TRANSPORTATION DATA COLLECTION AND

DISSEMINATION PRACTICES IN DELAWARE

by

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ABSTRACT

Delaware Department of Transportation (DelDOT) owns more than 90% of the roadways and majority of the traffic signals. To address the growing problem of congestion, delays, and overall traffic issues, DelDOT established the Transportation Management Center (TMC) in 1997. The purpose of this thesis was to evaluate the global responsibilities of DelDOT-TMC and assess the process that TMC uses to gather, process, analyze, and distribute traffic and roadway weather data to the public.

TMC coordinates and manages DelDOT's response to any incident that influences the multimodal transportation system within the state of Delaware. Among other things, DelDOT-TMC collects traffic, roadway weather, and hydrological data by using over a thousand monitoring devices installed throughout the state of Delaware. After data has been obtained, TMC analyzes and disseminates real-time travel information to the public through DelDOT's website (online interactive maps), smartphone application (DelDOT Mobile App), traffic advisory radio (WTMC 1380 AM), as well as multiple social media sites such as Twitter, Facebook, YouTube, Blog, and Flickr.

This research presented a step-by-step guideline on the standard way of conducting traffic data collection set by the Institute of Transportation Engineers (ITE) and American Association of State Highway and Transportation Officials (AASHTO). This thesis reviewed manual and automatic methods of traffic counting and provided

detailed information on traffic volume and vehicle classification studies. The purpose of presenting the manuals is to provide the standard data collection guidelines that all transportation management centers, including DelDOT-TMC, are required to follow when collecting traffic data.

This research also provided a detailed analysis of DelDOT-TMC websites and compared it to selected Department of Transportation websites such as Vermont, Connecticut, New Jersey, Pennsylvania, California, Texas, and Virginia. The purpose of the comparison was to analyze the data sources, accessibility, presentation formats, and style for each state and see how it compared to DelDOT-TMC. Although there were some similarities, there were two main differences that stood out the most. It was discovered that TMC Extranet had an extremely long website registration approval process than the other states and traffic counts provided is only in Portable Document Format (PDF). Also, TMC disseminated traffic and roadway weather information through the mobile application, among other sources, but Delaware's hands-free law prevented drivers from using it. The overall results revealed that DelDOT-TMC provided limited traffic and roadway weather data, and presentation formats to the public compared to the other states.

Chapter 1

INTRODUCTION

1.1   Background

Due to the increase in population throughout the United States, transportation

networks are congested on a daily basis, especially in the morning and afternoon peak

hours. To avoid congested or closed routes, drivers rely on accurate and real-time

traffic information to start their trip.

During the last decade, technology has changed how traffic data is collected

and disseminated. Technology, especially mobile technology, is rapidly changing how

people consume traffic information. With the majority of drivers and public transit

users relying on the internet and smartphones to plan out their day, knowing the traffic

and roadway weather conditions ahead of time has become a daily need before

heading out on the road. In the state of Delaware, DelDOT has become the primary

source for travel information and roadway weather conditions as it relates to traffic.

DelDOT maintains over 90% of the roads throughout the state of Delaware (1).

Under DelDOT, TMC is a statewide 24 hours, seven days a week emergency

operation center that coordinates and manages DelDOT's response to any incident or

event that influences Delaware's multimodal transportation system (1). DelDOT-TMC

is responsible for collecting, processing, analyzing, and disseminating traffic and

roadway weather data to the public. It provides real-time travel information to allow

the public to make informed decisions concerning travel route, travel time, and mode choice. TMC might be collecting various types of traffic data, but the information and presentation formats that are provided for the intended users are limited.

1.2   Problem Statement

DelDOT-TMC has been collecting, analyzing, and disseminating traffic and roadway weather data since its inception to distribute the results to transportation professionals, academia, as well as the general public. TMC is currently providing real-time traffic data through a smartphone application, travel advisory radio, social media sites, different websites, and interactive maps that show the real-time traffic counts and incidents. Although this information is useful to the general public, the data lacks historical details such as traffic volume, roadway occupancy, delay, speed, classification, travel time, trip distribution, and origin-destination in various formats. These detailed historical data are crucial for the different divisions in DelDOT, academia, and state agencies to be able to use the given information for further analysis.

Furthermore, the TMC website does not provide a detailed historical traffic data in different presentation styles and formats. Exporting historical and real-time data in various forms (such as MS Excel spreadsheet, MS Word, Shapefiles, Tables, Charts, and others) are necessary for professionals and researchers who wish to use the raw data to analyze current highway traffic performance.

1.3   Purpose and Objectives

The purpose of this thesis is to thoroughly examine TMC's data processing methods and distribution of traffic and roadway weather data. A comparison and an examination will also be conducted between states to determine how DelDOT-TMC measures up to the other states' TMC. As previously stated, DelDOT's TMC method of presenting and providing traffic and roadway weather historical and real-time data to the public is limited. By thoroughly comparing and examining the different aspect of DelDOT-TMC, this thesis hopes to provide clarity as to why TMC supply limited traffic data and formats to the public.

The objectives of this study are to:

1. Examine the type of data that DelDOT-TMC is currently collecting;

2. Examine the presentation formats and styles that DelDOT's TMC uses to provide its traffic and roadway weather data to the public;

3. Conduct comprehensive research on DelDOT's TMC data collection equipment, technology, software, and telecommunication;

4. Conduct in-depth research on DelDOT's TMC sources of data dissemination;

5. Perform an extensive review of selected states' TMC;

6. Examine the standard data collection methods set by the ITE and AASHTO;

7. Perform a comparative analysis of DelDOT's TMC types of data and ways of data dissemination to the selected states' TMC.

1.4　Scope

Although there are various traffic data types that engineers and planners collect, the scope of this paper focuses only on traffic data collection for volume and vehicle classification studies. Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a specific location. These data can help identify critical flow time periods, assess the influence of large vehicles or pedestrians on vehicular traffic flow as well as document traffic volume trends.

The study also presents the comparative research of the DelDOT-TMC data presentation as it relates to other selected states' TMC. The selected states that this study focuses on are similar size states like Vermont and Connecticut, neighboring states such as New Jersey and Pennsylvania, and large states such as California, Texas, and Virginia. The scope of this study is to examine how the mentioned states' websites present transportation data information via the Internet to their intended users.

DelDOT-TMC provides real-time traffic information to allow the public to make informed decisions concerning travel route, travel time, and mode choice. In this research, the term "public" is defined as the individuals who use Delaware's roadways, employees of DelDOT, different state of Delaware departments, local counties (New Castle, Sussex, and Kent), Wilmington Area Planning Council (WILMAPCO), and academia (staff, faculty, and students).

1.5   Research Approach and Methodology

This research uses the AASHTO Guidelines for Traffic Data Programs and ITE Manual of Transportation Engineering Studies as guidance on the standard methods of conducting traffic data collection within the transportation field.

These two documents reveal necessary steps that must be followed when conducting raw data such as procedures, techniques for reducing and analyzing data, type of equipment used, personnel (data collectors), level of training needed, and the minimum data that is required for a volume and classification studies.

This research will examine a few of the previously mentioned states' Department of Transportation websites. The purpose of the examination is to analyze how these states provide historical and real-time traffic information to their intended users. The results will then be compared to the products and dissemination methods of DelDOT's TMC traffic and roadway weather data.

1.6   Implications and Outcomes

Collecting, analyzing, and managing traffic data using the standards set by ITE and AASHTO allow states' transportation management centers to provide the necessary traffic data in many valuable presentation formats such as MS Excel, MS Word, Tables, Charts, and others. TMC can reach its intended users with accurate historical and real-time traffic and roadway weather data.

Therefore, DelDOT-TMC can use the results of this study to offer Delawareans direct access to exportable and downloadable historical and real-time traffic and weather data for further analysis. Also, comparing where other states are in regards to providing truthful historical and real-time traffic and roadway weather data will allow DelDOT-TMC to further work in delivering its data in various formats and presentation styles.

1.7   Organization of The Thesis

This thesis includes six chapters.

Chapter one provides the introduction of the research. It also includes the problem statement, purpose and objectives, scope, approach, and methodology, as well as the implication and outcomes of the study.

Chapter two focuses on the introduction to DelDOT-TMC and the type of data that DelDOT-TMC collects, analyzes and disseminates to the intended users. It also discusses the kind of equipment, technology, and software that TMC uses to deliver its traffic and roadway weather data to the public.

Chapter three examines seven different states' Department of Transportation (DOT) public websites. The selected states that this study focuses on are similar size states like Vermont and Connecticut, neighboring states such as New Jersey and Pennsylvania, and large states such as California, Texas, and Virginia. This research will examine the type of data and how each states' DOT provides traffic data to their respective users.

Chapter four uses the AASHTO Guidelines for Traffic Data Programs and ITE Manual of Transportation Engineering Studies to provide basic guidelines and detailed description on the standard method of data collection, processing, analyzing and managing data. More specifically this chapter will mainly focus on volume and classification counts studies.

Chapter five discusses the differences and similarities of products that DelDOT-TMC has compared to other selected states' TMCs. It examines the type of data sources and accessibility, the kind of data, and the presentation format that each of these states provides transportation data to their intended users.

Chapter six summarizes, concludes and suggests recommendations based on the comparisons that are discussed in the previous sections. Also, future research that could be done in traffic and roadway weather data collection, analysis, management, and distribution is explained.

Chapter 2

DELAWARE DEPARTMENT OF TRANSPORTATION-TRANSPORTATION MANAGEMENT CENTER (DELDOT-TMC)

2.1   Introduction to DelDOT-TMC

DelDOT is an agency of the state of Delaware, and it has been responsible for maintaining the majority of the state's public roadways since 1917 (1). Managing the state's traffic conditions is one of the department's primary responsibilities. To operate the state's transportation efficiently, DelDOT announced its initial integrated transportation management strategic plan in 1997, with the goal of reducing congestion and delay, increasing safety, reducing operating costs, and improving systems' performance (2).

The 1997 Strategic plan acknowledged different strategies with associated actions to monitor the implementation of transportation management in the state of Delaware. Implementing a centralized TMC was the primary goal set by the department to create the necessary infrastructure to support the state's transportation management team (2).

Through TMC, strategic plans were set to provide a safe and accurate traffic data. The first strategic plan was to disseminate accurate real-time traffic information so that users can make informed decisions concerning travel route, travel time, and mode choice. The second strategy was to develop partnerships with County Emergency Operations Centers (EOCs) and State Police to support transportation

management activities. By doing so, DelDOT would be able to implement a coordinated, and timely incident response as well as have the opportunity to partner with the private sector, counties, and local agencies. Developing an internal capacity to support transportation management by providing staff training and organizational structure was identified as the third strategic plan (2).

Although the strategic plan was published in 1997, DelDOT established and started operating a full time centralized TMC in 2002 (2). TMC was found to be the center for a databank, meaning that it would be the primary traffic and roadway weather data source for different divisions within DelDOT. Currently, TMC is a 24 hours a day, 365 days a year statewide operating system that coordinates and manages DelDOT's response to any incidents or events that influence the multimodal transportation system within the state of Delaware (2).

The TMC consistently updates the original strategic plan with the same goals that were set in 1997. The updates will allow DelDOT-TMC to work towards the original goals that include creating infrastructures, disseminating real-time information, developing a partnership, and developing internal capacity to support the state's transportation management (2).

2.2 DelDOT-TMC Traffic Studies

As DelDOT's TMC data collection program (3), the state conducts traffic studies including highway classification, vehicle classification, and volume count. Federal Highway Administration (FHWA), which oversees federal funds used for

constructing and maintaining the national highway system, requires highways and streets to be grouped into functional classes or systems. DelDOT provides a functional classification of highways based on traffic characteristics and the function that each roadway serves as part of the entire network (3). DelDOT then issues and updates the functional classification maps of the highway network for each county and state as needed. DelDOT has established eight traffic pattern groups (TPG 1 through TPG 8) to represent the traffic characteristics of all Delaware roads (3). These eight Delaware's traffic pattern groups are (3):

- TPG 1 = Interstate, Freeways & Expressways
- TPG 2 = Other Urban Arterials
- TPG 3 = Urban Collectors
- TPG 4 = Urban Local Street
- TPG 5 = Rural Arterials
- TPG 6 = Rural Major Collectors
- TPG 7 = Rural Minor Collectors & Local Roads
- TPG 8 = Recreational Routes

Also, all highway vehicles are classified under the current FHWA vehicle classification scheme. DelDOT conducts classification counts when a high percentage of heavy trucks exist or if a vehicle mix at the crash site is suspected as contributing to the crash problem. As per FHWA requirement, DelDOT classifies cars, station wagons, pickup and panel trucks, and motorcycles as passenger cars. Other trucks and buses are classified as trucks. School buses and farm equipment are recorded separately. The observer records the classification of the vehicles and the vehicle's' direction of travel at the intersection (3). DelDOT classifies vehicles in 13 classes, these are (3):

- Class 1 = Motorcycles;
- Class 2 = Passenger Cars;
- Class 3 = Other Two-Axle, $ Tire Single Units;
- Class 4 = Buses;
- Class 5 = Two-Axle, 6 Tire Single Units;
- Class 6 = Three Axle Single Units;
- Class 7 = Four or More Axle Single Units;
- Class 8 = Four or Less Axle Single Trailers;
- Class 9 = Five Axle Single Trailers;
- Class 10 = Six or More Axle Single;
- Class 11 = Five or Less Axle Multi-Trailers;
- Class 12 = Six Axle Multi-Trailers;
- Class 13 = Seven or More Axle Multi-Trailers.

In addition to functional and vehicle classification, DelDOT collects traffic flow using traffic volume counter stations called Automatic Traffic Recorder (ATR), which is permanently installed throughout the road inventory network covering all functional classifications of highways. These ATR stations are equipped with loop detector that count the number of all vehicles passing through each location, continuously throughout the year, and transmit the recorded data to the traffic monitoring computers at the Office of Information Technology (OIT) headquarters for electronic data processing (3).

2.3   Types of Data TMC Collects

DelDOT-TMC collects traffic data using both manual and automated methods (2). Manual counts are conducted using trained personnel and data collectors. Most studies of manual counts require small samples of data at any given location. Manual counts are sometimes used when the effort and expense of automated equipment are not justified or are not available. Automatic counts are collected using sensors,

detectors, and cameras. Examples of automated data include traffic, roadway weather, and hydrological conditions, (2).

In its 2017 coverage count program, out of the 3459 DelDOT's road segments, 86 links were operational, records continuous, accurate hour-by-hour traffic volume, processed and analyzed. The remaining 3373 links were estimated based on short-term traffic count. DelDOT conducts approximately 900 short-duration counts annually, mostly performed for a one-week period. About 300 counts are performed for a 48-hour duration (3).

According to DelDOT's website, Delaware travelers have much information available in various ways. DelDOT-TMC collects real-time traffic information, which contains live traffic video, travel time, travel advisories (incidents), travel restrictions and closures, traffic volume, roadway occupancy, delay, speed, classification, travel time, trip distribution and origin-destination (4). Real-time roadway weather data, which includes air temperature, barometric pressure, relative humidity, precipitation type and volume, pavement temperature as well as subsurface temperature are collected and disseminated through interactive maps (4).

Lastly, hydrological data, which includes stream and river depths, water velocity, and tide height, are also collected. To provide real-time data and store historical data, DelDOT installed a statewide network of flood monitoring equipment. Although TMC collects traffic and roadway weather data, Hydrological data is collected by the United States Geological Survey (USGS) on behalf of DelDOT (2).

2.4   DelDOT's TMC Data Collection Equipment

DelDOT-TMC uses various types of devices and tools to collect automated data, which includes both fixed and portable sites. These tools and devices, which are mostly used for incident detection including control, information, and monitoring, are discussed below (1):

- *Variable speed limit (VSL) sign* allows TMC to adjust the posted speed limit remotely. TMC uses these electronic signs to increase the traffic flow and reduce the risk of crashes due to congestion. Electronic signs are also used to provide information in support of incident management, construction activities, adverse environmental conditions, changes in traffic patterns, and special events.

- *Weigh Station* is used as a checkpoint along a highway. The purpose of a weight station is to inspect the weight of trucks and commercial vehicles. Weigh-in-motion technology is used to screen trucks for weight.

- *Traffic Signals* are responsible for controlling the flows of traffic. By monitoring traffic signals, TMC can adjust traffic patterns based on volume and speed data.

- *HAWK signals* are high-intensity beacons triggered by pedestrian requests at crosswalks to stop road traffic to allow pedestrians to cross safely.

- *Variable message signs (VMS)* display relevant information for Delaware commuters. Variable message signs are electronic traveler information signs are used to provide information in support of incident management, construction activities, adverse environmental conditions, and changes in traffic patterns and special events.

- *Dashboard cameras* are attached to vehicles to capture live video and still photos. The other type of cameras that DelDOT-TMC possesses are fixed video cameras, primarily used for monitoring traffic conditions and verifying roadway incidents such as Crashes, Disabled Vehicles, Construction, and Maintenance activity.

- *Computer-Aided Dispatch (CAD)* is centralized statewide control and management of the Computer Aided Dispatch (CAD) to CAD connections with County Emergency Operations Centers (EOCs) and State Police.

- *Signal System Loop Detectors* are responsible for collecting real-time data along signalized corridors. The primary purpose of these detectors is to provide current traffic volumes so that TMC can use it to determine signal-timings.

- *Microwave Detection (Wavetronix)* allows TMC to detect vehicles by lane, to classify vehicles by length and, to provide real-time traffic volume, speed, and delay (5).

- *Automatic Traffic Recorders (ATRs)* is used to measure volume, class, and speed. Automatic ATRs are installed in the road to electronically collect data such as measure count, classification, and speed. The data is then recorded in memory so that the information can be downloaded and viewed for further analysis.

- *Bluetooth detection* is set-up to detect signals that are being emitted from discoverable Bluetooth devices within vehicles as the vehicles pass the Bluetooth monitoring station. This technology is also used to obtain real-time travel information such as average travel times, travel speeds, and travel patterns.

- *Roadway Weather Information System (RWIS)* allows TMC to measure atmospheric pressure, pavement, and water level conditions. Water level conditions include air temperature, surface and subsurface temperature, dew temperature, relative humidity, wind direction, wind speed, wind gust, visibility, and precipitation.

- *Hydrology Monitoring System* is designed to monitor rainfall events. These are composed of a group of stations (gauges) that are arranged and operated to capture flooding and erosion.

DelDOT's coverage count program uses pneumatic rubber hoses to count axles, not vehicles (3).

2.5   Telecommunication and Software

Equipment, monitoring devices, software, and telecommunication are required to control, monitor and disseminate the massive amount of traffic data. Telecom is the crucial technology that DelDOT-TMC uses to provide large amounts of traffic and roadway weather data to the public, especially during severe incidents. DelDOT, Delaware's Department of Technology and Information (DTI), and Division of Communications (DivComm) have jointly created a state-owned telecommunications network (2).

Using this network, DelDOT is currently utilizing both hard-wire (fiber optics) and wireless connections to connect the TMC system to the field (2). Typical hardwire connections are achieved by using a single or multi-mode fiber optic cable, a twisted copper pair cable, or a T1 connection. A regular wireless connection is accomplished via CDMA signals, 4.9GHz, 800 MHz NextGen project and new telecom plans are also underway (4). Both hard-wire and wireless systems provide connectivity between the TMC system and the devices deployed in the field.

After data collection, TMC uses the following transportation database and software to analyze the collected raw data. TMC uses software such as traffic database (TransStat), internal user interface (Electronic Operations, EOPs), external user interface (Extranet), and an incident management system (Tracker) to collect, process, analyze, and distribute information to the public (2). Tracker is a data system that DelDOT uses to automate the validation process of construction and incident

information (2). As per DelDOT's publication (4), TMC uses the internal user

interface EOPs to monitor the traffic heartbeat (Figure 2.1).

Figure 2.1: EOPs Showing Traffic Data Trend

[Referenced from (4)]

DelDOT-TMC also plans to add more data to the Extranet website as they

become available so that external users can access more traffic counts. Unlike other

states' DOT, DelDOT owns all the software mentioned above and processes its

information to ensure accuracy and sustainability. Since DelDOT doesn't use a third

party vendor to modify software, the options of viewing, analyzing, and storing traffic

data are limitless (2).

2.6 Ways of Communication to The Public

After data is captured and processed, TMC disseminates real-time information allowing customers to make informed decisions regarding travel time and mode choice. Real-time monitoring is defined as the same time that condition occurs. DelDOT considers real-time to be within a 5-minute time frame (2). TMC uses real-time monitoring to provide customers traffic and roadway weather information using various websites, DelDOT smartphone app (the DelDOT Mobile App), traffic advisory radio, and social media sites.

2.6.1 Traffic and Roadway Weather Data from Various Websites

DelDOT's TMC uses multiple websites to disseminate traffic and roadway weather data to the public. These websites include DelDOT's website, TMC Extranet, TMC "data map" website, TMC "Weather Summary" website, travel advisory radio, and social media sites such as Twitter, Facebook, and YouTube. Using these websites, TMC provides access to travel advisories and live traffic cameras.

DelDOT's Public Website

The first website that TMC uses to provide traffic data on its interactive travel map is through the DelDOT's public website. DelDOT's website offers real-time traffic and roadway weather information to the public. The site allows users to access traffic travel information through interactive travel maps, real-time schedule of DART transit, real-time travel advisories, events (such as road closures, beach traffic, and

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special events), construction projects, news (including press release and traffic alerts), and workshops (6). It also allows users to report road issues to TMC, listens to live traffic advisory radio, which enables users to receive information hands-free, as well as provides the opportunity to access the social media sites through the website. DelDOT's public website also provides Interactive Google maps, which displays the location of traffic cameras, weather stations, and travel advisories, and road closures throughout the state of Delaware (6). Any form of data or information that is available on the DelDOT's public website is in PDF files (7).

TMC Extranet Website

DelDOT-TMC uses TMC Extranet website to provide downloadable and printable traffic counts to the public. On the site, two tabs provide count studies data and documents for various preparedness plans (9).

Under the "Count studies" tab, the current Extranet website (9) contains downloadable PDF files of historical traffic data and traffic counts dating back to 2006. The site allows users to access different traffic data categories such as turning movement counts, classification counts, travel time runs, tube data and radar data (Figure 2.2).

TMC Extranet website also provides evacuation maps and information for all types of incidents and hazards for each county. The "TMC Docs" tab includes preparedness plans include bridge closure, debris management, toll plaza,

transportation incident and event management, and all hazard evacuation to the public

all in PDF files (9).
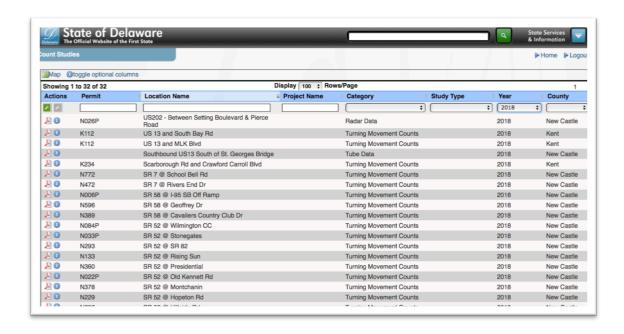
Figure 2.2:   TMC's Traffic Counts in PDF files

[Screenshot from (9)]

TMC "Data Map" Website

Another website that TMC has to provide traffic data is through TMC's "data

map" website (10). This website is not easily searchable by the public using regular

web surfing. This website provides the following real-time data (figure 2.3):

199 Waze Alerts;	28 Tracker Advisories;
112 Project Restrictions;	614 Traffic Flows;
298 Segments' Travel Time;	29 Weather Stations;

171 Traffic Cameras;   118 Transit Information & Schedule;

322 Snow Plow.
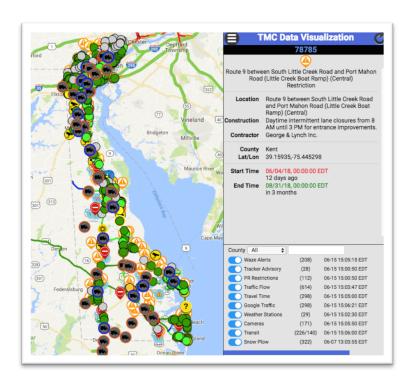
Figure 2.3:   Types of Traffic Data Provided on DelDOT's TMC Website

[Screenshot from (10)]

The TMC "data map" website (10) provides real-time traffic volume through the "TMC Data Visualization" tab. This data is provided for each location (latitude and longitude) and counties (Kent, Sussex and New Castle) within the state of Delaware (Figure 2.4).
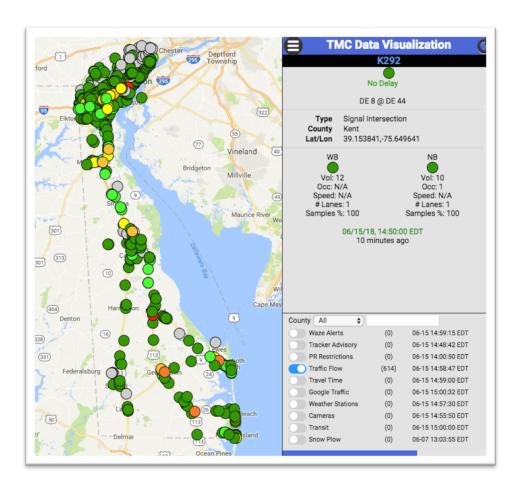
Figure 2.4:   Traffic Flow

[Screenshot from (10)]

The website also allows users to view real-time travel time between two points on any given segment of highway or street. It provides the base and current travel time side by side. The "TMC data visualization" window offers travel time of 298 possible road segments (Figure 2.5) (10).
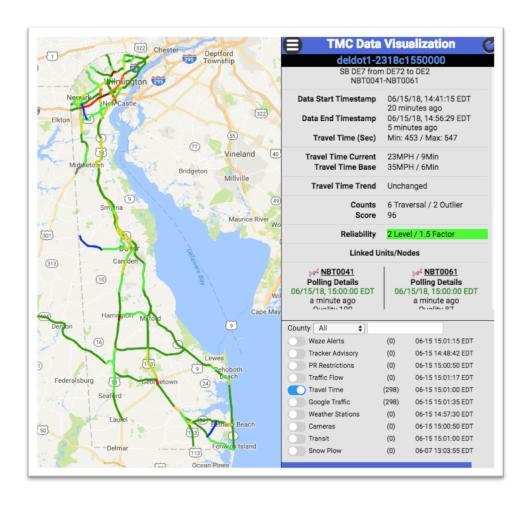
Figure 2.5:   Travel Time

[Screenshot from (10)]

The TMC "data map" website also provides users with access to live traffic cameras that are installed throughout the state's highway and intersections (10). The traffic cameras tab is a useful tool that allows the user to view real-time traffic flow as well as any incidents that may have occurred during that time (Figure 2.6).
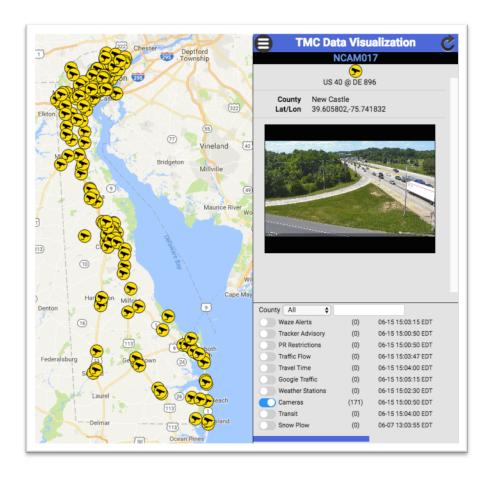
Figure 2.6:   Traffic Camera

[Screenshot from (10)]

      The TMC's "data map" website offers transit information such as DART bus schedules (10). It also informs the public about the bus number, the location of the bus stop, and the arrival time for each county (Figure 2.7).
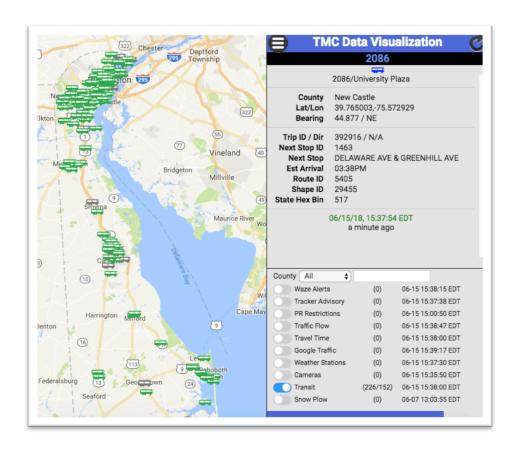
Figure 2.7:   DART Transit

[Screenshot from (10)]

TMC "Weather Summary" Website

In addition to traffic data, TMC also disseminates roadway weather data using its own "Weather Summary" website (11). In this website, a map-based weather monitoring system throughout Delaware is provided. As per the department's website, the current Delaware weather and weather advisories are generated from the National Oceanic and Atmospheric Administration (NOAA). However, the site is not visible to the public (11).

Grouping / Location	Sfc	Subsrf	Air	RH	Dew	Prcp	Visbity	Wind	Gusts	Direct
District - North	109°	88°	77°	33%	51°	0.0 iph	1.9 mi	6 mph	13 mph	
District - Canal	115°	85°	81°	33%	50°	0.0 iph	1.3 mi	8 mph	14 mph	
District - Central	110°	90°	77°	32%	51°	0.0 iph	3.1 mi	6 mph	9 mph	
District - South	117°	86°	79°	29%	52°	0.0 iph	1.1 mi	9 mph	14 mph	
State - Coastline	109°	82°	79°	30%	51°	0.0 iph	1.8 mi	7 mph	12 mph	
State - Center	113°	91°	78°	32%	51°	0.0 iph	2.5 mi	8 mph	12 mph	
State - Western Border	114°	91°	80°	36%	51°	0.0 iph	1.2 mi	6 mph	14 mph	

Figure 2.8:   Weather Stations Summaries

[Screenshot from (11) Table Format]

In this "weather summary" site, the "weather station summaries" tab allows users to access weather data by location (11). Users can expand each location to view all the detailed real-time weather data (Figure 2.8). The "weather stations" tab provides the different weather data that includes: surface and subsurface temperature, air temperature, relative humidity, dew temperature, precipitation, visibility, wind speed, wind gust, and wind direction (Figure 2.9). The "weather charts" tab provides real-time weather information using (Time Vs. Weather Data) charts for each weather station (Figure 2.10).

Figure 2.9:   Weather Stations
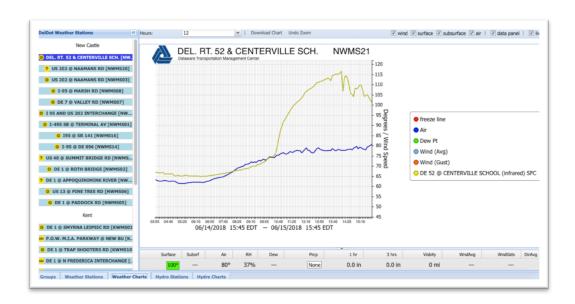
Figure 2.10: Weather Data Vs. Time

[Screenshot from (11) Charts]

The "hydro stations" tab has eleven hydro stations including 9 in Sussex

County, 1 in Kent and 1 in New Castle (11). These stations provide real-time water

level data (in feet) versus the time in which the data was collected (Figure 2.11). The

last tab offers users with a chart of the hydro data for the eleven stations (Figure 2.12).

Location	County	Permit	Feet	Level @ Time	Battery @ Time	Survey Ft
RED CLAY CREEK @ TRIB	New Castle	NWMS17	16.34	+16' 4 1/12" @ 06/15/18 15:44 EDT	13.3v @ 06/15/18 10:19 EDT	n/a
US 13 SOUTH @ GARRISONS LAKE	Kent	KWMS14	5.89	+5' 10 2/3" @ 06/15/18 15:38 EDT	13.3v @ 06/15/18 14:53 EDT	n/a
CEDAR CREEK @ SLAUGHTER BEACH	Sussex	SWMS29	-0.86	-0' 10 1/3" @ 06/15/18 15:43 EDT	14.1v @ 06/15/18 12:07 EDT	n/a
HAVEN LAKE @ US 113 SOUTH	Sussex	SWMS13	14.04	+14' 0 1/2" @ 06/15/18 15:19 EDT	13.4v @ 06/15/18 15:19 EDT	n/a
REHOBOTH BAY @ DEWEY BEACH	Sussex	SWMS14	0.22	+0' 2 7/11" @ 06/15/18 15:45 EDT	13.9v @ 06/15/18 12:51 EDT	n/a
HEARNS POND @ RD 544 B	Sussex	SWMS12	24.96	+24' 11 1/2" @ 06/15/18 15:38 EDT	13.7v @ 06/15/18 13:23 EDT	n/a
INDIAN RIVER INLET @ INLET RD	Sussex	SWMS15	-1.63	-1' 7 5/9" @ 06/15/18 15:45 EDT	14.0v @ 06/15/18 11:09 EDT	n/a
INDIAN RIVER @ ROSEDALE BEACH	Sussex	SWMS16	-0.05	-0' 0 3/5" @ 06/15/18 15:42 EDT	13.3v @ 06/15/18 12:18 EDT	n/a
VINES CREEK RD @ VINES CREEK	Sussex	SWMS17	-0.56	-0' 6 5/7" @ 06/15/18 15:42 EDT	13.8v @ 06/15/18 11:32 EDT	n/a
FRED HUDSON RD @ UNNAMED DITCH	Sussex	SWMS18	0.35	+0' 4 1/5" @ 06/15/18 15:30 EDT	13.7v @ 06/15/18 10:12 EDT	n/a
LITTLE ASSAWOMAN BAY @ MADISON	Sussex	SWMS19	0.28	+0' 3 4/11" @ 06/15/18 15:47 EDT	13.8v @ 06/15/18 09:23 EDT	n/a

Figure 2.11:   Hydro Stations
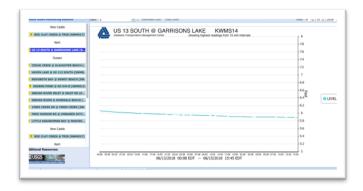
Figure 2.12:   Hydro Chart

[Screenshot from (11) Level of Water Vs. Time]

2.6.2 Smartphone Application (DelDOT Mobile App)

TMC administers the DelDOT smartphone application (DelDOT Mobile App), which is a breakthrough to optimize DelDOT's access to the public. The DelDOT Mobile App can be used throughout an entire multimodal trip to provide information for drivers, transit riders, and pedestrians (1).

DelDOT Mobile App provides real-time traffic and roadway weather information to the public (13). The application allows users to access traffic travel information through interactive travel map, real-time bus schedule of DART transit, real-time travel advisories, events (such as road closures, beach traffic, and special events), construction projects, news (including press releases and traffic alerts), and workshops. It also allows users to report roadway condition such as traffic, potholes, debris, streetlights and other road issues to TMC. The Mobile App allows listening to live traffic advisory radio with one-touch activation for hands-free access to traffic information, as well as provides the opportunity to access the social media pages (Figure 2.13). Also, through a new partnership, DelDOT and Waze exchange traffic data, which allows public who use Waze to report incidents and traffic slow-downs.
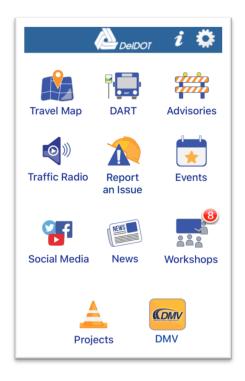
Figure 2.13: DelDOT Mobile App Homepage

[Screenshot from the App Homepage]

The DelDOT Mobile App provides travel map (figure 2.14) to users so they

can be informed on the latest traffic and roadway weather information before starting a

trip. The interactive travel map includes:

- View streaming traffic cameras;
- Advisories for accidents, other incidents;
- Travel delays;
- Average speeds;
- Virtual travel times;
- Lane restrictions and road closures;
- Variable message signs;
- Variable speed limit signs;
- Red light enforcement cameras;

- Roadway weather;
- Snow plows and snow accumulations;
- Woodland ferry information.

DelDOT Mobile App provides real-time traffic information on the interactive travel map; doesn't offer historical and real-time downloadable data. It furnishes the following real-time travel information:

- Status (Delay);
- Average speed;
- Volume (5-minute volume, 5-minutes maximum, 1-hour, projected 1-hr. and 1-hour maximum;
- Roadway occupancy;
- Volume and Sample size.

Figure 2.14: Travel Map Information on DelDOT Mobile App

[Screenshot from the App Travel Information Page]

2.6.3 Traffic Data From 1380 AM Radio

Through DelDOT's designated AM radio frequency (WTMC 1380 AM), TMC broadcasts traffic advisory radio to update travelers on roadway and transit conditions (13). The WTMC 1380 AM radio station is a service of the Delaware Department of Transportation broadcasting located near the city of Wilmington, Delaware and there are eleven repeater sites throughout the state. In addition to the radio itself, this travel advisory communication can also be accessed through the DelDOT Mobile App. As a means of advertisement, signs are often posted to inform motorists to tune in to the radio station for any traffic advisories.

The traffic advisory radio station provides users with daily real-time traffic information, weekly construction information, transit information, and public workshop announcements.

2.6.4 Traffic Information Through Social Media

Social media sites such as Twitter, Facebook, YouTube, Flickr, and Blog have also become other methods that DelDOT-TMC uses to disseminate traffic information (15). Users can access the DelDOT's social media sites either directly from the DelDOT Mobile App or by going to the department's social media accounts. DelDOT informs and updates the public through social media by posting travel advisories to let Delawarean's know the current traffic conditions so they can make better and well-informed decision before heading out on the road.

2.7   DelDOT's TMC Duties When Incidents Occur

According to publications available on TMC's Extranet website, TMC is also responsible for emergency management planning such as bridge closure plans, debris management plans, toll plaza plans, transportation incidents and events management plan, and all hazard evacuation plans. A PowerPoint presentation prepared by DelDOT presents the three critical functions that TMC performs monitoring, controlling and providing information to manage the state's transportation system efficiency (15).

One of the job duties of a TMC staff is to provide an all-day monitoring system of the transportation system. When accidents or delays occur, TMC staffs are responsible for ensuring safety for drivers through traffic control. To maintain traffic safety, TMC staff works with responders to manage lanes, provide variable speed limit signs, and monitor digital traffic signals.

According to DelDOT's publications, TMC coordinates the planning and management of DelDOT's response to daily incidents and events, which include accidents, disabled vehicles, debris in roadways, planned and emergency construction, traffic signal complaints, missing or damaged signs, traffic operation complaints (4). Also, TMC is responsible for coordinating the planning and management of DelDOT's response to natural disasters such as snow and ice storms, hurricanes, nor'easters, HAZMAT incidents, radiological incidents, weapons of mass destruction and other disasters (4).

2.8   Technology

DelDOT is responsible for nearly all traffic signals in the state. Majority of Delaware's highly traveled roadways contain intersections controlled by traffic signals (2). As a result of incidents and evacuations, traffic signals can play an important role in accommodating larger than average volumes of traffic due to traffic diversions. Computerized traffic signal system is vital when doing simple tasks such as changing signal timings whenever necessary. It also comes in handy when a transportation manager is required to help traffic during a special event or incident (2).

Although a computerized traffic signal system is very vital to the transportation industry, all traffic signals are not in the system. The system has become one of the state's most important goals that have been set by transportation managers in DelDOT's TMC. Having all traffic signals in the system means those transportation managers in TMC can control the signal settings from their location in Smyrna rather than making the adjustments in the field.

The future hope of Delaware is to have all corridors (logical groupings of traffic signals) in traffic responsive operation, and that eventually means that the computer system will automatically adjust the signal system timings parameters to changes in traffic demand. TACTICS is DelDOT's cutting-edge signal software system, and it can automatically adjust signal system timings parameters to changes in traffic demand (2). The traffic signal system has become one of the most crucial

control systems for the state of Delaware, and DelDOT needs to continue investing in all aspects of enhancement, maintenance, and operations.

2.9   Chapter Summary

Since 2002, DelDOT created a full-time TMC with the purpose of disseminating accurate real-time traffic data to Delaware roadway users. Within the state of Delaware, TMC is currently responsible for coordinating and managing DelDOT's response to any incidents or events that affect the multimodal transportation system. DelDOT disseminates presently travel information on construction activity, incidents, roadway weather and travel time on its website.

When collecting data, DelDOT-TMC uses both the manual and automated methods. Once the data is captured, TMC uses state-owned telecommunications system to monitor, control, and disseminate vast amounts of real-time traffic and roadway weather data to the public, especially during severe incidents. To provide traffic and roadway weather information to the public, TMC uses various methods such as DelDOT's public website, TMC Extranet website, TMC data map website, TMC Weather Summary website, travel advisory radio, and social media.

The traffic data presentation formats are either interactive map through the DelDOT's Public website and the DelDOT Mobile App or PDF files on the TMC Extranet website. Other forms of data presentation styles such as MS Excel, MS word, Shapefile, Tables, and Charts are not options from DelDOT-TMC. Along with providing traffic and roadway weather data, TMC is responsible for ensuring safety

for drivers through traffic signals and traffic control when any delay, accidents, or natural disasters such as snow occurs.

Chapter 3

EXAMPLES FROM SELECTED STATES

3.1   Introduction to the Selected States

As an example, this thesis examines and presents selected states' methods and

formats of data presentation to their intended users on the web. It also discusses the

type of products that are disseminated by states that are similar in size to Delaware

such as Vermont and Connecticut, and neighboring states such as New Jersey and

Pennsylvania. Also, this chapter discusses three different states that are larger in size

to Delaware, which is the state of California, Texas, and Virginia.

3.2   Similar Size States

This section examines the data presentation methods and data types of two

states; Vermont and Connecticut. More specifically, this paper will explore how these

states provide traffic data to the intended users. These two states are selected due to

their similarity in size to the state of Delaware.

3.2.1   Vermont Agency of Transportation

As a traffic data management system, Vermont Agency of Transportation

(VTrans) disseminates various types of traffic data through its web-based interactive

map website. This website uses Transportation Data Management System, also known

as TDMS. This system is helpful to users for viewing and downloading traffic count

data including traffic volume, vehicle classification, vehicles speeds and vehicle weights (18).

An AADT report for each traffic segment along any route is the famous report. The routes are divided into three reports, which are interstate, US routes, and VT state highways (18). The reports are updated by VTrans every three years. Local roads are not included in the Route Log AADT reports, however; VTrans has a program in place to conduct a limited number of traffic counts on local roads (18). These counts and their associated AADTs may be found on the web-based TDMS. The TDMS defaults to the as Traffic Count Database System (TCDS) module. The other modules are shown across the top of the page; TMC, TCLS, TTDS, and others. As shown in figure 3.1 below, the only two modules currently available to the public are the TCDS and TMC (Turning Movement Count) modules.

Figure 3.1:   Modules Available from VTrans (TCDS and TMC)

Figure 3.2 below provides a two-screen database, which allows users to browse the location and its associated traffic data. The two screens allow users to search for

traffic data; the left side of the screen is referred to as the Form View, and the right

side is the map screen.
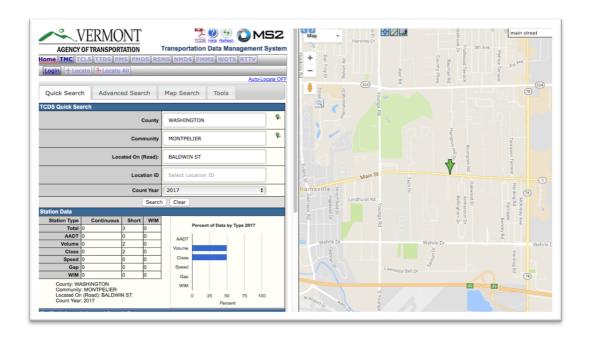
Figure 3.2:   VTrans' TDMS Homepage Screens

[Screenshot from VTrans' Website]

The TCDS module provides users with access to the automatic traffic recorder

(ATR) count including both continuous and short-term counts. VTrans counts offer a

historical count data that dates back to the late 1990s. The TMC module is where users

will find VTrans turning movement counts going back to 2008. VTrans requires users

to log in to the system to have access to more reports or graphs.

The process of storing count data in TCDS involves collecting, uploading, and

verifying count data quality as well as assigning count data to count/specific locations.

The TCDS is a powerful tool for traffic engineers or planners to organize an agency's traffic count data. It allows users to upload data from a traffic counter; view graphs, lists and reports of historical traffic count data; search for count data using either the database or the Google map; and print or export data to their computer.

From the Homepage, users can perform such TCDS tasks/ have the ability to add new locations, upload counts, search for existing counts, edit or delete existing counts, generate reports and graphs. The TCDS Homepage provides Quick Search (figure 3.3), Advanced Search, Map Search, and Tools (including Build Search and SQL Query Builder). These search tools allow users to find the TCDS Stations (also called Locations or Locals) and counts users are interested in from among all the count data processed over the years.
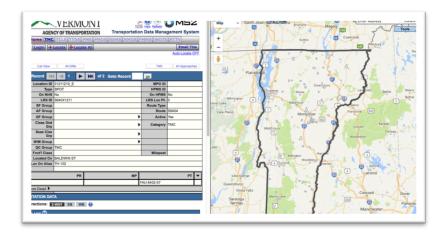
Figure 3.3:   Quick Searching for Data or Record, VTrans TCDS

Users can also search traffic data using the map side of the screen to the TCDS information. The Google map integrated into the right side of the TCDS screen provides users with a geographic interface to access their count information. Users can then pull up count location details from the map.

Users must be logged in to "MS2" to access the "Report Center." When users log in, the system defaults to the TCDS Module (19). The user can scroll down to the "Volume Count" block to view the dates of the count. Users should click the "Output" tab to check if the report is what the users require. If so, clicking on the drop-down menu by the disk symbol allows users to choose the type of presentation format they wish to print or download the report such as Comma-Separated Values (CSV), Portable Document Format (PDF), MS Excel, and Tagged Image File Format (TIFF) (19).

To find a specific intersection in the TMC module, users can navigate to it on the map, or look up the 8-character ID in the Turning Movement Listing Report and enter it in the "INT ID" field. If users choose the 8-character ID to search for an intersection, they can then click search, and this will bring up the Intersection Data, Notes/Files, and TMC Counts. At the top of the turning movement count data page, users can choose to print a variety of reports in PDF file or MS Excel format. Report options are highlighted in blue, and it includes reports on the following: Cars (only), Trucks (only), Cars & Trucks (both included but separated on the report), and Cars + Trucks (both included but combined on the report) (19).

The Annual Average Daily Traffic (AADT) history for each traffic count location can be reported and provided in MS Excel. Many traffic counts capture vehicle classification as well as the volume of vehicles. Functional and vehicle classification reports offer the most recent summary for each count location in PDF and MS Excel format (19).

The New England 511 website provides a map with real-time traffic information for three states including New Hampshire, Maine, and Vermont (20). As shown in figure 3.4 below, the map provides information regarding traffic incident, roadwork, future events, traffic speeds, special events, traffic cameras, weather stations, driving conditions, and message signs of each state.
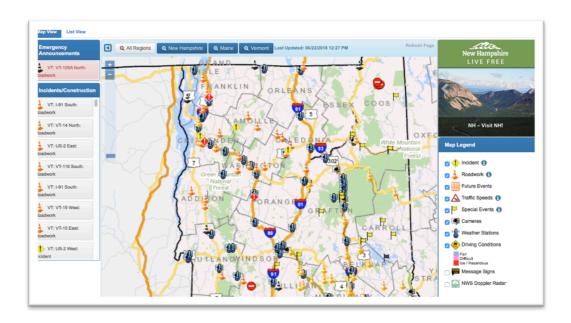
Figure 3.4:   Vermont Traffic Information, New England 511

VTrans provides a data website that is open to the public through "VTransparency Public Information Portal." The portal provides information and data on projects map, road conditions, plow finder, weather cameras, maintenance districts, crash fatality report, crash query tool, daily traffic volumes, highway closures, bridge inspections, pavement conditions and performance, maintenance work, rail asset inventory, and open data portal. The free data portal allows users to download raw data for the transportation-related and other data set of the state of Vermont to do their analysis (21).

Vermont Agency of Transportation also uses social media such as Twitter, Facebook, YouTube and Flickr to provide additional traffic information. For instance, the state uses "511VT Twitter" site to offer travel reports from VTrans Transportation Management Center during business hours (21).

3.2.2 Connecticut Department of Transportation

Connecticut Department of Transportation (CTDOT) counts all of its state-maintained roadways once every three years to determine the average daily traffic (ADT) of the roadway. Counters are placed across the roadways for 24-hours to record the daily traffic and the hourly traffic breakdown. According to the department's website, for expressways, counters are set on the ramps, and mainline volumes are calculated from known controls on the mainline (22). The state also uses Portable traffic recorders take counts with tubes laid across the pavement. This equipment automatically records the vehicles as they pass over the tubes. In the state, an average

of 5000 counts is taken for this purpose each year. Coverage counts provide a broader picture of growth and traffic changes on Connecticut's roadway system (22).

The state provides ADT maps for traffic volumes at specific locations in PDF format through the department's website with various sizes. This ADT interactive map to permanent count stations includes traffic data in Microsoft Excel spreadsheet for each station (22). Figure 3.5 shows the interactive map with its available traffic data for multiple years.
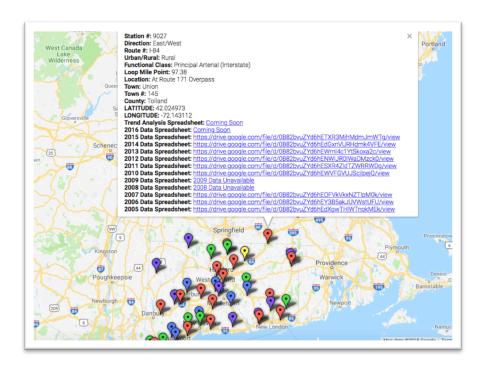
Figure 3.5:   Available ADT Data for Different Years

[Screenshot from CTDOT website]

Users are allowed to select the station that they want to view. Clicking on one of the links that the users wish to download allows accessing the MS Excel spreadsheet version of the ADT data. Once downloading the file and opens the spreadsheet, clicking "enable editing" permits users to manipulate the data further. After enabling the workbook editing, users will be allowed to use the drop down features. Figure 3.6 below shows the introductory worksheet in the spreadsheet, which provides information about the selected continuous count station. This specific worksheet contains links to other sheets within the workbook (22).
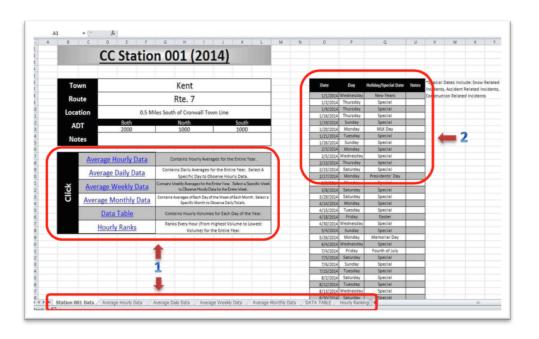
Figure 3.6:   Summary of Average Traffic Data

[Referenced from Permanent Count Station Spreadsheet Tutorial (ct.gov) That Shows Hourly, Daily, Weekly, & Monthly Traffic Data]

Selecting a link from the introductory worksheet allows users to gain access to other sheets within the workbook. Each continuous count station spreadsheet contains the following worksheets:

- *Average Hourly Data*: contains the average traffic count for each hour of the day.

- *Average Daily Data*: contains the average total traffic for each day of the week, the daily totals for the entire year, and a drop-down feature that allows users to view any day's hourly volumes.

- *Average Weekly Data*: contains the average weekday, weekend, and daily traffic for each week of the year. This worksheet also contains a drop-down feature that allows users to view the hourly volumes for each day of the selected week.

- *Average Monthly Data*: contains the average volume for each day of the week, average weekday, average weekend, and average daily volume for each month of the year. This worksheet also contains a drop-down feature that allows users to view the daily totals for each month, as well as a monthly report that displays a breakdown for each day of the week for the selected month.

- *Data Table*: contains the data for each hour of each day of the year.

- *Hourly Ranks*: ranks each hour of the year from highest volume to lowest volume.

In this workbook, the first worksheet provides the average volume for each hour of the day. As per the Excel user's guide, each volume for the selected hour of the day for the entire year is averaged. The chart below (Figure 3.7) shows how many times that particular hour was counted during the year and the average volume for the peak hour.
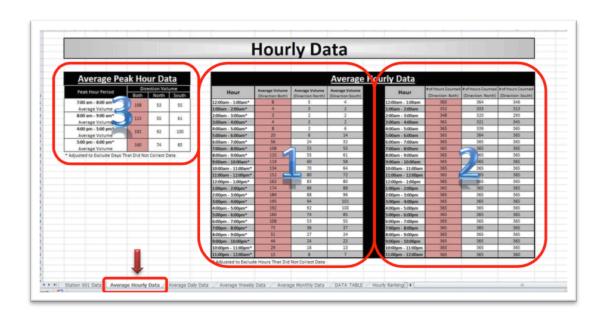
Figure 3.7:   Average Hourly Volume in MS Excel

[Referenced from Permanent Count Station Spreadsheet Tutorial (ct.gov)]

The average daily data is given in the spreadsheet on the second worksheet. This feature is a drop down bar that allows users to view any day of the year. Upon selecting the desired day, the corresponding data will be displayed in these charts. Figure 3.8 below shows that choosing the day that users wish to view in the drop down bar under chart-1 displays the required data on the other charts from 2 to 6.
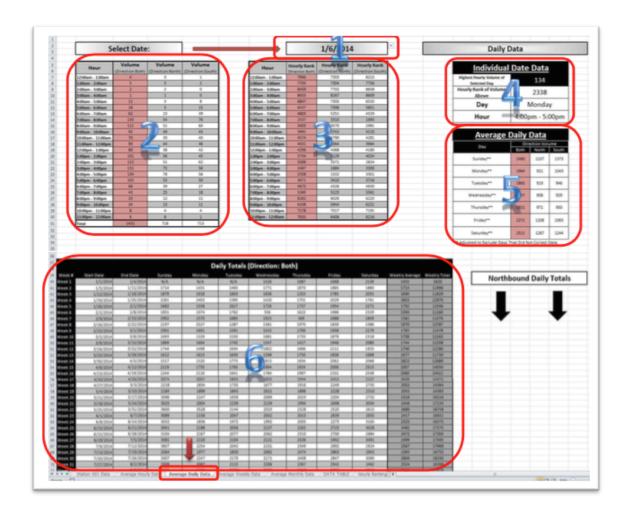
Figure 3.8:   Average Daily Data in MS Excel

[Referenced from Permanent Count Station Spreadsheet Tutorial (ct.gov)]

The workbook also provides users with the average weekly and monthly data but in different worksheets. Furthermore, the website offers historical ADT data in PDF format and zipped files from the year 2000 to 2014 (22).

In addition to ADT, CTDOT disseminates vehicle classification reports. These reports are grouped by year (from 1995 to 2013) and can be viewed by direction

(North/South and East/West) or as a combined report. To see these reports click on a year, town, and then the station of interest. According to ct.gov, Vehicle classification data is collected to determine the breakdown of the types of vehicles that are on the roads. Vehicles are stratified into 13 categories ranging from motorcycles, passenger cars, buses, trailer trucks, and all the way up to multi trailers. Vehicle classification data is collected at 100 locations, and this classification allows the development of factors to estimate vehicle classification data by roadway type and traffic volume (22).

CTDOT also offers "CT Travel Smart" website which provides users with real-time and personalized travel information (figure 3.9). Users can also access vital information such as incidents, travel speeds, cameras, roadwork, message signs, weather alerts, and weather forecasts. Under the "Travel Resources" tab, users are provided with real-time information from traffic cameras, travel information map, traffic incidents, travel times, public transportation, and others (23).

Figure 3.9:   CT Travel Smart Website

CTDOT also uses traffic and travel mobile apps to disseminate traffic information. The different apps that are offered and recommended by the CTDOT include Google maps, Waze, Transit App, Roadify, RoadAhead, INRIX Traffic, iTrans Metro-North and Amtrak. However, the site restricts users not to use these apps while driving for safety purposes (24). CTDOT provides more real-time traffic information through social media sites such as Twitter and Facebook.

3.3 Neighboring States

Along with the states mentioned above, the thesis also examines two neighboring states; New Jersey and Pennsylvania. This section will provide the type of data that are disseminated and formats of data presentation to their intended users.

3.3.1 New Jersey Department of Transportation

New Jersey Department of Transportation (NJDOT) provides traffic data to the intended users through their website. The types of data that are disseminated include traffic volume counts, vehicle classification, speed, truck weight, vehicle miles traveled, and highway functional classification. The roadway data sources that NJDOT uses are Functional Classification Maps, National Highway System (NHS), Public Roadway Mileage (HPMS), and Vehicle Miles Traveled (VMT) (25).

The National Highway System (NHS) consists of a network comprised of strategic highways within the United States, including the Interstate Highway System

and other roads serving major airports, ports, rail or truck terminals, railway stations, pipeline terminals, defense and mobility and other strategic transport facilities (25).

NJDOT also offers two new features on the Internet through Straight Line Diagrams (Automated Straight Line Diagrams and Roadway VideoLog). As per the state's website, the Automated Straight Line Diagrams allows users to customize pages and change the attributes that are displayed on the page. It shows a wider variety of data that is not posted on the traditional Straight Line Diagrams, which is currently provided in PDF. The Roadway VideoLog provides users with a windshield perspective of New Jersey's roadways, which are arranged in a slideshow format using digital imagery of all State, Toll Authority, and County roadways (25).

According to NJDOT public website, the state maintains a traffic monitoring program consisting of continuous and short-term elements. The traffic counting program is designed to utilize 48-hour short-term counts to produce estimates of Annual Average Daily Traffic (AADT). Traffic Counts are taken in all type of public roads statewide locations including 6,000 Short-Term (48-hour) Count sites, 90 permanent Weigh-in-Motion (WIM) system sites and, 95 Traffic Volume System (TVS) site. The state of New Jersey DOT has 50 major counting or classification sites (25).

To search traffic count reports, users can access the state's database website and view its Traffic Monitoring System Map (TMSM). The system provides users with traffic data such as weigh-in-motion, 48hrs volume, 48hrs classification, intersection count, seven days volume, continuous volume, and data for a ramp (25).

Figure 3.10 shows TMSM with data representation and a description of each data, which are discussed below (25):

- *AADT*: Annual Average Daily Traffic;

- *Classification 48hrs*: Vehicles are counted and classified for 48-hour period in accordance with the Federal Highway Administration classification scheme described in the Traffic Monitoring Guide;

- *Volume 48hrs*: Vehicles are counted for a 48-hour period;

- *Volume 7 days*: Vehicles are counted for a 7-day period;

- *Continuous Volume*: This type of station counts the number of vehicles hourly, 365 days/year;

- *Weigh-in-Motion*: (WIM) station captures the volume, classification, and weights of vehicles 365 days/year; Intersection Count: It is a turning movement counts to analyze traffic flows at intersections. A typical turning movement count will include AM (7 am to 9 am), Noon (11 am to 1 pm) and PM (4 pm to 6 pm) peak counts;

- *Ramps:* Vehicles are counted for 48-hour period on Interstate and State Routes.
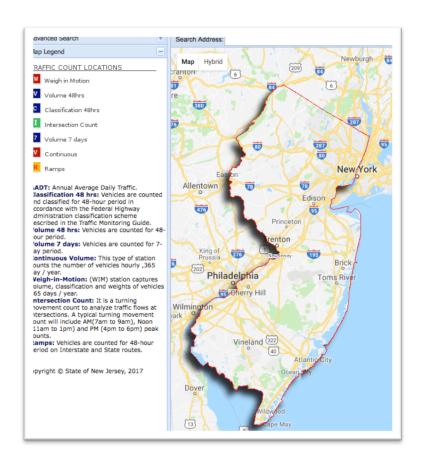
Figure 3.10: NJDOT's Traffic Monitoring System Map

[Screenshot from the NJDOT TMSM]

The website also allows users to obtain traffic counts for single or multiple locations by either printing or downloading the data. For instance, to access the functional classification map (figure 3.11) and National Highway System map files, users should first select a county on the state's image map (25).

Figure 3.11:   NJDOT's Functional Classification Maps

[Referenced from the NJDOT Website]

The Weigh-in-Motion (WIM) program for the NJDOT is maintained by the Bureau of Transportation Data & Safety. The WIM sites are set up to collect traffic data such as volume, classification, speed, and weight using in-pavement sensors. WIM devices are designed to capture and record axle weights, and gross vehicle weights as vehicles drive over a measurement site. As per NJDOT public website, the WIM systems are capable of measuring vehicles traveling at a reduced or normal traffic speed without requiring the vehicle to come to a full stop, unlike static scales (25).

Daily WIM data can be viewed or downloaded from the website. Users are allowed to navigate the data by day or month. Figure 3.12 shows daily data using charts that can be extracted from the WIM data. Users can select the month and year on the top left of the page to export the WIM data that they wish to acquire (25).
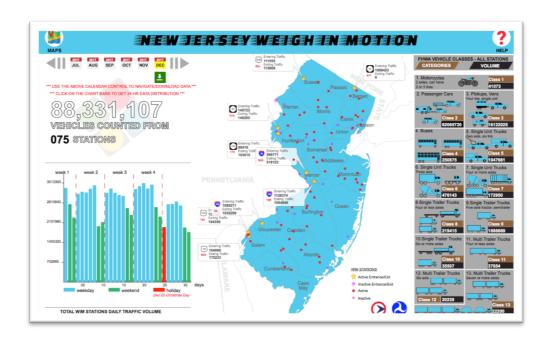
Figure 3.12:   NJDOT's Weigh-In-Motion Data Source

[Screenshot from the NJDOT WIM Data Source]

The New Jersey Department of Transportation's Geographic Information System (GIS) also consists of many transportation information including accidents, construction, congestion, road inventories, pavements, and safety, used to produce maps that support the department's work in planning, highway, rail, aviation and

maritime. Users of these applications can locate areas of interest, view and interact with NJDOT's GIS data, and query related to transportation data (25).

In addition to its public website, NJDOT uses interactive map through "511nj.org" site to provide real-time travel information such as live traffic speed, weather, traffic incidents, congestion, detour, construction, special events, and traffic cameras (26). NJDOT also uses social media sites such as Facebook, Twitter, YouTube, Instagram, and ReadyNJ Blog to provide additional travel and traffic information to the public.

Along with social media, NJDOT uses a smartphone app called "SafeTripNJ" to implement traffic data. The smartphone app provides real-time, hands-free traffic advisories for every major highway, bridge, and tunnel within the state of New Jersey. Users turn on the application before they start their trip and the app uses their phone's built-in GPS and the extensive data in the New Jersey 511 travel information system to determine when users are approaching traffic disruptions. When there is an incident nearby, SafeTripNJ broadcasts an advisory. Drivers are not required to read, click, or scroll through the app. By default, the app broadcasts advisories within a 10-mile radius, but users have the option to alter the range to their preferred distance. SafeTrip will automatically repeat advisories every 30 minutes while drivers remain within the scope of the incident, but users can change the setting as well (26).

3.3.2 Pennsylvania Department of Transportation

Pennsylvania Department of Transportation (PennDOT) monitors traffic
information, facilitates safe traffic counting cross the state, provides traffic and
Geographic Information Systems resources for partners and stakeholders, and much
more (27). Through its website, PennDOT disseminates highway statistics in PDF
format. Pennsylvania Highway Statistics is annually updated to summarize a variety of
highway mileage and travel information within the state. Most of the data is derived
from the Highway Performance Monitoring System (HPMS) and reflects the travel
activity and highway conditions of the entire state. PennDOT continuously improves
its annual report as a service to the public (27).

For instance, as per the 2016 Pennsylvania traffic data, the state collects traffic
data on 40,000 miles of PennDOT owned roads and 3,500 miles of local federal aid
roads in Pennsylvania. Approximately 10,000 raw traffic counts are harvested per year
(27). PennDOT collects the following data:

- *Volume:* The majority of the counts taken as part of our statewide count
  program record volume of traffic on a roadway. Volume is usually expressed
  as Annual Average Daily Traffic, (AADT) which represents traffic volume
  over an average 24-hour period.

- *Classification:* One method of data collection used for PennDOT count
  program is vehicle classification. Vehicles are classified into 13 classes
  ranging from cars to trucks in accordance with the Federal Highway
  Administration vehicle classification scheme.

- *Weight:* Truck weight data is collected from WIM stations.

- *Speed:* Speed data is collected from permanent traffic recorders.

PennDOT's traffic data collection sources include:

- *Automatic Traffic Recorders (ATRs):* 35 ATRs strategically located throughout the state count volume and speed data on a continuous basis 365 days per year.

- *Short-Term In-Pavement Sites (STIP):* Approximately 163 inductive loop sites, referred to as STIP sites are installed throughout the state of Pennsylvania. Volume data is collected from these permanent sites for a 24- hour period.

- *Continuous Automatic Vehicle Classifier (CAVC):* 56 CAVC sites collect continuous vehicle classification data.

- *Weigh-In-Motion (WIM):* 17 WIM stations provide continuous truck weight and vehicle classification data.

- *Pneumatic Tubes:* The majority of the counts are collected using pneumatic tubes. Axle counts are collected using a traffic counting device in association with a single pneumatic tube stretched across the roadway. An axle correction factor is applied to adjust vehicle axle base data for the incidence of vehicles with more than two axles. Two tubes are used to count and classify vehicles by type based on axle configuration.

- *Manual Counts:* are taken on sections of roadways that are not accessible to automated data collection equipment or have safety limitations. Observers classify vehicles by type based on axle configuration.

- *Toll Receipts:* The Delaware River Joint Toll Bridge Commission and the Delaware River Port Authority document traffic between Pennsylvania and New Jersey. The Pennsylvania Turnpike Commission toll receipt surveys provide data on the Commonwealth's toll roads.

According to 2016 Pennsylvania traffic data (Permanent Sites); the state maintains permanent traffic recorders of 108 strategically selected locations throughout the state. These permanent sites collect traffic volume data on a continuous basis throughout the year. This data is used to develop daily and seasonal factors, and it was also used to identify changes in traffic patterns. Based on a research study performed by Pennsylvania State University and West Virginia University, it was

determined that PennDOT locations in the traffic pattern groups were acceptable according to the FHWA Traffic Monitoring Guide (27).

The permanent sites use magnetic loops embedded in the pavement for vehicle detection. Additionally, CAVC sites utilize piezoelectric sensors for vehicle classification, and WIM sites use LineasTM quartz sensors to obtain vehicle weight. The data is stored on-site in traffic counters, before being automatically polled every night through the use of modems located at each permanent site.

PennDOT provides traffic data by state, county, and district. Mileage and Travel data for the entire year, selected routes, Federal aid/ Non-Federal aid system, and for the total system are provided for both statewide and county measure. The website also offers mileage and travel for Rural, Small Urban, and Urbanized Areas separately. Another type of traffic data that the state disseminates is Travel by vehicle type and highway classification (28).

PA highway statistics for Functional Classification (2016) states how the state classifies the highway system in the state. The Interstate System (A) is the highest classification of arterial roads and streets and provides the highest level of mobility, at the highest speed, for a long uninterrupted distance. Arterials (B and C), Collectors (D) and local roads and streets (E) are the other classifications (27).

National Highway System (NHS) and County Functional Class Maps with the list of each county to choose from are provided in the states' database.
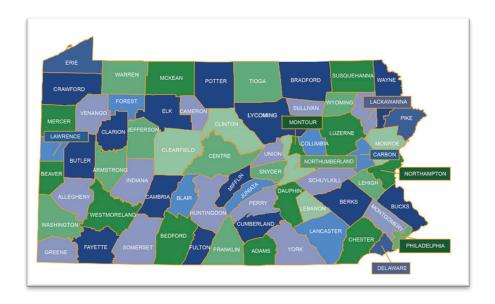
Figure 3.13: PennDOT County Functional Class and NHS Maps

[Screenshot from the PennDOT NHS Maps]

On the website, traffic data reports from 2012 to 2016 are provided in PDF formats. Users are reminded that the data contained in this PDF format is to be used only for traffic counts and not for future projected growth (28).

PennDOT uses "511PA Travel Info" website to provide real-time traffic information to the public. The site shows information such as traffic incident, speed, construction, traffic cameras, weather stations, weather forecast, weather alerts, and special events (29).

The Pennsylvania DOT also uses a free "511PA Travel Info to Go" smartphone application to provide real-time traffic information. 511PA offers real-time, hands-free traffic advisories for every PennDOT roadway in the state, and for essential roads in neighboring states of NJ and WV. The app uses users phone's built-

in GPS and extensive data in PA, NJ, and WV travel information system to determine

when users are approaching congestion, an accident scene or some other disruption.

When there is an incident or slowdown nearby, 511PA broadcasts an advisory.

Users are not required to read, click, or scroll through the application to obtain

incident information. Users can also customize their alerts by type, distance, and

frequency based on their location (29). PennDOT also updates the public through

social media sites such as Facebook, Twitter, YouTube, and Instagram.

3.4 Larger States

States such as California, Texas, and Virginia are much larger in size than

Delaware. The traffic data type and sources for disseminating information from these

three different states will be examined.

3.4.1 California Department of Transportation

California Department of Transportation (Caltrans) obtains traffic data from

the Caltrans Performance Measurement System (PeMS). The PeMS is a software tool

designed specifically for the California Department of Transportation and was started

in 1999 as a university research project. Now it is deployed statewide across

California and serves as the centralized source for all of Caltrans' real-time traffic

data. PeMS utilizes a web-based interface that allows anyone with an Internet

connection and a standard web browser to access the system (30). According to the

Caltrans' public website, users are required to establish an online account through the

PeMS Homepage at http://pems.dot.ca.gov to download the data they need in different formats without charge (30). PeMS data source enables easy access to real-time traffic data that might otherwise be dispersed across multiple districts and more difficult to obtain. It provides a consolidated database of traffic data collected by Caltrans placed on state highways throughout California, as well as other Caltrans and partner agency data sets (31).

PeMS provides access to real-time and historical performance data in many useful formats and presentation styles such as MS Word, MS Excel, Portable Document Format (PDF), charts, and tables to the public. The presentation formats and styles help managers, engineers, planners, and researchers understand transportation performance, identify problems, and formulate solutions (31). With PeMS, users can conduct a uniform and comprehensive assessment of freeway performance. It also allows users to base operational decisions on knowledge of the current state of the freeway network and to analyze congestion bottlenecks to determine potential remedies and make better overall decisions (31).

PeMS gets its data from nearly 40,000 individual detectors spanning the freeway system across the state of California. The data are collected mainly from the Intelligent Transportation System (ITS), Vehicle Detector Stations (VDS) and traffic counters (including traffic census stations and Weight-In-Motion (WIM) Sensors). PeMS also receives data from other data sets, which includes California Highway Patrol (CHP) incident data, the Caltrans Traffic Accident Surveillance and Analysis System (TASAS) accident data, lane closure information from the Caltrans lane

closure system, Electronic Toll Collection (ETC) reader data, changeable message signs (real-time information only) (31).

The data collected by vehicle detectors are relayed from the field to Caltrans Transportation Management Centers (TMCs) and then sent to PeMS. PeMS is a real-time Archive Data Management System (rt-ADMS) that collects, stores, and processes raw data in real-time. PeMS can be accessed via a standard Internet browser and contains a series of built-in analytical capabilities to support a variety of uses (31).

Data and reports can be downloaded from PeMS in various formats, namely dashboards, maps, plots and graphs, tables, export to text/spreadsheet files and animation video. A performance measure is a quantitative or qualitative characteristic describing the performance of a transportation facility to analyze the transportation system. PeMS is a tool for assessing the performance of the State of California's freeway network. The system currently operates more extensively along urban area freeways since detection devices are more densely deployed on those routes to monitor congestion. PeMS also features tools for assessing the performance of arterials and transit facilities (31). There are many different performance measures used by transportation agencies, and PeMS calculates a number of measures used by Caltrans.

As per the PeMS user manual, for each freeway station or Vehicle Detector Stations (VDS), PeMS allows users to report on many performance measures, including flow (volume), Annual Average Daily Traffic (AADT), Monthly Average Daily Traffic (MADT), Occupancy (% time over detector), speed, Vehicle Miles

Traveled (VMT), Vehicle Hours Traveled (VHT), Travel Time Index (TTI, the ratio of

the actual average travel time to free-flow travel time), delay (expressed in vehicle

hours), lost Productivity (shown in lane mile hours), and Level of Service (LOS) (31).

According to PeMS user manual, some of the benefits of the PeMS include:

- It allows users to request freeway traffic data (both current and historical), compute freeway performance measures, and conduct various analyses;

- Users can view summary reports on current freeway conditions, past system performance, detection system health, and incidents;

- Various performance data are available, such as volumes, speeds, delay, vehicle miles traveled (VMT), vehicle hours traveled (VHT), travel times, and annual average daily traffic (AADT);

- The data can be used for simulation model input and for completing Project Study Reports and other types of transportation planning and analysis documents.

- Users can compute performance measures for model calibration, verification of external study findings, and assessment of overall traffic conditions to determine appropriate operational or capital improvements;

- PeMS can assist with conducting simple to advanced traffic analyses, including Highway Capacity Manual analyses, Synchro analyses, and computer simulation.

In summary, PeMS can help provide valuable evidence of actual traffic

conditions that will lead to project recognition, support, approval, and funding. The

user's manual also presents some of the examples that PeMS can do are (31):

- Computes standard transportation performance measures, such as VMT, VHT, Delay (expressed in vehicle-hours), and Level of Service (LOS);

- Calculates travel time and travel time reliability measures, such as the Buffer Time Index, the Travel Time Index, and other descriptive statistics;

- Produces summary reports, such as locations with low traffic flow or high VMT over several years;

- Imputes (i.e., uses an algorithm to approximate) data for missing or bad detector data in real-time;

- Provides speed as reported by detectors, or computed speed (using an algorithm) based on flow and occupancy if the detector does not report speed;

- Enables exporting of data in several formats including plots, HTML tables, CSV text files, and XLS spreadsheets;

- Supports integration with common Internet-based mapping services (e.g., Google Maps, Google Earth);

- Computes special performance measures (e.g., travel time ratio, VMT ratio) by vehicle occupancy for managed lane facilities (i.e., High Occupancy Vehicle lanes) through a managed lanes interface;

- Allows users to incorporate incidents from third-party sources through a modular framework;

- Identifies bottlenecks through a special algorithm that can spot and quantify recurrent congestion;

- Provides animated graphics to help visualize freeway conditions, including incidents, for any day in the past when data was being collected;

- Supports engineering analyses, such as the identification of bottlenecks, non-recurrent congestion, and traffic safety problems;

- Supports special applications (including managed facility performance measures, Lane Closure System (LCS) analysis, Corridor System Management Plan (CSMP) analysis, and in some cases arterial and transit system analysis).

The aggregate detector data plots are the cornerstones of PeMS. These plots allow the user to examine the detector data at many different levels of spatial and temporal aggregation as well as averages over the time of day and days of the week (30).
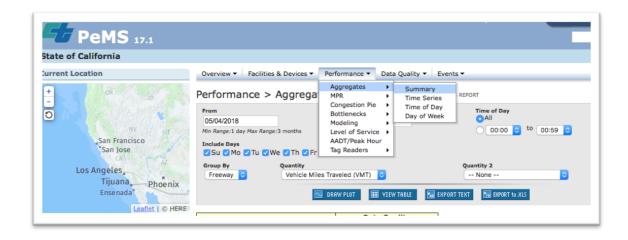
Figure 3.14:   Caltrans' PeMS Aggregate Summary Data

[Screenshot from the Caltrans PeMS Homepage, Performance Tab]

There are many different quantities, which Caltrans let users view. The quantities available to the users are a function of the geographic level. At the lowest level, the individual station, users can see all of the amounts. When PeMS aggregate spatially across a region, like for a district, some of the quantities no longer make sense, like flow, occupancy, and speed. Hence when looking at a geographic region (instead of a single station), the site doesn't allow users to make plots of these quantities. Below is a list of quantities that are specified whether they can be plotted at each geographic level (31):

- *Flow (Volume)*: This is the number of vehicles per time period of granularity. The granularity is user selectable and ranges from 5 minutes to 1 month. The flow values plotted are the sum over the unit of granularity. The flow is available only at the station level.

- *Occupancy*: The percentage of time that the detector is on. This is only available at the station level.

- *Speed:* The speed at the detector. This is only available at the station level.

- *Truck Flow*: The number of trucks per time period at this station. Depending on the configuration, this quantity can be an estimate of the truck flow or an actual measurement.

- *Truck Proportion:* The percentage of flow that is trucks.

- *Vehicle Miles Traveled (VMT):* The total miles driven by the vehicles during that time period for that geographical segment. When plotting this over spatial regions this quantity is simply the sum of the VMT from the individual detectors. This is available at all levels.

- *Vehicle Hours Traveled (VHT):* The total amount of time spent by all of the vehicles on the freeway. When plotting this over spatial regions this quantity is simply the sum of the VHT from the individual detectors. This is available at all levels.

- *Q:* This is the sum of the VMT in a region divided by the sum of the VHT in the same region. For a single detector, it's the speed. For a region, over time it's a measure of the efficiency of the transportation system. This is available at all levels.

- *Travel Time Index (TTI):* This is the ratio of the average travel time for all users across a region to the free-flow travel time. The free-flow travel time is taken to be 60MPH. This is available at all levels.

- *Delay:* This is the amount of extra time spent by all the vehicles over and above the time it takes to traverse a link at a threshold speed. PeMS compute the value of delay at many different threshold speeds, which are specified in the drop-down list. This is available at all levels.

- *Lost Productivity:* This is the number of lane-mile-hours that are lost due to the freeway operating under congested conditions. When the freeway is in congestion - which PeMS take to be when the speed is below a certain, user-selectable, threshold - PeMS find the ratio between the measured the flow and the capacity for this location. This drop in capacity is due to the fact that the freeway is operating in congested conditions instead of in free flow. PeMS then multiply one minus this ratio by the length of the segment to determine the number of equivalent lane-miles-hours of a freeway, which this represents.

In the title of each plot PeMS show the following four lines of information:

- *Title and units:* This is the title of the plot. It usually contains the units being displayed as well.

- *Data quality information:* This shows the number of 5-minute lane data points, which went into the plot. In addition, it shows the percentage of those points, which are completely observed. A point is either observed or imputed.

- *Geographic segment:* This is the type of geographic segment (like County, or VDS) and the name of the segment, like Los Angeles, or 6000620.

- *Time range:* The time range for the data included in this plot.

The state of California, therefore, provides various types of traffic data in many presentation styles and formats to their intended users. PeMS allows users to report on many performance measures, including flow (volume), AADT, MADT, Occupancy, Speed, VMT, VHT, TTI, delay, lost Productivity, and LOS.

Caltrans QuickMap smartphone application is another source that the California Department of Transportation uses to disseminate the state's traffic information. The Caltrans QuickMap app displays a map of any location in the state of California along with the real-time traffic information including freeway speed, traffic camera snapshots, lane closures, incidents, highway information, changeable message signs, snow plows, Waze data (accidents, traffic jam, hazard, construction and road closing) and others. In this app traffic data is updated every few minutes (31).

In addition to the PeMS and Caltrans QuickMap application, CalTransit smartphone app provides real-time travel information. Berkley students specifically for UC Berkley community design CalTransit. This application includes data from all of the major transit systems in the Berkley area including Alameda-Contra Costa (AC Transit), Bay Area Rapid Transit (BART trains), Bear Transit, and Bear Walk. Users

can view nearby stops, see all upcoming departures, and see real-time bus locations, schedule, and arrival notifications by using the app. Caltrans also uses social media sites such as RSS (Real Simple Syndication) feeds, YouTube, Twitter, and Facebook, to communicate with the Californians.

3.4.2 Texas Department of Transportation

Texas Department of Transportation (TxDOT) uses Traffic Count Database System (TCDS) to organize an agency's traffic count data for traffic engineers and planners. The state uses this system to disseminate traffic data. TCDS allows users to upload traffic data and view graphs, lists, and reports of historical traffic count data. It also allows users to search for count data using either the database or the Google map, and print or export data to users computer (32). User's guide is available on the public website that provides users with the tools to carry out many common tasks including (33):

- Searching for existing counts in the database;
- Interacting with the map to obtain count information;
- Creating reports of count details;
- Uploading new counts;
- Creating new TCDS Locations

The process of storing count data in TCDS involves collecting traffic count data, uploading count data, verifying count data quality, and assigning count data to count locations (33).

Users have to start at the Homepage to perform such TCDS tasks as adding new locations, uploading counts, searching for existing counts, editing or deleting existing counts, generating reports and graphs.

The TCDS Homepage provides Quick Search, Advanced Search, Map Search, and Tools. These search tools allow users to find the TCDS Stations (also called Locations or Locals) and counts users are interested in from among all the count data the state has processed over the years.

The Quick Search tab provides quick access to a handful of common search criteria that should handle most of users needs, including County, Community (e.g., City, Township, Village), Located On, Location ID, Count Year. Users can fill their information to acquire the traffic data they require (33).

To search for traffic data from TCDS home page, first users should enter search criteria in the County and Community fields. For users convenience, the field performs an on-the-fly lookup as they type so that users can quickly see and select from existing values. Users can include more fields to narrow their search (i.e., Located On for limiting to a specific road) or click the Search button to see the results.

As shown in the figure 3.15 below, the bottom portion of the page lists all the Counts of various types (Volume, Class, Speed, Gap, and others) that have been performed at this Location over the years. Users will also see any AADT's that have been calculated for that Location (33).
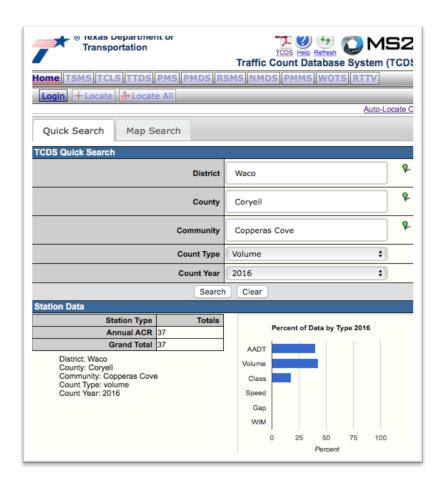
Figure 3.15:   Quick Search Tab in TCDS (TxDOT)

[Screenshot from the TxDOT Traffic Count database System]

Users can also search traffic data using the map side of the screen to the TCDS information. The Google map integrated into the right side of the TCDS screen provides users with a geographic interface to access their Count information. Figure 3.16 shows quick search from the map side of TCDS (33).
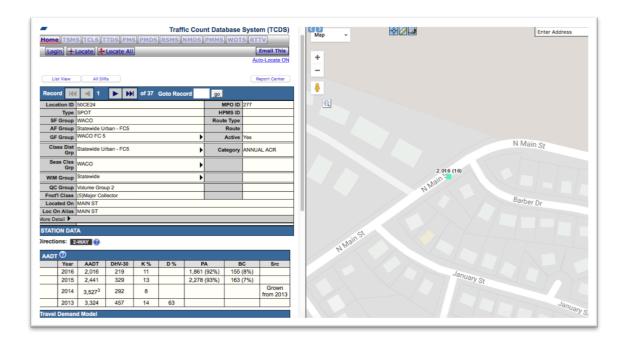
Figure 3.16:   Quick Searching for Data or Record (TxDOT)

[Screenshot from the TxDOT TCDS]

Texas DOT, Transportation Data Management System (TDMS) provides a wide range of report generating capabilities. In the TCDS module, there are four different report categories available to authenticated users (users who have logged into the system with their username and password) (33):

- Single station, single day reports;
- Single station, multiple day reports;
- Multiple stations, multiple day reports;
- Report Center reports.

These reports are either for a single station and single day, a single station and multiple days or multiple stations and multiple days. Report Center reports are for

multiple stations and multiple days and provide additional report customization features to users.

TDMS reports are based upon a "search first" methodology. First, search for the station or stations to be included in the report, and then choose the desired report. Using the TCDS Quick Search, the system can quickly narrow users search to a particular District, County, Community, Count Type, or Count Year. Users could also use the Advanced Search, Map Search, or Tools tabs for additional searching features (33).

Single Station, Single Day reports are accessed via the search results "Form View" page. Different Single Station, Single Day reports will be available depending on the type of data that a station collects. The most common report types are Volume Count Report, Classification Report, Speed Report, and WIM Report. In some places, a Per-Vehicle Report is also available. In addition to the default tabular report view, several of the reports have additional views available at the bottom of the page including view calendar, bar graph, line graph, tabular options (e.g., Weekly Report, Hourly Volume by Lane), and several MS Excel export options (33).

Single Station, Multiple Day reports are accessed via the search results Form View page. Users access Single Station, Multiple Day reports by clicking on the "Graphs/Reports" button within the section of data that we want to view. Different Single Station, Multiple Day reports will be available depending on the type of data that a station collects. Some of the different types of data include volume, speed, class,

gap, WIM (Weigh-In-Motion), MEPDG (Mechanistic-Empirical Pavement Design Guide), and Bulk Reports (33).

Multiple Stations, Multiple Day reports are accessed via the search results Form View page. Users access Multiple Station, Multiple Day reports by clicking on the "Graphs/Reports" button at the top of the search results page.

The Multiple Station, Multiple Day reports use a reporting interface that is similar to the Single Station, Multiple Day reporting interfaces described in the previous section. The critical difference is that the reports generated use data for ALL of the stations that are in the search results. Once again, Multiple Station, Multiple Day reports will be available depending on the type of data that a station collects.

There are also other types of reports that can be exported from Texas DOT data bank including Report Center Reports, Classic Reports, and Federal Reports. The "Report Center Reports" can be accessed via the "Report Center" link at the top of the Multiple Station, Multiple Days page. The Report Center interface is different from all of the other reporting interfaces and is designed to give users more flexibility in creating reports. Like the Multiple Station, Multiple Day reports, users can run reports against all the stations in the search results; however, Report Center also provides the ability to run reports against user-selected sub-sets of one or more locations within the search reports (33).

The Classic Reports may be generated for Locations, Volume, Class, Gap, Speed, WIM, and the Latest Count or AADT. After searching for the desired

Locations, users may create several reports to organize their search results and allow for easy management of data and information for field technicians.

TxDOT uses a mobile app, "Texas State Roads" that allows users to access live traffic reports and camera for Texas including Houston and Dallas. This app can be downloaded for a $9.99 fee. Through a map view, it allows users to access 1965 live traffic cameras covering the state of Texas, the nearest current traffic incidents.

DriveTEXAS website also provides real-time traffic conditions throughout the state. It includes information about road closures, construction projects, traffic cameras, damage, and others (34). Texas DOT also uses social media sites such as Facebook, Twitter, YouTube, and Texas Highways magazine to communicate, and inform users about real-time traffic conditions.

3.4.3 Virginia Department of Transportation

VDOT's traffic monitoring program includes more than 100,000 segments of roads and highways ranging from several mile sections of Interstate highways to very short sections of city streets. As per Virginia Department of Transportation website, the Department conducts a program where traffic count data are gathered from sensors in or along streets and highways. From these data, estimates of the average number of vehicles that traveled each segment of road are calculated, and then VDOT periodically publishes booklets listing these estimates. All of these published traffic data are available to the public on the department's public website (35).

According to VDOT's publications and booklets "Average Daily Traffic Volumes with Vehicle Classification Data, on Interstate, Arterial and Primary Routes" contains a list of each Interstate and Primary highway segment with the estimated Annual Average Daily Traffic (AADT) for that segment. This booklet also includes information such as estimates of the percentage of the AADT made up of six different vehicle types. The info ranging from cars to double trailer trucks; estimated Annual Average Weekday Traffic (AAWDT), which is the number of vehicles estimated to have traveled the segment of a highway during a 24 hour weekday averaged over the year; as well as Peak Hour and Peak Direction factors used by planners to formulate design criteria (35).

VDOT provides Average Daily Traffic volumes with vehicle classification data on Interstate, Arterial and Primary routes of each city and towns in the state of Virginia in PDF and MS Excel spreadsheet formats. VDOT summary traffic data is also available as a Keyhole Markup Language (KML), Shapefile or Gene Expression Omnibus (GEO) Database (35).

In addition to the Primary and Interstate publication, one hundred books are published periodically, one for each of 100 areas across the state defined by VDOT for record-keeping purposes. These books (Daily Traffic Volumes Including Vehicle Classification Estimates) include traffic volume estimates for roads within the county, cities, and towns within the area.

Also, many reports are available summarizing the average VMT in selected jurisdictions and other categories of highways. Because the user determines the value

of each presentation, the reports have been redesigned based on user requests and feedback; there are many different ways to present traffic volume summary information (35).

VDOT provides a compact disc (CD) that includes files in the Adobe® Portable Document Format (PDF) that can be displayed, searched, and printed using common desktop computer equipment. The CD contains the publications described above as well as many other reports, including specialized VMT summaries, and smaller AADT reports for each city and town separately (35).

"VDOT 511" website also provides real-time traffic and roadway weather. The site uses interactive map (map views) to disseminate real-time weather such as air temperature, dew point, relative humidity, wind speed, wind gusts, wind direction, visibility, precipitation, pavement temperature, and condition. The site also allows text views that provide information in table format. Information includes incident, road conditions, travel times, mobile feeds and others (36).

VDOT also operates a network of Highway Advisory Radio transmitters throughout the state to keep motorists informed on traffic and travel conditions and construction projects information. According to its website, transmitters broadcast on 1620 AM in VDOT's northern, southwestern and central regions, and on 1680 AM in the eastern region. The broadcasts are aired 24 hours a day, seven days a week (35).

VDOT "511 Virginia Traffic" mobile application is the other source that VDOT uses to disseminates the traffic information. The app combines official information from VDOT, driving and transit directions from Google, navigation from

Waze, and other sources of information to provide reliable and accurate travel information across Virginia (36). Users can access the VDOT cameras, incident reports, construction, bridge openings, and more. The app also allows users to access Twitter feeds, cameras by route, travel times for predefined road segments, and links to other commuter services for the users' area. Additional information available in this app includes Virginia Rail Express (VRE) and Potomac and Rappahannock Transportation Commission (PRTC) bus schedules and routes, along with real-time VRE train locations in Northern Virginia. VDOT uses social media such as RSS (Real Simple Syndication) feeds, YouTube, Twitter, Flickr, Facebook, and Instagram to communicate with the eight million Virginians.

3.5   Chapter Summary

In this chapter, seven different states have been examined for the type and means of transportation data dissemination that are being available on their websites and other Internet-based references. These observed states are states that are similar in size to Delaware such as Vermont and Connecticut, neighboring states such as New Jersey and Pennsylvania, and states that are larger in size to Delaware such as California, Texas, and Virginia.

All of these states have their website or a separate traffic database that can be accessed by users. Most of these states have a mobile app, travel advisory radio, and various social media sites to update their respective customers with real-time travel

information. Unlike DelDOT-TMC, states such as California, Texas, and Vermont have a separate traffic count database that allows users to access real-time as well as historical traffic information.

Although DelDOT-TMC has its own mobile app, states like New Jersey and Pennsylvania offer a hands-free mobile application, which allows drivers not to hold their phone while driving. It is useful for drivers to avoid accidents, as the app uses users phone's built-in GPS and the extensive data in the NJ and PA to determine when approaching traffic disruptions, and then automatically broadcasts the travel advisory.

Chapter 4

VOLUME AND CLASSIFICATION COUNTS STUDIES

4.1 Introduction to Volume and Classification Counts

Motor vehicles continue to be the primary transportation means in the United

States and all over the world. The future dominance of motor vehicles transportation is

undeniable. Therefore, problems such as congestion, delay, pollution, safety and

parking will continue to occur. To solve the transportation problems and improve

transportation facilities and services, understanding the magnitude and the location of

the issues or the need for improvements is vital. Such understanding comes from

accurate traffic data collection (37).

Traffic data is an essential element in programming, planning, designing, and

evaluating the performance of individual roads (AADT and axle-load data) as well as

the entire road system (vehicle-miles of travel, or "VMT"). When conducting a

highway performance measure, traffic data can often be a useful tool for users such as

Department of Transportation, metropolitan/local planning, Federal Highway

Administration (FHWA), and the general public (39).

The AASHTO guidelines consider various components of traffic data program.

The program must have a planning stage to take customer's traffic needs and available

resources for the program into account. Once a plan is in place, it must be managed

and monitored on a continuous basis. The design stage of a traffic data program should include types of equipment, quality control, reporting, and maintaining the data (39).

Data collection, analysis, reporting, and equipment maintenance should be considered to ensure the quality of data.

The ITE manual provides various types of traffic studies, which includes volume, spot speed, travel-time and delay, intersection and driveway, inventories, traffic access and impact, parking, traffic accident, traffic conflict, pedestrian, traffic control device, public transportation, goods movement and queuing (37). However, according to AASHTO Guidelines for Traffic Data Program, there are four essential types of traffic studies that are collected by TMC which are volume counts, classification counts, speed data, and weight data. Other types of traffic data collected by state Departments of Transportation comprise of speed, travel time, lane occupancy, and vehicle occupancy data. This thesis focuses on volume count and classification count studies (39). Using the ITE Manual of Transportation Engineering Studies and AASHTO Guidelines for Traffic Data Program, this study examines the methods, procedures, equipment, personnel, and levels of training needed for traffic data collection.

Traffic volume studies are conducted to determine the number, movements, and classification of roadways and vehicles at a given location. These data can assist in identifying critical flow time periods, assessing the influence of large vehicles or pedestrians on vehicular traffic flow, or documenting traffic volume trends. The length

of the sampling period can depend on the type of count that is conducted and the intended use of the data recorded (40).

According to the ITE manual, engineers often use counts when examining the number of vehicles or pedestrians at a given intersection. Pedestrians are analyzed when passing a certain point, entering an intersection, or using a particular facility such as travel lane, crosswalk, or sidewalk using the counting method (37). Although continuous counting is sometimes performed for specific situations or circumstances, traffic counts are usually samples of actual volumes. Sampling periods may range from a few minutes to a month or more. Volume and classification counts should be collected as continuously as possible throughout the year to develop seasonal factors and day-of-week (DOW) variation in total and truck volume. These factors are then used to convert short-duration counts to get estimates of annual average daily traffic (AADT) and AADT by vehicle class (39).

4.2   Coverage Counts

The AASHTO Guidelines specifies that coverage count program involves the collection of short-term and continuous vehicle weight, classification, volume, and speed data for the production of system-level traffic estimates. The AASHTO Guidelines for Traffic Data Program also refers system-level to traffic estimation for the road system and classifications of roadways, rather than site-specific traffic estimates.

Coverage count programs typically include weigh-in-motion (WIM), vehicle classification, volume, and speed data collection programs. The short-term coverage count sample size recommended for traffic volume, and vehicle classification is based on a system-wide statistical sample. The short-term volume, vehicle classification, and weigh-in-motion counts, and supplemental counts taken within the special needs part of the program comprise the coverage count program (39).

4.3   Volume and Vehicle Classification Counts

According to AASHTO Guidelines for Traffic Data Programs, the most basic form of traffic data collection is volume count. Volume counts are collected as a combination of continuous counts and short-term counts. Continuous counts are obtained from permanently installed equipment in, along, or above the roadbed that is operated continuously. Short-term counts are frequently collected through the use of pneumatic tubes gathering axle impulses that are factored in the later time. Short-term volume counts represent the bulk of any coverage count program (39).

4.4   Methods of Counting

There are two primary methods of conducting traffic volume count, which is manual observation and mechanical or automatic recording. The vehicles stream is classified through either manual observation or automated equipment. Manual observation is short-term, and it is often based on the number of axles and the vehicle's body style. Automated equipment can be used continuously or for short-term

periods. This particular equipment classifies vehicles through either axle distances or total vehicle length. Vehicle classification data can be aggregated to fulfill a volume count requirement. Some automated vehicle classification systems can also provide speed data (39).

The selection of a traffic study method should be determined using the count period (37). The count period should represent a specific time of day, month, and year for the study location. For example, counts of a summer resort would not be taken in January. The count period should also avoid special events or compromise weather conditions (41). Typical count periods are 15 minutes or 2 hours for peak periods, 4 hours for morning and afternoon peaks, 6 hours for the morning, midday, and afternoon peaks, and 12 hours for daytime periods (37). For example, if a counting agency were conducting a 2-hour peak period count, eight 15-minute counts would be required.

4.4.1 Manual Observation

Manual observations are the original traffic data collection method. When traffic monitoring equipment becomes problematic to place, agencies often use manual counts to conduct short duration counts. One of the main reasons for performing a manual count is because traffic counts such as vehicle occupancy, pedestrians, and turning movements, require classifications that are obtained more easily and accurately with trained observers. Another reason for conducting manual counts is

time and resource (37). The effort and expense to set up and remove automated

equipment, for less than ten hours of data at any given location, is not justified (37).

Data Collection Equipment to Conduct Manual Counts

The ITE Manual presents three methods to record manual counts: tally sheets,

mechanical counting boards, and electronic counting boards. The first and most

straightforward means of conducting manual counts are tally sheets. To record each

detected vehicle, observers should tally the counting with a tick mark on a prepared

field form. Observes can use a form based on the specific classifications that may be

desired. A new form is used at the start of each interval, and a watch or a stopwatch is

required to cue the observer to the desired count interval. Raw counts are then tallied,

summarized, and keyed into a computer upon returning to the office (37).

The second type of equipment is Mechanical Count Boards. This particular

equipment consists of various combinations of accumulating counters that are

mounted on a board to facilitate the type of count being made. Push button devices

with three to five registers gather typical counters. Four counters would be positioned

on each side of a board to represent each approach to the intersection to conduct a

four-way intersection count. If vehicle-turning movements were exclusively desired,

each counter would have three registers (for left, thru, and right turns). If pedestrians

were also being included, four or five registers would make up each counter (37).

Many configurations of registers and counters are possible.
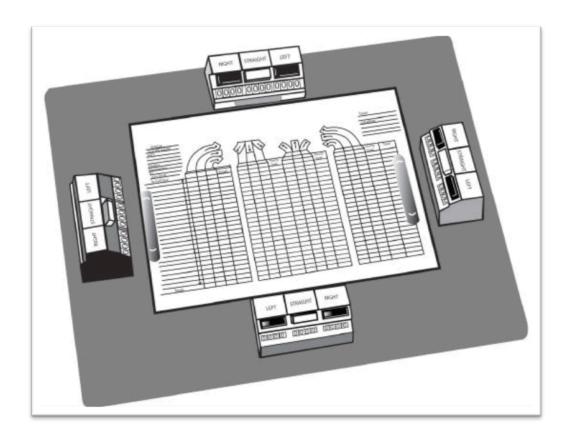
Figure 4.1:   Example of Mechanical Counting Board

[Referenced from Traffic Volume Counts]

     The third type of equipment that is used to conduct manual observation is Electronic Count Boards. This equipment is battery-operated, handheld, and it is currently the most common device to aid in the collection of traffic count data. The electronic count board operates in a fashion similar to that of mechanical count boards, with a few critical differences. The electronic count board is lightweight, more compact, and easier to handle. This particular board contains an internal clock that separates the data by whatever interval is chosen. It also precludes the need for manual data reduction and summary. Upon completing the observation, data may be

transferred directly from the field to an office computer through a modem. Data are then summarized, analyzed, and finally displayed in a selected presentation format utilizing computer software. It eliminates the data reduction step required with tally sheets and mechanical count boards. Many electronic count boards are capable of handling several types of common traffic studies, including turning movement, classification, gap, stop delay, saturation flow rate, stop sign delay, spot speed, and travel-time studies (37).
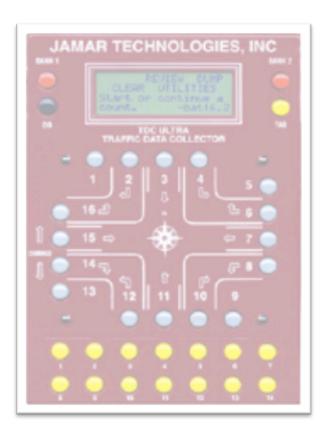
Figure 4.2:   Example of Electronic Counting Board

Personnel Needed in a Manual Count Study

For manual counts, one or more staff is sent to a location to observe and record traffic data. Traffic data includes traffic volume, vehicle classifications and other statistics that can be observed with the human eye (39).

The size of the data collection team depends on the length of the counting period, the type of count being performed, the number of lanes or crosswalks being observed, and the volume level of traffic (37). The number of personnel needed also depends on the study data required. For example, one observer can easily count turning movements at a four-way, low-volume, signalized intersection with one lane approach as long as particular classifications and vehicle occupancy are not required. As any or all of the foregoing variables increase, the complexity of the counting task increases and additional observers are required to provide an accurate count (37).

As per ITE Manual of Transportation Engineering Studies, manual traffic counting requires trained observers. They must be relieved periodically to avoid fatigue and degraded performance. Therefore, breaks of 10 to 15 minutes are recommended for every two hours of observation. If the data collection period is more than eight hours, breaks of 30 to 45 minutes are suggested for every four hours of observation (37). The purpose of rest periods between inspections is to avoid or at least minimize error. Error rates in manual classification counts tend to increase significantly after the staff member has been working for about three consecutive hours. The concentration of most observers tends to wander after three hours of counting, which causes the number of errors to increase (39).

Field Procedures for Manual Count Study

Once equipment and observers are chosen, data collectors are required to follow three essential steps when conducting manual count studies. The first step is to perform the necessary office preparation before going into the field for counting. Secondly, observers are required to select a specific location in the area. Lastly, assigned data collectors have to label the data sheets and began the manual counting process.

- *Office Preparation Before Conducting Manual Count*

Preparation often begins in the office to achieve accurate and reliable manual traffic count. A checklist can be a valuable aid to ensure that all preparations for the field study have been completed before heading to the counting site. The checklist provides a list of equipment items such as pens, batteries, stopwatches, and blank videotapes. Preparations should start with a review of the purpose and type of count to be performed, the count period and time intervals required, and any information known about the site. (i.e., geometric layout, volume levels by time of day, signal timing, and others). This information will help determine the type of equipment to be used, the field procedures to follow, and the number of observers required (37). Having to return forgotten items may delay the start of the study or cause it to be postponed. An inadequate number of forms to complete the study could also invalidate the study, resulting in a wasted resource.

The selection of equipment will dictate the types of data forms needed if any. Before heading out to the field, header information should be filled out with as much information as possible. The forms should also be organized in the order in which they will be used. Also, the equipment must operate properly to ensure accurate counting. Right counting boards have firm keys that provide the observer with tactile and audio confirmation when a key has been pressed successfully. Units with soft keys should be repaired or discarded. Each observer must make sure that his or her counter adds one and only one to the total when a key is pressed and that clearing the count resets total to zero.

Table 4.1: Sample preparation checklist for manual counts study

Before going to the site	Check when completed	Notes
Obtain tally sheet/ calibrated counting board		
Obtain watch (include spare)		
Obtain batteries for all equipment		
Select location		
Map showing the site or direction to the site		
Select time and day		
Determine availability of recorders		
Obtain hardhat, safety vest, sunglasses, sunburn protection, extra clothes, gloves		
Contact other jurisdictions/ schools/ police		
Contact adjacent residents/ businesses		

4.1   Continued

Before going to the site	Check when completed	Notes
Contact number of engineer/ supervisor		
Others (paper, pens, clipboards, folding chairs)		

[Referenced: Idea taken from (44)]

- ***Observer Location for Manual Count Study***

When conducting a manual count study, observers must be positioned at a location where they can have a clear vision of the traffic count (37). Vantage points blocked by trucks, buses, parked cars, or other features must be avoided. Observers should also be located well away from the edge of the travel way, both as a personal safety precaution and to prevent distracting drivers. If several observers are counting at the same site, they must maintain visual contact with one another and be able to communicate to coordinate their activities. Protection from the elements is also an essential consideration for the observer. Proper clothing to suit prevailing weather conditions is paramount. Safety vests should be worn if the observer is near traffic at any time. Also, observers may count from inside vehicles as long as their view is unobstructed. During inclement weather, sitting in the automobile is safer and more comfortable than sitting outside. As long as the objects are not distracting to drivers, observers may use chairs to prevent fatigue and umbrellas for sun protection while sitting outside. A sign should be placed indicating that a traffic count is underway to satisfy driver's curiosity (37).

- ***Data Recording Using Manual Count Method***

Keeping the data labeled and organized correctly is key to successful traffic counts. Counts may produce a large number of data forms, and each form must be marked with information such as the count location, observer's name, time of the study, and conditions under which the counts are made (37). The form itself should indicate the movements, classifications, and time interval. The observer must concentrate his or her attention on accurately recording each count in the proper place or with the appropriate button. Special care must be taken with electronic counting boards to ensure that they are correctly oriented to the geographic and geometric layout of the intersection (37). When two or more observers are working together, time intervals must be maintained and coordinated accurately. Using a form or a log, observers should examine and make a note of any temporary traffic events, such as accidents or maintenance activities that may lead to unusual traffic counts.

Provisions must be made to record the accumulated counts and reset the counters at the end of each interval when mechanical count boards are used. Two procedures may be used to accomplish this without significant error. They are referred to as the short-break and alternating counts procedures (42). The short-break count procedure is to take a 1-to-3- minute break at the end of, but included in, each count interval. The observers use this time to record their counts and reset their counters. The volume for the counting period is estimated by extrapolating the actual count over the short-break portion of the count interval using the following (37):

$$V' = V \times CF \qquad\qquad CF = \frac{CP}{CP - SB}$$

Where:

CF = Count expansion factor
CP = Counting period, in minutes
SB = Short break in minutes
V' = Adjusted count, vehicles
V = Actual count, vehicle

Table 4.2: Example of the short-break and alternating count procedure combined

| Counting Period | 4-Min. counts | | Adjusted counts[a] | | |
	Mvt. A	Mvt.B	CF	Mvt.A	Mvt. B
5:00 - 5:05 P.M.	120	-	5/4	150	b
5:05 - 5:10 P.M.	-	98	5/4	144	123
5:10 - 5:15 P.M.	110	-	5/4	138	127
5:15 - 5:20 P.M.	-	104	5/4	139	130
5:20 - 5:25 P.M.	112	-	5/4	140	127
5:25 - 5:30 P.M.	-	99	5/4	136	124
5:30 - 5:35 P.M.	105	-	5/4	131	131
5:35 - 5:40 P.M.	-	110	5/4	130	138
5:40 - 5:45 P.M.	102	-	5/4	128	132
5:45 - 5:50 P.M.	-	100	5/4	b	125

aRounded to the nearest vehicles.
bEnd count may be extrapolated but cannot be interpolated.
[Referenced: Idea taken from (42)]

During an alternating count procedure, the observer performs a full count

every other interval, resting during alternate intervals. Interpolation will be used to

estimate the volumes occurring during the missing count intervals. The longer the gaps

are between the actual counts, the more vulnerable extrapolations and interpolations

are to error. With either the short-break or alternating count procedure, it is important

that all observers be in communication with one another so they can start and end simultaneously. It is also important that all data forms be marked with the procedure used.

4.4.2 Automatic Counts

Automatic counting is the second method that is used for conducting traffic volume counts. A simple count of vehicles is sufficient for many applications of volume data that requires a simple classification. Often, these types of counts are needed for extended periods of time (i.e., days, weeks, or even months) and hiring observers to collect the data would have cost prohibitive. Automatic counting provides the means of gathering large amounts of volume data at a reasonable expenditure of time and resources (37). However, one of the main disadvantages of automatic counts relative to manual counts is equipment reliability. An analyst must prepare contingency plans to use in case of equipment failure, as current equipment may fail during a given study due to malfunctions, vandalism, high vehicle interference, weather, or other threats. Advances in technology have created equipment that has the capability of recording sophisticated vehicle classification counts (37). Turning movement counts are being recorded automatically by connecting count recorders to vehicle detectors installed at signalized intersections.

Data Collection Equipment for Automatic Counting

There are a variety of different types and models of automatic volume data collection equipment that are available. To detect the presences of vehicles and pedestrians, the two primary components of data collection that are required for automatic counting are data recorders and sensors. Although the types of sensors that observers use may vary, the recording component is mostly the same for both portable and permanent applications. Some equipment also has the capability of communicating the collected data to a central facility for processing. Automatic counters are employed in two principal ways: as portal counters or as permanent counters (37). Three main types of automatic recorders are discussed below.

- *Portable Counters*

The first type of automatic recorder is a portable counter. Manual counting is a form of portable counting because a team of observers is dispatched to a specific location to collect data for a limited period and then moves to another position for a different count. Portable counters serve in the same temporary manner but through the use of automatic counting equipment. The period of data collection is usually more extended for automatic counting than for manual counts.

Portable counters are used to perform short-duration counts at a large number of locations (39). Portable counters require the following attributes: easily transportable, easy and fast to install, contain a sufficiently large power source to allow the device to operate until it is retrieved, theft and vandalism resistant.

As per AASHTO guidelines, road tube sensors are used in most common portable traffic volume counter technology. They are inexpensive and easy to install on moderate and low-volume roads. Under low- to moderate- traffic volumes, road tube sensors can count axle passages with a high degree of accuracy (39).

Portable counters generally use pneumatic road tubes, piezoelectric strips, tape switches, or temporary induction loop detectors. Technicians place these sensors across the travel lanes being counted and then connect them to the recording component.

According to the ITE manual, portable counters are most commonly used for 24-hour counts but may be deployed for periods of days or weeks. They may also be used in situations where safety precludes the use of observers. (e.g., in tunnels, on bridges, or in adverse weather) (37).

- *Permanent Counters*

The second type of counters is a permanent counter, which is counter permanently installed. According to the ITE Manual, agencies establish permanent count stations where they desire long-term, continuous counts (e.g., 24 hours a day, 365 days a year). The volumes collected at these stations are usually part of an area-wide program to monitor traffic characteristics and trends over time. The same recording component may be used as with portable counters. The sensors, however, are usually more permanent in nature. The most common type of permanent detector in use today is the induction loop, which is installed in the pavement. Other forms of

permanent detectors that are also in use are radar, sound, microwaves, and infrared light (37).

Before installing a permanent traffic monitoring equipment, AASHTO provides the following guidelines (39):

- Sensors that can withstand the harsh roadway environment for long periods of time;

- Power sources (either electrical power or solar power with battery backup);

- Communications (landlines, cellular communications, or other communication systems);

- Environmental protection (from temperature, moisture, dirt, and electrical surges on power and communications lines).

A variety of systems can be used to classify vehicles in the traffic stream. The ideal vehicle classifier would be able to measure a range of vehicle characteristics to differentiate vehicles by several factors (e.g., body type, engine type, axle configuration, overall vehicle length). However, such equipment does not exist at a price that can be afforded by state highway agencies (39). There are also some alternative vehicle classification systems or technologies that allow manual observation, axle-based classification, and vehicle length-based classification. These different approaches to vehicle classification result in different classification systems, which are not uniform subsets of one another.

When deciding on the type of equipment, data collection agencies should first determine if there is a need for whether axle-based classifications or if a less complex, length-based classification is acceptable. This decision significantly affects which

equipment should be considered, regardless of whether the equipment will be used for short-duration counts or permanent, continuous counts. Mostly, the primary classification issue is separating "heavy" vehicles from "light" vehicles because heavy vehicles cause more pavement and bridge damage and tend to have poor acceleration and braking characteristics (39).

Weigh-in-motion equipment is installed to collect the axle and vehicle weight data that is required to estimate the traffic loads that pavements and bridges experience. This same data can provide information on the approximate size and nature of overloaded vehicles operating on monitored roadways. Along with collecting axle weight information, WIM devices must also classify the trucks to which those weights belong (39).

- *Videotape*

The third type of equipment that Transport Management Centers use for automatic counting is videotape. As per ITE manual, observers can count volumes by viewing videotapes that were previously recorded. Observers can log their counts with an electronic count board, tick marks on a tally sheet, mechanical counters, or directly into a computer. With adequate light conditions and a good vantage point, one camera can capture all turning movements at a typical intersection (37).

The significant advantages of using videotape for turning movement counts are the fact that it is accurate and it can be used for other studies. Higher accuracy is possible with videotape than with any other standard method of counting volume

because observers can view the tape repeatedly. The first observation of tape is likely to be less accurate than conducting a manual observation in the field. However, observers can regularly view the tape to obtain a precise count or if additional study is needed. Also, an engineer can see the tape to answer questions about the classification of particular vehicles or the impact of unusual events during the count period.

Along with the mentioned advantages of using videotapes for turning movement counts, there are also disadvantages. For instance, most agencies are not required to have accurate counts. Also, videotape cameras and players are relatively expensive. Not to mention that setting up the camera, recording, and viewing the tape requires more labor than other methods (43). Generally, the disadvantages of using videotapes for volume counts usually outweigh the advantages.

Equipment Selection

Before selecting a traffic data collection equipment, the AASHTO guidelines program recommends the following attributes be considered (39):

- The accuracy of the system;
- The traffic attributes that the equipment collects and stores;
- The expected longevity of the system;
- The installation requirements of the system (in time, cost, and staffing);
- The operational requirements of the system, including power and   communications needs;
- The cost of the system;
- The amount of vendor support provided;

- The compatibility of the data and the data retrieval software with the agencies' existing and planned databases and data management systems;

- The amount of vendor support provided; and

- The compatibility of the data and the data retrieval software with the agencies' existing and planned databases and data management systems.

Personnel Needed in an Automatic Count Study

As per ITE manual, personnel for automatic counts are needed mainly to install and recover equipment. Crew sizes of two or three are usually sufficient to deploy most portable counting equipment. One observer can handle the recording component; however, one or two persons are required to install the road tubes or tape switches, while an additional observer monitors the traffic. The installation of permanent counters with induction loop detectors may require a larger crew and closure of travel lanes. Once the count study is complete, one or two observers are usually sufficient to recover the equipment (37).

Field Procedure for Conducting Automatic Count Studies

When conducting an automatic count study, three main steps should be followed. First, observers should perform the necessary office preparation before installing a recorder into the field. Second, an observer is required to deploy and calibrate data collection equipment. The final step consists of checking the collected data and retrieving apparatus before heading to the field.

- *Office Preparation Before Automatic Counting*

The first step for conducting automatic count studies is office preparation. Fieldwork should never be started without proper preparation in the office. Therefore, a prepared checklist is an important aid, even for the most routine task. The purpose of the count will drive the type of equipment to be used and the deployment procedures to follow. All equipment should be checked to make sure that it is functioning properly. Also, an ample supply of accessories and tools should be on hand.

Table 4.3: Sample checklist for Automatic Count Study preparation

Before Automatic Study	Check when completed	Notes
Obtain equipment		
Obtain or read user's manual		
Select time and day for the study		
Select proper location		
Obtain measuring tape for spacing tubes		
Obtain scissors for trimming tubes		
Obtain software selected for the study		
Select method for attaching tubes to the travel way		
Obtain recorders		
Obtain new batteries for recorders		
Obtain hardhat, safety vest, sunglasses, sunburn protection, extra clothes, gloves		
Contact other jurisdictions/ schools/ police		
Others		

[Referenced: Idea taken from Traffic Volume Counts (44)]

- **Data Collection Equipment Deploy and Calibrate**

The second step involves deploying and calibrating data collection equipment. Selecting the count location is also vital, and it's often determined in the field. Agencies are required to decide the street or highway location in which the count will be conducted and the general location (midblock or intersection) where the counters will be placed. Depending on the type of study being performed, the exact count and sensor location may vary. Below are some guidelines on the proper way of deploying automatic counter that is set by the ITE Manual of Transportation Engineering Studies (37):

- Sensors should not be placed across parking lanes where a parked vehicle could activate the sensor continuously;

- Placing sensors on pavement expansion joints, sharp pavement edges, or curves should be avoided;

- Sensors need to be deployed at a right angle to the traffic flow, and for directional counts;

- At least one foot of space should be kept between the sensor and the centerline of the roadway;

- The sensor must be securely fastened to the pavement with nails, clamps, or tapes in order to avoid data collection errors and to prevent pedestrians from hazard;

- At intersections or near driveways, place sensors where double counting of turning vehicles can be avoided;

- Count recorders located near a sign post or tree should be secured with a lock and chain to prevent vandalism;

- Cable or tube that connects the sensor ought to be kept to the recorder as short as possible;

- A test vehicle must be used to ensure that bidirectional counters are recording the proper direction;

- Installation should be checked periodically to ensure that the deployed counter is in place and functioning properly;

- In cold-climate states, data collection agencies should check sensors whenever it snows to ensure that snow plows have not removed the sensors from the road.

Installation and maintenance of the sensors, data collection electronics, and communications modules are critical to the accurate collection of data, (39).

Installation and Retrieval of Automatic Recorders

The final step for conducting an automatic counting is installation and retrieval of recorders. As per ITE manual, the primary concern during installation and retrieval operations is the safety of the field crew. The crew's vehicle should be visible to traffic and should be parked away from the traveled way. All crewmembers should wear reflective clothing at all times. Deployments and recoveries should be accomplished during periods of low traffic volume and excellent visibility. If nighttime operations are necessary, the crew should employ extra safety measures (i.e., lights, cones, warning signs). Anytime that crewmembers must enter the roadway, at least one crewmember should have the sole duty of watching for traffic and warning the rest of the crew. Police assistance may be required to ensure the safety of the team and the public. When the data collection period has ended, the recorded data are checked for accuracy. Crews recover data collection equipment by reversing the process they used to deploy it (as previously mentioned).

4.5   Reduction and Analysis of Traffic Volume

After collection of traffic data, raw data must be reduced in a form appropriate for analysis. This reduction usually consists of converting tally marks to numbers, summarizing the data by calculating subtotals and totals, and arranging the data into a format for analyses. The analysis may range from a simple extraction of descriptive information to a more sophisticated statistical treatment of the data. The review will depend on the type of study being conducted (37).

4.5.1   Manual Versus Automatic Data Reduction

Data collected manually by observers using tally marks or count boards must be reduced to form a suitable analysis. Tally marks are counted for each time interval and classification before it is entered on summary sheets. Analysts can summarize data from count boards in a similar manner. Summary data may also be displayed in a graphics format. Continuous count recorders (mechanical counters) data either on registers or paper tape. These data also must be reduced and tabulated similarly (37).

Computer-driven counters do not require manual data reduction. Count data are kept in a summary form in the county recorder's memory and then stored in the computer either in the office or the field via a modem. Computer software accomplishes the reductions and produces summaries of the data and desired calculated values (e.g., average daily traffic, peak-hour factors, and percent turn). These tools save analyst time and often eliminate errors (37).

4.5.2 Converting Axle Counts to Vehicle Counts

Counters driven by a single point sensor (such as pneumatic road tubes, tape switches, or loops) exclusively records axles rather than vehicles. Each axle crossing the sensor causes a pulse that is then corded. According to AASHTO guidelines, axle correction is used for short-term traffic counts that measure axle impulses (39). If there were no vehicles with more than two axles in the traffic stream, dividing the total by two will provide the total number of vehicles. However, not all cars have two axles, and the axle count cannot just be divided by two. Instead, it must be adjusted to reflect the proportion of vehicles that have more than two axles and that are within the traffic stream (37). To adjust the axle count, analysts use a short classification count of the number of vehicles that have a different number of axles. An average number of axles is calculated from the sample, which is assumed to represent the entire count. As per the AASHTO guideline, axle-correction factors generally should be developed using only weekday data since most short-term counts are collected on weekdays. It should also be generated using data collected on the same day (or days) as the axle counts are obtained (39).

The number and duration of sample counts needed to depend on the different varieties of a vehicle over the course of a day or week. If the proportion of vehicle types remains relatively constant over the count period, a 1 to 2 hours long sample should be sufficient. The example is shown below (table 4.4) illustrates how to use the results of a sample classification count. A 2-hour sample is used to adjust a count of

9000 axles on a two-lane rural highway during a 24-hour period to obtain an estimate

of the total number of vehicles per day (42).

Table 4.4:   Example of conversion of axle counts to vehicle counts

Results of Two-Hour Classification Counts		
Classification		Number of Vehicles
2-axle		100
3-axle		14
4-axle		6
5-axle		4
Conversion Computations		
Classification	Number of vehicles	Number of axles
2-axle	X 100	= 200
3-axle	X 14	= 42
4-axle	X 6	= 24
5-axle	X 4	= 20
	124	286
Average number of axles/veh		= 286/124 = 2.31
24-hour vehicle count		= 9000/2.31 = 3896 vpd

[Referenced: Idea taken from (44)]

4.5.3   Count Periods

The counting period selected for a given location depends on the planned use

of the data and the methods available for collecting the data. The count period should

represent a specific time of day, week, or month for the particular study. For example,

Mondays and Fridays are usually not typical weekdays since they don't represent the

actual traffic flow (37). Engineers and planners rarely need turning movement counts,

vehicle classifications, or pedestrian counts during the nighttime, Sundays, or

holidays. Saturday counts are sometimes needed for shopping areas. During a count period, special events and the adverse weather should be avoided unless the purpose is to study such phenomena.

Count periods can often range from an hour to a year. Manual counts are usually for periods less than one day. Typical count periods for turning movements, sample counts, vehicle classifications, and pedestrian include: 2 hours for peak periods, 4 hours for morning and afternoon peak periods, 6 hours for morning, midday, and afternoon peak periods, 12 hours for daytime (e.g. 7:00 A.M. – 7:00 P.M.).

Automatic counts are usually taken for a minimum of 24 hours. They may extend for seven days, a month, or a year. The interval that is commonly used is one hour. Smaller intervals may be desired for specific purposes. However, smaller ranges require greater computer storage space or a reduction time (37).

4.5.4   Sample Counts and Count Expansions

All counts are considered samples. Even permanent count stations represent a sample of specific locations among the many sites in a given area. Count periods are also a sample of the overall long-term traffic flow. Time and resources do not permit the continuous counting of every intersection and individual roadway section on all existing streets and highways. Consequently, sample counts are taken over shorter time periods at specific locations. These counts are then adjusted and expanded to

produce estimates of the expected traffic flow for that location or similar locations

(37).

4.5.5   Short-Term Counts

The AASHTO guideline defines a short-term count to consist of a minimum of 24 consecutive hours of data for all lanes in a single or both directions. Short-term counts may be volume counts, classification counts, speed counts, or WIM counts (39).

The short-break and alternating count procedures were described in the data recording section of this chapter and involve alternating counts and rest periods. Interpolation is used to fill in the rest periods. Similarly, hourly counts may be obtained by expanding short counts of 5, 6, 10, 12, 15, 20 or 30 minutes by use of appropriate multiplier (e.g., four times a 15-minute count provides an hourly estimate). The level of accuracy of such expansions increases with the length of the sample count. If traffic flows relatively constant over the hour, a short sample count will produce a reliable estimate of the hourly flow. If a flow is highly variable during the hour, a more extended sampling period will be needed to obtain a reasonable estimate. Short counts of sub-hourly flow allow a team of observers to cover several locations in the time it would take to perform a 1-hour count at a single location (37).

4.5.6 Small Network Counts

As per the ITE Manual, short counts may be expanded by use of control station. If many sample counts are needed in a relatively small area, analyst selects one location representative of the area streets to be sampled. It is essential that the control station service the same type of roads to be sampled. It is also vital that the control station service the same type of road and variations of traffic being sampled on the other roads. The control station is counted continuously during the entire sampling period using the same count interval (e.g., 15 minutes) as on the sampled streets. The counts taken at the sampling locations are called coverage counts. Both the coverage and control counts are made at midblock to avoid the complexity of turning movements. Each link or street segment to be sampled should be counted at least once during the sampling period. The counts may be made manually or with automatic counters (37).

The control count data establishes the volume variation pattern for the entire sampling period. The pattern is quantified by calculating the proportion of total sampling period volume occurring during each count interval. Assuming that this pattern applies to all of the sampled locations in the study area, the full sampling period volume for a coverage count location is obtained by dividing the sample count by the control count proportion for the corresponding count interval. Table 4.5 below shows an illustration of the procedure. For the illustration below, a control station was

used, and four coverage counts were made over a 2-hour sampling period. The count
interval was 15 minutes beginning at each quarter hour.

Table 4.5:   Count expansion examples

Control Station				
	Time	Count	Proportion of Period of Total	
	7:00-7:15 A.M	750	750/6895	0.109
	7:15-7:30 A.M	775	775/6895	**0.112**
	7:30-7:45 A.M	840	840/6895	0.122
	7:45-8:00 A.M	950	950/6895	**0.138**
	8:00-8:15 A.M	1025	1025/6895	0.149
	8:15-8:30 A.M	985	985/6895	**0.143**
	8:30-8:45 A.M	870	870/6895	0.126
	8:45-9:00 A.M	700	700/6895	**0.102**
	Total	6895	Vehicles	
Expansion of Coverage Counts				
Location	Time	Count	2-Hour Volume (Estimated)	
1	7:15-7:30 A.M	790	790/0.112	7029
2	7:45-8:00 A.M	1185	1185/0.138	8587
3	8:15-8:30 A.M	856	856/0.143	5992
4	8:45-9:00 A.M	522	522/0.102	5142

[Referenced: Idea taken from (37)]

4.6   Volume Data Presentations

Traffic volume data may be portrayed in the number of ways. The selection of
the method of presentation can depend on the audience and the objective of the data.
Analysts most often depict volume data in summary tables or one of several graphical

forms. Graphs and charts are suitable for illustrating traffic volumes over time. Pie

charts are useful to show proportions of volumes by type of vehicle.

4.7   Specific Counting Studies

Traffic volume counting is not always a simple and straightforward task. Some

types of volume studies are complex and challenging to perform. They require special

preparations and trained observers. There are specific complex counting studies that

challenge data collectors to conduct the studies, which include intersection counts,

pedestrian counts, cordon counts, screen line counts, area-wide counts and control

counts (37).

4.7.1   Intersection Counts

As per ITE manual, an intersection is the most complex located in a traffic

system (37). Intersection counts are often used for timing traffic signals, designing

channelization, planning turn prohibitions, computing capacity, analyzing high crash

intersections, and evaluating congestion (45). The manual count method is usually

used to conduct an intersection count. Intersections have up to four possible turning

movements: U, left, through, and right. At a four-leg intersection, an observer could be

faced with recording 48 separate data elements during each sampling period. In most

cases, intersection counts require multiple observers but in a very light traffic

condition, a single observer insufficient. If many vehicle classes are to be examined at

a busy intersection with several simultaneous movements, each observer must be able

to record data for two or three lines. Simplified methods of identifying vehicle classes are sometimes desirable. The classification scheme must be well understood by all observers before the beginning of the count.

4.7.2 Signalized Intersections

According to ITE manual, an observer may alternate counting movements in two directions (e.g., eastbound and southbound) as the signal phase changes. Some models of electronic count boards are equipped with a separate box attached by a cable to the main box. It allows one record to be made while two observers each count two approaches. Counts at signalized intersections are complicated because one or more movements can occur during each phase, each signal cycle may contain two or more phases, and the green time for each period is not often equal to the other phases. The count interval must be an even multiple of the signal cycle length To avoid bias towards the count of any particular set of movements. If the short-break method is being used, both the count interval and the short-break interval must be even multiples of the cycle length (37).

Actuated signals can further complicate counting being that both the cycle lengths and the green times may often vary from cycle-to-cycle. One rule of thumb is to select counting intervals that will include at least five cycles, using the maximum cycle length to determine the interval (42).

- *Arrival Versus Departure Volumes*

Intersection volume counts are usually recorded as vehicles cross the stop bar and enter the intersection. This point is chosen so that turning movements can be observed accurately. If the intersection becomes saturated (demand exceeds capacity), queues that may require more than a single cycle to dissipate will develop. If this occurs, the departure counts will not reflect the demand volumes. In these cases, arrival volumes should be recorded (37).

Arrival volumes are not easy to observe because the queues are continually changing and may extend beyond the line of vision of the observer. Additional observers are typically needed to count queue lengths while the primary observers count departure volume. For highest accuracy, the queue should be counted during every cycle. However, the line may also be counted at the end of each counting interval if desired. All lines are made at the beginning of a red phase. Table 4.6 illustrates how to estimate arrival volumes by observing departures and queue lengths. One can calculate the arrival count for each interval by adding the net change in queue length to the observed departure count (37).

Table 4.6:   Example of Estimating Arrival Volume from Departure Counts

Time period	Total Departure Count (veh.)	Queue Length (veh.)	Arrival Volume (veh.)	
4:00-4:15 P.M	55	0	55+0=	55
4:15-4:30 P.M	65	0	65+0=	65
4:30-4:45 P.M	60	4	60+4=	64
4:45-5:00 P.M	70	12	70+12-4=	78
5:15-5:30 P.M	60	10	60+10-12=	58
5:30-5:45 P.M	62	5	62+5-10=	57
5:45-6:00 P.M	65	0	65+0-5=	60
	50	0		50
	487			487

[Referenced: Idea taken from (42)]

4.7.3   Pedestrian Counts

Pedestrian count data are frequently used in planning applications. Pedestrian counts are used to evaluate sidewalks and crosswalk needs, to justify pedestrian signals, and to time traffic signals When pedestrians are tallied, those 12 years or older are customarily classified as adults (37). Persons of grade school age or younger are classified as children. Pedestrian counts are usually taken at intersection crosswalks, at midblock crossings, or along sidewalks or walking paths. The observer records the direction of each pedestrian crossing the roadway. These data are then used for a traffic signal, and crosswalks warrant studies, for capacity analysis, in accident studies, for site impact analysis, and in other planning applications (37).

4.7.4 Cordon Counts

Agencies make a cordon count by encircling an area such as a central business district or other majority activity with an imaginary boundary and counting vehicles and pedestrians at all of the points where streets cross the cordon. Using 15-to-60-minute intervals, observers classify each vehicle by type, the direction of travel, and occupancy. The counts show the amount of entering or leaving and enable an estimation of the vehicle and person accumulations within the area. Cordon counts are used as part of an origin-destination survey as a basis for expanding interview data. They are also used for trend analysis. Usually, for this application conduct cordon counts one weekday each year, during a month with average daily traffic (ADT) that is close to the annual average daily traffic (AADT) and the counts are made at the same time each year. The distribution of traffic at each crossing location is critical to the determination of accumulation; therefore short counts should not be used (37).

Summing the entering and leaving counts at all count stations by time interval find vehicle accumulations within the cordon. The counts usually begin when the street system is at its lowest flow. When the study starts, the number of vehicles parked on and off the street can be counted to estimate the number of vehicles inside the cordon (37).

Table 4.7:   Accumulation Computations for a Cordon Count

Time	Vehicles Entering	Vehicles leaving	Accumulation (veh.)
4:00-5:00 A.M	-	-	245
5:00-6:00 A.M	102	25	322
6:00-7:00 A.M	146	34	434
7:00-8:00 A.M	189	42	581
8:00-9:00 A.M	289	78	792
9:00-10:00 A.M	346	120	1018
10:00-11:00 A.M	336	210	1144
11:00-12:00 NOON	350	345	1149
12:00-1:00 P.M	255	289	1115
1:00-2:00 P.M	290	367	1038
2:00-3:00 P.M	180	450	768
3:00-4:00 P.M	110	345	533
4:00-5:00 P.M	117	312	338

[Referenced: Idea taken from (42)]

4.7.5 Screen Line Counts

Screen line counts are made to record travel time from one area to another. It is some form of a natural or human-made barrier with a limited number of crossing points. Usually, screen line counts are used to check and adjust the results of origin-destination (O-D) studies. They may also be used to detect trends or long-term changes in land use, commercial activity, and travel patterns. Hourly intervals for a 12 to 24-hour period are usually used on a weekday to conduct screen line counts. Upon completion of the count, the screen line crossings (hourly or total) are compared to the crossings predicted by the home-interview study. The result is then used to adjust the model that predicts O-D flows (37).

4.7.6 Daily and Seasonal Adjustment Factors

Average Daily Traffic (ADT) counts represent a 24-hour count that has been conducted at a specific location. These counts are obtained by placing an automatic counter at the analysis location for a 24-hour period. The accuracy of the ADT data depends on the count being performed during a typical roadway, weather, and traffic demand conditions. A local government will typically conduct this type of count (37).

Permanent-count stations provide the most accurate source of data for computing daily and seasonal adjustment factors. First, a computation to find the average volume for each day of the week over the entire year is needed. The average of this 7-day profile is the ADT of a typical week. The daily adjustment factor is found by dividing the ADT by the average volume for each day of the week. Table 4.8 below illustrates the computation of daily adjustment factors (37).

Table 4.8:   Illustration of Computation Daily Variation Factor

Day	Average Yearly Volume for Day (vpd)	Daily Factor		
Monday	1350	1435/1350	=	1.06
Tuesday	1270	1435/1270	=	1.13
Wednesday	1300	1435/1300	=	1.10
Thursday	1320	1435/1320	=	1.09
Friday	1400	1435/1400	=	1.03
Saturday	1600	1435/1600	=	0.90
Sunday	1800	1435/1800	=	0.80
Total =	10040	Vehicles		
ADT =	1435	Vpd		

[Referenced: Idea taken from (37)]

Annual Average Daily Traffic (AADT) counts represent the average 24-hour traffic volume at a given location averaged over a full 365-day year. AADT volume counts have the following uses (37):

- Measuring or evaluating the present demand for service by the roadway or facility;

- Developing the major or arterial roadway system;

- Locating areas where new facilities or improvements to existing facilities are needed;

- Programming capital improvements.

The computation of seasonal or monthly variation factors is shown in table 4.9 below. The ADT for each month is the monthly volume from the permanent-count station divided by the number of days in a month. To find the monthly adjustment factor, the AADT is computed and then divided by the volume of days in a month.

Table 4.9: Illustration of Computation Of Monthly Variation Factors

Month	Total Traffic (veh.)	ADT for Month (vpd)	Monthly Factors (AADT/ADT)
January	20,000	20,000/31 = 645	803/645 = 1.24
February	17,000	17,000/28 = 607	803/607 = 1.32
March	21,000	21,000/31 = 677	803/677 = 1.19
April	24,000	24,000/ 30 = 800	803/800 = 1.00

4.9   continued

Month	Total Traffic (veh.)	ADT for Month (vpd)	Monthly Factors (AADT/ADT)
May	26,000	26,000/31 = 839	803/839 = 0.96
June	26,500	26,500/30 = 883	803/883 = 0.91
July	27,600	27,600/31 = 890	803/890 = 0.90
August	30,000	30,000/31 = 968	803/968 = 0.83
September	29,000	29,000/30 = 967	803/967 = 0.83
October	27,000	27,000/31 = 871	803/871 = 0.92
November	23,000	23,000/30 = 767	803/767 = 1.05
December	22,000	22,000/31 = 710	803/710 = 1.13
Total =	293,100		
AADT =	293,100/365 =	803	

[Referenced: Idea taken from (37)]

4.7.7   Estimation of Annual Average Daily Traffic (AADT)

The AASHTO guideline presents the following procedure that can be used to convert any short-term volume count (of at least 24 hours duration) into an estimate of AADT (39):

1. Summarize the count as a set of hourly counts;

2. Divide each hourly count by the appropriate seasonal traffic ratio (or multiply by the appropriate seasonal traffic factor);

3. For each hour of the day, average the results of Step 2, producing 24 hourly averages;

4. Sum the 24 hourly averages to produce estimated AADT.

To adjust a 24-hour count for a given location to an estimate of AADT, multiply the count by the appropriate day and monthly variation factors. The factors used should be from a permanent or control count station location similar in geometry and traffic characteristics to the location of the coverage count (37).

4.8   Traffic Data Reporting and Management

Traffic data are mostly collected using taxpayers' revenue, which technically means that the public "owns" traffic data results. Therefore, traffic data should be made accessible to both in-house consumers and the public. While the public does, in fact, have rights to access traffic data, it is the responsibility of the collecting agency to minimize the incorrect use of those data (39). The AASHTO guideline provides the following suggestions to prevent improper use of data (39):

- Provide public access to official reports generated by the collecting agency as portable document format (PDF) or hypertext mark-up language (HTML) files on a web site;

- Do not provide direct public access to the underlying, detailed traffic database;

- If public access to the database is provided, restrict access to carefully constructed views on the underlying database;

- Staff within the collecting agency should mediate raw data files when access is permitted to underlying detailed data;

- Any public access to traffic should be restricted to those with a legitimate need for such data, and to those who understand how to use the data.

In traffic data management, the main problem is the extent of the amount of data that becomes huge, so a large number of resources can be consumed to manage these data without an effective management system.

The main problem in traffic data management is the amount of data that becomes huge. So a large number of resources can be consumed to manage these data without an effective management system. As per the AASHTO Guidelines for Traffic Data Programs, the total amount of traffic data and the need for effective dissemination of traffic statistics make it nearly mandatory that all such measures and statistics be stored in a modern "industrial strength" database. Many excellent relational database management systems are available on the market (39).

After traffic data are collected, edited, and summarized, they are reported to users. Web portals are the current mechanism available to disseminate traffic information. Using Web portals, the simplest way to distribute traffic data is by generating the reports and printing them as PDF files. The public can then access these files on a Web site. Another option is to allow users to select these parameters and have the system create real-time reports. This option allows more flexibility in report creation but requires that the underlying report programs permit this kind of parameterization. Many states provide web-based reporting tools that enable their users to generate reports over the Internet (39).

The day-to-day work of most state agencies usually requires responding to internal and external requests for traffic information. Microsoft Office products, particularly word processors and spreadsheets, are a convenient way to perform this

work. Some specialized reporting packages are explicitly designed for report preparation from an external database. These tools usually have both powerful report formatting capabilities and data manipulation tools. They allow custom functions, sub-reports, charting, and other skills. These tools also will allow the report format to be saved and used again for periodic reporting capabilities (39).

As per AASHTO Guidelines, it has been observed that the most frequently requested reports are for typical roadway traffic volumes. Reporting daily traffic presents the variation of traffic demand. The periodic distribution of traffic within a day is termed as "diurnal distribution." Some traffic reports, such as diurnal distributions, should incorporate graphic presentation of data (39).

There should be common reporting conventions among state agencies to easily compare data. Traffic reports are used throughout the transportation profession. The way in which traffic data are reported should be responsive to users need. The following table 4.10 lists some necessary traffic information published by state agencies.

Table 4.10: Categories of Traffic Information

Type or Statistics	Abbreviation
Volume:	
Annual Average Daily Traffic	AADT
Design Hour Volume	DHV
Peak Hour Traffic Percentage	K
Directional Split	D
Peak-Period Volume	Peak-Period
Diurnal Distribution	
Turning Movements	
Vehicle Miles of Travel	VMT
Vehicle Classifications:	
Heavy Commercial Annual Average Daily Traffic	HCAADT
Diurnal Distribution	
Percentage of Trucks in Peak	T
Percentage of Vehicle Class	VC%
Truck Weights	
Gross Vehicle Weights	GVW
Equivalent Single-Axle Loads	ESAL
Diurnal Distribution	
Load Spectra	

[Referenced: Idea taken from (39)]

4.9   Chapter Summary

This chapter reviewed the ITE Manual of Transportation Engineering Studies (37) and the AASHTO Guidelines for Traffic Data Programs (39) to provide methods and guidelines on conducting traffic volume and classification counts studies. It reviewed manual and automatic methods of counting and provided detailed

information on traffic volume and vehicle classification studies. The section discussed

data collection equipment and personnel needed, as well as field procedures for both

manual and automatic methods of counting.

Moreover, the technique of converting axle counts to vehicle counts; reduction

and analysis of traffic volume, and sample count expansions for both manual and

automatic traffic counting are discussed. Also, various types of specific counting

studies such as intersection, pedestrian, cordon, and screen line counts are presented.

Traffic volume data presentation, reporting, and management techniques were

also discussed in detail. According to these two publications, data presentation

formats, which are summary tables, graphs, and charts are suitable to illustrate traffic

volume counts. Also, Microsoft Office products, particularly word processors and

XLS spreadsheets, are a convenient way to disseminate traffic information.

Finally, based on these two documents, standard methods of daily and seasonal

adjustment factors calculations, and estimation of AADT with examples are also

presented.

Chapter 5

COMPARISON OF DELDOT-TMC TO SELECTED STATES

5.1 Introduction to comparison

This chapter presents a comparative analysis of DelDOT's TMC products and data presentation formats to different states that are similar in size to Delaware such as Vermont and Connecticut, neighboring states like New Jersey and Pennsylvania, and larger states such as California, Texas, and Virginia. This chapter will focus on traffic data, and it will examine the data source, accessibility, presentation formats, and styles for each of the selected states.

5.2 Comparison by Data Source and Its Accessibility

5.2.1 DelDOT-TMC

DelDOT collects, analyzes, manages, and disseminates historical and real-time traffic and roadway weather data to Delawareans. To provide real-time traffic and roadway weather data, DelDOT uses the following website: DelDOT's public website, TMC Extranet, "TMC Data Map," and "TMC Weather Summary."

DelDOT's public website and TMC Extranet website are accessible and user-friendly. However, TMC Extranet website requires users to register before gaining access to the site. The March 13, 2018 "Integration of Operations and Planning

Advisory Committee Meeting" document provides links to the " TMC Data Map" and "TMC Weather Summary" websites. These two websites revealed detailed traffic and roadway weather data. However, these sites are not accessible to the public through standard web browsing.

The other source that DelDOT uses to disseminate traffic and roadway weather information to the public is through its smartphone application known as DelDOT Mobile App. However, Delaware's hands-free law prevents drivers from access their Mobile App while driving. According to Delaware's office of highway safety "JUST DRIVE, Arrive Alive DE" website, hands-free is the law in the state of Delaware. It means that drivers are restricted from using their phones to talk, text, email, Snapchat or post while driving in the state of Delaware. Drivers who use their cellphones while driving will be fined up to $100.00 for a first-time offense. A second offense could cost drivers up to $300.00 with additional court costs (46).

The third type of product that DelDOT-TMC uses to provide traffic and travel information is through its travel advisory radio (WTMC 1380 AM). The travel advisory radio, which is also available on DelDOT's Mobile App, provides users with daily real-time traffic, weekly construction, and transit information. For Delaware drivers, this is TMC's friendliest source for travel information since the radio is a hands-free device.

Lastly, as a means of updating and communicating with the public, DelDOT releases travel information through various social media sites (such as Twitter, Facebook, YouTube, Flickr, and blog).

5.2.2 Similar Size States (Vermont and Connecticut)

The state of Vermont and Connecticut were chosen due to their similarity in size to Delaware. These two states also provide real-time traffic data through their websites, mobile applications, and social media sites.

The Vermont Agency of Transportation (VTrans) uses Transportation Data Management System, also known as TDMS, to disseminate various types of traffic data through its web-based interactive map. However, as mentioned in chapter 3, only two of the modules (TCDS and TMC) are accessible to the public. To obtain the other modules, as well as additional reports, VTrans requires that all individuals create a user account.

VTrans provides a data website that is open to the public through "transparency Public Information Portal." The open data portal allows users to download raw transportation data sets. VTrans also uses a website called "New England 511", which provides a map of real-time traffic information for three different states (New Hampshire, Maine, and Vermont).

The Connecticut Department of Transportation (CTDOT) disseminates traffic data through its public website and the "CT Travel Smart" website. Both of these websites are available to the public, and it is effortless to use. The CTDOT website provides links to some traffic and travels mobile apps such as Google maps, Waze, Transit App, Roadify, RoadAhead, and INRIX Traffic. However, RoadAhead highway exit finder application requires a fee of $1.99 to download. The other mentioned mobile applications are free.

VTrans and CTDOT also disseminate real-time traffic conditions through their social media sites. VTrans uses Twitter, Facebook, YouTube, and Flickr to provide traffic information to their users. CTDOT delivers information through Twitter and Facebook.

5.2.3 Neighboring States (New Jersey and Pennsylvania)

The thesis also compares DelDOT-TMC to two of its neighboring states' TMC; New Jersey and Pennsylvania.

As stated in chapter 3, the NJDOT website provides traffic information through the following tabs; Functional Classification Maps, National Highway Systems (NHS), Public Roadway Mileage (HPMS), and Straight Line Diagrams. However, to use Straight Line Diagrams (Automated Straight Line Diagrams and New Jersey Roadway Videolog), users are required to install Microsoft Silverlight software. Once Silverlight is downloaded, traffic data by routes and municipality are easily attainable. The interactive map through "511nj.org" website provides additional travel and traffic information to the public.

Pennsylvania Department of Transportation (PennDOT) uses its public website and "511PA Travel Info" website to monitor traffic information, facilitate safe traffic counting across the state, as well as provide traffic and GIS resources to the public.

Both NJDOT and PennDOT provide real-time traffic information through their hands-free mobile app, "SafeTripNJ" and "511PA Travel Info to Go". By utilizing the user's built-in GPS, the smartphone applications for both states use the PA and NJ

travel information data system to inform drivers on current traffic disruptions (construction, conjunctions, accidents, and others) that are in close range. These applications are free to download and easy to use. When there is an incident nearby, both SafeTripNJ and "511PA Travel Info to Go" mobile apps broadcast traffic advisory. There is nothing to read, click, or scroll through to use these apps.

Both NJDOT and PennDOT also update the public about traffic conditions through the social media sites. NJDOT uses social media sites such as Facebook, Twitter, YouTube, Instagram, and ReadyNJ Blog. PennDOT uses Facebook, Twitter, YouTube, and Instagram to provide travel and traffic information to their intended users.

5.2.4   Larger States (California, Texas, and Virginia)

This section of the thesis will also compare three states that are larger than the state of Delaware; California, Texas, and Virginia. California Department of Transportation (Caltrans) obtains traffic data from the Caltrans Performance Measurement System (PeMS). Users are required to establish an online account to access or download traffic data through the PeMS web-based interface systems. Once users are approved, they can immediately access PMS. The Caltrans website provides users with a variety of traffic data information.

Texas Department of Transportation (TxDOT) uses Traffic Count Database System (TCDS) to organize and distribute traffic count data. The TXDOT website provides a direct link to the DriveTEXAS website to access more real-time traffic

conditions throughout the state. Virginia Department of Transportation (VDOT) conducts a program where sensors gather traffic data that are in or along the state highway. "VDOT 511" website also provides real-time traffic and roadway weather. VDOT periodically produce booklets that consist of traffic data and estimates and then published on the department's website.

Other sources that Caltrans uses to disseminate traffic data are through "Caltrans QuickMap" and "CalTrans" smartphone applications. TxDOT and VDOT also use a mobile application. TxDOT uses a mobile app called the Texas State Roads. Users can download the app for a fee of $9.99 to access 1965 live traffic cameras covering the state of Texas. "VDOT uses "511 Virginia" traffic mobile application, and it also operates a network of highway advisory radio transmitters throughout the state to provide real-time traffic conditions.

All these three states use social media sites. Caltrans updates its users through social media such as RSS (Real Simple Syndication) feeds, YouTube, Twitter, and Facebook. TxDOT uses Facebook, Twitter, YouTube, as well as Texas Highways magazine to communicate and inform users about real-time traffic conditions. VDOT offers real-time traffic information through RSS (Real Simple Syndication) feeds, YouTube, Twitter, Flickr, Facebook, and Instagram.

5.3   Comparison by Data Types

5.3.1   DelDOT-TMC

DelDOT-TMC provides real-time and historical traffic, roadway weather, and hydrological data through the different sources. When it comes to real-time traffic information, TMC provides data such as traffic volume, roadway occupancy, delay, speed, travel time, travel advisories (incidents), travel restrictions and closures, construction projects, schedule of DART transit, traffic cameras, as well as variable message sign locations.

The DelDOT's public website and interactive map deliver real-time weather information such as charging station locations, roadway weather, water level, snow accumulation, and snow plow tracking. For instance, the roadway weather allows users to access real-time information about air temperature, dew temperature, relative humidity, wind speed, wind gust, wind direction, heat index, visibility, and precipitation.

The " TMC data map" website provides real-time traffic information including travel time, traffic cameras, traffic flows, tracker advisories, DART transit schedules, snow plow as well as weather station locations through interactive travel maps.

The "TMC weather summary" website provides weather stations, surface and subsurface temperature, air temperature, relative humidity, dew temperature, precipitation, visibility, wind speed, wind gust, and wind direction. This roadway

weather interactive map also presents hydrological information such as hydro stations, stream and river depth, water velocity, and tide height in real-time.

Through the TMC Extranet website, DelDOT-TMC also disseminates historical traffic data, which includes traffic counts, classification counts, tube data, and radar data. In addition to the traffic counts, information about preparedness plans is also provided all in PDF files through this website.

5.3.2   Similar Size States (Vermont and Connecticut)

The VTrans TDMS currently offers two modules namely Traffic Count Database System (TCDS), which contains both continuous and short-term counts and TMC Turning Movement Count (TMC) modules. Through TCDS, VTrans organizes an agency's traffic count data. It allows users to upload data from a traffic counter; view graphs, list and report historical traffic count data; search for count data using either the database or the Google map; and print or export data to their computer. The AADT data is a traffic count data report that can be viewed or downloaded from the VTrans' public website. These data reports are updated by VTrans every three-years.

VTrans offers "transparency Public Information Portal", which is an open data portal that provides information and data including projects map, road conditions, plow finder, weather cameras, maintenance districts, crash fatality report, crash query tool, daily traffic volumes, highway closures, bridge inspections, pavement conditions and performance, maintenance work, rail asset inventory, and open data portal. The "New England 511" website also provides information about a traffic incident,

roadwork, future events, traffic speeds, special events, traffic cameras, weather stations, driving conditions, and message signs.

Similar to VTrans, CTDOT also counts all of its state-maintained roadways once every three years to determine the average daily traffic (ADT) of the road. CTDOT provides ADT maps for traffic volumes at specific locations through an interactive map. It offers continuous count station spreadsheet, which contains an average hourly, daily, weekly, and monthly traffic counts. CTDOT also disseminates vehicle classification reports through its public website. Through the "CT Travel Smart" website, users can access information including travel speeds, cameras, incidents, roadwork, message signs, weather alerts, and weather forecasts.

5.3.3   Neighboring States (New Jersey and Pennsylvania)

NJDOT provides traffic information including traffic volume counts, vehicle classification, speed, truck weight, vehicle miles traveled, and highway functional classification. NJDOT also maintains a traffic-monitoring program consisting of continuous and short-term elements. The state's Traffic Monitoring System Map (TMSM) disseminates traffic data such as weigh-in-motion, 48hrs-volume and classification, intersection count, seven days-volume, continuous volume, and data for ramps. Users are allowed to navigate daily or monthly weigh-in-motion data from the public website. Transportation data such as accidents, construction, congestion, road inventories, pavements, and safety are used to produce maps that support the department's work in planning, highway, rail, aviation, and maritime. Users can

access these transportation data from the NJDOT Geographic Information System (GIS). Through "511nj.org" website, NJDOT interactive map provides real-time travel information such as live traffic speed, roadway weather, traffic incidents, congestion, detour, construction, special events, and traffic cameras.

Pennsylvania Highway Statistics updates and summarize a variety of highway mileage and travel information annually and then reports the summary to the public. PennDOT collects and disseminates traffic data including volume, vehicle classification, highway functional classification, truck weight, and speed by state, county, and district. Both NJDOT and PennDOT provide real-time travel advisories through their hands-free mobile applications and social media sites.

5.3.4 Larger States (California, Texas, and Virginia)

Caltrans PeMS allows users to report on many performance measures including flow (volume), Annual Average Daily Traffic (AADT), Monthly Average Daily Traffic (MADT), Occupancy (percent time over detector), speed, Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), Travel Time Index (TTI), delay (expressed in vehicle hours), lost productivity (shown in lane mile hours), and Level of Service (LOS). Through QuickMap app, Caltrans provides real-time traffic information including freeway speed, traffic camera snapshots, lane closures, incidents, highway information, changeable message signs, snow plows, Waze data (accidents, traffic jam, hazard, construction, and road closing) and others.

TxDOT provides various types of counts (volume, class, speed, gap, and others) that have been performed at a specific location over the years. Users can also view any AADT's that have been calculated for that location. In its TCDS module, there are four different report categories available to authorized users which are a single station, single day reports; single station, multiple day reports; multiple stations, multiple day reports; and "Report Center" reports.

VDOT periodically publishes booklets that list the type of traffic data that the department provides through its public website which includes AADT, average weekday traffic, peak hour, and peak direction factors. A summary report of the VMT within selected jurisdictions is also available. "VDOT 511" website also provides real-time traffic and roadway weather on the interactive map (map views). The website provides real-time roadway weather such as air temperature, dew point, relative humidity, wind speed, wind gusts, wind direction, visibility, precipitation, pavement temperature, and condition.

5.4   Comparison by Data Presentation Styles and Formats

5.4.1   DelDOT-TMC

Most of the selected states disseminate transportation data using various presentations formats such as MS Excel, MS word, Shapefiles, CSV files, TIFF, tables, and charts. On the other hand, DelDOT uses PDF files as the main presentation format to provide historical traffic counts. For instance, TMC Extranet website provides traffic counts for some of the state's roadways and intersections in PDF file.

Real-time traffic and roadway weather information is disseminated through the interactive travel maps, which are not exportable to any other formats.

5.4.2 Similar Size States (Vermont and Connecticut)

VTrans allows the public to choose the report format (CSV, PDF, Excel, TIFF File) that users wish to print or download through the TCDS module. The TMC module allows users to choose from a variety of reports to print/export to either PDF or MS Excel files. The AADT history for each traffic count location can be reported and provided in MS Excel. Functional and vehicle classification reports, which show the most recent summary for each count location, is provided in PDF and MS Excel files. The open data portal "transparency Public Information Portal" allows users to download raw data for transportation-related purposes.

The state of Connecticut provides ADT maps for traffic volumes at specific locations in PDF files with various sizes through the department's website. Also, users have the opportunity to download the MS Excel spreadsheet version of the ADT data.

5.4.3 Neighboring States (New Jersey and Pennsylvania)

Both NJDOT and PennDOT offer transportation information in PDF files. Also, NJDOT provides downloadable traffic counts for single or multiple locations through its website. Users can download these traffic data from the functional classification map.

PennDOT disseminates highway statistics for different years through its website to the public. For instance, traffic data reports from 2012 to 2016 provided in PDF files. However, the report warns users that the data contained in this format is to be used only for traffic counts and not for future projected growth.

5.4.4 Larger States (California, Texas, and Virginia)

Caltrans PeMS provides access to real-time and historical performance data in many useful formats and presentation styles such as dashboards, maps, plots and graphs, tables, export to text/spreadsheet files and, animation video to the public.

TxDOT's TCDS allows users to upload traffic data and view graphs, lists, and reports of historical traffic count data. In addition to the default tabular report view, several of the reports have additional views available at the bottom of the page including view calendar, bar graph, line graph, tabular options and several MS Excel export options. Using either the database or the Google map, the website also allows users to search for count data as well as export or print the data.

VDOT provides Average Daily Traffic volumes with vehicle classification data on Interstate, Arterial, and Primary routes of each city and towns in the state of Virginia in PDF and MS Excel spreadsheet files. VDOT summary traffic data is also available as a KML, Shapefile or Geo Database file. VDOT also provides a compact disc (CD), which includes data in the Adobe® Portable Document Format (PDF) that can then be displayed, searched, and printed using a conventional desktop computer.

5.5   Chapter Summary

This chapter focused on the comparison of DelDOT-TMC to the selected states' Department of Transportation by the data sources, accessibility, type, and presentation formats. The overall results of the comparative analysis revealed that DelDOT-TMC and all of the selected states provide a wide range of real-time traffic data through various sources include websites, mobile applications, travel advisory radios, and social media sites.

Although data source and accessibility for all of the chosen states' DOTs examined, below are the review of the most noticeable differences and similarities. For example, the study recognized that the state of California (Caltrans) and Texas (TxDOT) had a better database system than Delaware. Caltrans collects and provides traffic data through a system called Performance Measure System (PMS). TxDOT uses Traffic Count Database System (TCDS) to organize and distribute traffic count data. Unlike DelDOT's TMC website, PMS and TCDS allow users to download historical and real-time traffic raw data in various formats via a standard Internet browser.

In addition to other data sources, New Jersey and Pennsylvania provided travel information to their users through a hands-free mobile app. The mobile apps broadcast traffic advisory when nearby incidents occur, and the hands-free tool allows drivers to concentrate on the road. Although Delaware provides real-time traffic and travel information through the DelDOT Mobile App, the hands-free law prevents drivers from using the App.

Most of the chosen states' department of transportation websites and databases (Connecticut, New Jersey, Pennsylvania, Texas, and Virginia) were freely available to the public while other states (California, Vermont, and Delaware) required registration. As previously stated, Vermont provides traffic data information through their website, under the TCDS and TMC tab. However, users are required to register, if further access is desired. Both TMC Extranet and California's Department of Transportation (Caltrans) website requires that users register before obtaining access to their traffic database and overall website. However, Caltrans users offered an immediate approval. TMC Extranet's approval process, on the other hand, can take up to a couple of weeks. Although all of the state's websites have some similarities and differences, it was discovered that all of the states website and database systems were user-friendly and easily accessible to the general public.

This chapter also observed the different data types for each state. It was discovered that all of the selected jurisdictions and DelDOT-TMC provided traffic data types including flow (volume), roadway occupancy, delay, AADT, speed as well as travel time. Although all of the states had similar data categories, Caltrans provided the most abundant data types. Caltrans PMS had additional traffic data types such as Monthly Average Daily Traffic (MADT), Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT), Travel Time Index (TTI), lost productivity (expressed in lane mile hours), and Level of Service (LOS).

The final section of the chapter compared data presentation, styles, and formats for each state. The findings revealed that DelDOT presented real-time traffic data on

interactive maps and historical data in PDF files. Unlike DelDOT-TMC, some state's

DOT such as Caltrans, TxDOT, and NJDOT disseminate data in many presentation

formats and styles. For example, Caltrans PeMS provides downloadable data and

reports in various forms, namely dashboards, maps, plots, graphs, and tables. It also

allows users to export the data in MS Words and MS Excel.

Table 5.1:   Summary of Comparison Between DelDOT-TMC and Selected States

Description	DE	VT	CT	NJ	PA	CA	TX	VA
Data Sources:								
Websites	Y	Y	Y	Y	Y	Y	Y	Y
External Database	Y	Y	Y	Y	Y	Y	Y	Y
Mobile App	Y	N	Y	Y	Y	Y	Y	Y
Travel Advisory Radio	Y	N	N	Y	Y	N	N	Y
Social Media Sites	Y	Y	Y	Y	Y	Y	Y	Y
User friendliness:								
Websites	Y	Y	Y	Y	Y	Y	Y	Y
External Database	Y	Y	Y	Y	Y	Y	Y	Y
Mobile App	Y/N	N	Y	Y	Y	Y	N	Y
Travel Advisory Radio	Y	N	N	Y	Y	N	N	Y
Social Media Sites	Y	Y	Y	Y	Y	Y	Y	Y
Accessibility:								
Websites	Y	Y	Y	Y	Y	Y	Y	Y
External Database	Y/N	Y/N	Y	Y	Y	Y/N	Y	Y
Mobile App	Y/N	N	N	Y	Y	Y	N	Y
Travel Advisory Radio	Y	N	N	Y	Y	N	N	Y
Social Media Sites	Y	Y	Y	Y	Y	Y	Y	Y
Type of Data available:								
Volume Counts	Y	Y	Y	Y	Y	Y	Y	Y
Vehicle Classification	Y	Y	Y	Y	Y	Y	Y	Y
Highway Classification	Y	Y	Y	Y	Y	Y	Y	Y
AADT	Y	Y	Y	Y	Y	Y	Y	Y
VMT	N	Y	N	Y	N	Y	N	Y

5.1:   Continued

Description	DE	VT	CT	NJ	PA	CA	TX	VA
Others	Y	Y	Y	Y	Y	Y	Y	Y
Data format	PDF	V	XLS	PXV	PDF	M	G	PXK
Improvement needed:								
Websites	Y	Provide data in variety of presentation formats						
External Database	Y	TMC Extranet needs faster approval process						
Mobile App	Y	Provide hands-free App.						
Travel Advisory Radio	N							
Social Media Sites	N							

Y = Yes = 100%   N = No = 0   Y/N = about 50%

V = various styles such as CSV, PDF, XLS, Word, TIFF, Shape files
PXV = PDF, XLS, Video
M = dashboards, maps, plots & graphs, tables, XLS, Word, Video
G = Graphs, Lists, Maps, PDF
PXK = PDF, XLS, KML, Shape file, GEO database files

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1   Summary

In 2002, DelDOT established a full-time centralized Transportation

Management Center (TMC) to provide accurate traffic data to the public. Since its

foundation, TMC has been collecting, analyzing, managing, and disseminating real-

time traffic and roadway weather information. As previously discussed in Chapter 2,

DelDOT-TMC installed more than a thousand monitoring devices within Delaware's

streets and highways to collect data. Using this equipment and sensors, DelDOT-TMC

collects real-time traffic, roadway weather, and hydrological data. Once data has been

obtained, TMC uses telecommunication and software to process and disseminate data

to the public. The primary sources that DelDOT-TMC uses to provide real-time and

historical traffic, as well as roadway weather data, are through DelDOT's public

website, TMC Extranet, DelDOT Mobile App, WTMC 1380 AM travel advisory

radio, and various social media sites such as Twitter, Facebook, and YouTube.

Chapter 3 examined seven specific states and provided a detailed analysis of

each state's TMC system. For each state, a close examination of how traffic data was

collected, processed, and disseminated to the public was reviewed. The following

states were studied in detail; states that are similar in size to Delaware such as

Vermont and Connecticut, neighboring states like New Jersey and Pennsylvania, as

well as larger size states such as California, Texas, and Virginia.

Chapter 4 reviewed the ITE Manual of Transportation Engineering Studies and the AASHTO Guidelines for Traffic Data Programs to provide different methods and guidelines that should be considered when conducting volume and classification counts studies. This chapter reviewed manual and automatic modes of counting and provided detailed information on traffic volume and vehicle classification studies. Moreover, the techniques of converting axle counts to vehicle counts, reduction and analysis of traffic volume, and sample count expansions for both manual and automatic traffic data were discussed. Also, various types of specific counting studies such as intersection, pedestrian, cordon, and screen line counts were presented.

Chapter 5 examined and compared DelDOT's TMC products to the selected states' TMC products that were discussed in Chapter 3. This thesis specifically reviewed the data source, accessibility, presentation formats, and styles for each of the mentioned states. It was discovered that DelDOT-TMC and all of the selected states provide a wide range of historical and real-time traffic data through various sources including websites, mobile applications, travel advisory radios, and social media sites. The overall results revealed that compared to the other states' DOT sources; DelDOT-TMC provided limited traffic and roadway weather data with limited presentation formats to the public.

6.2   Conclusions

There is a tremendous need for transportation data to conduct research on the various aspects of highway performance. Traffic and roadway weather information is

not only crucial for professionals, but for the general public as well. DelDOT-TMC is responsible for providing real-time traffic and roadway weather information through various sources. Thus, this thesis provided an in-depth examination of the history and the overall responsibility of DelDOT-TMC.

The primary objective of this thesis was to conduct a thorough examination of the procedures that DelDOT's TMC used to collect, process, and disseminate data to the public. In Chapter 2, it was discovered that DelDOT-TMC used the latest equipment, technology, software, and devices that are installed throughout the state of Delaware to collect a variety of traffic, roadway weather, and hydrological data. Traffic data included highway classification, vehicle classification, and volume count. Real-time roadway weather data includes air temperature, barometric pressure, relative humidity, precipitation type and volume, pavement temperature as well as subsurface temperature. Hydrological data studies focused on stream and river depths, water velocity, and tide height.

Objective 4 of the study focused on producing in-depth research of DelDOT's TMC sources of data dissemination. In Chapter 2, it was discovered that DelDOT-TMC used various sources and websites to display traffic and roadway weather information such as the public websites, TMC Extranet, the DelDOT Mobile App, travel advisory radio, and social media sites. However, most of the mentioned websites and application provided limited information. For example, the public website used interactive maps to provide real-time traffic information, however, historical data were unavailable. Also, users were presented with the selection to view

traffic and weather information, but the option to download or export the given data was unavailable. It was also discovered that the DelDOT-TMC websites and mobile application presented the data in PDF files or through the interactive maps.

Out of all of the sources, " TMC Data Map" and "TMC Weather Summary" were the best websites that DelDOT-TMC had to offer. These two websites have more detailed traffic, roadway weather, and hydrological information than the Extranet and the interactive map websites. Unfortunately, the " TMC Data Map" and "TMC Weather Summary" sites are not readily accessible to the public. If these two websites provide more detailed data information than the other sites, why doesn't DelDOT-TMC provide it as the primary source?

Objective 5 and 7 focused on the evaluation and comparative analysis between DelDOT's TMC and the selected states' TMC, which was discussed in Chapter 3 and 5. After the comparative study, the results showed that there were some similarities and differences between the states' TMC. It was discovered that DelDOT-TMC and all of the selected states had a variety of data equipment and collection methods to gather traffic data. In most cases, each of the state's website was easily accessible and user-friendly. Although some of the states' sources were more detailed than others, all of the states provided real-time traffic data through various sources including websites, mobile applications, travel advisory radios, and social media sites. However, there were two very noticeable differences between DelDOT-TMC and the chosen states.

First, the TMC Extranet website requires that potential users register before they are provided access to the department's website and database. However, TMC Extranet approval process can take up to a couple of weeks before the application is approved. Compared to the mentioned selected states, TMC Extranet was the only website that had an extremely long approval process. Also, the site provides historical traffic count information exclusively in PDF files; different presentation formats are not offered.

The second noticeable difference is the travel advisory radio, which is a part of the mobile App. DelDOT Mobile App offers drivers with real-time travel information through interactive maps. Although this is a useful tool, it does not provide users with a hands-free option. Thus, using the mobile App while driving can be very distracting and dangerous. Not to mention Delaware's hands-free law, which prevents users from accessing their smartphone application while driving.

Objective 6 of the thesis was to examine the standard data collection methods as per the ITE and AASHTO manual. Using these two references, Chapter 4 of this thesis presented a very detailed review of the conventional data collection methods. Although TMC's practice of collecting data was never obtained, it can be assumed that TMC is following the standard data collection guidelines that all transportation management centers are required to follow when conducting transportation engineering studies. If DelDOT-TMC is following these mandatory guidelines, there should then be an extensive amount of traffic and weather information data to provide to the public.

The general objective of this thesis was to examine the overall aspect of DelDOT-TMC as it relates to traffic and roadway weather data. To fully accomplish this, the thesis provided manuals for guidance and detailed comparison of different states DOT to DelDOT-TMC. After a careful and an in-depth review, it is determined that all of the objectives of the thesis have been achieved.

6.3 Recommendations

DelDOT-TMC is a fundamental division of Delaware's transportation industry. Real-time and historical traffic data, as well as roadway weather data, is essential information for not only for the public, but also for academia, students, engineering consultants, and the different divisions in DelDOT. Although DelDOT-TMC has provided a lot of travel information through the previously mentioned sources, there is room for improvement. The following are suggestions to DelDOT-TMC on possible improvements based on the research results:

- Improve the database to allow the public to download or export the collected data in multiple formats;

- Expedite the approval process for users or provide free access to the website;

- Provide real-time and historical data on all of the sites so that users can search for data information based on a specific range of time and date;

- Provide transportation data in formats other than merely PDF files;

- Offer easy access to the " TMC Data Map" and "TMC Weather Summary" websites;

- Produce an automatic broadcast traffic advisory system through the mobile application in compliance with Delaware's hands-free law.

As the number of drivers continues to increase, so will the need for traffic and road weather information. Therefore, more research will be needed to improve our transportation system. This thesis was written based on the current resources that TMC offered to the public. However, future researchers should try to obtain more information by contacting TMC directly. By interviewing or communicating with TMC staff directly and getting access to more resources, one can find out vital information that is not available online.

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Appendix

ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	Association of State Highway and Transportation Officials
AAWDT	Annual Average Weekday Traffic
AC Transit	Alameda-Contra Costa Transit
ADT	Average Daily Traffic
App	Application (Mobile)
ATR	Automatic Traffic Recorder
BART	Bay Area Rapid Transit
CAD	Computer Aided Dispatch
Caltrans	California Department of Transportation
CAVC	Continuous Automatic Vehicle Classifier
CD	Compact Disc
CHP	California Highway Patrol
CSMP	Corridor System Management Plan
CSV	Comma-Separated Values
CTDOT	Connecticut Department of Transportation
DART	Delaware Authority for Regional Transit

DelDOT	Delaware Department of Transportation
DelDOT-TMC	Department of Transportation- Transportation Management Center
DivComm	Department of safety & Homeland Security: Division of Communications
DMV	Division Of Motor Vehicles
DOW	Day-of-Week
DTI	Department of Technology and Information
EOC	Emergency Operations Center
EOP	Electronic Operations
ETC	Electronic Toll Collection
GEO	Gene Expression Omnibus
GIS	Geographic Information System
HPMS	Public Roadway Mileage
HTML	Hypertext Markup Language
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation System
KML	Keyhole Markup Language
LCS	Lane Closure System
LOS	Level of Service
MADT	Monthly Average Daily Traffic
MEPDG	Mechanistic-Empirical Pavement Design Guide

MS	Microsoft
NHS	National Highway System
NJDOT	New Jersey Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
O-D	Origin-Destination
OIT	Office of Information Technology
PDF	Portable Document Format
PeMS	Performance Measurement System
PennDOT	Pennsylvania Department of Transportation
PRTC	Potomac and Rappahannock Transportation Commission
RSS	Real Simple Syndication
rt-ADMS	real-time Archive Data Management System
RWIS	Roadway Weather Information System
STIP	Short-Term-In-Pavement Sites
TASAS	Traffic Accident Surveillance and Analysis System
TCDS	Traffic Count Database System
TDMS	Transportation Data Management System
TIFF	Tagged Image File Format
TMC	Transportation Management Center
TMC	Turning Movement Count
TMSM	Traffic Monitoring System Map

TPG	Traffic Pattern Group
TSMO	Transportation Systems Management and Operations
TTI	Travel Time Index
TVS	Traffic Volume System
TxDOT	Texas Department of Transportation
USGS	United States Geological Survey
VDOT	Virginia Department of Transportation
VDS	Vehicle Detector Stations
VHT	Vehicle Hours Traveled
VMS	Variable Message Sign
VMT	Vehicle Miles Traveled
VRE	Virginia Rail Express
VSL	Variable Speed Limit
VTrans	Vermont Agency of Transportation
WILMAPCO	Wilmington Area Planning Council
WIM	Weigh-In-Motion
WV	West Virginia
XLS	Microsoft Excel