic data from vehicle sensors. As the region grows and the capability of data providers grow, the connection with RMIS may change over time.
Figure 3-3 High-level architecture of the RMIS.

The logical and physical architecture of PDN-RMIS is based on all of the previously mentioned concepts and architectures. Most importantly, the architecture is consistent with goals and objectives of the system. The logical and physical architecture is divided into three main processes – data extraction, data fusion and storage, and data dissemination.

DATA EXTRACTION PROCESS – The objective of data extraction process is to extract ITS data from multiple sources. This process includes independent or autonomous applications (executables) specifically built to extract data from a particular ITS data source. Most of these applications were built using either VB.NET or C# applications.

DATA FUSION AND STORAGE PROCESS – The objective of data fusion and storage process is to filter, aggregate, and query ITS data using pre-defined business logics. This was implemented inside Microsoft SQL Server. The process also fuses ITS data from multiple sources based on common dimensions. Vehicle detector data is stored in multiple FACT tables and are “fused” together using DIMENSION tables.

DATA DISSEMINATION PROCESS – The objective of data dissemination process is to relay archived ITS data and advanced traveler information through various display mechanisms, such as internet, mobile...
Regional Transportation Data Warehouse

phones etc. Archived data are displayed in a public domain website using a series of pre-defined static and dynamic reports. While advanced traveler information data are displayed over a web-based mapping interface through a single window website.

3.6 Transportation Data Elements

It is important to identify transportation data providers in the region prior to design and development of a system. Not only that, several meetings with data providers were held to identify scope of available data. For example, vehicle sensor data was only available for Border Highway and not IH-10, which is the major thorough fare in the region. Ways to establish connections between RMIS and data providers were also discussed in detail. Table 3-1 provides a list of transportation data providers in the region. A large portion of ITS data on state highways is provided by the TxDOT. At this time, the City of El Paso does not have the capability to provide data elements related to traffic flow and speed on the city maintained major arterials.

<table>
<thead>
<tr>
<th>Data Elements</th>
<th>Data Provider</th>
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<tbody>
<tr>
<td>Traffic Flow on State Highways</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>Dynamic Message Sign Information on State Highways</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>Highway Surveillance Images on State Highways</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>Lane Control Signal Information on State Highways</td>
<td>Texas Department of Transportation</td>
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<tr>
<td>Highway Advisory Radio Information on State Highways</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>Incident Reports</td>
<td>City of El Paso</td>
</tr>
<tr>
<td>Road Closure Information on State Highways</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>Public Transit Schedules and Routes</td>
<td>Sun Metro and County Transit</td>
</tr>
<tr>
<td>Local Weather</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
</tbody>
</table>
4. DATA EXTRACTION PROCESS

4.1 Introduction

The objective of data extraction process is to obtain ITS data from multiple sources and agencies. This process includes autonomous applications (executables) specifically built to extract data from a particular ITS data source. ITS data, except vehicle detector data, are extracted by “grabbing” information from agency websites (traffic incidents, border wait times) and through RSS provided by agencies (hourly weather information, dynamic message signs, highway advisory radio etc. Extracted ITS data are filtered, parsed, geo-coded, and converted to XML (Extended Markup Language) format for display over the internet. For example, the city of El Paso provides current incidents on its website (without geo-coded location of incidents). An application extracts current incidents from the website, parses and geo-codes the incident location, stores the data in the data warehouse, and finally converts the data into XML format to display the information as advanced traveler information.

PDN-RMIS extracts and integrates a broad set of ITS data to provide ADUS and ATIS services. It is important to identify transportation data providers in the region to understand the availability of ITS data and their data generating and sharing capabilities. In most cases, data providers are also users and stakeholders of archived data user service. One of the challenges in designing and implementing PDN-RMIS was to “fuse” disparate and diverse set of ITS data for ATIS and ADUS. There are no formalized data exchange mechanisms between the agencies and PDN-RMIS. The only mechanism to extract data from these sources was to “grab” data from agency websites, except vehicle detector data from TxDOT for which PDN-RMIS infrastructure is physically connected to TxDOT to extract vehicle detector data.

4.2 Deployment of Vehicle Detectors in El Paso

The Texas Department of Transportation has installed several microwave vehicle detection system (MVDS) on highways in El Paso. These detectors are side-mounted, multiple detection zone radars which project their footprint perpendicular to the traffic flow direction and provide data corresponding to several lanes of traffic. These detectors operate in either of two microwave bands, employing the FMCW
(Frequency Modulated Continuous Wave) principle. It transmits a low-power microwave signal of constantly varying frequency in a fixed fan-shaped beam. The beam "paints" a long elliptical footprint on the road surface. Any non-background targets will reflect the signal back to the detectors where the targets are detected and their range measured.

The detectors range measurement resolution of 2 meters (7 ft.) allows the "slicing" of the footprint ellipse into 32 range-slices. The user can define a number (1 - 8) of detection zones, each consisting of one or more range slices. The detectors internal microcomputer controls in realtime 8 opto-isolator relays corresponding to the detection zones. Relay contacts are closed when a target is present within the respective detection zone. The contact-pairs can be connected directly to traffic controllers. In addition, short-term statistical data on each zone are accumulated and transmitted by the detectors via its serial port. Typically, every 30 to 300 seconds a message containing the Volume, Occupancy, Average Speed and Classification by length data in each detection zone is transmitted. The long microwave wavelength and the range-measurement capability make the detectors immune to all weather effects and to most occlusion situations allowing vehicles hidden behind other vehicles to be detected, as shown in the diagram. [http://www.eistraffic.com/rtms_principles.html](http://www.eistraffic.com/rtms_principles.html)

![Figure 4-1 Principle of microwave vehicle detection technology.](http://www.eistraffic.com/rtms_principles.html)
TxDOT has been deploying microwave vehicle detectors on state highways for various purposes, including providing advanced traveler information. In this effort, TxDOT has installed 44 detectors on Border Highway and is adding more detectors on I10, US54 and Loop375. The detectors on Border Highway are shown in the Figure 4-2.

![Figure 4-2 Location of microwave vehicle detectors installed by TxDOT on Border Highway in El Paso.](image-url)
4.3 Data Transfer Between Transvista and RMIS

The raw data from vehicle detectors are also sent to specific tables in the data warehouse for archiving. For example, the El Paso District of TxDOT has deployed over 100 microwave vehicle detectors on several state highways in the region and is deploying another 140 vehicle detectors. These detectors collect vehicle data (volume, speed, and occupancy) using multiple detection zone radars. Vehicle detectors aggregate traffic data for each lane into 30-second packets and transmit the data packets to a server at TRANSVISTA. The server then transmits data packets to a database server in PDN-RMIS where the packets are filtered, aggregated, and archived. The vehicle detector data transmission between TRANSVISTA and PDN-RMIS is illustrated in Figure 4-3.

![Diagram of data transfer between Transvista and RMIS]

**Figure 4-3 Extraction of real-time traffic volume and speed data from vehicle detectors to RMIS.**
4.4 Incident Reports

Traffic and other hazardous incidents are reported by the City of El Paso Police Department through a public website, as shown in Figure 4-4. These incident reports consist of time and location of incident, response and status of the incident. Since, a process has not been set up to transfer incident data between the City of El Paso and the RMIS, an application was developed to “grab” the content of the website, parse the data and convert the data into appropriate format for storage and dissemination. The process is illustrated in Figure 4-5.

Source: http://www.elpasotexas.gov

Figure 4-4 City of El Paso Police Department’s Incident Notification System website.
Figure 4-5 Process to extract traffic incident information from the City’s website.
4.5 Information from Field ITS Devices

Texas Department of Transportation has installed several varieties of ITS field devices on state highways. These devices include closed circuit surveillance cameras, lane control signals, highway advisory radio, dynamic message signs. TxDOT provides dynamic URL to individual cameras and RSS sites for other ITS devices. Autonomous applications read the RSS information and either sent to the RMIS website directly or through a dynamic XML data file, as illustrated in Figure 4-6.

![Diagram](image)

Figure 4-6 Process to extract field ITS device information from Transvista.

4.6 Weather Information and Amber Alerts

National Oceanic and Atmospheric Administration (NOAA) relays hourly forecast of weather for the El Paso area through four weather stations - El Paso, Cd. Juarez, Santa Teresa, Las Cruces using real simple syndication (RSS) websites. An autonomous applications reads the RSS website and archives the data in the data warehouse.
5. DATA FUSION PROCESS

5.1 Relational Database Model

With recent development of data warehouse technology, multi-dimension models are predominantly used. In this model, data are arranged in FACT and DIMENSION tables. FACT tables consist of aggregated vehicle detector data (volume, speed, and occupancy), incident locations, border wait times, number of inspection lanes open at ports of entry, weather etc. Each record in the FACT table is associated with one or more dimensions of date, time, and location.

One of the benefits of arranging data into FACTS and DIMENSIONS is that this allows less restrictive normalization of data, which results in faster data access. DIMENSION tables also allow disparate FACT tables to be “joined” using common dimensions of time and location, as illustrated in Figure 5-1. In addition, a phased implementation of the data warehouse is possible using common dimensions that integrate old and new data subjects and facilitate queries across all these subjects.

![Figure 5-1 FACT and DIMENSION tables.](image-url)
5.2 Archived Vehicle Detector Data

In PDN-RMIS, archived data is arranged in FACT and DIMENSION tables. FACT tables consist of aggregated vehicle detector data (volume, speed, and occupancy), incident locations, border wait times, number of inspection lanes open at ports of entry, weather condition etc. Each record in the FACT table is associated with one or more DIMENSION tables, which defines location of each record in FACT tables. The structure of DIMENSION tables is illustrated in Figure 5-2.

![Figure 5-2 Structure of DIMENSIONS tables consisting of highway segments and sensor locations.](image)

Aggregate vehicle detector data for different time intervals (5, 15, 60 minutes etc.) are stored in separate tables (also illustrated in Figure 5-3), and are linked with DIMENSION tables.
Figure 5-3 Structure of FACT tables consisting of archived vehicle detector data.

5.3 Aggregation of Vehicle Detector Data

Traffic data from vehicle detectors are sent to the data warehouse as 30-second data packets, which are considered “real-time” data for this research purpose. Each record in the data packet consists of volume, average speed and occupancy per lane collected over 30 second period. PDN-RMIS aggregates
“real-time” data packets into 1, 5, 15, 60 minutes, 24 hours, and monthly periods. Vehicle detector data are aggregated into 15-minute interval and 60-minute interval using 5-minute data. Similarly, data aggregated into 60 minutes intervals are used to aggregate into 24 hours interval. Table 5-1 includes a list of tables that stores raw and aggregated vehicle detector data.

Figure 5-4 illustrates a flow chart of data aggregation process starting from the 30-second raw data, which are converted to 1-minute volume and average speed for each sensor zones (lanes). 15-minute and 60-minute aggregations are required to estimate peak hour factors, level of service and other congestion indicators, as described in Section 7.5 and stored in 24-hour tables with each record representing hourly value. Then on, monthly and annual vehicle miles traveled, vehicle hours travelled, annual average daily traffic, and total delay are estimated from the hourly data for individual roadway segments.

![Figure 5-4 Aggregation schedule of raw vehicle detector data.](image)
### Table 5-1 List of Tables that Stores Raw and Aggregated Vehicle Detector Data

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Agg15min_Year]</td>
<td>Stores 15 min aggregate and/or average of various highway performance indices on individual segments.</td>
</tr>
<tr>
<td>[Agg60min_Year]</td>
<td>Stores 60 min aggregate and/or average of various highway performance indices on individual segments.</td>
</tr>
<tr>
<td>[Agg24hr_Year]</td>
<td>Stores 24 hour aggregate and/or average of various highway performance indices on individual segments.</td>
</tr>
<tr>
<td>[Aggregate15minDay]</td>
<td>Stores 15 minute aggregate of total volume of passenger vehicles and trucks on individual roadway segments (2006 only)</td>
</tr>
<tr>
<td>[Aggregate60minDay]</td>
<td>Stores 60 min aggregate of total volume of passenger vehicles and trucks on individual roadway segments (2006 only)</td>
</tr>
<tr>
<td>[Aggregate24hrYear]</td>
<td>Stores 24 hour aggregate of total volume of passenger vehicles and trucks on individual roadway segments (2006 only)</td>
</tr>
<tr>
<td>[AggRoute_Year]</td>
<td>Stores 15 minute aggregate and/or average of various highway performance indices aggregated by individual roadway direction.</td>
</tr>
<tr>
<td>[RTMSDataDetail_Year_Month]</td>
<td>Stores 1 min aggregate and/or average of speed, volume, truck volume, sensor occupancy for individual detection zone, sensor, and roadway segment</td>
</tr>
<tr>
<td>[RealTimelmin_Year_Month]</td>
<td>Stores 1 min aggregate and/or average of speed, volume, truck volume, sensor occupancy at individual roadway segments</td>
</tr>
<tr>
<td>[Dashboard_Year]</td>
<td>Stores monthly VMT, truck VMT, and total delay by each roadway direction</td>
</tr>
</tbody>
</table>

Several stored procedures were created mostly to filter and aggregate the raw data. Some stored procedures are executed in a pre-defined schedule and others are executed by the database administrator on as needed basis. In addition to stored procedures, several triggers and SQL Server Integration Services (SSIS) packages are also used in aggregating the data. These programs were built to take advantage of their capabilities that are not provided by stored procedures.

Stored procedures are extremely similar to the constructs seen in other programming languages, except that structure query language (SQL) statements are required to create stored procedures. Stored procedures accept data in the form of input parameters that are specified at execution time. These input parameters (if implemented) are utilized in the execution of a series of statements that produce result. Stored procedures reduce client/server traffic and increase efficiency of code reuse. In Microsoft SQL Server 2005, stored procedures are included as database objects.
5.4 Filtering of Vehicle Detector Data

Archived data user service in PDN-RMIS includes formal rules and procedures (as part of the business logics) to control the quality of ITS data, especially vehicle detector data. Except vehicle detector data, other ITS data do not require rigorous quality control and is achieved by parsing and storing the data in a consistent format. In the case of vehicle detector data, complex filtering processes have been established which tags specific error codes to individual records of vehicle detector data.

Since microwave vehicle detectors installed in the region are relatively new and are still undergoing maintenance, review of archived data from vehicles detectors has shown large blocks of missing data - mostly attributed to detector malfunction or maintenance shut downs. Hence, PDN-RMIS has not developed and implemented methods to estimate missing data. However, as ITS deployment in the region matures and the reliability of vehicle detectors increases, efficient methods to estimate missing data will be implemented.

Traffic data from vehicle detectors are sent to the data warehouse as 30-second data packets, which are considered “real-time” data for this research purpose. Each record in the data packet consists of volume, average speed and occupancy per lane collected over 30 second period. PDN-RMIS aggregates “real-time” data packets into 1, 5, 15, 60 minutes, 24 hours, and monthly periods. Vehicle detector data are aggregated into 15-minute interval and 60-minute interval using 5-minute data. Similarly, data aggregated into 60 minutes intervals are used to aggregate into 24 hours interval. A study by the Texas Transportation Institute and Cambridge Systematics, Inc. found the following basis tests for quality control of archived traffic data (11):

- Maximum volume threshold (e.g., greater than 250 vehicles per lane for 5 minutes);
- Maximum occupancy threshold (e.g., greater than 90 percent for 5 minutes);
- Maximum speed threshold (e.g., greater than 80 mph for 5 minutes);
- Maximum speed threshold (e.g., less than 3 mph);
- Inconsistency of traffic data values (volume, occupancy, and speed) within the same data record or with traffic flow theory (e.g., occupancy is less than 3 percent but speed is less than 45 mph);
- Speed equals zero but volume is non-zero; and, occupancy is greater than zero but volume and speed are zero; and
- Sequential volume test (e.g., if the same volume is reported for 4 or more consecutive time periods, assume that the detector is malfunctioning).

The filtering algorithms (through stored procedures) filter the raw vehicle detector data before sending the data to table that store “normalized and aggregated” data. Data from each sensor zone (lane) are filtered and flagged with error codes based on following logics:

- If SPEED = 0 and VOLUME = 0 (and OCC = 0): Error code - 1
- If VOLUME > 25 (30 seconds): Error code - 2
- If OCC > 95% (20 to 30 seconds): Error code - 3
- If SPEED > 100 mph (20 to 30 seconds): Error code - 4
- If SPEED = 0 and VOLUME > 0 (and OCC > 0): Error code - 5
- If VOLUME = 0 and SPEED > 0: Error code - 6
- If SPEED = 0 and VOLUME = 0 and OCC > 0: Error code - 7

The filtering algorithms (through stored procedures) also filter aggregated vehicle detector data. Data from each sensor zone (lane) are filtered and flagged with error codes based on following logics (3):

Filtering logic for 1-minute aggregated data
- If Volume > 50: Error Code - 1
- If Occupancy > 80%: Error code - 2

Filtering logic for 5-minute aggregated data
- If Volume > 250 (5 minutes): Error code - 1
- If Vehicles per hour per lane > 3000: Error code - 2
- If Occupancy > 80% (1 to 5 minutes): Error code - 3

Report percentage of good data using in aggregation, in a separate field.

Percentage Good Data = Number of good data x 100/Total number of data polled in 5-minutes
These very basic tests will identify blatant data errors; however, more advanced tests may be required if a more rigorous quality control process is sought (7). Advanced quality control can include the following tests:

- **Sequential data checks** — identifies rapid fluctuations in data values for consecutive time periods (e.g., speeds typically do not go from 60 mph to 20 mph and back to 60 mph in consecutive 5-minute periods);
- **Spatial/corridor data checks** — identifies inconsistencies between detectors in adjacent lanes or between upstream/downstream detectors (e.g., volume into a link should approximately equal volume out); and
- **Historical data checks** — examines the changes from one year to the next for reasonableness (e.g., high increases in volume or drastic changes in speeds without a corresponding change in traffic volume).

Data quality checks are only the first step in the quality control process. Once suspicious or erroneous data are detected, an action must be taken. Possible actions include simply flagging or marking the data, or entirely replacing the data. Methods for replacing data that fails quality control, as well as for imputing missing data, offer the chance to improve data completeness. Such methods would be based on “good” data from surrounding locations for the same time period as well as using historical data at that same location.

### 5.5 Highway Performance Indices

State highways are divided into basic freeway and freeway merge/weave sections according to the Highway Capacity Manual. For example, Border Highway was divided into 12 segments in eastbound direction and 13 segments in the westbound direction. Each section contains at least one vehicle detector. Other highway segments (with limited access) will be segmented using similar concept. Highway performance indices are determined for individual segments. At present, performance indices for ramps have not been developed, but is planned for the future. Table 5-2 provides list of performance indices to measure traffic throughput and congestion.
<table>
<thead>
<tr>
<th>Performance Index</th>
<th>Data Granularity</th>
<th>Function Name</th>
<th>Spatial Granularity</th>
<th>Spatial Granularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>15 Minutes</td>
<td>Volume_15Minute</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Volume</td>
<td>15 Minutes</td>
<td>Volume_Hourly</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Volume</td>
<td>60 Minutes</td>
<td>Volume_Daily</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Volume</td>
<td>60 Minutes</td>
<td>Volume_Weekday</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Volume</td>
<td>60 Minutes</td>
<td>Volume_Weekend</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>VMT</td>
<td>60 Minutes</td>
<td>VMT_Daily</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>VMT</td>
<td>60 Minutes</td>
<td>VMT_Weekday</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>VMT</td>
<td>60 Minutes</td>
<td>VMT_Weekend</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>VMT</td>
<td>24 Hours</td>
<td>VMT_Monthly</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>Truck_VMT</td>
<td>60 Minutes</td>
<td>Truck_VMT_Daily</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>Truck_VMT</td>
<td>60 Minutes</td>
<td>Truck_VMT_Weekday</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>Truck_VMT</td>
<td>60 Minutes</td>
<td>Truck_VMT_Weekend</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>Truck_VMT</td>
<td>24 Hours</td>
<td>Truck_VMT_Monthly</td>
<td>Route</td>
<td>-</td>
</tr>
<tr>
<td>PHF</td>
<td>15 Minutes</td>
<td>PHF_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>TruckPercent</td>
<td>15 Minutes</td>
<td>TruckPercent_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>VCRatio</td>
<td>15 Minutes</td>
<td>VCRatio_15Minute</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>VCRatio</td>
<td>15 Minutes</td>
<td>VCRatio_Hourly</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Density_LOS</td>
<td>15 Minutes</td>
<td>Density_LOS_15Minute</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Density_LOS</td>
<td>15 Minutes</td>
<td>Density_LOS_Hourly</td>
<td>-</td>
<td>Segment</td>
</tr>
<tr>
<td>Speed</td>
<td>15 Minutes</td>
<td>Speed_15Minute</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>Speed</td>
<td>15 Minutes</td>
<td>Speed_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>AvgTravelTime</td>
<td>15 Minutes</td>
<td>TravelTime_15Minute</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>AvgTravelTime</td>
<td>15 Minutes</td>
<td>TravelTime_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>TravelTimeIndex</td>
<td>15 Minutes</td>
<td>TravelTimeIndex_15Minute</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>TravelTimeIndex</td>
<td>15 Minutes</td>
<td>TravelTimeIndex_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>TotalDelay</td>
<td>15 Minutes</td>
<td>Delay_15Minute</td>
<td>Route</td>
<td>Segment</td>
</tr>
<tr>
<td>TotalDelay</td>
<td>15 Minutes</td>
<td>Delay_Hourly</td>
<td>Route</td>
<td>Segment</td>
</tr>
</tbody>
</table>

The following sections describe calculations used to estimate various performance indices in accordance to the Highway Capacity Manual.
5.5.1 Average Travel Time, Travel Time Index, and Total Delay

Calculation of Average Travel Time (15 minute interval) at \( i^{th} \) Section:

\[
ATT_i = \frac{L_i \times 60}{S_i}
\]

Where,

\( AFT_i = \) Average travel time at \( i^{th} \) section for a specified time period (minutes)

\( S_i = \) Weighted average speed at \( i^{th} \) section for a specified time period (left-most lane only) (miles per hour)

\( L_i = \) Length of \( i^{th} \) section (miles)

Calculation of Average Travel Time (15 minute interval) for \( j^{th} \) Route:

\[
ATT_j = \sum \frac{L_i \times 60}{S_i} = \sum ATT_i
\]

Where,

\( AFT_j = \) Average travel time at \( j^{th} \) route for a specified time period (minutes)

\( S_i = \) Weighted average speed at \( i^{th} \) section for a specified time period (left-most lane only) (miles per hour)

\( L_i = \) Length of \( i^{th} \) section (miles)

Calculation of Free Flow Travel Time (15 minute interval) at \( i^{th} \) Section:

\[
FTT_i = \frac{L_i \times 60}{FFS_i}
\]

Where,

\( FTT_i = \) Free flow travel time at \( i^{th} \) section for a specified time period (minutes)

\( FFS_i = \) Free flow speed at \( i^{th} \) section for a specified time period (miles per hour)

\( L_i = \) Length of \( i^{th} \) section (miles)
Calculation of Free Flow Travel Time (15 minute interval) for jth Route:

\[ FTT_j = \sum L_i \times \frac{60}{FFS_i} = \sum FTT_i \]

Where,

- \( FTT_j \) = Free flow travel time at jth route for a specified time period (minutes)
- \( FFS_i \) = Free flow speed at ith section for a specified time period (miles per hour)
- \( L_i \) = Length of ith section (miles)

Calculation of Travel Time Index (15 minute interval) at ith Section:

\[ TTI_i = \frac{ATT_i}{FTT_i} \]

Where,

- \( TTI_i \) = Travel time index at ith section for a specified time period
- \( ATT_i \) = Average travel time at ith section for a specified time period
- \( FTT_i \) = Free flow travel time at ith section for a specified time period

Calculation of Travel Time Index (15 minute interval) at ith Route:

\[ TTI_j = \frac{ATT_j}{FTT_j} \]

Where,

- \( TTI_j \) = Travel time index at ith section for a specified time period
- \( ATT_j \) = Average travel time at ith section for a specified time period
- \( FTT_j \) = Free flow travel time at ith section for a specified time period

Calculation of Delay (15 minute interval) at ith Section:

\[ ATT_i > FTT_i \]

\[ D_i = \frac{(ATT_i - FTT_i) \times V_i}{60} \]
\[ ATT_i \leq FTT_i \]
\[ D_i = 0 \]

Where,
\[ D_i = \text{Delay at } i^{th} \text{ section for a specified time period, vehicle-hours} \]

Travel Delay – Route

Calculation of Delay (15 minute interval) for jth Route:
\[ D_j = \sum D_i \]

Where,
\[ D_j = \text{Delay at } j^{th} \text{ route for a specified time period, vehicle-hours} \]

### 5.5.2 Peak Hour Factor and Level of Service

Calculate Level of Service of a Basic Freeway Section:

Requirements:
- Determine LOS of freeway segments at every clock-hour only, using aggregate volume.
- Store the archived LOS information of all freeway sections in a separate table.
- In addition to letter grade LOS (letters A through F), also store parameters determined by the system, which includes

Determine Free Flow Speed (FFS) of the Section:

\[ FFS = BFFS - f_{lw} - f_{lc} - f_N - f_{id} \]

- \( FFS \) = free-flow speed (mph)
- \( BFFS \) = base free-flow speed, 70 mph (urban), 75 mph (rural)
- \( f_{lw} \) = adjustment for lane width (mph)
- \( f_{lc} \) = adjustment for right-shoulder lateral clearance (mph)
- \( f_N \) = adjustment for number of lanes (mph)
- \( f_{id} \) = adjustment for interchange density (mph)
Base free-flow speed:
Assume BFFS = 70 mph for Loop 375

Adjustment for lane width:
Assume Lane Width = 12 ft for all sub-sections of Loop 375
Hence, $f_{lw} = 0.00$

<table>
<thead>
<tr>
<th>Lane Width (ft)</th>
<th>Reduction in Free-Flow Speed, $f_{lw}$ (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.0</td>
</tr>
<tr>
<td>11</td>
<td>1.9</td>
</tr>
<tr>
<td>10</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Adjustment for right-shoulder lateral clearance:
Assume right shoulder clearance > 6 ft
Hence, $f_{lc} = 0.00$

<table>
<thead>
<tr>
<th>Right Shoulder Lateral Clearance (ft)</th>
<th>Reduction in Free-Flow Speed, $f_{lc}$ (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lanes in One Direction</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>≥6</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.6</td>
</tr>
<tr>
<td>4</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>1.8</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td>1</td>
<td>3.0</td>
</tr>
<tr>
<td>0</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Adjustment for number of lanes:

For 2-lane section, $f_N = 4.5$ mph and 3-lane section, $f_N = 3.0$

<table>
<thead>
<tr>
<th>Number of Lanes (One Direction)</th>
<th>Reduction in Free-Flow Speed, $f_N$ (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥5</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Adjustment for interchange density:

Assume, interchange density < 0.5, $f_{ID} = 0.0$

<table>
<thead>
<tr>
<th>Interchanges per Mile</th>
<th>Reduction in Free-Flow Speed, $f_{ID}$ (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>0.75</td>
<td>1.3</td>
</tr>
<tr>
<td>1.00</td>
<td>2.5</td>
</tr>
<tr>
<td>1.25</td>
<td>3.7</td>
</tr>
<tr>
<td>1.50</td>
<td>5.0</td>
</tr>
<tr>
<td>1.75</td>
<td>6.3</td>
</tr>
<tr>
<td>2.00</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Determine Flow Rate:

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

$v_p$ = 15-minute passenger-car equivalent flow rate (pcphpl),

$V$ = hourly volume (veh/hr),

$PHF$ = peak hour factor,

$N$ = number of lanes in one direction,

$f_{HV}$ = heavy-vehicle adjustment factor,

$f_p$ = driver population adjustment factor

Peak hour factor (PHF):
Peak hour factor (PHF) = Hourly volume/(4 x maximum of 15 minute volumes)

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 – 7:15</td>
<td>200</td>
</tr>
<tr>
<td>7:15 – 7:30</td>
<td>300</td>
</tr>
<tr>
<td>7:30 – 7:45</td>
<td>150</td>
</tr>
<tr>
<td>7:45 – 8:00</td>
<td>200</td>
</tr>
</tbody>
</table>

PHF (7AM-8AM) = (200+300+150+200)/(4 x 300) = 0.71
If PHF is not available, use default value of PHF=0.85.

Heavy Vehicle Adjustment Factor:
If no heavy vehicle is present during the analysis period, f_{HV} = 1.0
Otherwise,

\[ f_{HV} = \frac{1}{1 + P_T (E_T - 1)} \]

Assuming, proportion of RVs in the traffic stream = 0
\[ f_{HV} = \text{Heavy vehicle adjustment factor} \]
\[ E_T = \text{Passenger-car equivalents for trucks/buses and RVs} \]
\[ P_T = \text{Proportion of trucks/buses and RVs in traffic stream} \]

<table>
<thead>
<tr>
<th>Factor</th>
<th>Type of Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
</tr>
<tr>
<td>ET (trucks and buses)</td>
<td>1.5</td>
</tr>
<tr>
<td>ER (RVs)</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Assume, type of terrain as rolling for Loop 375. Hence, \( E_T = 2.5 \)

Driver Population Adjustment Factor:
Assume, \( f_P = 1.0 \)
Determine Average Passenger Car Speed:

For $70 < \text{FFS} \leq 75$ mph AND $\text{vp} \leq (3400 - 30\text{FFS})$

$S = \text{FFS}$

For $70 < \text{FFS} \leq 75$ mph AND $(3400 - 30\text{FFS}) < \text{vp} \leq 2400$

$$S = \text{FFS} - \left[ \left( \frac{\text{FFS} - 160}{3} \right) \left( \frac{\text{vp} + 30\text{FFS} - 3400}{30\text{FFS} - 1000} \right)^{2.6} \right]$$

For $55 < \text{FFS} \leq 70$ mph AND $(3400 - 30\text{FFS}) < \text{vp} \leq (1700 + 10\text{FFS})$

$$S = \text{FFS} - \left[ \frac{1}{9} \left( 7\text{FFS} - 340 \right) \left( \frac{\text{vp} + 30\text{FFS} - 3400}{40\text{FFS} - 1700} \right)^{2.6} \right]$$

For $55 < \text{FFS} \leq 75$ mph AND $\text{vp} < (3400 - 30\text{FFS})$

$S = \text{FFS}$

Determine Density:

$$D = \frac{\text{vp}}{S}$$

$D =$ density (pc/mi/ln)
$\text{vp} =$ flow rate (pc/hr/ln)
$S =$ average passenger-car speed (mph)
### Determine Level of Service:

Determine LOS using the following density range

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Density Range (pc/mi/ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 11</td>
</tr>
<tr>
<td>B</td>
<td>11 – 18</td>
</tr>
<tr>
<td>C</td>
<td>18 – 26</td>
</tr>
<tr>
<td>D</td>
<td>26 – 35</td>
</tr>
<tr>
<td>E</td>
<td>35 – 45</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 45</td>
</tr>
</tbody>
</table>

#### 5.5.3 Volume to Capacity Ratio

The link capacity of a freeway segment is provided by the following equation:

\[
c = Q \times N \times f_{hv} \times f_p \times PHF
\]

Where
- \(C\) = Capacity (vph)
- \(Q\) = PCE Capacity (pc/hr/lane)
- \(N\) = Number of through lanes (ignoring auxiliary and exit-only lanes)
- \(f_{hv}\) = Heavy-vehicle adjustment factor
- \(f_p\) = Driver population adjustment factor
- \(PHF\) = Peak hour factor

#### 5.5.4 Vehicle Miles Traveled

For 15 Minutes, 60 Minute and 24 Hour Intervals:

1. \(VMT = \text{Summation of (Total volume of each section x section length)}\)

   For example,

   VMT on Eastbound LP375 at 7:00 – 7:15 AM = SUM (Total Volume of each section on LP375 EB at 7:00-7:15 AM x Length of the Section (in miles))
2. Truck VMT = Summation of (Truck Volume at each section x section length)
   
   For example,
   
   Truck VMT on Eastbound LP375 at 7:00 – 7:15 AM= SUM (Truck Volume of each section on LP375 EB at 7:00-7:15 AM x Length of the Section (in miles))
6. DATA DISSEMINATION PROCESS

6.1 Advanced Traveler Information

Advanced traveler information service is a decision support system that enables traveling public to make informed decisions about their trip. Advanced traveler information service includes pre-trip information, en-route driver information, route guidance, ride matching, traveler services information etc. One of the main objectives of PDN-RMIS was to provide pre-trip information to motorists and traveling public by extracting ITS data from multiple sources and displaying travel conditions using a single window website.

ITS data are extracted by “grabbing” information from agency websites (traffic incidents, border wait times), through RSS links provided by agencies (hourly weather information, dynamic message signs, highway advisory radio etc.), and through a physical connection with TxDOT (microwave vehicle detector data). Extracted ITS data is filtered, parsed, geo-coded, and converted to XML format for display over the internet.

Advanced traveler information service is provided on a public-domain website using a “single window”. ITS data extracted by autonomous applications are converted into XML format, which includes geographic location of ITS data. The PDN-RMIS website is built upon Microsoft Live Maps© technology to take advantage of geo-coding capabilities of Live Map’s Application Programming Interface (API). For example, incident locations are automatically geo-coded by Live Maps API using intersection information reported by the source (City of El Paso). Geographic location of field ITS devices (dynamic message signs, vehicle detectors, roadway segments, land control signals) are already assigned latitude and longitude, which is included in the XML data packet and read by the Live Maps API. A snapshot of web-based user interface and components of advanced traveler information is shown in Figure 6-1 and Figure 6-2.
Figure 6-1 Map-based website to view advanced traveler information and other traffic conditions.

Table 6-1 provides a list of ITS data that are displayed in PDN-RMIS website. Depending on type of advanced traveler information data, frequency of update (over the internet) varies, as listed in Table 6-1. For example, traffic flow volume and average speed on highway segments are updated over the internet every minute. Mapped location of traffic incident reports are updated every 30 minutes. Border wait times and number of inspection lanes open at the border are updated every hour.

<table>
<thead>
<tr>
<th>ITS Data</th>
<th>Update Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Flow Volume and Average Speed on Highway Sections</td>
<td>1 minute</td>
</tr>
<tr>
<td>Dynamic Message Signs on State Highways</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Highway Surveillance Images on State Highways</td>
<td>1 minute</td>
</tr>
<tr>
<td>Lane Control Signals on State Highways</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Highway Advisory Radio Information on State Highways</td>
<td>Daily</td>
</tr>
<tr>
<td>Incident Reports</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Service</td>
<td>Frequency</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Road Closure Information on State Highways</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Border Wait Times</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Inspection Lanes Open</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Homeland Security Threat Level Advisory</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Port of Entry Traffic Conditions</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Local Weather</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Airport Information</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>
Figure 6-2 Map-based website with geometric attributes to show detailed traffic conditions.
6.2 Archived Transportation Data

PDN-RMIS uses a multitude of static and interactive web-based reports to provide multi-granular view (temporal and spatial) of transportation system performance and conditions. One of the unique features of PDN-RMIS is that web-based reports (static and interactive) are stored in a central repository in a server outside the data warehouse. These reports are connected to tables in the data warehouse using pre-defined stored procedures and web pages encapsulate the reports to provide access to users. This mechanism of creating a central repository of reports facilitates a server-based creation, management, and delivery of reports.

6.3 Web-Based Reports

Static and interactive reports have been categorized as Congestion Monitoring, Performance Monitoring, Micro and Macroscopic Calibration Tools, Research Tools, Aggregated Volume and Speed, and Dashboard. For simplicity, reports showing volume-capacity ratio, density, level of service, average speed, average travel time, travel time index, and delay are categorized as Congestion Monitoring indices. Performance monitoring indices include vehicle miles traveled, volume, peak hour factor, and truck percentage. Microscopic and macroscopic calibration tools include reports to query relationships between volume, density, and speed. Research tools include reports to compare congestion and performance indices between different user selected segments and at different periods. Aggregated Volume and Speed consists of interactive reports to view and download bulk detector data. Figure 6-3 shows a snapshot of static and interactive web-based reports to access archived data.
Figure 6-3 Web-based user interface and components of archived data user service.
6.3.1 Dashboard

Dashboard was designed to view mobility and performance indices of roadways in the El Paso region. The current design includes vehicles miles traveled, truck vehicle miles traveled, truck vehicle miles traveled and total delay aggregated every month for a selected route by direction. Users can view and query the monthly trend of these mobility indices, a snapshot of the website is shown in Figure 6-4. The computation of these mobility indices is described in Chapter 5. At present, mobility indices are only available for Border Highway and once TxDOT completes installation of vehicle sensors on IH-10, similar or combined mobility indices will be developed.

Figure 6-4 Dashboard showing monthly mobility indices on Border Highway.
6.3.2 Congestion Monitoring

Using the web-based interface, users can query average travel time, travel time index, and delay on individual roadway segments (or entire highway segment) of the Border highway for a given date and time. These indices are displayed with 15 minute time intervals, as shown in Figure 6-5.

Figure 6-5 Web-based user interface to query congestion indices.
6.3.3 Performance Monitoring

Using the web-based interface, users can query volume-capacity ratio and density of individual roadway segments (or entire highway segment) of the Border Highway for a given date and time. These indices are displayed with 15 minute time intervals, as shown in Figure 6-6.

![Web-based user interface to query performance indices.](image)
6.3.4 Calibration Tools

The free flow speed on freeways are used in determine performance indices, calibrate simulation models, determine traffic design parameters. Free flow speed can be deduced from a speed-density relationship fitted to the field data. The 30-second volume and occupancy data from individual vehicle detectors can be used to established the speed-density relationship. Users can query relationships between speed-density-volume for individual roadway segments (or entire highway segment) of the Border Highway for a given year. The web-based report collects all the individual 30-second raw data for the entire year and displays the information on scattered charts, as shown in Figure 6-7.

Figure 6-7 Web-based user interface to view volume-density-speed relationships.
6.3.5 Research Tools

Several pre-defined tools have been included in the web-based reports section. These report tools were designed to demonstrate the feasibility of adding similar reports as needed by planning agencies in the region. Figure 6-8 show a snapshot of a user interface to compare performance of all roadway segments in one direction of the Border Highway using volume and average speed. This will assist planners in identifying future improvement needs at hot spots (worst performing sections).

![Figure 6-8 Online report to compare performance of all roadway segments based on speed and volume.](image)

Figures 6-8: Visualizing the impact of adverse weather on performance of roadway segments is important from the safety standpoint and also to analyze how the motorists respond to warning messages, dynamic message signs during low visibility situations. Figure 6-9 show a snapshot of a user interface to compare performance of both directions of the Border Highway. Visibility (in miles) is obtained from...
the National Oceanic and Atmospheric Administration and is compared with hourly average speed and volume of the highway.

Figure 6-9 Online report to analyze the performance of all roadway segments during low visibility situations by monitoring speed and volume.

Comparing performance of a roadway segment at two different dates is a useful while analyzing the impact of various freeway management strategies, lane closures during construction, major roadway incidents etc. Figure 6-10 shows a snapshot of a tool to compare aggregated hourly volume and average speed of a roadway segment at two different dates and time periods.
Figure 6-10 Web-based user interface to compare roadway performance of a roadway segment between different time periods.

Comparing performance of multiple roadway segment (consecutive or otherwise) is a useful while analyzing the impact of various freeway management strategies, lane closures during construction, major roadway incidents etc. Figure 6-11 shows a snapshot of a tool to compare average speed and distribution of up to 3 consecutive roadway segment.
Figure 6-11 Web-based user interface to compare roadway performance of up to 3 consecutive roadway segment.

Analyzing the impact of traffic incidents on performance of freeway segments at a microscopic level (change in speed, flow, density of vehicles) is unfeasible without the presence of vehicle detectors. Its even more difficult in cases when vehicle detectors are managed and operated by state agencies and incidents are reported by local agencies and there are no automated methods to link one with the other. The data warehouse archives incident locations in addition to vehicle detector data. Hence, a tool was created (as shown in Figure 6-12) to view the performance of roadway segment where an incident was recorded. Users select an incident from the list, which will display a graph showing average speed and volume (aggregated every 2 minutes) 1 hour before and after the incident.
Figure 6-12 Web-based user interface to compare performance of a roadway segment where an incident was recorded.
6.3.6 Vehicle Miles Traveled, Volume and Speed

Using the web-based interface, users can query daily and hourly vehicle miles traveled, aggregated volume and average speed on individual roadway segments (or entire highway segment) of the Border Highway for a given date and time. These indices are displayed in 15 minute time intervals, as shown in Figure 6-13 and Figure 6-14.

![Web-Based User Interface to Query Vehicle Miles Traveled](image)

**Figure 6-13 Web-Based User Interface to Query Vehicle Miles Traveled**
Figure 6-14 Web-Based User Interface to Query Average Speed and Aggregated Volume
7. BIBLIOGRAPHY


