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Developing Criteria for the Provision of Alabama Service Assistance Program (ASAP) Service

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DEVELOPING CRITERIA FOR THE PROVISION OF ALABAMA SERVICE ASSISTANCE PROGRAM (ASAP) SERVICE

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ABSTRACT

The Alabama Department of Transportation's (ALDOTs) Alabama Service Assistance Program (ASAP) helps facilitate the safe and efficient movement of people and goods by providing Safety Service Patrols (SSP) along major interstates in Alabama and utilizing effective incident management strategies to minimize the impacts of freeway incidents. Efficient operation of ASAP improves timely emergency response, increases operational efficiency of the transportation facilities, improves user satisfaction, and results in safety benefits including prevention of secondary crashes. This study focused on developing a new methodology that can determine with greater efficiency when and where ASAP services are needed. The proposed methodology can replace the Incident Factor (IF) method that ALDOT uses currently for deploying the assistance patrol teams which does not consider day, time, and seasonal variations of traffic; traffic composition; or special events. The proposed methodology is demonstrated using a case study in north Alabama. The case study considers a portion of the Alabama interstate network near Huntsville that includes northbound and southbound directions of I-65 and eastbound and westbound directions of I-565. Data on the different segments that made up the study corridors such as the truck percentages, and AADTs were obtained from RITIS and ALDOT. A threshold

known as Standard Normal Deviate (SND) was calculated for each segment, for days and time periods being considered and used to identify segments that had recurrent and non-recurrent congestion presence. SND values greater than -1.5 indicated recurrent congestion while those less than or equal to -1.5 were categorized as non-recurrent congestion. After identification of congested segments and classification of the congestion type as recurrent or non-recurrent congestion, associated delays were computed for each segment and the dollar value of these delays was calculated. This research presents a method that considers ADT, hourly volumes, traffic composition, day of the week, and cost of congestion in the determination of ASAP service needs. Adoption of the newly developed criteria is expected to improve the efficiency of deployment of ASAP patrol teams and help reduce the impact and cost associated with non-recurrent congestion.

Keywords: Alabama Service Assistance Program (ASAP), traffic congestion, Alabama Department of Transportation (ALDOT), Traffic Message Channel (TMC) codes, delay cost.

DEDICATION

This thesis is dedicated to Obiamaka Agusiobo.

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LIST OF ABBREVIATIONS

AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ALDOT	Alabama Department of Transportation
ASAP	Alabama Service Assistance Patrol
ATRI	American Transportation Research Institute
BLS	Bureau of Labor Statistics
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FSP	Freeway Service Patrol
FSPE	Freeway Service Patrol Evaluation
GIS	Geographic Information Systems
HSIS	Highway Safety Information System
IF	Incident Factor
INDOT	Indiana Department of Transportation

MPLG	Maintenance Program Leadership Group
NCDOT	North Carolina Department of Transportation
NPRMDS	National Performance Management Research Data Set
ODOT	Oregon Department of Transportation
RITIS	Regional Integrated Transportation Information System
SIM	Statewide Incident Management
SND	Standard Normal Deviate
SSP	Safety Service Patrol
TMC	Traffic Message Channel
VDOT	Virginia Department of Transportation

CHAPTER 1

INTRODUCTION

1.1 Overview

Road incidents lead to non-recurrent congestion and have undesirable implications on traffic operations and safety. They often result in delay for motorists, increase the chances of secondary crashes and have negative impacts on the economy, health, and the environment. According to (Houston , et al., 2008), the Federal Highway Administration (FHWA) estimates that about 25% of congestion can be attributed to traffic incidents. The Alabama Department of Transportation (ALDOT) has defined the Alabama Service and Assistance Patrol (ASAP) as a body that helps to restore the safe and efficient movement of goods and people following interstate incidents with the help of incident management strategies. These incident management strategies aim at minimizing traffic congestion that result from crashed, stalled vehicles or other unsafe road conditions that could create traffic congestion and safety issues. According to ALDOT (ALDOT, Alabama Service Assistance Patrol (ASAP), 2022), ASAP is centered on five distinct services which include traffic incident management, motorist assistance, road maintenance, emergency operations and work zone management. The ASAP crew works with the law enforcement agencies, fire, and rescue, towing and recovery services, emergency responders to improve the viability of the transportation network and restore operations in a timely and efficient manner.

Presently, the services of ASAP are available in Mobile, Montgomery, Birmingham, and Tuscaloosa and Huntsville. ASAP patrols operate primarily on interstate routes, although the services have recently been expanded to non-interstate routes to address congestion (e.g., US 280 in Birmingham) or traffic associated with special events (e.g., Montgomery and Tuscaloosa). The activities of the ASAP patrols are dovetailed by the Traffic Management Center (TMC) in the respective regional offices. Such coordination is to ensure timely emergency response, notification of the motorists, restoration of mobility, and prevention of secondary events on the roadway (ALDOT, Alabama Service Assistance Patrol (ASAP), 2022).

1.2 Statement of Problem

ALDOT currently uses an evaluation tool known as the Incident Factor (IF) equation to determine where ASAP patrols are needed. The equation calculates IF based on the Average Annual Daily Traffic (AADT) and the annualized number of crashes over a predetermined segment with the length of the segment. The IF equation is shown in Equ.(1) below.

$$IF = \frac{(\text{AADT}) * (\text{average annual number of crashes/length of segment in miles})}{100{,}000} \tag{1}$$

Based on AADT volumes and crash data, the tool can evaluate whether a particular highway segment (a) warrants ASAP patrols, (b) is close to warranting ASAP patrols, or (c) does not warrant patrols. For any segment under check to receive further consideration, the resulting IF should have a value of 4 or higher. The tool does not, however, consider specific days of the week or times of day when patrols are warranted, frequency of service, or whether there are seasonal variations that may lead to need for patrol services. It also does not consider geometric features of a roadway segment that can influence whether ASAP patrols may be needed. Finally, it does not address patrol needs that may be associated with special events or tourist traffic.

To address such shortcomings, ALDOT would like to refine the tool to consider a broader range of influencing factors, including:

- Truck volumes
- Time of Day variations in traffic volumes
- Daily and seasonal variations in traffic volumes
- Segment V/C ratio
- Roadway geometry (# lanes, shoulder presence and width, guardrail)
- Industry presence (just-in-time delivery corridors), and
- Special events

1.3 Aim and Objectives

The goal of this study was to develop a refined tool for determining the need for SSP deployment for the ASAP program in Alabama. The tool will be applicable to interstate and non-interstate routes and will:

- Identify segments that warrant ASAP patrols based on passenger car and truck volumes, crashes, roadway geometry, and adjacent land uses.
- Identify segments that warrant ASAP patrols based on seasonal volumes or special events.

- Determine times of day when patrols are warranted.
- Determine the frequency of patrols needed during operating periods.
- Determine the frequency and extent of patrols during off-peak periods.

The tool will also be able to identify roadway segments which may not currently warrant ASAP service, but will likely warrant service soon. This will provide ALDOT with time to plan for expansions in service in a timely manner in order to address future needs.

1.4 Scope of Study

ALDOT has continually sought to improve the efficiency of their current model used for deploying ASAP patrol vehicles. In the Huntsville area, ASAP patrol is deployed in some segments of the interstates I-65 and I-565. I-65 is a major north-south interstate highway that connects the Great Lakes in the north to the Gulf of Mexico in the south. Starting from IN, and going through KY, TN, and AL, it carries high daily traffic and high percentage of trucks and is a vital corridor for both passenger and freight transportation. Interstate I-565 currently has the ASAP patrol teams along the entire stretch. This work uses these interstates in the Huntsville area as study corridors to document the impact of the new criteria on the efficiency of the ASAP patrol service. Specifically, the study site covers segments from the Alabama/Tennessee border to the Exit 318 on I-65 (both Northbound and Southbound) and the East and Westbound alignments of I-565 from Exit 1 to Exit 20. Data used were obtained over a 31-day period in the month of March, 2021.

1.5 Limitations of Study

The study considered only one-month worth of data for the study interstate highway road segments in the Huntsville area. Traffic volumes of the segments under study were obtained from count stations set up by ALDOT at interstate exits to count the vehicular movements on the interstates. However, these count stations do not cover every interstate exit for the segments under study, thus count stations were zoned to cover the different exits or segments. While the data used in this study were deemed sufficient for demonstration purposes, it is recommended that the study scope is expanded in the future to include traffic data obtained over an extended time period, as well as additional study corridors in order to better account for variations of traffic, geometric, and other conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In order to minimize adverse impacts of incident-induced congestion Ozbey and Karchroo stated that most large and medium sized cities have initiated incident management programs (Ozbay & Kachroo, 1999). The objective of these programs is to identify and respond to incidents swiftly and find ways of restoring the roadway to full capacity after these incidents occur. The use of freeway service patrols is one method used by several states to support their incident management efforts. This chapter summarizes selected relevant research and works related to deployment criteria for safety patrols used by other Departments of Transportation (DOTs). It shares practices considered while setting up their state's road assistance services for decongestion of traffic on the roadways.

2.2 Priority-Ranking and Expanding Freeway Service Patrols (FSP) – North Carolina

As the state's population grew, and the urban areas in North Carolina experienced relative high traffic volumes and congestion, there arose the need to find an accurate, systematic method to identify the potential road segments that will receive highest deployment priority of freeway service patrols (FSP). Thus, the North Carolina Department of Transportation (NCDOT) with assistance from the FHWA Highway Safety Information System developed a decision support tool that allows easy planning and operational assessment of road segments. This was accomplished by comparing performance values between these segments, modeling the effect of using Freeway Service Patrols and estimating the key potential benefits of having the FSPs.

The NCDOT provided crash data with location information while the Highway Safety Information System (HSIS) database provided the facility information such as the annual average daily traffic and number of lanes. The crash data were used to check the occurrence of incidents on freeway facilities and pick out expansion criteria. According to Khattak et al., three index statistics were used to capture safety and congestion for each of the segments checked, namely crashes per 100 million vehicle-mi, crashes per mile per year and AADT per lane (Khattak A, Rouphail, Monast, & Havel, 2004), The research developed a decision support tool that allows users to easily access delays, and evaluate existing or future FSP deployment. The tool provides (a) a statewide ranking for planning-level analysis, (b) single incident assessment to examine the incident effects without the presence of an FSP and (c) operational level of analysis to determine the annual benefits of implementing an FSP based on the annual number of crashes entered by the user. The decision support tool requests as inputs the values of length of road segment, AADT, and the total number of annual crashes of the desired stretch of roadway. The cost of implementing an FSP is then calculated with the tool based on anticipated number of operating hours, cost of operating a vehicle for one hour and the total number of patrol vehicles necessary for covering the needs of existing facilities. Using the regression equation calibrated with the North Carolina FSP data, the decision tool is also able to predict the number of vehicles necessary for new facilities (Zhan, Gan, & Hadi, 2009). The vehicle estimation results, operating hours and costs are determined and benefit-cost analysis is performed to determine the most beneficial options for FSPs deployment. The research concluded that the FSP benefits would be higher if fuel and air quality savings were included in the calculations (Khattak A, Rouphail, Monast, & Havel, 2004). They researchers further recommended that a more thorough analysis of the effects of FSPs be conducted for FSP operating hours, segment lengths covered by the patrol teams, number of patrol vehicles, peak and nonpeak incidents and different roadway geometries.

2.3 Florida Department of Transportation (FDOT) and Road Rangers

The Florida Department of Transportation has a contract with the Road Rangers whose job includes motorist assistance, temporary traffic control and incident management. The Road Rangers help mitigate the impacts of incidents on roadways by training and equipping their staff on vehicle disablements, handling roadway debris and traffic control set up at crash scenes. Construction presence, air quality monitoring, traffic volume, volume-to-capacity ratio, crash frequency and available shoulder width are all considered in decision making to establish routes for the Road Rangers. According to the Florida Department of Transportation (FDOT), the Road Rangers program was set up in 2013 and provided 374,971 assists that year and more than 4.3 million assists since then (Florida Department of Transportation, 2015). A 2010 study funded by the FDOT showed that the benefit-cost ratio of the Road Ranger program was 6.68:1 as quoted by Lin et al. (Lin, Fabregas, Chen, Zhou, & Wang, 2012). The quest for provision of a decision support system for FDOT staff came because of the difficulty in reaching a consensus on whether a roadway needs the services of a safety service patrol (SSP). This led to the identification of the critical factors that are important for deployment decisions on service patrols such as traffic volume, number of crashes, available funding, and design attributes of the roadway segments. To check these critical factors with the planning guidelines of the SSP, a cross tabulation was performed using national survey results. These survey results were weighted differently from the most important to the least important. Five years' worth of data of traffic crashes (from 2011 to 2015) on Florida freeways were used to evaluate the crash-critical factors as the crashes were normalized to AADT and number of lanes, and employed in the computation of the number of incidents using the negative binomial regression model. The results from the model computation showed segment length and AADT having positive coefficients, which indicated that increased exposure yielded increased incidents (Florida Department of Transportation, 2015). Furthermore, Carrick et al. reported that a negative coefficient was observed with respect to the number of lanes, meaning that an increase in the number of lanes resulted in fewer incidents per lanes, assuming all other factors were constant (Carrick, Jermprapai, Srinivasan, & Yin, 2017). An increase in portion of trucks increased the predicted number of incidents for two models but decreased incidents in the other two. Also, Carrick et al. noted that segments that had neither end as an interchange had fewer total incidents than those that had one or both ends as interchanges (Carrick, Jermprapai, Srinivasan, & Yin, 2017). A user friendly and practice ready spreadsheet program was created to collect user input, perform calculations, apply decision logic, and render a recommendation to enable the decision-making process of deploying SSPs in an easy and effective manner.

2.4 The Oregon Department of Transportation (ODOT) and Safety Service Patrol.

The ODOT put up a warrant process to deploy Safety Service Patrol (SSP) in the state. As stated by Wood, the thought behind the warrant process is the link between the crash frequency and traffic volumes (Wood, 2003).. Wood summarized the seven warrants developed by ODOT as incidents reach acute levels when the Annual Daily Traffic (ADT) gets close to 75,000 vehicles per day causing rise in delay to motorists. The safety service patrol teams that assuage these incidents are deployed using the warrants shown as follows (Wood, 2003):

1. Construction, Holiday, and Special Event. Construction, holidays, and special events were considered as short-term incidents as they reduce capacity or cause peaks in traffic volume.
2. Air Quality Conformity/Transportation System Management. Metropolitan Planning Organizations often identify SSPs as a method of achieving air quality attainment goals in the urban areas.
3. Critical Infrastructure (includes bottleneck locations). Areas of a freeway like bridges, tunnels and interchanges are critical to the efficient flow of traffic in a region.
4. ADT greater than 75,000. Freeway volume is directly correlated to the incident frequency. A critical threshold is reached at around 75,000 ADT.
5. Volume-to-Capacity Ratio greater than 1. The warrant suggests that the presence of recurrent congestion can mandate the use of Safety Service Patrols.
6. Crash Frequency greater than 200. A 2-mile segment of freeway with 3-year crash history of 200 or more crashes warrants the need for SSP.

7. Shoulder Width less than 6 feet. Sections of the roadway with insufficient shoulder widths offer no space for vehicular breakdowns or debris. This reduces the capacity when an incident occurs thereby creating a safety hazard.

ODOT suggests that it is permissive to deploy SSPs if a single warrant is met, leaving the implementation decision to the discretion of the management. However, if warrants 4 and 5 or warrant 6 are meet, deployment of SSP is recommended because of the certainty that the affected section of freeway has deficiencies in its operation.

2.5 California Department of Transportation (Caltrans) and Freeway Service Patrol

The California Department of Transportation (Caltrans) with assistance from researchers at the University of California-Berkeley created a Freeway Service Patrol Evaluation (FSPE) model. Skabardonis and Mauch stated that the FSPE model calculates a benefit-cost ratio for the Freeway Service Patrol beats or routes based on the cost of the FSP service on a beat and reductions in delay of motorists, fuel consumptions, emissions that are attributed to the FSP operations (Skabardonis & Mauch, 2005). They also reported that the FSPE model predicts the cost-effectiveness of providing FSP service on freeway sections without FSP service. The model is able to tell the total number of FSP assists based on the traffic characteristics, the geometry and the service patrol’s hours of operation, after which it calls on the model to guesstimate the route as if the FSP assists were known (Virginia Transportation Research Council, 2006).

2.6 Virginia Department of Transportation (VDOT) and Safety Service Patrol

A Safety Service Patrol program was developed for the VDOT to respond to local needs in different areas. While the need for SSP arose, the Virginia DOT's Maintenance Program Leadership Group Report (MPLG) and the Statewide Incident Management Committee (SIM) were challenged to identify solutions to traffic problems resulting from incidents on Virginia's interstate roadways. A methodology often referred to as the MPLG methodology was developed in 1996 based on the criteria listed below (Virginia Department of Transportation, Maintenance Program Leadership Group Report, 1996):

1. Level of Service – a measure of traffic performance on the freeway segment.
2. Incident history- the number of incidents in the prior 3 years.
3. Planned projects- VDOT uses dollar value of projects in 6- year improvement program to check for safety implications of work zones.
4. Air quality- Using the binary variable of yes/no to decree attainment and non-attainment areas.
5. Access distance- The maximum distance an emergency vehicle must travel from an interchange to assist an incident that occur on the segment.
6. Length of structure- Structures that are long such as bridge or tunnel usually have reduced shoulder widths, hence making it unsafe for the motorist involved with breakdown vehicles to get assistance.
7. Annual Average Daily Traffic – to give information on the number of customers served by an SSP patrol.
8. Daily truck volume- indicating the number of trucks traveling the segment in 1 day.

The VDOT's SSP program falls in line with the incident detection/verification and response which are the cores of incident management. The program's mission is to provide initial response and promote and enhance the goals of incident management by patrolling the Commonwealth's interstate system and providing customer service related assistance for the safe and efficient transportation of motorist, goods and services in support of the economic, environmental and public demands placed on the system (Virginia Department of Transportation, Operations and Maintenance Field Operation Guideline for Patrollers, 2002), (Landis, Mclane, Irving, & Thompson , 2006). The SSP placed priority on incidents on the travel portion of the highway, over incidents on the shoulder area and incidents in the rest areas, in that order. However, these priorities may differ due to the type of incidents such as HAZMAT spills and personal injury (Virginia Department of Transportation, Northern Virginia Incident Management Team, 2002), (Dougald & Demetsky, 2006). According to VDOT and Landis et al., VDOT SSP staff were interviewed to gather information on the core set of functions for the VDOT's rural and urban SSP programs (Virginia Department of Transportation, Northern Virginia Incident Management Team, 2002) and (Landis, Mclane, Irving, & Thompson , 2006). The following information was obtained from these interviews:

1. Scene Management: To let the state police know about abandoned cars; provide cellular service to disabled motorists; provide directions and the state map of Virginia if requested by motorists; provide basic first aid and CPR if needed; communicate activities with State Traffic Centers and provide information to other responders; initiate maintenance action reports for any state property damage as a result of the incidents.

2. Traffic Management: To assist in controlling traffic at incident scenes; manage lane closures; verify, and manage operation of ramp-metering gates or High Occupancy Vehicle (HOV) gates in the urban areas.
3. Incident Clearance: To help jump start vehicles, provide gas, change tires, and provide air; remove debris; push vehicles to the shoulder; perform some minor mechanical repairs.

There were some limitations in the development of the VDOT SSP deployment planning tool. These limitations prevent its appositeness to statewide deployment decisions for the SSP, and include:

1. Limited data and inadequate model specification for incident history
2. Limited data for deriving the threshold score
3. Outdated threshold score
4. The methodology provides a binary answer for patrol deployment on a freeway section without paying attention to the time of day.
5. The criteria also seemed to be suited to urban areas than rural areas with greater point values for LOS and incident history.

After these limitations were identified, data related to all the routes were obtained. Traffic related data such as AADTs, lengths of sections, traffic flow profiles, percentage of trucks were all obtained from VDOT's traffic monitoring systems database. Data on the road geometry such as number of lanes, availability of left and/or right shoulders, and presence of high occupancy vehicle lanes were obtained from the VDOT's GIS online server. To obtain enough data for the estimation of the regression model used for the analysis, the (Virginia Transportation Research Council, 2006) noted that the segments defined by the Traffic Management Systems website for each SSP route were used as independent observers. Washington et al. explained that Poisson and negative binomial (NB) regression are two major methods used extensively for traffic safety research (Washington , Karlaftis, & Mannering, 2003). Initially considered in the development of this SSP model, was the use of the Poisson model but the deviance and Pearson chi-square values obtained were higher than 1.0 indicating that the data were overdispersed. Overdispersion indicates that the variance is greater than the mean and hence the assumption of a Poisson distribution is invalid, as in Poisson distributions, the mean is equal to the variance (Virginia Transportation Research Council, 2006). To take care of the overdispersion, Washington et al. recommended the use of negative binomial model for this study (Washington , Karlaftis, & Mannering, 2003). The final regression equation obtained using the NB model showed that the coefficient of the percentage of trucks variable is negative. This implies that as the percentage of trucks increases, the number of incidents decreases. However, caution must be applied as the rural segments had lower incidents, higher truck percentages, lower AADTs, and lower average daily percent of ADT served. The MPLG study indicated some modifications as they derived additional segment-based decision variables. The study was then modified by using the incident history to replace the annual incidents per mile. Level of service, air quality, maximum access distance, maximum structure length, AADT, and daily truck volume remained the same. The complete planning tool was programmed into Microsoft Excel using a Visual Basic macro. This was developed to provide VDOT SSP with an easy-to-use mechanism to rank potential SSP routes.

The limitations of the planning tool are highlighted below (Virginia Transportation Research Council, 2006):

1. The shoulder widths, which affect incident occurrence, were not specified in the model as inconsistencies were found in the data sources. Some of the freeway segments had both left and right shoulders, and the binary descriptors for the presence of shoulders were not included in the planning model.
2. Only one year's worth of incident data was analyzed because of the short timeline of the project. It is often advised that incident data in the prior 3 to 4 years be used to build the regression model.
3. The evaluation scale and weights for the segment-based variables were adopted from the MPLG study. There were claims that the weights applied to the variables were based on the MPLG committee's recommendations and are subjective in nature.
4. It was not possible to test the validity of the model in the study because all available incident data captured by VDOT's SSPs were utilized for the development of the incident planning model.

The study recommended that the decision-makers of the Safety Service Patrol team should prioritize the core functions of their programs in relation to the direct, indirect, and incidental benefits each provides, with emphasis placed on the functions that provide the most direct benefits (Virginia Transportation Research Council, 2006). It was also recommended that a statewide consistency with SSP core functions be maintained, and that each regional SSP manager should communicate and keep abreast of changes in core function priorities in other operations regions. The recommendation accented that the SSP deployment planning tool be used by VDOT's regional operations directors when considering the deployment of new patrols or altering existing ones. To achieve this, all existing and potential patrol routes need to be included in the evaluation. For future studies, it was recommended also that the directors of the VDOT regional operations should consider additional research that expands upon the current dataset.

2.7 The Hoosier Helper Program in Northwest Indiana

The Hoosier Helper program which is supported by the Indiana Department of Transportation (INDOT) roves about the 16-miles stretch of the six-lane Interstate 80-94 freeway commonly known as the Borman Expressway. The program also covers some other stretches of major highways in the state seeking and responding to incidents. The program, provides support at crash sites, supplies fuel, changing flat tires and calling private tow truck operators for motorists that need assistance. A simulation model was developed to carter for the freeway service patrols in the northwestern part of Indiana. The effort was driven by the need to tackle the issues of reliability of an emergency response system, facility location problem and to evaluate the effectiveness of a freeway service patrol program. Thus, the simulation model was created to estimate the effectiveness of the service patrol program for a wide range of parameters. The model according to Pal and Sinha (2002) was created in four phases that covered the replication of the incidence occurrence, the traffic flow in different links at different times, the response vehicle movement in their respective patrol areas and the clearance of the incident (Pal & Sinha, 2002). Because the number of incidents occurring per day is a non-negative integer, Poisson distribution was used. Poisson distribution is a count distribution suitable for random variables with non-negative integers as outcome as predicted by (Law & Kelton, 1991). Also, the nonhomogeneous Poisson distribution was used to model the incident generation as the rate of incident occurrence varied with time of day. The seasons, weekdays and weekends were incorporated into the model. Longitudinal location of incidents on various segments were assumed to be uniformly distributed along the entire link length while the lateral position of the incident with respect to shoulder presence or on lane was determined using probability distribution (Pal & Sinha, 2002). As the program patrolmen recorded the information regarding the incident, INDOT collected this information and used it to obtain the distribution of incidents by time of year and type of incident. The Poisson distribution was employed in calculating the number of incidents occurring in each hour as it generated nonnegative integers. The incident generation model was validated with the chi square test by juxtaposing the simulated and observed incidents. The two sets of data – simulated and observed, had similar confidence level values and critical values with little differences during certain hours of day. It was observed that the simulated speed was higher than the observed speed at night with the opposite happening during the day especially at the peak periods. This disparity according to Pal and Sinha is as a result of different truck percentages (Pal & Sinha, 2002). With all these findings, the Hoosier Helper program currently uses three response vehicles to cover the patrol area at peak hours while two patrol vehicles are deployed at off peak hours and at nights. The researchers advised that higher savings can be obtained if the deployment schedule is modified as well as improving the areas of operations, beat design and fleet size (Pal & Sinha, 2002).

Earlier studies provide valuable guidance on factors that need to be considered for determining the need for freeway service patrols and deployment of their services. However, localized studies are also important to better capture state need and reflect local conditions and needs in the decision-making process, both during the planning, and deployment phases.

CHAPTER 3

METHODOLOGY

This chapter presents the methodology developed in this study for identifying freeway segments that warrant ASAP patrol use as well as checks to see if the currently patrolled areas warrant the patrol service. First, the study site is introduced and details about the properties of the road segments that were used for this study are provided. These properties include study segment lengths, Annual Average Daily Traffic, Average Daily Traffic and information related to the presence of ASAP service. Next, the methods used in this study for determining the type of congestion present (recurrent versus non-recurrent) and calculating delays encountered along study segments over time are discussed. Finally, the steps that need to be taken to quantifying the cost of congestion are highlighted.

3.1 Study Site

ALDOT's ASAP currently provides Safety Service Patrols in Mobile, Montgomery, Birmingham, Tuscaloosa, and Huntsville areas. Segment covered by ASAP services are summarized in Table 1 and Figure 1.

Table 1: Areas covered by the ASAP team. Source: (ALDOT, ASAP Coverage, 2022) and Google maps

City	Segment	Length (miles)
Huntsville	I-65 Exit 334, Decatur – I-65 Exit 340BTanner	7
Huntsville	I-565 Exit 1– Halsey Ave NE (Exit 20, along I-565)	21
Anniston	I-20 (around Coves Point drive)- Alabama/Georgia State line	50.5
Birmingham	I-65 (at US 31 Alabaster) – I-65N exit 275	36.7
Birmingham/Tuscaloosa	I-59 at Deerfoot Pkway exit 143 – exit 68, I-59S	75.7
Birmingham	I-59 & I-459 at Edwards lake – I-459 & I-20/59 at McCalla exit 106	33
Birmingham	I-20 at Moody Parkway – I-20W at Deadman’s curve exit 130	14.7
Birmingham	US31 at Richard Arrington – Doug baker & US280	12.7
Montgomery	Exit 151- Alpha Springs Rd	35.1
Montgomery	Exit 171 – County Road 30 (Al 229)	26.2
Montgomery	Cox Road – Alabama/Georgia state line	30.2
Montgomery	I-65 Exit 219 – Exit 200	19
Mobile	I-10 exit 17A (Rangeline Road) – I-10 exit 20	3
Mobile	I-10 exit 20 – Baybridge Road	12
Mobile	Baybridge Road – I-10 at US 90	12.7
Mobile	I-10 Exit 20 – I-10 (exit 4) and AL 59	24.2

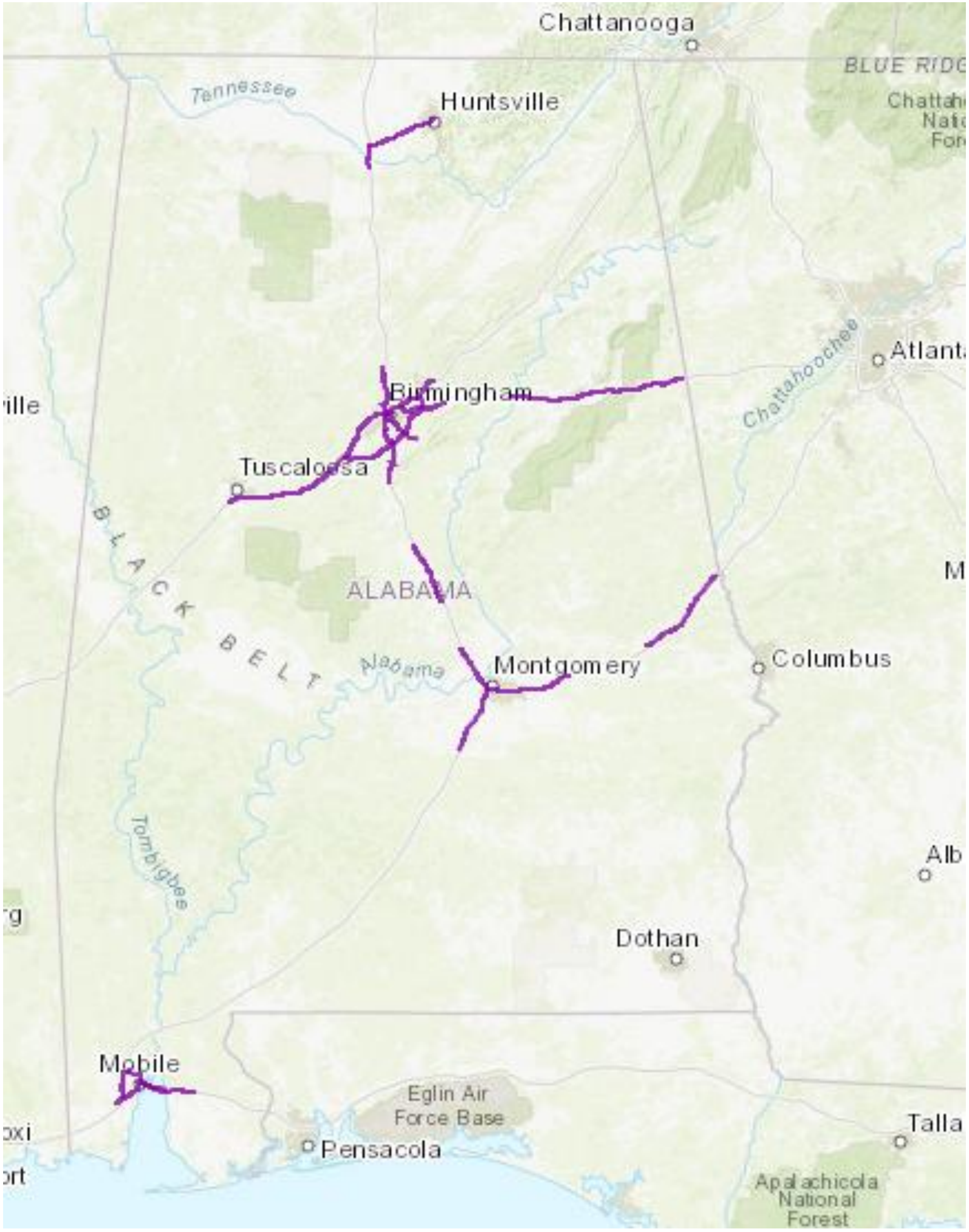

Figure 1: Map showing the areas under ASAP coverage. (ALDOT, ASAP Coverage, 2022)

ALDOT has worked tirelessly to ensure that the ASAP deployment model satisfies the criteria based on which the model currently runs and continuously seeks ways of improving these criteria. For this particular study, the northern part of Alabama, around the Huntsville area was selected as a case study. The area has a history of high volumes of truck traffic movements into Alabama from Tennessee and vice versa and was used to showcase the impact of the new deployment criteria being developed in this study on ASAP patrol use along segments of the I-65 and the entire stretch of I-565 in the Huntsville area.

The study segments are visually depicted in Figure 2 and their characteristics are summarized in Table 2. More specifically, the study segments cover Northbound and Southbound alignments of I-65, and Eastbound and Westbound alignments of I-565. On I-65, Exit 318 in Morgan County marks the beginning of the segment and ends at the Alabama/Tennessee border in limestone county. On I-565, the segment begins at exit 1in limestone county and ends at exit 20 in Madison County. The lengths were obtained from google maps.

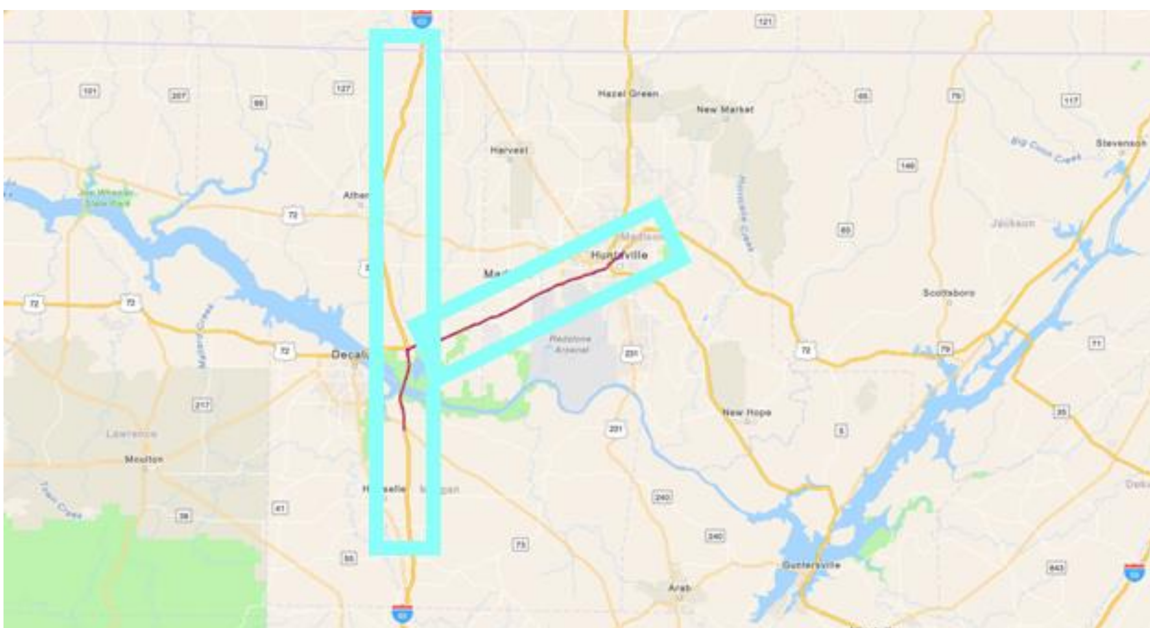

Figure 2: Map showing the study areas

Table 2: The study segments and their characteristics

Segment	From	To	Length(miles)	Remarks
I-65	Exit 318	Exit 322	4	No ASAP
I-65	Exit 322	Exit 325	3	No ASAP
I-65	Exit 325	Exit 328	3	No ASAP
I-65	Exit 328	Exit 334	6	No ASAP
I-65	Exit 334	Exit 340	6	ASAP
I-65	Exit 340	Exit 340 B	1	ASAP
I-565	Exit 1	Exit 20	21	ASAP
I-65	Exit 340 B	Exit 347	7	No ASAP
I-65	Exit 347	Exit 351	4	No ASAP
I-65	Exit 351	Exit 354	3	No ASAP
I-65	Exit 354	Exit 361	7	No ASAP
I-65	Exit 361	Exit 365	4	No ASAP
I-65	Exit 365	Alabama/Tennessee Border	1.7	No ASAP

3.2 Generation of Traffic Message Channel (TMC) Codes

TMC codes set up to convey location information relating to traffic are used by the Traffic Management Centers to monitor traffic and identify related problems on highway systems. TMC codes were used for this research as they provide means to efficiently highlight the detailed traffic information of different roads. These detailed traffic data summarized in TMC tables define the characteristics of the segments that span the distance between roadway intersections or each break in access (such as from one on-ramp to the next off-ramp) and make it easy for one to see the peculiarities of different road segments.

As defined by the Traveller Information Services Association, the creation of TMC codes involves encoding a TMC in a digital map to interpret road geometries at each location (Traveller Information Services Association, 2017). The positive and negative direction of a chain of TMC points cover the geographic locations of the TMC links. These links are typically the road segments between the first/last exit or entrance of a particular

TMC point also known as the internal TMC links, while the External TMC links comprise of the road segments between successive TMC points where one necessarily would end up at the internal links of a TMC point. The P and + denote the North and East directions of the exit/ entrance interchanges and the road segment respectively while the N and – denote the South and West bounds of the exit/entrance interchanges and the road segment respectively.

The information for each TMC located along study segments included the TMC code, the road, direction, intersection, presence or absence of ASAP service (represented with 1 or 0 respectively), the AADT for 2021 and truck percentages. Such data were all obtained from the National Performance Management Research Data Set (NPRMDS) through an account with the Regional Integrated Transportation Information System (RITIS) (Ritis, 2022) and are summarized in the table below. The TMC codes and their properties along I-65 and I-565 study segments are summarized in Tables 3 and 4 respectively.

Table 3: TMC codes with the properties along I-65 study segments

TMC. codes	Road	Direction	Intersection	Length (Miles)	ASAP Presence	AADT (veh)	Truck %
101P05053	I-65	NORTHBOUND	ALABAMA/TENNESSEE STATE LINE	0.050212	0	19749	40.00
101N05053	I-65	SOUTHBOUND	ALABAMA/TENNESSEE STATE LINE	0.050212	0	19749	40.00
101+05053	I-65	NORTHBOUND	AL--TN STATE BORDER	1.102879	0	19749	40.00
101-05052	I-65	SOUTHBOUND	AL-53/EXIT 365	1.159616	0	19749	40.00
101P05052	I-65	NORTHBOUND	AL-53/EXIT 365	0.574755	0	21054	38.28
101N05052	I-65	SOUTHBOUND	AL-53/EXIT 365	0.415673	0	21011	38.33
101+05052	I-65	NORTHBOUND	AL-53/EXIT 365	0.811883	0	22145	37.00
101-05052	I-65	SOUTHBOUND	AL-53/EXIT 365	1.159616	0	19749	40.00
101P05051	I-65	NORTHBOUND	ALABAMA WELCOME CENTER	0.458381	0	22145	37.00
101N05051	I-65	SOUTHBOUND	ALABAMA WELCOME CENTER	0.447748	0	22145	37.00
101+05051	I-65	NORTHBOUND	ALABAMA WELCOME CENTER	2.079141	0	22145	37.00
101-05051	I-65	SOUTHBOUND	ALABAMA WELCOME CENTER	0.914316	0	22145	37.00
101+05050	I-65	NORTHBOUND	SANDLIN RD/THACH RD/EXIT 361	6.041008	0	28299	44.00
101-05050	I-65	SOUTHBOUND	SANDLIN RD/THACH RD/EXIT 361	2.121131	0	22145	37.00
101P05050	I-65	NORTHBOUND	SANDLIN RD/THACH RD/EXIT 361	0.47439	0	25125	40.82
101N05050	I-65	SOUTHBOUND	SANDLIN RD/THACH RD/EXIT 361	0.44856	0	25494	41.23
101+05049	I-65	NORTHBOUND	US-31/EXIT 354	3.039139	0	25953	44.00
101-05049	I-65	SOUTHBOUND	US-31/EXIT 354	6.315942	0	28299	44.00
101P05049	I-65	NORTHBOUND	US-31/EXIT 354	0.393122	0	28299	44.00
101N05049	I-65	SOUTHBOUND	US-31/EXIT 354	0.5816	0	26812	44.00
101-05048	I-65	SOUTHBOUND	US-72/EXIT 351	2.500189	0	25864	44.00
101P05048	I-65	NORTHBOUND	US-72/EXIT 351	0.454266	0	29576	40.93
101N05048	I-65	SOUTHBOUND	US-72/EXIT 351	0.478469	0	28722	41.56
101+05048	I-65	NORTHBOUND	US-72/EXIT 351	3.008621	0	32494	39.00
101+53705	I-65	NORTHBOUND	HUNTSVILLE BROWNSFERRY RD	6.385974	0	32478	39.00
101-53705	I-65	SOUTHBOUND	HUNTSVILLE BROWNSFERRY RD	3.026587	0	32494	39.00
101P53705	I-65	NORTHBOUND	HUNTSVILLE BROWNSFERRY RD	0.690276	0	32486	39.00
101N53705	I-65	SOUTHBOUND	HUNTSVILLE BROWNSFERRY RD	0.730549	0	32487	39.00

101+05047	I-65	NORTHBOUND	I-565/OLD AL-20/EXIT 340B	5.87509	1	47391	27.00
101-05047	I-65	SOUTHBOUND	I-565/OLD AL-20/EXIT 340B	6.741528	1	32478	39.00
101P05047	I-65	NORTHBOUND	I-565/OLD AL-20/EXIT 340B	1.308693	1	39382	32.31
101N05047	I-65	SOUTHBOUND	I-565/OLD AL-20/EXIT 340B	0.644416	1	39516	32.21
101-05046	I-65	SOUTHBOUND	AL-67/EXIT 334	6.084927	1	47391	27.00
101P05046	I-65	NORTHBOUND	AL-67/EXIT 334	0.589749	1	45288	28.95
101N05046	I-65	SOUTHBOUND	AL-67/EXIT 334	0.491733	1	46076	28.20
101+05046	I-65	NORTHBOUND	AL-67/EXIT 334	5.30611	1	44235	30.00
101-05045	I-65	SOUTHBOUND	AL-36/EXIT 328	5.46671	0	44235	30.00
101P05045	I-65	NORTHBOUND	AL-36/EXIT 328	0.373441	0	42622	30.00
101N05053	I-65	SOUTHBOUND	ALABAMA/TENNESSEE STATE LINE	0.050212	0	19749	40.00
101+05045	I-65	NORTHBOUND	AL-36/EXIT 328	2.064809	0	41190	30.00
101+05044	I-65	NORTHBOUND	THOMPSON RD/EXIT 325	2.496965	0	40836	19.68
101-05044	I-65	SOUTHBOUND	THOMPSON RD/EXIT 325	2.038501	0	41190	30.00
101P05044	I-65	NORTHBOUND	THOMPSON RD/EXIT 325	0.521914	0	41028	25.30
101N05044	I-65	SOUTHBOUND	THOMPSON RD/EXIT 325	0.510891	0	41030	25.36
101+05043	I-65	NORTHBOUND	CR-55/EXIT 322	3.115377	0	38626	31.00
101-05043	I-65	SOUTHBOUND	CR-55/EXIT 322	2.499513	0	40836	19.68
101P05043	I-65	NORTHBOUND	CR-55/EXIT 322	0.705883	0	39718	25.25
101N05043	I-65	SOUTHBOUND	CR-55/EXIT 322	0.715706	0	39717	25.26
101+05042	I-65	NORTHBOUND	US-31/EXIT 318	7.452181	0	37586	32.00
101-05042	I-65	SOUTHBOUND	US-31/EXIT 318	3.031052	0	38626	31.00
101P05052	I-65	NORTHBOUND	AL-53/EXIT 365	0.574755	0	21054	38.28
101N05052	I-65	SOUTHBOUND	AL-53/EXIT 365	0.415673	0	21011	38.33

Table 4: TMC codes with the properties along I-565 study segments

TMC codes	Road	Direction	Intersection	Length (Miles)	ASAP Presence	AADT (veh)	Truck %
101P04498	I-565	EASTBOUND	I-65/EXIT 1 & 1	0.393892	1	36391	9.00
101+04499	I-565	EASTBOUND	MOORESVILLE RD/EXIT 2	0.618797	1	62822	12.00
101-04499	I-565	WESTBOUND	MOORESVILLE RD/EXIT 2	1.647097	1	59717	10.00
101-04498	I-565	WESTBOUND	I-65/EXIT 1 & 1	0.584901	1	63650	12.00
101P04499	I-565	EASTBOUND	MOORESVILLE RD/EXIT 2	0.558442	1	61849	11.12
101N04499	I-565	WESTBOUND	MOORESVILLE RD/EXIT 2	0.600395	1	61584	10.98
101+04500	I-565	EASTBOUND	GREENBRIER RD/EXIT 3	1.636499	1	59717	10.00
101-04500	I-565	WESTBOUND	GREENBRIER RD/EXIT 3	2.23584	1	63727	8.00
101P04500	I-565	EASTBOUND	GREENBRIER RD/EXIT 3	0.588649	1	61626	9.02
101N04500	I-565	WESTBOUND	GREENBRIER RD/EXIT 3	0.561014	1	62057	8.80
101+04501	I-565	EASTBOUND	AL-20/EXIT 5	2.120699	1	63727	8.00
101-04501	I-565	WESTBOUND	AL-20/EXIT 5	0.992157	1	63434	9.03
101P04501	I-565	EASTBOUND	AL-20/EXIT 5	0.163279	1	63727	8.00
101N04501	I-565	WESTBOUND	AL-20/EXIT 5	0.977783	1	63533	8.65
101+04502	I-565	EASTBOUND	GLENN HEARN BLVD/EXIT 7	1.664227	1	63489	8.80
101-04502	I-565	WESTBOUND	GLENN HEARN BLVD/EXIT 7	0.447941	1	63635	10.00
101P04502	I-565	EASTBOUND	GLENN HEARN BLVD/EXIT 7	0.492068	1	63523	9.46
101N04502	I-565	WESTBOUND	GLENN HEARN BLVD/EXIT 7	0.424859	1	63635	10.00
101+04503	I-565	EASTBOUND	WALL TRIANA HWY/EXIT 8	0.615687	1	63635	10.00
101-04503	I-565	WESTBOUND	WALL TRIANA HWY/EXIT 8	3.646089	1	79901	7.88
101P04503	I-565	EASTBOUND	WALL TRIANA HWY/EXIT 8	0.648762	1	69689	9.01
101N04503	I-565	WESTBOUND	WALL TRIANA HWY/EXIT 8	0.832569	1	72496	8.61
101+04504	I-565	EASTBOUND	AL-20/EXIT 13	3.566833	1	77189	8.00
101-04504	I-565	WESTBOUND	AL-20/EXIT 13	0.353346	1	106897	7.00
101P04504	I-565	EASTBOUND	AL-20/EXIT 13	0.354355	1	106843	7.00
101N04504	I-565	WESTBOUND	AL-20/EXIT 13	0.294058	1	106897	7.00
101+04505	I-565	EASTBOUND	AL-255/RIDEOUT RD/EXIT 14	0.301852	1	106897	7.00
101-04505	I-565	WESTBOUND	AL-255/RIDEOUT RD/EXIT 14	0.573229	1	118537	7.00

101P04505	I-565	EASTBOUND	AL-255/RIDEOUT RD/EXIT 14	1.119386	1	111775	7.00
101N04505	I-565	WESTBOUND	AL-255/RIDEOUT RD/EXIT 14	0.942738	1	114483	7.00
101+04506	I-565	EASTBOUND	OLD MADISON PIKE/EXIT 15	0.719327	1	118537	7.00
101-04506	I-565	WESTBOUND	OLD MADISON PIKE/EXIT 15	0.242277	1	118519	7.00
101P04506	I-565	EASTBOUND	OLD MADISON PIKE/EXIT 15	0.252259	1	118537	7.00
101N04506	I-565	WESTBOUND	OLD MADISON PIKE/EXIT 15	0.249822	1	118537	7.00
101+04507	I-565	EASTBOUND	SPARKMAN DR/BOB WALLACE AVE/EXIT 15	0.242118	1	118516	7.00
101-04507	I-565	WESTBOUND	SPARKMAN DR/BOB WALLACE AVE/EXIT 15	0.411929	1	117935	7.00
101P04507	I-565	EASTBOUND	SPARKMAN DR/BOB WALLACE AVE/EXIT 15	0.263412	1	117935	7.00
101N04507	I-565	WESTBOUND	SPARKMAN DR/BOB WALLACE AVE/EXIT 15	0.288614	1	117935	7.00
101+04508	I-565	EASTBOUND	AL-53/JORDAN LN/EXIT 17	0.419935	1	117935	7.00
101-04508	I-565	WESTBOUND	AL-53/JORDAN LN/EXIT 17	1.161861	1	96756	6.00
101P04508	I-565	EASTBOUND	AL-53/JORDAN LN/EXIT 17	0.629222	1	105810	6.48
101N04508	I-565	WESTBOUND	AL-53/JORDAN LN/EXIT 17	0.825869	1	103276	6.35
101+04509	I-565	EASTBOUND	US-231/US-431/MEMORIAL PKWY/EXIT 19	1.268702	1	96756	6.00
101-04509	I-565	WESTBOUND	US-231/US-431/MEMORIAL PKWY/EXIT 19	0.087312	1	53248	7.00
101P04509	I-565	EASTBOUND	US-231/US-431/MEMORIAL PKWY/EXIT 19	0.54643	1	86300	6.15
101N04509	I-565	WESTBOUND	US-231/US-431/MEMORIAL PKWY/EXIT 19	0.508037	1	79346	6.27
101P04510	I-565	EASTBOUND	WASHINGTON ST/EXIT 19	0.523926	1	53248	7.00
101N04510	I-565	WESTBOUND	WASHINGTON ST/EXIT 19	0.437808	1	53248	7.00
101+04510	I-565	EASTBOUND	WASHINGTON ST/EXIT 19	0.080184	1	53248	7.00
101-04510	I-565	WESTBOUND	WASHINGTON ST/EXIT 19	0.036855	1	53248	7.00
101P04511	I-565	EASTBOUND	PRATT AVE/EXIT 19	0.228293	1	53248	7.00
101N04511	I-565	WESTBOUND	PRATT AVE/EXIT 19	0.354016	1	53248	7.00
101+04512	I-565	EASTBOUND	AL-20/OAKWOOD AVE/EXIT 20	0.336287	1	53248	7.00
101-04512	I-565	WESTBOUND	AL-20/OAKWOOD AVE/EXIT 20	0.704868	1	48117	7.00
101+04511	I-565	EASTBOUND	PRATT AVE/EXIT 19	0.00965	1	53248	7.00
101-04511	I-565	WESTBOUND	PRATT AVE/EXIT 19	0.331969	1	53248	7.00
101P04512	I-565	EASTBOUND	AL-20/OAKWOOD AVE/EXIT 20	0.522581	1	51134	7.00
101N04512	I-565	WESTBOUND	AL-20/OAKWOOD AVE/EXIT 20	0.443175	1	49967	7.00
101+04513	I-565	EASTBOUND	US-72 ALT	0.9207	1	48117	7.00

101P04513	I-565	EASTBOUND	US-72 ALT	0.255463	1	49169	6.66
101N04513	I-565	WESTBOUND	US-72 ALT	0.3192	1	48117	7.00

3.3 Calculation of the Average Daily Traffic (ADT)

Every TMC code in the spreadsheet has an Annual Average Daily Traffic (AADT) value associated with it. The AADT value is the total volume of vehicle traffic of a road segment for a year divided by 365 days and represents the number of vehicles using a specific segment of roadway on any given day of the year (Molugaram & Shanker Rao, 2017). Average Daily Traffic (ADT) refers to the average number of vehicles passing a specific point on an average day. AADT is different from ADT because it represents data for the entire year.

In this study, in order to obtain the ADTs for the Northbound, Southbound, Eastbound and Westbound of the weekdays and weekends, the count stations were examined, and the data for the month of March 2021 were extracted from ALDOT publicly available records (ALDOT, https://aldotgis.dot.state.al.us/TDMPublic/, 2022). It is worthy to note that not all the exits have count stations. For this reason, the count stations were zoned to cover the different exits or segments that are close to the count stations. The different zones for the count stations are tabulated in Table 5 and Table 6 below.

Table 5: The different zones for the count stations and TMC Segments along I-65 study segments

TMC ZONES	A	B	C	D
SEGMENTS	354-361	351-354	325-328	310-318
COUNT STATION	831	250	56	55

Table 6: The different zones for the count stations and TMC Segments along I-565 study segments

TMC ZONES	E	F	G	H	I	J	K	L	M
SEGMENTS	1-2	2-3	3-7	7-8	11-13	14-15	15-17	17-19	20-21
COUNT STATION	409	541	536	448	447	92	89	451	453

Table 7: Representation of the TMCs with the zones and directions

TMC/ZONES			
Northbound	**Southbound**	**Eastbound**	**Westbound**
A	**A**	**E**	**E**
101P05053	101N05053	101P04498	101-04499
101+05053	101-05052	101+04499	101-04498
101P05052	101N05052	101P04499	101N04499
101+05052	101-05052	**F**	**F**
101P05051	101N05051	101+04500	101-04500
101+05051	101-05051	101P04500	101N04500
101+05050	101-05050	**G**	**G**
101P05050	101N05050	101+04501	101-04501
101+53705	101-53705	101P04501	101N04501
101P53705	101N53705	101+04502	101-04502
101+05047	101-05047	101P04502	101N04502
101P05047	101N05047	**H**	**H**
101P05046	101-05046	101+04503	101-04503
101+05046	101N05046	101P04503	101N04503
101P05052	101N05053	**I**	**I**
B	101N05052	101+04504	101-04504
101+05049	**B**	101P04504	101N04504
101P05049	101-05049	**J**	**J**
101P05048	101N05049	101+04505	101-04505
101+05048	101-05048	101P04505	101N04505
C	101N05048	101+04506	101-04506
101P05045	**C**	101P04506	101N04506
101+05045	101-05045	101+04507	101-04507
101+05044	101-05044	101P04507	101N04507
101P05044	101N05044	**K**	**K**
D	**D**	101+04508	101-04508
101+05043	101-05043	101P04508	101N04508
101P05043	101N05043	**L**	**L**
101+05042	101-05042	101+04509	101-04509
		101P04509	101N04509
		101P04510	101N04510
		101+04510	101-04510
		101P04511	101N04511
		101+04511	101-04511
		M	**M**
		101P04512	101-04512
		101+04513	101N04512
		101P04513	101N04513

To account for volume variations between weekdays and weekends, two ADT values have been estimated for each TMC zone (each count station), namely weekday ADT, and weekend ADT. The values for the weekday ADT were obtained by averaging the month's weekdays data (Monday through Friday) while the Weekend ADT values were obtained by averaging the ADTs for all Saturdays in March 2021. Saturday was chosen to represent weekends as the values were higher than values for Sundays. These values are tabulated in Table 8 below.

Table 8: Study count stations and their respective ADTs

Month	Year	Location		County	I-65-NB		I-65-SB	
		Exit	Exit		Weekday ADT	Weekend ADT	Weekday ADT	Weekend ADT
March	2021	310	318	Cullman	23380	23953	23325	27523
March	2021	325	328	Morgan	25616	24820	25386	29046
March	2021	351	354	Limestone	17353	17546	17567	20944
March	2021	354	361	Limestone	15150	13274	13838	12135

Month	Year	Location		County	I-565-EB		I-565-WB	
		Exit	Exit		Weekday ADT	Weekend ADT	Weekday ADT	Weekend ADT
March	2021	1	2	Limestone	33597	23506	40480	28626
March	2021	2	3	Limestone	39842	27581	37388	26956
March	2021	3	7	Limestone	43546	29360	40015	27393
March	2021	7	8	Madison	43429	29570	38203	26948
March	2021	11	13	Madison	49585	32000	47088	31042
March	2021	14	15	Madison	67075	48399	78130	50148
March	2021	15	17	Madison	70019	47246	72537	48950
March	2021	17	19	Madison	54934	38686	57506	39236
March	2021	20	21	Madison	29469	19264	30449	19370

After the TMCs were grouped into zones, a factor was developed to find a relationship between the AADTs and ADTs. The computation of these factors is explained in the next section.

3.4 Computation of factors f_{week}, f_{sat} and f_{hour}

For zones that have more than three TMC codes in them, a factor was developed to estimate a relationship between the Annual Average Daily Traffic (AADT) and the Average Daily Traffic (ADT). This is because zones that had several TMC codes in them had more variations in their traffic volumes, while zones with three TMC codes or less still maintained the same AADTs and ADTs. A TMC code that matched the location of the count station in that zone (highlighted in yellow in Tables 9, 10, 11, 12) was picked from each of these large zones to represent the zone after careful examination of GIS data. Equ. (2) and Equ. (3) below shows the relationship between the AADT and ADT for each zone.

$$f_{week} = \frac{ADT_{weekday}}{AADT_{tmc}} \tag{2}$$

$$f_{sat} = \frac{ADT_{sat}}{AADT_{tmc}} \tag{3}$$

where $ADT_{weekday}$ = Average Daily Traffic for weekday for a particular count station

ADT_{sat} = Average Daily Traffic for Saturday for a particular count station

$AADT_{tmc}$ = Annual Average Daily Traffic for each TMC code

f_{week} = factor for converting AADT to weekday ADT

f_{sat} = factor for converting AADT to weekend ADT

The computed factors were then used to multiply AADTs of each TMC code to obtain an ADT for each TMC. Tables 9, 10, 11 and 12 below show these factors, the selected TMC code (highlighted) having the count station and the corresponding daily traffic volumes.

Table 9: The TMC codes with the factors for Northbound I-65

TMC zone	TMC code	AADT	f_week	f_sat	ADT_week	ADT_Sat
A						
	101P05053	19749	0.54	0.47	10573	9264
	101+05053	19749	0.54	0.47	10573	9264
	101P05052	21054	0.54	0.47	11271	9876
	101+05052	22145	0.54	0.47	11855	10387
	101P05051	22145	0.54	0.47	11855	10387
	101+05051	22145	0.54	0.47	11855	10387
	101+05050	28299	0.54	0.47	15150	13274
	101P05050	25125	0.54	0.47	13451	11785
	101+53705	32478	0.54	0.47	17387	15234
	101P53705	32486	0.54	0.47	17392	15238
	101+05047	47391	0.54	0.47	25371	22229
	101P05047	39382	0.54	0.47	21083	18473
	101P05046	45288	0.54	0.47	24245	21243
	101+05046	44235	0.54	0.47	23681	20749
	101P05052	21054	0.54	0.47	11271	9876
B						
	101+05049	25953	0.67	0.68	17353	17546
	101P05049	28299	0.67	0.68	18922	19132
	101P05048	29576	0.67	0.68	19775	19995
	101+05048	32494	0.67	0.68	21727	21968
C						
	101P05045	42622	0.62	0.60	26507	25683
	101+05045	41190	0.62	0.60	25616	24820
	101+05044	40836	0.62	0.60	25396	24607
	101P05044	41028	0.62	0.60	25515	24722
D						
	101+05043	38626	0.61	0.62	23380	23953
	101P05043	39718	0.59	0.60	23380	23953
	101+05042	37586	0.62	0.64	23380	23953

Table 10: The TMC codes with the factors for Southbound I-65

TMC zone	Tmc code	AADT	f_week	f_sat	ADT_week	ADT_Sat
A						
	101N05053	19749	0.62	0.55	12341	10822
	101-05052	19749	0.62	0.55	12341	10822
	101N05052	21011	0.62	0.55	13129	11514
	101-05052	19749	0.62	0.55	12341	10822
	101N05051	22145	0.62	0.55	13838	12135
	101-05051	22145	0.62	0.55	13838	12135
	101-05050	22145	0.62	0.55	13838	12135
	101N05050	25494	0.62	0.55	15931	13970
	101-53705	32494	0.62	0.55	20305	17806
	101N53705	32487	0.62	0.55	20301	17802
	101-05047	32478	0.62	0.55	20295	17797
	101N05047	39516	0.62	0.55	24693	21654
	101-05046	47391	0.62	0.55	29614	25969
	101N05046	46076	0.62	0.55	28792	25249
	101N05053	19749	0.62	0.55	12341	10822
	101N05052	21011	0.62	0.55	13129	11514
B						
	101-05049	28299	0.62	0.74	17567	20944
	101N05049	26812	0.62	0.74	16644	19843
	101-05048	25864	0.62	0.74	16055	19142
	101N05048	28722	0.62	0.74	17830	21257
C						
	101-05045	44235	0.57	0.66	25386	29046
	101-05044	41190	0.62	0.71	25386	29046
	101N05044	41030	0.62	0.71	25386	29046
D						
	101-05043	40836	0.57	0.67	23325	27523
	101N05043	39717	0.59	0.69	23325	27523
	101-05042	38626	0.60	0.71	23325	27523

Table 11: The TMC codes with the factors for Eastbound I-565

TMC zone	Tmc code	AADT	f_week	f_sat	ADT_week	ADT_Sat
E						
	101P04498	36391	0.92	0.70	33597	25306
	101+04499	62822	0.53	0.40	33597	25306
	101P04499	61849	0.54	0.41	33597	25306
F						
	101+04500	59717	0.67	0.46	39842	27581
	101P04500	61626	0.65	0.45	39842	27581
G						
	101+04501	63727	0.68	0.46	43546	29360
	101P04501	63727	0.68	0.46	43546	29360
	101+04502	63489	0.68	0.46	43383	29250
	101P04502	63523	0.68	0.46	43407	29266
H						
	101+04503	63635	0.68	0.46	43429	29570
	101P04503	69689	0.62	0.42	43429	29570
I						
	101+04504	77189	0.64	0.41	49585	32000
	101P04504	106843	0.46	0.30	49585	32000
J						
	101+04505	106897	0.57	0.41	60488	43646
	101P04505	111775	0.57	0.41	63249	45638
	101+04506	118537	0.57	0.41	67075	48399
	101P04506	118537	0.57	0.41	67075	48399
	101+04507	118516	0.57	0.41	67063	48390
	101P04507	117935	0.57	0.41	66734	48153
K						
	101+04508	117935	0.59	0.40	70019	47246
	101P04508	105810	0.66	0.45	70019	47246
L						
	101+04509	96756	0.57	0.40	54934	38686
	101P04509	86300	0.57	0.40	48998	34505
	101P04510	53248	0.57	0.40	30232	21290
	101+04510	53248	0.57	0.40	30232	21290
	101P04511	53248	0.57	0.40	30232	21290
	101+04511	53248	0.57	0.40	30232	21290
M						
	101P04512	51134	0.58	0.38	29469	19264
	101+04513	48117	0.61	0.40	29469	19264
	101P04513	49169	0.60	0.39	29469	19264

Table 12: The TMC codes with the factors for Westbound I-565

TMC zone	Tmc code	AADT	f_week	f_sat	ADT_week	ADT_Sat
E						
	101-04499	59717	0.68	0.48	40480	28626
	101-04498	63650	0.64	0.45	40480	28626
	101N04499	61584	0.66	0.46	40480	28626
F						
	101-04500	63727	0.59	0.42	37388	26956
	101N04500	62057	0.60	0.43	37388	26956
G						
	101-04501	63434	0.63	0.43	40015	27393
	101N04501	63533	0.63	0.43	40077	27436
	101-04502	63635	0.63	0.43	40142	27480
	101N04502	63635	0.63	0.43	40142	27480
H						
	101-04503	79901	0.48	0.34	38203	26948
	101N04503	72496	0.53	0.37	38203	26948
I						
	101-04504	106897	0.44	0.29	47088	31042
	101N04504	106897	0.44	0.29	47088	31042
J						
	101-04505	118537	0.66	0.42	78130	50148
	101N04505	114483	0.66	0.42	75458	48433
	101-04506	118519	0.66	0.42	78118	50140
	101N04506	118537	0.66	0.42	78130	50148
	101-04507	117935	0.66	0.42	77733	49893
	101N04507	117935	0.66	0.42	77733	49893
K						
	101-04508	96756	0.75	0.51	72537	48950
	101N04508	103276	0.70	0.47	72537	48950
L						
	101-04509	53248	1.08	0.74	57506	39236
	101N04509	79346	1.08	0.74	85691	58466
	101N04510	53248	1.08	0.74	57506	39236
	101-04510	53248	1.08	0.74	57506	39236
	101N04511	53248	1.08	0.74	57506	39236
	101-04511	53248	1.08	0.74	57506	39236
M						
	101-04512	48117	0.63	0.40	30449	19370
	101N04512	49967	0.61	0.39	30449	19370
	101N04513	48117	0.63	0.40	30449	19370

After calculations of the ADTs for the corresponding TMC codes, it was germane that the amount of traffic that occurred during each hour of the day for each TMC code be calculated. A factor f_{hour} that relates the hourly volume and ADT for each count station was obtained. This factor f_{hour} shows the fraction of the total traffic that occurs at each hour of day for the different TMC zones/count stations for the two ADT groups (Weekday ADT, and Weekend ADT) and was obtained from Equ. (4) below.

$$f_{hour} = \frac{hourly\ vol_{tmc\ zone}}{ADT_{tmc\ zone}} \tag{4}$$

The hourly volumes of first Wednesday and first Saturday of each TMC zone were used to represent the weekday ADT and weekend ADT respectively. The first Wednesday and Saturday were chosen because from observation of the collated data, the first Wednesday and Saturday had the highest volumes of traffic for March 2021. This influenced the choice of using first Wednesday as Weekday ADT and first Saturday as Weekend ADT.

The f_{hour} was then used to establish a relationship between the calculated ADTs of all TMC codes and the hourly volumes for the different times of day. The hourly volumes for each of the TMC codes were obtained from Equ. (5) below.

$$\text{Hourly volume}_{\text{tmc code}} = f_{hour} * ADT_{tmc\ code} \tag{5}$$

These hourly volumes were divided by four to get the 15-minute volumes for calculation of total delay as shown in the succeeding sections. The values of the factor f_{hour} with the calculated hourly volumes for all TMC codes have been tabulated in Tables 13 to 20 below.

Table 13: TMC codes with the weekday factors and hourly volumes for Northbound I-65

Time of day			0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC zone	TMC code																									
A		**Weekday** f_{hour}	**0.011**	**0.008**	**0.009**	**0.008**	**0.014**	**0.019**	**0.032**	**0.050**	**0.047**	**0.049**	**0.060**	**0.066**	**0.066**	**0.070**	**0.079**	**0.079**	**0.086**	**0.073**	**0.053**	**0.038**	**0.031**	**0.022**	**0.018**	**0.013**
	101P05053	Hourly vol	116	89	90	87	147	199	341	524	492	517	630	695	698	744	835	836	913	774	561	400	327	237	187	134
	101+05053		116	89	90	87	147	199	341	524	492	517	630	695	698	744	835	836	913	774	561	400	327	237	187	134
	101P05052		124	95	96	93	156	212	364	559	525	551	672	741	744	793	890	891	973	825	598	426	348	253	199	143
	101+05052		130	100	101	98	164	223	383	588	552	580	706	779	783	834	936	937	1023	868	629	448	366	266	210	151
	101P05051		130	100	101	98	164	223	383	588	552	580	706	779	783	834	936	937	1023	868	629	448	366	266	210	151
	101+05051		130	100	101	98	164	223	383	588	552	580	706	779	783	834	936	937	1023	868	629	448	366	266	210	151
	101+05050		167	127	130	125	210	285	489	751	705	741	903	995	1000	1066	1197	1198	1308	1109	804	573	468	340	268	193
	101P05050		148	113	115	111	186	253	434	667	626	658	801	884	888	946	1062	1064	1161	985	714	509	416	302	238	171
	101+53705		191	146	149	143	241	327	561	862	809	850	1036	1142	1148	1223	1373	1375	1501	1273	923	658	537	390	308	221
	101P53705		191	146	149	143	241	327	561	862	809	851	1036	1143	1148	1223	1374	1375	1501	1273	923	658	537	390	308	221
	101+05047		279	213	217	209	352	478	819	1257	1181	1241	1512	1667	1675	1785	2004	2006	2190	1857	1346	960	784	569	449	323
	101P05047		232	177	180	174	292	397	681	1045	981	1031	1256	1385	1392	1483	1665	1667	1820	1543	1119	797	651	473	373	268
	101P05046		267	204	208	200	336	457	783	1202	1128	1186	1445	1593	1601	1706	1915	1917	2093	1775	1287	917	749	543	429	308
	101+05046		261	199	203	195	328	446	764	1174	1102	1158	1411	1556	1564	1666	1870	1872	2044	1733	1257	896	732	531	419	301
	101P05052		124	95	96	93	156	212	364	559	525	551	672	741	744	793	890	891	973	825	598	426	348	253	199	143
B		**Weekday** f_{hour}	**0.009**	**0.007**	**0.006**	**0.009**	**0.016**	**0.019**	**0.036**	**0.051**	**0.053**	**0.051**	**0.056**	**0.064**	**0.064**	**0.067**	**0.072**	**0.083**	**0.082**	**0.078**	**0.055**	**0.037**	**0.030**	**0.023**	**0.020**	**0.012**
	101+05049	Hourly vol	149	124	110	155	286	334	628	889	916	893	966	1105	1108	1154	1251	1433	1424	1354	955	646	526	392	343	211
	101P05049		163	135	120	169	312	364	685	969	998	974	1053	1205	1208	1259	1364	1563	1552	1476	1041	705	574	428	374	230
	101P05048		170	142	126	177	326	380	716	1013	1043	1018	1101	1260	1263	1315	1425	1634	1622	1543	1088	736	600	447	391	240
	101+05048		187	156	138	194	358	418	786	1113	1146	1118	1209	1384	1388	1445	1566	1795	1782	1695	1195	809	659	491	430	264
C		**Weekday** f_{hour}	**0.007**	**0.006**	**0.006**	**0.010**	**0.019**	**0.046**	**0.069**	**0.070**	**0.066**	**0.058**	**0.059**	**0.059**	**0.060**	**0.063**	**0.066**	**0.067**	**0.061**	**0.057**	**0.043**	**0.031**	**0.027**	**0.019**	**0.017**	**0.011**
	101P05045	Hourly vol	188	169	164	278	513	1230	1836	1855	1736	1547	1556	1555	1595	1679	1743	1773	1630	1510	1150	832	715	501	464	286
	101+05045		182	163	158	269	496	1189	1774	1793	1678	1495	1504	1503	1541	1623	1685	1714	1575	1459	1111	804	691	484	448	277
	101+05044		180	162	157	267	491	1179	1759	1777	1664	1482	1491	1490	1528	1609	1670	1699	1562	1447	1102	797	685	480	444	274
	101P05044		181	163	158	268	494	1184	1767	1786	1672	1489	1498	1497	1535	1616	1678	1707	1569	1454	1107	801	688	482	446	276
D		**Weekday** f_{hour}	**0.008**	**0.007**	**0.009**	**0.010**	**0.017**	**0.038**	**0.054**	**0.054**	**0.053**	**0.060**	**0.054**	**0.059**	**0.059**	**0.069**	**0.069**	**0.070**	**0.070**	**0.066**	**0.035**	**0.052**	**0.033**	**0.024**	**0.018**	**0.012**
	101+05043	Hourly vol	191	154	201	222	409	885	1265	1265	1246	1408	1266	1379	1373	1603	1623	1637	1644	1546	828	1212	771	568	413	274
	101P05043		191	154	201	222	409	885	1265	1265	1246	1408	1266	1379	1373	1603	1623	1637	1644	1546	828	1212	771	568	413	274
	101+05042		191	154	201	222	409	885	1265	1265	1246	1408	1266	1379	1373	1603	1623	1637	1644	1546	828	1212	771	568	413	274

Table 14: TMC codes with the weekend factors and hourly volumes for Northbound I-65

Time of day		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC code																									
A	**Saturday** f_{hour}	**0.011**	**0.007**	**0.008**	**0.008**	**0.008**	**0.012**	**0.020**	**0.035**	**0.047**	**0.054**	**0.069**	**0.077**	**0.077**	**0.091**	**0.089**	**0.084**	**0.074**	**0.058**	**0.047**	**0.039**	**0.032**	**0.024**	**0.017**	**0.013**
101P05053	Hourly vol	102	69	71	73	72	112	190	324	432	498	636	709	717	845	822	776	688	534	439	362	296	219	156	122
101+05053		102	69	71	73	72	112	190	324	432	498	636	709	717	845	822	776	688	534	439	362	296	219	156	122
101P05052		109	74	75	78	77	119	202	345	461	531	679	756	765	901	876	827	734	569	468	386	316	233	166	130
101+05052		115	78	79	82	81	125	213	363	484	558	714	795	804	947	922	870	772	598	492	406	332	245	175	137
101P05051		115	78	79	82	81	125	213	363	484	558	714	795	804	947	922	870	772	598	492	406	332	245	175	137
101+05051		115	78	79	82	81	125	213	363	484	558	714	795	804	947	922	870	772	598	492	406	332	245	175	137
101+05050		146	99	101	105	103	160	272	464	619	714	912	1016	1028	1210	1178	1111	986	765	629	519	424	313	223	175
101P05050		130	88	90	93	91	142	241	412	550	634	810	902	913	1075	1046	987	876	679	559	461	377	278	198	156
101+53705		168	114	116	120	118	184	312	533	711	819	1047	1166	1180	1389	1352	1275	1132	878	722	596	487	360	256	201
101P53705		168	114	116	120	118	184	312	533	711	819	1047	1166	1180	1390	1352	1276	1132	878	722	596	487	360	256	201
101+05047		245	166	169	175	172	269	455	778	1037	1195	1527	1701	1721	2027	1973	1861	1651	1280	1054	869	711	525	374	293
101P05047		204	138	141	146	143	223	378	646	862	993	1269	1414	1430	1684	1639	1546	1372	1064	876	722	591	436	311	244
101P05046		234	159	162	168	165	257	435	743	991	1142	1460	1626	1645	1937	1885	1778	1578	1224	1007	831	679	501	357	280
101+05046		229	155	158	164	161	251	424	726	968	1116	1426	1588	1607	1892	1841	1737	1541	1195	984	811	664	490	349	274
101P05052		109	74	75	78	77	119	202	345	461	531	679	756	765	901	876	827	734	569	468	386	316	233	166	130
B	**Saturday** f_{hour}	**0.010**	**0.008**	**0.009**	**0.007**	**0.011**	**0.014**	**0.024**	**0.032**	**0.048**	**0.060**	**0.067**	**0.076**	**0.079**	**0.086**	**0.081**	**0.082**	**0.072**	**0.061**	**0.053**	**0.039**	**0.029**	**0.024**	**0.016**	**0.014**
101+05049	Hourly vol	176	140	151	131	200	239	415	553	842	1048	1170	1342	1380	1514	1428	1444	1258	1069	926	677	502	413	275	254
101P05049		192	153	165	143	218	260	452	603	918	1142	1275	1463	1505	1650	1557	1575	1372	1166	1009	738	547	451	300	277
101P05048		200	159	173	149	228	272	473	631	960	1194	1333	1529	1573	1725	1627	1646	1434	1219	1055	771	572	471	313	290
101+05048		220	175	190	164	251	299	519	693	1054	1312	1464	1680	1728	1895	1787	1808	1575	1339	1159	847	628	518	344	318
C	**Saturday** f_{hour}	**0.009**	**0.007**	**0.006**	**0.007**	**0.012**	**0.019**	**0.024**	**0.030**	**0.040**	**0.055**	**0.062**	**0.073**	**0.072**	**0.076**	**0.078**	**0.081**	**0.077**	**0.066**	**0.060**	**0.042**	**0.037**	**0.028**	**0.023**	**0.015**
101P05045	Hourly vol	238	168	159	173	300	482	616	767	1037	1424	1594	1873	1857	1941	2014	2093	1982	1703	1545	1089	938	723	585	385
101+05045		230	163	153	167	290	466	595	741	1002	1376	1540	1810	1794	1876	1946	2022	1915	1646	1493	1052	906	698	565	372
101+05044		228	161	152	166	287	462	590	735	994	1364	1527	1794	1779	1860	1930	2005	1899	1632	1480	1043	898	692	560	368
101P05044		229	162	153	167	289	464	593	738	998	1371	1534	1803	1787	1869	1939	2014	1908	1639	1487	1048	903	696	563	370
D	**Saturday** f_{hour}	**0.009**	**0.007**	**0.007**	**0.007**	**0.011**	**0.016**	**0.022**	**0.031**	**0.040**	**0.055**	**0.063**	**0.073**	**0.077**	**0.077**	**0.080**	**0.080**	**0.079**	**0.067**	**0.055**	**0.044**	**0.036**	**0.029**	**0.021**	**0.014**
101+05043	Hourly vol	223	169	157	160	262	382	522	746	961	1312	1509	1740	1835	1856	1911	1925	1881	1603	1318	1053	871	703	514	341
101P05043		223	169	157	160	262	382	522	746	961	1312	1509	1740	1835	1856	1911	1925	1881	1603	1318	1053	871	703	514	341
101+05042		223	169	157	160	262	382	522	746	961	1312	1509	1740	1835	1856	1911	1925	1881	1603	1318	1053	871	703	514	341

Table 15: TMC codes with the weekday factors and hourly volumes for Southbound I-65

TMC zone	Tmc code	Time of day	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
A		**Weekday** f_{hour}	**0.010**	**0.007**	**0.009**	**0.011**	**0.019**	**0.038**	**0.057**	**0.071**	**0.055**	**0.057**	**0.065**	**0.059**	**0.064**	**0.068**	**0.066**	**0.070**	**0.066**	**0.057**	**0.041**	**0.032**	**0.027**	**0.020**	**0.018**	**0.011**
	101N05053	Hourly vol	122	89	108	142	237	467	707	878	673	708	797	732	786	835	813	865	817	709	512	399	335	249	224	138
	101-05052		122	89	108	142	237	467	707	878	673	708	797	732	786	835	813	865	817	709	512	399	335	249	224	138
	101N05052		129	95	115	151	252	497	752	934	716	753	848	779	836	888	865	921	869	754	545	424	356	264	239	147
	101-05052		122	89	108	142	237	467	707	878	673	708	797	732	786	835	813	865	817	709	512	399	335	249	224	138
	101N05051		136	100	121	159	266	523	793	984	755	794	894	821	881	936	911	970	916	795	574	447	375	279	252	155
	101-05051		136	100	121	159	266	523	793	984	755	794	894	821	881	936	911	970	916	795	574	447	375	279	252	155
	101-05050		136	100	121	159	266	523	793	984	755	794	894	821	881	936	911	970	916	795	574	447	375	279	252	155
	101N05050		157	115	139	183	306	603	913	1133	869	914	1029	945	1014	1078	1049	1117	1055	915	661	515	432	321	290	179
	101-53705		200	147	178	233	390	768	1163	1444	1108	1165	1312	1205	1293	1374	1337	1424	1344	1167	842	656	551	409	369	228
	101N53705		200	147	178	233	390	768	1163	1444	1108	1165	1311	1204	1292	1373	1337	1423	1344	1166	842	656	550	409	369	228
	101-05047		200	147	178	233	390	768	1163	1444	1107	1164	1311	1204	1292	1373	1337	1423	1344	1166	842	655	550	409	369	228
	101N05047		243	178	216	283	474	934	1414	1757	1347	1417	1595	1465	1572	1671	1626	1731	1635	1419	1024	797	669	497	449	277
	101-05046		292	214	259	340	569	1120	1696	2107	1616	1699	1913	1757	1885	2003	1951	2076	1961	1701	1228	956	803	597	539	332
	101N05046		284	208	252	330	553	1089	1649	2048	1571	1652	1860	1708	1833	1948	1896	2019	1906	1654	1194	930	781	580	524	323
	101N05053		122	89	108	142	237	467	707	878	673	708	797	732	786	835	813	865	817	709	512	399	335	249	224	138
	101N05052		129	95	115	151	252	497	752	934	716	753	848	779	836	888	865	921	869	754	545	424	356	264	239	147
B		**Weekday** f_{hour}	**0.008**	**0.008**	**0.011**	**0.012**	**0.020**	**0.043**	**0.067**	**0.078**	**0.058**	**0.056**	**0.065**	**0.063**	**0.060**	**0.060**	**0.059**	**0.061**	**0.062**	**0.055**	**0.037**	**0.036**	**0.029**	**0.020**	**0.017**	**0.013**
	101-05049	Hourly vol	135	145	198	204	351	751	1174	1368	1022	989	1145	1112	1060	1053	1039	1079	1088	973	656	639	517	345	298	226
	101N05049		128	137	188	193	333	712	1112	1296	969	937	1084	1054	1005	998	985	1022	1031	922	621	605	490	327	282	214
	101-05048		123	132	181	186	321	687	1073	1250	934	904	1046	1017	969	963	950	986	995	889	599	584	472	316	272	207
	101N05048		137	147	201	207	356	763	1192	1388	1038	1003	1162	1129	1076	1069	1055	1095	1105	988	666	649	525	351	302	229
C		**Weekday** f_{hour}	**0.009**	**0.007**	**0.008**	**0.010**	**0.014**	**0.027**	**0.042**	**0.057**	**0.057**	**0.055**	**0.062**	**0.060**	**0.063**	**0.063**	**0.069**	**0.078**	**0.086**	**0.081**	**0.045**	**0.033**	**0.029**	**0.020**	**0.014**	**0.012**
	101-05045	Hourly vol	223	167	198	244	349	678	1074	1452	1447	1408	1577	1518	1598	1606	1763	1984	2184	2049	1153	841	730	501	346	298
	101-05044		223	167	198	244	349	678	1074	1452	1447	1408	1577	1518	1598	1606	1763	1984	2184	2049	1153	841	730	501	346	298
	101N05044		223	167	198	244	349	678	1074	1452	1447	1408	1577	1518	1598	1606	1763	1984	2184	2049	1153	841	730	501	346	298
D		**Weekday** f_{hour}	**0.009**	**0.007**	**0.008**	**0.010**	**0.014**	**0.026**	**0.041**	**0.057**	**0.062**	**0.060**	**0.064**	**0.067**	**0.064**	**0.064**	**0.073**	**0.075**	**0.073**	**0.074**	**0.043**	**0.034**	**0.029**	**0.020**	**0.015**	**0.011**
	101-05043	Hourly vol	208	171	197	236	324	598	956	1328	1442	1392	1490	1563	1495	1490	1708	1745	1713	1724	1013	791	679	456	341	264
	101N05043		208	171	197	236	324	598	956	1328	1442	1392	1490	1563	1495	1490	1708	1745	1713	1724	1013	791	679	456	341	264
	101-05042		208	171	197	236	324	598	956	1328	1442	1392	1490	1563	1495	1490	1708	1745	1713	1724	1013	791	679	456	341	264

Table 16: TMC codes with the weekend factors and hourly volumes for Southbound I-65

	Time of day		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC zone	**Tmc code**																									
A		**Saturday** f_{hour}	**0.014**	**0.010**	**0.010**	**0.014**	**0.016**	**0.024**	**0.034**	**0.049**	**0.073**	**0.081**	**0.084**	**0.074**	**0.067**	**0.064**	**0.061**	**0.060**	**0.059**	**0.053**	**0.045**	**0.037**	**0.025**	**0.020**	**0.015**	**0.011**
	101N05053	Hourly vol	152	109	107	147	176	262	366	532	791	872	914	800	723	691	664	646	641	568	489	404	269	216	158	123
	101-05052		152	109	107	147	176	262	366	532	791	872	914	800	723	691	664	646	641	568	489	404	269	216	158	123
	101N05052		162	116	114	156	187	279	390	566	841	928	972	852	770	735	707	688	682	605	520	430	286	229	168	131
	101-05052		152	109	107	147	176	262	366	532	791	872	914	800	723	691	664	646	641	568	489	404	269	216	158	123
	101N05051		170	123	120	165	197	294	411	597	887	978	1024	898	811	775	745	725	719	637	548	453	301	242	177	138
	101-05051		170	123	120	165	197	294	411	597	887	978	1024	898	811	775	745	725	719	637	548	453	301	242	177	138
	101-05050		170	123	120	165	197	294	411	597	887	978	1024	898	811	775	745	725	719	637	548	453	301	242	177	138
	101N05050		196	141	138	189	227	338	473	687	1021	1126	1179	1033	934	892	857	834	827	734	631	522	347	278	204	159
	101-53705		250	180	176	241	290	431	602	876	1301	1435	1503	1317	1190	1137	1093	1063	1055	935	805	665	442	355	260	202
	101N53705		250	180	176	241	289	431	602	876	1301	1435	1503	1317	1190	1137	1093	1063	1054	935	804	665	442	355	260	202
	101-05047		250	180	176	241	289	431	602	876	1300	1435	1502	1316	1190	1137	1092	1063	1054	935	804	665	442	355	260	202
	101N05047		304	219	214	294	352	524	733	1065	1582	1746	1828	1602	1447	1383	1329	1293	1283	1137	978	809	538	432	316	246
	101-05046		365	262	257	352	422	629	879	1278	1898	2093	2192	1921	1736	1659	1594	1551	1538	1364	1173	970	645	518	379	295
	101N05046		355	255	250	342	411	611	854	1242	1845	2035	2131	1868	1688	1613	1550	1508	1495	1326	1141	943	627	503	369	287
	101N05053		152	109	107	147	176	262	366	532	791	872	914	800	723	691	664	646	641	568	489	404	269	216	158	123
	101N05052		162	116	114	156	187	279	390	566	841	928	972	852	770	735	707	688	682	605	520	430	286	229	168	131
B		**Saturday** f_{hour}	**0.010**	**0.011**	**0.009**	**0.011**	**0.014**	**0.022**	**0.035**	**0.047**	**0.070**	**0.081**	**0.083**	**0.075**	**0.072**	**0.064**	**0.066**	**0.063**	**0.061**	**0.054**	**0.047**	**0.034**	**0.025**	**0.021**	**0.015**	**0.009**
	101-05049	Hourly vol	216	238	184	227	285	468	737	981	1464	1704	1739	1578	1500	1337	1383	1316	1273	1130	978	722	528	440	323	193
	101N05049		205	225	175	215	270	443	698	929	1387	1615	1648	1495	1421	1267	1310	1247	1206	1071	926	684	501	417	306	183
	101-05048		198	217	168	207	260	427	674	896	1338	1558	1590	1442	1371	1222	1264	1203	1164	1033	894	660	483	402	295	177
	101N05048		219	241	187	230	289	475	748	995	1485	1730	1765	1601	1523	1357	1404	1336	1292	1147	992	733	536	447	328	196
C		**Saturday** f_{hour}	**0.010**	**0.008**	**0.009**	**0.008**	**0.012**	**0.018**	**0.029**	**0.048**	**0.074**	**0.077**	**0.081**	**0.074**	**0.073**	**0.069**	**0.065**	**0.070**	**0.063**	**0.054**	**0.042**	**0.038**	**0.030**	**0.021**	**0.014**	**0.012**
	101-05045	Hourly vol	279	230	255	225	351	535	855	1404	2144	2233	2361	2140	2120	2017	1891	2039	1842	1576	1229	1090	857	623	407	342
	101-05044		279	230	255	225	351	535	855	1404	2144	2233	2361	2140	2120	2017	1891	2039	1842	1576	1229	1090	857	623	407	342
	101N05044		279	230	255	225	351	535	855	1404	2144	2233	2361	2140	2120	2017	1891	2039	1842	1576	1229	1090	857	623	407	342
D		**Saturday** f_{hour}	**0.009**	**0.008**	**0.008**	**0.008**	**0.012**	**0.018**	**0.029**	**0.049**	**0.072**	**0.077**	**0.081**	**0.079**	**0.070**	**0.070**	**0.063**	**0.070**	**0.065**	**0.057**	**0.043**	**0.037**	**0.028**	**0.021**	**0.013**	**0.012**
	101-05043	Hourly vol	249	216	231	219	338	496	787	1346	1995	2123	2238	2179	1925	1933	1748	1918	1791	1572	1179	1030	760	569	355	327
	101N05043		249	216	231	219	338	496	787	1346	1995	2123	2238	2179	1925	1933	1748	1918	1791	1572	1179	1030	760	569	355	327
	101-05042		249	216	231	219	338	496	787	1346	1995	2123	2238	2179	1925	1933	1748	1918	1791	1572	1179	1030	760	569	355	327

Table 17: TMC codes with the weekday factors and hourly volumes for Eastbound I-565

TMC zone	Tmc code	Time of day	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
E		**Weekday f_{hour}**	**0.006**	**0.004**	**0.006**	**0.008**	**0.019**	**0.056**	**0.073**	**0.076**	**0.069**	**0.060**	**0.055**	**0.054**	**0.054**	**0.054**	**0.057**	**0.063**	**0.064**	**0.065**	**0.051**	**0.035**	**0.026**	**0.019**	**0.016**	**0.010**
	101P04498	Hourly vol	210	142	189	267	623	1891	2454	2545	2315	2025	1832	1812	1801	1813	1912	2122	2161	2172	1729	1181	881	649	521	350
	101+04499		210	142	189	267	623	1891	2454	2545	2315	2025	1832	1812	1801	1813	1912	2122	2161	2172	1729	1181	881	649	521	350
	101P04499		210	142	189	267	623	1891	2454	2545	2315	2025	1832	1812	1801	1813	1912	2122	2161	2172	1729	1181	881	649	521	350
F		**Weekday f_{hour}**	**0.005**	**0.004**	**0.005**	**0.006**	**0.013**	**0.053**	**0.085**	**0.102**	**0.074**	**0.058**	**0.055**	**0.052**	**0.051**	**0.050**	**0.054**	**0.060**	**0.065**	**0.065**	**0.050**	**0.031**	**0.022**	**0.017**	**0.013**	**0.009**
	101+04500	Hourly vol	216	153	212	233	527	2112	3388	4046	2964	2318	2182	2089	2035	1994	2142	2381	2606	2572	1989	1252	882	673	504	370
	101P04500		216	153	212	233	527	2112	3388	4046	2964	2318	2182	2089	2035	1994	2142	2381	2606	2572	1989	1252	882	673	504	370
G		**Weekday f_{hour}**	**0.005**	**0.004**	**0.008**	**0.006**	**0.016**	**0.042**	**0.070**	**0.093**	**0.070**	**0.056**	**0.052**	**0.053**	**0.052**	**0.049**	**0.054**	**0.062**	**0.079**	**0.077**	**0.055**	**0.034**	**0.022**	**0.017**	**0.012**	**0.010**
	101+04501	Hourly vol	230	178	336	249	687	1833	3051	4056	3055	2422	2265	2305	2279	2145	2350	2719	3461	3350	2383	1478	969	759	531	454
	101P04501		230	178	336	249	687	1833	3051	4056	3055	2422	2265	2305	2279	2145	2350	2719	3461	3350	2383	1478	969	759	531	454
	101+04502		229	177	335	248	684	1826	3039	4041	3044	2413	2257	2297	2271	2137	2341	2709	3448	3338	2374	1473	965	756	529	452
	101P04502		229	178	335	248	684	1827	3041	4043	3046	2414	2258	2298	2272	2138	2342	2711	3450	3340	2375	1473	965	756	529	453
H		**Weekday f_{hour}**	**0.005**	**0.004**	**0.007**	**0.005**	**0.014**	**0.037**	**0.066**	**0.094**	**0.075**	**0.059**	**0.054**	**0.053**	**0.054**	**0.049**	**0.055**	**0.063**	**0.080**	**0.075**	**0.055**	**0.033**	**0.021**	**0.017**	**0.013**	**0.010**
	101+04503	Hourly vol	218	195	299	228	604	1615	2861	4076	3271	2559	2347	2318	2356	2117	2393	2756	3482	3271	2385	1446	891	725	571	444
	101P04503		218	195	299	228	604	1615	2861	4076	3271	2559	2347	2318	2356	2117	2393	2756	3482	3271	2385	1446	891	725	571	444
I		**Weekday f_{hour}**	**0.005**	**0.004**	**0.006**	**0.005**	**0.011**	**0.029**	**0.055**	**0.090**	**0.080**	**0.057**	**0.054**	**0.052**	**0.052**	**0.052**	**0.058**	**0.071**	**0.089**	**0.081**	**0.056**	**0.034**	**0.019**	**0.015**	**0.013**	**0.010**
	101+04504	Hourly vol	242	222	289	264	522	1448	2738	4482	3963	2848	2661	2588	2573	2588	2866	3500	4397	4032	2797	1708	955	760	625	517
	101P04504		242	222	289	264	522	1448	2738	4482	3963	2848	2661	2588	2573	2588	2866	3500	4397	4032	2797	1708	955	760	625	517
J		**Weekday f_{hour}**	**0.004**	**0.004**	**0.004**	**0.005**	**0.007**	**0.016**	**0.041**	**0.075**	**0.075**	**0.058**	**0.055**	**0.055**	**0.057**	**0.059**	**0.065**	**0.080**	**0.092**	**0.086**	**0.062**	**0.035**	**0.024**	**0.020**	**0.013**	**0.010**
	101+04505	Hourly vol	266	219	240	272	449	968	2477	4507	4519	3505	3305	3352	3438	3562	3956	4836	5559	5173	3725	2131	1436	1180	810	602
	101P04505		278	229	251	285	470	1012	2590	4713	4725	3665	3455	3505	3595	3725	4136	5057	5812	5409	3894	2229	1501	1234	847	629
	101+04506		294	243	266	302	498	1073	2747	4998	5011	3887	3664	3717	3813	3950	4386	5362	6164	5737	4130	2363	1592	1309	899	667
	101P04506		294	243	266	302	498	1073	2747	4998	5011	3887	3664	3717	3813	3950	4386	5362	6164	5737	4130	2363	1592	1309	899	667
	101+04507		294	243	266	302	498	1073	2747	4997	5010	3886	3664	3716	3812	3949	4386	5362	6163	5736	4129	2363	1592	1308	898	667
	101P04507		293	242	265	301	496	1068	2733	4973	4986	3867	3646	3698	3793	3930	4364	5335	6133	5707	4109	2351	1584	1302	894	664
K		**Weekday f_{hour}**	**0.005**	**0.003**	**0.004**	**0.004**	**0.007**	**0.015**	**0.039**	**0.070**	**0.073**	**0.058**	**0.054**	**0.055**	**0.058**	**0.059**	**0.066**	**0.081**	**0.093**	**0.090**	**0.064**	**0.036**	**0.025**	**0.020**	**0.013**	**0.010**
	101+04508	Hourly vol	332	240	259	285	460	1068	2714	4924	5105	4032	3764	3845	4050	4112	4592	5694	6540	6310	4458	2503	1776	1375	900	684
	101P04508		332	240	259	285	460	1068	2714	4924	5105	4032	3764	3845	4050	4112	4592	5694	6540	6310	4458	2503	1776	1375	900	684
L		**Weekday f_{hour}**	**0.005**	**0.004**	**0.004**	**0.005**	**0.007**	**0.015**	**0.034**	**0.064**	**0.066**	**0.055**	**0.052**	**0.055**	**0.058**	**0.060**	**0.069**	**0.084**	**0.099**	**0.090**	**0.063**	**0.037**	**0.027**	**0.022**	**0.014**	**0.011**
	101+04509	Hourly vol	291	206	202	255	378	835	1846	3528	3653	3019	2867	3010	3209	3280	3795	4592	5433	4956	3466	2050	1501	1200	779	585
	101P04509		259	184	180	227	337	745	1647	3147	3258	2693	2557	2685	2862	2925	3385	4096	4846	4421	3091	1828	1339	1070	695	522
	101P04510		160	113	111	140	208	459	1016	1942	2010	1662	1578	1656	1766	1805	2088	2527	2990	2728	1907	1128	826	660	429	322
	101+04510		160	113	111	140	208	459	1016	1942	2010	1662	1578	1656	1766	1805	2088	2527	2990	2728	1907	1128	826	660	429	322
	101P04511		160	113	111	140	208	459	1016	1942	2010	1662	1578	1656	1766	1805	2088	2527	2990	2728	1907	1128	826	660	429	322
	101+04511		160	113	111	140	208	459	1016	1942	2010	1662	1578	1656	1766	1805	2088	2527	2990	2728	1907	1128	826	660	429	322
M		**Weekday f_{hour}**	**0.005**	**0.003**	**0.004**	**0.005**	**0.009**	**0.017**	**0.028**	**0.041**	**0.044**	**0.041**	**0.042**	**0.051**	**0.055**	**0.059**	**0.072**	**0.088**	**0.117**	**0.114**	**0.072**	**0.047**	**0.035**	**0.024**	**0.015**	**0.009**
	101P04512	Hourly vol	150	92	129	158	268	506	826	1222	1288	1215	1244	1504	1622	1734	2130	2589	3437	3349	2129	1388	1044	720	447	278
	101+04513		150	92	129	158	268	506	826	1222	1288	1215	1244	1504	1622	1734	2130	2589	3437	3349	2129	1388	1044	720	447	278
	101P04513		150	92	129	158	268	506	826	1222	1288	1215	1244	1504	1622	1734	2130	2589	3437	3349	2129	1388	1044	720	447	278

Table 18: TMC codes with the weekend factors and hourly volumes for Eastbound I-565

	Time of day		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC zone	**Tmc code**																									
E		**Saturday f_{hour}**	**0.010**	**0.008**	**0.006**	**0.006**	**0.011**	**0.030**	**0.043**	**0.038**	**0.042**	**0.049**	**0.059**	**0.063**	**0.059**	**0.061**	**0.066**	**0.066**	**0.070**	**0.070**	**0.068**	**0.056**	**0.041**	**0.032**	**0.025**	**0.019**
	101P04498	Hourly vol	254	215	152	161	266	752	1082	951	1057	1248	1490	1602	1495	1554	1679	1676	1763	1768	1730	1412	1049	818	645	488
	101+04499		254	215	152	161	266	752	1082	951	1057	1248	1490	1602	1495	1554	1679	1676	1763	1768	1730	1412	1049	818	645	488
	101P04499		254	215	152	161	266	752	1082	951	1057	1248	1490	1602	1495	1554	1679	1676	1763	1768	1730	1412	1049	818	645	488
F		**Saturday f_{hour}**	**0.010**	**0.008**	**0.006**	**0.006**	**0.009**	**0.027**	**0.047**	**0.042**	**0.044**	**0.052**	**0.062**	**0.064**	**0.046**	**0.042**	**0.057**	**0.074**	**0.077**	**0.074**	**0.074**	**0.060**	**0.042**	**0.033**	**0.025**	**0.020**
	101+04500	Hourly vol	282	217	156	169	240	756	1292	1162	1208	1426	1713	1770	1276	1152	1576	2031	2110	2044	2032	1648	1165	915	698	541
	101P04500		282	217	156	169	240	756	1292	1162	1208	1426	1713	1770	1276	1152	1576	2031	2110	2044	2032	1648	1165	915	698	541
G		**Saturday f_{hour}**	**0.010**	**0.008**	**0.008**	**0.006**	**0.007**	**0.021**	**0.039**	**0.040**	**0.041**	**0.047**	**0.054**	**0.065**	**0.045**	**0.051**	**0.069**	**0.079**	**0.079**	**0.078**	**0.076**	**0.059**	**0.041**	**0.032**	**0.025**	**0.019**
	101+04501	Hourly vol	301	228	231	176	211	626	1138	1173	1197	1382	1595	1896	1321	1510	2021	2323	2329	2286	2245	1724	1216	935	729	567
	101P04501		301	228	231	176	211	626	1138	1173	1197	1382	1595	1896	1321	1510	2021	2323	2329	2286	2245	1724	1216	935	729	567
	101+04502		300	227	231	175	210	623	1134	1169	1192	1377	1589	1889	1316	1504	2013	2314	2321	2278	2236	1717	1212	932	726	565
	101P04502		300	227	231	175	210	624	1134	1169	1193	1378	1590	1890	1317	1505	2014	2315	2322	2279	2237	1718	1212	932	726	565
H		**Saturday f_{hour}**	**0.010**	**0.007**	**0.006**	**0.005**	**0.007**	**0.019**	**0.035**	**0.037**	**0.042**	**0.050**	**0.062**	**0.068**	**0.057**	**0.064**	**0.071**	**0.077**	**0.075**	**0.073**	**0.073**	**0.052**	**0.038**	**0.030**	**0.024**	**0.019**
	101+04503	Hourly vol	299	207	175	141	200	563	1039	1096	1229	1489	1839	2003	1684	1878	2110	2284	2209	2145	2163	1524	1120	897	721	553
	101P04503		299	207	175	141	200	563	1039	1096	1229	1489	1839	2003	1684	1878	2110	2284	2209	2145	2163	1524	1120	897	721	553
I		**Saturday f_{hour}**	**0.010**	**0.007**	**0.006**	**0.004**	**0.006**	**0.017**	**0.034**	**0.039**	**0.043**	**0.053**	**0.063**	**0.070**	**0.065**	**0.070**	**0.071**	**0.076**	**0.072**	**0.069**	**0.068**	**0.052**	**0.035**	**0.028**	**0.025**	**0.019**
	101+04504	Hourly vol	333	229	189	144	190	531	1082	1235	1376	1685	2009	2250	2066	2238	2279	2420	2291	2196	2185	1673	1114	904	789	593
	101P04504		333	229	189	144	190	531	1082	1235	1376	1685	2009	2250	2066	2238	2279	2420	2291	2196	2185	1673	1114	904	789	593
J		**Saturday f_{hour}**	**0.010**	**0.006**	**0.004**	**0.004**	**0.005**	**0.009**	**0.024**	**0.034**	**0.043**	**0.056**	**0.065**	**0.073**	**0.069**	**0.075**	**0.078**	**0.076**	**0.072**	**0.070**	**0.069**	**0.048**	**0.036**	**0.030**	**0.023**	**0.017**
	101+04505	Hourly vol	422	270	190	165	214	389	1069	1495	1898	2441	2847	3182	3026	3292	3417	3327	3146	3076	3033	2075	1580	1320	1009	764
	101P04505		441	282	199	173	224	407	1118	1563	1984	2552	2977	3328	3165	3442	3573	3479	3289	3216	3171	2170	1652	1380	1055	798
	101+04506		468	299	211	183	237	431	1186	1658	2104	2707	3157	3529	3356	3650	3790	3690	3488	3411	3363	2301	1752	1463	1118	847
	101P04506		468	299	211	183	237	431	1186	1658	2104	2707	3157	3529	3356	3650	3790	3690	3488	3411	3363	2301	1752	1463	1118	847
	101+04507		468	299	211	183	237	431	1185	1657	2104	2706	3156	3528	3355	3649	3789	3689	3488	3410	3363	2300	1752	1463	1118	846
	101P04507		466	298	210	182	236	429	1179	1649	2094	2693	3141	3511	3339	3632	3770	3671	3471	3394	3346	2289	1743	1456	1113	842
K		**Saturday f_{hour}**	**0.010**	**0.006**	**0.004**	**0.004**	**0.005**	**0.009**	**0.023**	**0.034**	**0.043**	**0.055**	**0.062**	**0.072**	**0.069**	**0.076**	**0.080**	**0.077**	**0.073**	**0.072**	**0.070**	**0.049**	**0.037**	**0.030**	**0.024**	**0.017**
	101+04508	Hourly vol	451	293	189	186	224	410	1110	1593	2035	2601	2934	3424	3244	3608	3763	3625	3436	3414	3314	2325	1757	1405	1114	790
	101P04508		451	293	189	186	224	410	1110	1593	2035	2601	2934	3424	3244	3608	3763	3625	3436	3414	3314	2325	1757	1405	1114	790
L		**Saturday f_{hour}**	**0.010**	**0.007**	**0.005**	**0.004**	**0.005**	**0.008**	**0.021**	**0.032**	**0.042**	**0.054**	**0.061**	**0.073**	**0.070**	**0.077**	**0.080**	**0.078**	**0.074**	**0.072**	**0.068**	**0.051**	**0.038**	**0.031**	**0.024**	**0.017**
	101+04509	Hourly vol	371	252	176	155	185	322	797	1240	1626	2095	2357	2814	2701	2989	3091	3008	2848	2797	2617	1979	1476	1215	915	659
	101P04509		331	225	157	139	165	287	711	1106	1450	1869	2103	2510	2409	2666	2757	2683	2540	2495	2334	1766	1317	1084	816	588
	101P04510		204	139	97	86	102	177	438	682	895	1153	1297	1548	1486	1645	1701	1655	1568	1540	1440	1089	813	669	503	363
	101+04510		204	139	97	86	102	177	438	682	895	1153	1297	1548	1486	1645	1701	1655	1568	1540	1440	1089	813	669	503	363
	101P04511		204	139	97	86	102	177	438	682	895	1153	1297	1548	1486	1645	1701	1655	1568	1540	1440	1089	813	669	503	363
	101+04511		204	139	97	86	102	177	438	682	895	1153	1297	1548	1486	1645	1701	1655	1568	1540	1440	1089	813	669	503	363
M		**Saturday f_{hour}**	**0.012**	**0.008**	**0.007**	**0.005**	**0.006**	**0.010**	**0.017**	**0.034**	**0.041**	**0.050**	**0.056**	**0.067**	**0.069**	**0.075**	**0.081**	**0.076**	**0.071**	**0.070**	**0.066**	**0.057**	**0.044**	**0.035**	**0.025**	**0.019**
	101P04512	Hourly vol	228	150	139	91	120	187	335	652	781	959	1079	1292	1320	1452	1553	1472	1360	1347	1278	1097	840	672	488	372
	101+04513		228	150	139	91	120	187	335	652	781	959	1079	1292	1320	1452	1553	1472	1360	1347	1278	1097	840	672	488	372
	101P04513		228	150	139	91	120	187	335	652	781	959	1079	1292	1320	1452	1553	1472	1360	1347	1278	1097	840	672	488	372

Table 19: TMC codes with the weekday factors and hourly volumes for Westbound I-565

	Time of day		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC zone	**Tmc code**																									
E		**Weekday** f_{hour}	**0.007**	**0.004**	**0.007**	**0.006**	**0.010**	**0.022**	**0.040**	**0.062**	**0.057**	**0.048**	**0.049**	**0.049**	**0.053**	**0.056**	**0.066**	**0.090**	**0.098**	**0.099**	**0.068**	**0.039**	**0.026**	**0.019**	**0.014**	**0.010**
	101-04499	Hourly vol	278	170	271	230	408	874	1619	2525	2299	1963	1970	1987	2150	2276	2674	3663	3957	4009	2751	1572	1068	783	564	418
	101-04498		278	170	271	230	408	874	1619	2525	2299	1963	1970	1987	2150	2276	2674	3663	3957	4009	2751	1572	1068	783	564	418
	101N04499		278	170	271	230	408	874	1619	2525	2299	1963	1970	1987	2150	2276	2674	3663	3957	4009	2751	1572	1068	783	564	418
F		**Weekday** f_{hour}	**0.007**	**0.004**	**0.006**	**0.006**	**0.012**	**0.023**	**0.042**	**0.064**	**0.059**	**0.050**	**0.048**	**0.050**	**0.054**	**0.057**	**0.069**	**0.090**	**0.087**	**0.090**	**0.068**	**0.041**	**0.027**	**0.020**	**0.014**	**0.010**
	101-04500	Hourly vol	273	150	236	216	444	860	1582	2404	2199	1866	1810	1883	2000	2121	2567	3375	3267	3377	2539	1519	1004	762	541	392
	101N04500		273	150	236	216	444	860	1582	2404	2199	1866	1810	1883	2000	2121	2567	3375	3267	3377	2539	1519	1004	762	541	392
G		**Weekday** f_{hour}	**0.006**	**0.004**	**0.004**	**0.006**	**0.011**	**0.032**	**0.067**	**0.076**	**0.059**	**0.050**	**0.048**	**0.050**	**0.054**	**0.057**	**0.068**	**0.086**	**0.077**	**0.079**	**0.058**	**0.038**	**0.026**	**0.020**	**0.016**	**0.009**
	101-04501	Hourly vol	230	150	151	232	423	1268	2680	3029	2356	2000	1934	2009	2172	2290	2734	3437	3071	3156	2339	1523	1059	781	622	370
	101N04501		231	150	151	232	423	1270	2685	3034	2359	2003	1937	2012	2176	2293	2739	3442	3076	3161	2343	1525	1060	782	623	370
	101-04502		231	150	151	232	424	1272	2689	3039	2363	2006	1940	2015	2179	2297	2743	3448	3081	3166	2347	1528	1062	783	624	371
	101N04502		231	150	151	232	424	1272	2689	3039	2363	2006	1940	2015	2179	2297	2743	3448	3081	3166	2347	1528	1062	783	624	371
H		**Weekday** f_{hour}	**0.005**	**0.004**	**0.004**	**0.006**	**0.012**	**0.033**	**0.070**	**0.071**	**0.055**	**0.048**	**0.046**	**0.051**	**0.053**	**0.058**	**0.067**	**0.087**	**0.088**	**0.075**	**0.057**	**0.039**	**0.027**	**0.020**	**0.015**	**0.009**
	101-04503	Hourly vol	204	145	138	235	474	1244	2690	2700	2108	1825	1742	1953	2030	2221	2556	3314	3369	2864	2175	1498	1027	758	591	343
	101N04503		204	145	138	235	474	1244	2690	2700	2108	1825	1742	1953	2030	2221	2556	3314	3369	2864	2175	1498	1027	758	591	343
I		**Weekday** f_{hour}	**0.005**	**0.003**	**0.004**	**0.006**	**0.013**	**0.035**	**0.073**	**0.077**	**0.061**	**0.047**	**0.044**	**0.049**	**0.051**	**0.056**	**0.062**	**0.078**	**0.087**	**0.083**	**0.058**	**0.036**	**0.027**	**0.020**	**0.015**	**0.009**
	101-04504	Hourly vol	241	162	210	298	600	1649	3417	3617	2883	2235	2061	2309	2422	2623	2919	3676	4082	3927	2731	1710	1278	933	684	423
	101N04504		241	162	210	298	600	1649	3417	3617	2883	2235	2061	2309	2422	2623	2919	3676	4082	3927	2731	1710	1278	933	684	423
J		**Weekday** f_{hour}	**0.004**	**0.003**	**0.003**	**0.004**	**0.009**	**0.027**	**0.057**	**0.079**	**0.072**	**0.053**	**0.049**	**0.054**	**0.058**	**0.057**	**0.063**	**0.073**	**0.082**	**0.082**	**0.059**	**0.040**	**0.029**	**0.020**	**0.015**	**0.009**
	101-04505	Hourly vol	331	238	266	309	678	2104	4451	6135	5630	4154	3790	4204	4523	4474	4895	5734	6390	6374	4598	3140	2284	1577	1163	687
	101N04505		320	230	257	299	655	2032	4299	5925	5438	4012	3660	4060	4368	4321	4727	5538	6172	6156	4440	3033	2205	1523	1123	663
	101-04506		331	238	266	309	678	2104	4450	6134	5629	4154	3789	4204	4522	4474	4894	5733	6389	6373	4597	3140	2283	1577	1163	687
	101N04506		331	238	266	309	678	2104	4451	6135	5630	4154	3790	4204	4523	4474	4895	5734	6390	6374	4598	3140	2284	1577	1163	687
	101-04507		329	237	265	308	675	2093	4428	6104	5602	4133	3771	4183	4500	4452	4870	5705	6358	6342	4574	3124	2272	1569	1157	683
	101N04507		329	237	265	308	675	2093	4428	6104	5602	4133	3771	4183	4500	4452	4870	5705	6358	6342	4574	3124	2272	1569	1157	683
K		**Weekday** f_{hour}	**0.004**	**0.003**	**0.003**	**0.004**	**0.008**	**0.026**	**0.055**	**0.082**	**0.078**	**0.055**	**0.050**	**0.055**	**0.058**	**0.057**	**0.061**	**0.072**	**0.080**	**0.080**	**0.058**	**0.040**	**0.029**	**0.020**	**0.014**	**0.009**
	101-04508	Hourly vol	322	208	244	266	613	1893	4015	5935	5626	3993	3627	3954	4182	4117	4440	5245	5777	5787	4171	2879	2105	1438	1040	660
	101N04508		322	208	244	266	613	1893	4015	5935	5626	3993	3627	3954	4182	4117	4440	5245	5777	5787	4171	2879	2105	1438	1040	660
L		**Weekday** f_{hour}	**0.004**	**0.003**	**0.004**	**0.004**	**0.009**	**0.028**	**0.059**	**0.087**	**0.079**	**0.056**	**0.050**	**0.054**	**0.058**	**0.056**	**0.062**	**0.071**	**0.075**	**0.075**	**0.057**	**0.038**	**0.027**	**0.020**	**0.014**	**0.009**
	101-04509	Hourly vol	258	175	209	251	542	1631	3367	4992	4538	3196	2884	3118	3307	3235	3562	4057	4336	4301	3271	2197	1581	1159	806	532
	101N04509		384	260	312	374	808	2430	5017	7438	6763	4762	4298	4646	4927	4820	5308	6046	6461	6409	4874	3275	2356	1727	1201	793
	101N04510		258	175	209	251	542	1631	3367	4992	4538	3196	2884	3118	3307	3235	3562	4057	4336	4301	3271	2197	1581	1159	806	532
	101-04510		258	175	209	251	542	1631	3367	4992	4538	3196	2884	3118	3307	3235	3562	4057	4336	4301	3271	2197	1581	1159	806	532
	101N04511		258	175	209	251	542	1631	3367	4992	4538	3196	2884	3118	3307	3235	3562	4057	4336	4301	3271	2197	1581	1159	806	532
	101-04511		258	175	209	251	542	1631	3367	4992	4538	3196	2884	3118	3307	3235	3562	4057	4336	4301	3271	2197	1581	1159	806	532
M		**Weekday** f_{hour}	**0.004**	**0.002**	**0.003**	**0.005**	**0.010**	**0.037**	**0.077**	**0.123**	**0.101**	**0.069**	**0.058**	**0.052**	**0.055**	**0.052**	**0.059**	**0.063**	**0.062**	**0.053**	**0.045**	**0.024**	**0.016**	**0.012**	**0.008**	**0.007**
	101-04512	Hourly vol	132	74	99	145	297	1112	2359	3752	3083	2112	1780	1580	1677	1588	1804	1911	1898	1619	1367	735	479	366	255	223
	101N04512		132	74	99	145	297	1112	2359	3752	3083	2112	1780	1580	1677	1588	1804	1911	1898	1619	1367	735	479	366	255	223
	101N04513		132	74	99	145	297	1112	2359	3752	3083	2112	1780	1580	1677	1588	1804	1911	1898	1619	1367	735	479	366	255	223

Table 20: TMC codes with the weekend factors and hourly volumes for Westbound I-565

	Time of day		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
TMC zone	**Tmc code**																									
E		**Saturday f_{hour}**	**0.012**	**0.007**	**0.009**	**0.007**	**0.008**	**0.017**	**0.028**	**0.040**	**0.049**	**0.049**	**0.056**	**0.061**	**0.062**	**0.070**	**0.071**	**0.075**	**0.082**	**0.079**	**0.063**	**0.049**	**0.036**	**0.029**	**0.022**	**0.017**
	101-04499	Hourly vol	333	210	265	208	242	488	805	1146	1403	1407	1615	1752	1767	1996	2027	2139	2356	2254	1816	1408	1031	835	643	480
	101-04498		333	210	265	208	242	488	805	1146	1403	1407	1615	1752	1767	1996	2027	2139	2356	2254	1816	1408	1031	835	643	480
	101N04499		333	210	265	208	242	488	805	1146	1403	1407	1615	1752	1767	1996	2027	2139	2356	2254	1816	1408	1031	835	643	480
F		**Saturday f_{hour}**	**0.012**	**0.008**	**0.009**	**0.007**	**0.009**	**0.018**	**0.029**	**0.040**	**0.051**	**0.050**	**0.055**	**0.060**	**0.058**	**0.068**	**0.071**	**0.072**	**0.083**	**0.078**	**0.064**	**0.050**	**0.037**	**0.031**	**0.023**	**0.017**
	101-04500	Hourly vol	323	205	252	198	234	475	784	1077	1363	1336	1487	1625	1573	1843	1908	1935	2235	2103	1736	1351	1003	830	622	457
	101N04500		323	205	252	198	234	475	784	1077	1363	1336	1487	1625	1573	1843	1908	1935	2235	2103	1736	1351	1003	830	622	457
G		**Saturday f_{hour}**	**0.011**	**0.008**	**0.009**	**0.007**	**0.009**	**0.023**	**0.039**	**0.045**	**0.052**	**0.050**	**0.050**	**0.052**	**0.051**	**0.065**	**0.074**	**0.075**	**0.078**	**0.077**	**0.063**	**0.049**	**0.038**	**0.032**	**0.024**	**0.018**
	101-04501	Hourly vol	298	206	234	204	260	632	1074	1226	1419	1376	1376	1434	1407	1792	2038	2050	2124	2122	1737	1347	1035	863	651	490
	101N04501		298	206	234	204	260	633	1076	1228	1421	1378	1378	1436	1409	1795	2041	2053	2127	2125	1740	1349	1037	865	652	490
	101-04502		299	207	235	205	261	634	1078	1230	1424	1380	1380	1439	1412	1798	2044	2056	2130	2128	1742	1351	1039	866	653	491
	101N04502		299	207	235	205	261	634	1078	1230	1424	1380	1380	1439	1412	1798	2044	2056	2130	2128	1742	1351	1039	866	653	491
H		**Saturday f_{hour}**	**0.010**	**0.007**	**0.008**	**0.007**	**0.010**	**0.023**	**0.037**	**0.043**	**0.047**	**0.048**	**0.052**	**0.055**	**0.061**	**0.064**	**0.075**	**0.074**	**0.077**	**0.076**	**0.062**	**0.051**	**0.038**	**0.032**	**0.024**	**0.018**
	101-04503	Hourly vol	267	198	225	197	256	620	1001	1156	1264	1302	1412	1482	1639	1724	2010	2003	2079	2041	1683	1370	1026	864	641	489
	101N04503		267	198	225	197	256	620	1001	1156	1264	1302	1412	1482	1639	1724	2010	2003	2079	2041	1683	1370	1026	864	641	489
I		**Saturday f_{hour}**	**0.011**	**0.008**	**0.009**	**0.008**	**0.010**	**0.022**	**0.035**	**0.039**	**0.043**	**0.046**	**0.052**	**0.058**	**0.064**	**0.066**	**0.074**	**0.075**	**0.076**	**0.076**	**0.064**	**0.051**	**0.039**	**0.033**	**0.024**	**0.019**
	101-04504	Hourly vol	328	249	271	255	314	684	1079	1211	1333	1421	1605	1792	1982	2034	2311	2338	2349	2347	1987	1588	1207	1034	740	581
	101N04504		328	249	271	255	314	684	1079	1211	1333	1421	1605	1792	1982	2034	2311	2338	2349	2347	1987	1588	1207	1034	740	581
J		**Saturday f_{hour}**	**0.010**	**0.007**	**0.006**	**0.006**	**0.007**	**0.016**	**0.025**	**0.034**	**0.039**	**0.047**	**0.058**	**0.065**	**0.073**	**0.073**	**0.077**	**0.077**	**0.077**	**0.075**	**0.066**	**0.054**	**0.037**	**0.030**	**0.023**	**0.017**
	101-04505	Hourly vol	520	356	319	277	339	799	1276	1725	1964	2343	2924	3236	3659	3681	3857	3872	3863	3747	3306	2696	1856	1512	1152	871
	101N04505		502	343	308	268	327	772	1233	1666	1896	2263	2824	3125	3534	3555	3725	3739	3730	3619	3193	2604	1792	1460	1112	842
	101-04506		520	356	319	277	338	799	1276	1724	1963	2343	2923	3235	3659	3681	3856	3871	3862	3746	3306	2696	1855	1512	1151	871
	101N04506		520	356	319	277	339	799	1276	1725	1964	2343	2924	3236	3659	3681	3857	3872	3863	3747	3306	2696	1856	1512	1152	871
	101-04507		517	354	318	276	337	795	1270	1716	1954	2331	2909	3220	3640	3663	3837	3852	3843	3728	3290	2682	1846	1505	1146	867
	101N04507		517	354	318	276	337	795	1270	1716	1954	2331	2909	3220	3640	3663	3837	3852	3843	3728	3290	2682	1846	1505	1146	867
K		**Saturday f_{hour}**	**0.011**	**0.007**	**0.006**	**0.005**	**0.006**	**0.015**	**0.023**	**0.033**	**0.039**	**0.047**	**0.059**	**0.065**	**0.073**	**0.074**	**0.078**	**0.078**	**0.077**	**0.074**	**0.066**	**0.054**	**0.038**	**0.030**	**0.024**	**0.018**
	101-04508	Hourly vol	518	346	311	268	305	733	1142	1632	1915	2281	2883	3191	3590	3621	3799	3796	3771	3627	3248	2627	1837	1463	1165	882
	101N04508		518	346	311	268	305	733	1142	1632	1915	2281	2883	3191	3590	3621	3799	3796	3771	3627	3248	2627	1837	1463	1165	882
L		**Saturday f_{hour}**	**0.010**	**0.007**	**0.006**	**0.005**	**0.007**	**0.015**	**0.023**	**0.032**	**0.040**	**0.048**	**0.061**	**0.068**	**0.073**	**0.075**	**0.076**	**0.080**	**0.076**	**0.074**	**0.067**	**0.052**	**0.035**	**0.029**	**0.022**	**0.017**
	101-04509	Hourly vol	404	268	236	212	262	588	898	1240	1585	1895	2377	2660	2876	2953	2990	3135	2992	2893	2630	2053	1386	1150	883	670
	101N04509		603	399	351	316	390	875	1338	1847	2361	2824	3543	3964	4285	4400	4456	4671	4459	4311	3919	3059	2066	1713	1315	999
	101N04510		404	268	236	212	262	588	898	1240	1585	1895	2377	2660	2876	2953	2990	3135	2992	2893	2630	2053	1386	1150	883	670
	101-04510		404	268	236	212	262	588	898	1240	1585	1895	2377	2660	2876	2953	2990	3135	2992	2893	2630	2053	1386	1150	883	670
	101N04511		404	268	236	212	262	588	898	1240	1585	1895	2377	2660	2876	2953	2990	3135	2992	2893	2630	2053	1386	1150	883	670
	101-04511		404	268	236	212	262	588	898	1240	1585	1895	2377	2660	2876	2953	2990	3135	2992	2893	2630	2053	1386	1150	883	670
M		**Saturday f_{hour}**	**0.008**	**0.005**	**0.004**	**0.004**	**0.008**	**0.015**	**0.031**	**0.040**	**0.057**	**0.064**	**0.076**	**0.074**	**0.078**	**0.072**	**0.071**	**0.072**	**0.071**	**0.071**	**0.062**	**0.042**	**0.027**	**0.019**	**0.017**	**0.013**
	101-04512	Hourly vol	153	94	75	72	150	292	593	769	1109	1238	1469	1438	1505	1388	1376	1395	1384	1367	1207	809	529	375	334	247
	101N04512		153	94	75	72	150	292	593	769	1109	1238	1469	1438	1505	1388	1376	1395	1384	1367	1207	809	529	375	334	247
	101N04513		153	94	75	72	150	292	593	769	1109	1238	1469	1438	1505	1388	1376	1395	1384	1367	1207	809	529	375	334	247

3.5 Determination of Delays and Congestion Level

Considering the large amount of data for TMC codes downloaded from RITIS (Ritis, 2022), the data had to be strictly evaluated and overviewed before conducting the delay and congestion analyses. The purpose of these analyses is to identify segments that experience recurrent and non-recurrent congestion. As indicated in the report by Sullivan et al. (Sullivan, Sisiopiku, & Kallem, 2012), recurrent congestion is typically caused when traffic demand exceeds available roadway capacity, leading to congestion that tends to recur at the same times and in the same places every day. Non-recurrent congestion, on the other hand, is typically caused by incidents or events that either temporarily reduce roadway capacity or increase traffic demand, such as crashes, construction zones, bad weather, or special events. The presence of congestion was determined by estimating the delays on each of the TMC codes.

The data considered were aggregated over 15 minutes intervals and were extracted for the entire month of March 2021. The database used in this study include the TMC code, length of the segment, date, time interval, average speed, the reference speed, and the historical average speed. The *average speed* is the speed of the vehicles that passed through the TMC for the time intervals under consideration. The *reference speed* refers to the free flow speed, which is the average speed a motorist would have travelled, assuming there were no congestion or other adverse conditions. The *historical average speed* is the speed calculated based on years of historical data, considering the average speed expected on a particular segment. The historical average speed was used to calculate the historical average travel time while the reference speed was used in calculating the free flow travel time.

3.5.1 Speed Analysis and Congestion Characterization

The speed analysis serves the purpose of establishing the condition of the segments apropos congestion. For a segment to be considered congested in this study, the average speed ought to be less than 90% of the reference speed. This step separates the congested segments from the non-congested segments. The next step is finding the non-recurrent congested segments and recurrent congested segments. In doing so, the Standard Normal Deviate (SND) is considered which shows how much a variable deviates from a data set. According to Sullivan et al., values of SND that are less than a selected threshold of (-1.5) would indicate congestion beyond average levels and likely non-recurrent congestion. (Sullivan, Sisiopiku, & Kallem, 2012)

First, an excel spreadsheet containing the average speed for every 15 minutes over the 31 days of March 2021 for each TMC code was set up. Then, the speed values for each TMC code for every 15 minutes interval were averaged over the time periods for all the weekdays of the month of March and the same was done for the weekends. The standard deviations were also calculated for each row (each time interval) in the spreadsheet and used to determine the Standard Normal Deviate (SND). The Standard Normal Deviate (SND) for each speed (for a particular TMC segment, day, and time) was computed from all weekday and weekend data for the month at the period using the Equ. (6) below

$$(SND)_{ij} = [(Speed)_{ij} - (Avg\ Speed)_i\ ]/(Std\ Deviation)_i \tag{6}$$

Where:

$(SND)_{ij}$ = Standard Normal Deviate of the TMC code at time interval i for day j

$(Speed)_{ij}$ = Speed of the TMC code at time interval i for day j

i = 15-minute interval

j = particular day

Thus, after calculating the SNDs, the TMCs were classified with respect to congestion type (recurrent versus non-recurrent) based on a threshold value of -1.5. In other words, TMCs with SND values which deviated by more than -1.5 were considered as experiencing recurrent congestion at the occurrence times. TMC codes with SND values less than or equal to -1.5 were listed as segments with non-recurrent congestion.

3.5.2 Calculation of Delays

Economic impacts of congestion are associated with resulting traffic delays. Delay, according to the Federal Highway Administration (FHWA), represents the additional travel time actually experienced by a driver, passenger or pedestrian, as a result of congestion (Federal Highway Administration, 2021). The free flow travel time, i.e. the amount of time required to travel from one point to another on segment under free flow traffic conditions was determined first and then used to calculate recurrent delays and the non-recurrent delays.

Equ. (7), Equ. (8) and Equ. (9) show the relationships between the travel time and other variables as used in this project.

$$\text{Average travel time (in seconds)} = \frac{TMC\ length}{Average\ speed} * 3600 \tag{7}$$

$$\text{Free flow travel time (in seconds)} = \frac{TMC\ length}{Reference\ speed} * 3600 \tag{8}$$

$$\text{Historical average travel time (in seconds)} = \frac{TMC\ length}{Historical\ average\ speed} * 3600 \tag{9}$$

When the congestion was *recurrent*, the *Average Recurrent Delay* (in s) for each TMC and for each 15-minute time interval was determined as the difference between the Average Travel Time and the Free Flow Travel Time. For example, in Table 22, for TMC code 101-05050 Southbound on 3/1/2022 at 1:45, the Average Recurrent Delay was 17.94 s, equal to the difference between Average Travel Time (124 s) and Free Flow Travel Time (106.06 s). . However, if the historical average time was greater than the free flow travel time, then the Average Recurrent Delay was computed as historical average travel time minus the Free flow travel time. Segments without congestion had zero values for the Average Recurrent Delay.

If the calculated Average Recurrent Delay showed as negative, then the zero value was assigned because delay can only have a value of 0 or above. For example, in Table 21, for TMC code 101+53705 Northbound on 3/1/2022 at 0:30, the Average Recurrent Delay is 0 s, as the difference between Average Travel Time (321.53 s) and Free Flow Travel Time (328.42 s) is -6.89, indicating lack of congestion presence.

When the congestion was *non-recurrent*, the *Average Recurrent Delay* (in s) was calculated as the difference between the Historical Average Travel Time and the Free Flow Travel Time for the respective TMCs and time intervals considered. For example, in Table 21, for TMC code 101+53705 Northbound, on 3/1/2022 at 1:45 the Average Recurrent Delay was 4.76 s, equal to the difference between Historical Average travel Time (333.18 s) and Free Flow Travel Time (328.42 s).

After calculation of the Average Recurrent Delays for each TMC and each 15-minute time interval, the *Total Recurrent Delay* (in veh-s) was determined by multiplying the Average Recurrent Delay by the 15-minute volume for the respective 15-minute period.

For example, in Table 22, for TMC code 101-05050 Southbound on 3/1/2022 at 1:45, the Total Recurrent Delay was 448.5 s, equal to the 15-minute volume (24.99 veh) multiplied by the Average Recurrent Delay (17.94 s)

When the congestion was *recurrent*, the *Average Non- Recurrent Delay* (in s) for each TMC and for each 15-minute time interval was assigned a zero value as only non-recurrent congestion was considered for this scenario.

When the congestion was *non-recurrent*, the *Average Non-Recurrent Delay* (in s) for each TMC and for each 15-minute time interval was determined as the difference between the Average Travel Time and the Historical Average Travel Time. For example, in Table 21, for TMC code 101+53705 Northbound on 3/1/2022 at 1:45, the Average Non-Recurrent Delay was 249.3s, equal to the difference between Average Travel Time (582.46 s) and Historical average Travel Time (333.18 s). However, if the historical average time was greater than the Average Travel Time, then the Average Non-Recurrent Delay was assigned zero value because delay can only have a value of 0 or above. For example, in Table 21, for TMC code 101+53705 Northbound on 3/1/2022 at 0:30, the Average Non-Recurrent Delay is 0 s, as the difference between Average Travel Time (321.53 s) and Historical Average Travel Time (323.80 s) is -2.27, indicating lack of congestion presence.

After calculation of the Average Non-Recurrent Delays for each TMC and each 15-minute time interval, the *Total Non-Recurrent Delay* (in veh-s) was determined by multiplying the Average Recurrent Delay by the 15-minute volume for the respective 15-minute period. For example, in Table 21, for TMC code 101+53705 Northbound on 3/1/2022 at 1:45, the Total Non-Recurrent Delay was 9097.3 s, equal to the 15-minute volume (36.50 veh) multiplied by the Average Recurrent Delay (249.27 s)

The spreadsheets used in the analysis contained very large files with average of 76,000 rows and 18 columns for each direction of the interstate routes under study. For this reason, Tables 21 and 22 show only excerpts of the spreadsheets used for these calculations. The dataset in its entirety is available upon request.

Table 21: Sample delay calculation spreadsheet for the Northbound segments on the weekdays

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
TMC_code	**Length (miles)**	**Date**	**Raw time**	**Average speed (mph)**	**Historical average _speed (mph)**	**Reference _speed (mph)**	**Congestion condition**	**Weekday avg (mph)**	**Std. Dev.**	**SND**	**15-min vol (veh)**	**NRC Present?**	**Average travel time (s)**	**Free flow travel time (s)**	**Historical average travel time (s)**	**Average recurrent delay (s)**	**Total recurrent delay (veh-s)**	**Average non-recurrent delay (s)**	**Total non-recurrent delay (veh-s)**
101+53705	6.39	3/1/2021	0:00	66.99	71	70	NO	69.41	2.68	-0.90	47.83		343.18	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	0:15	60.5	71	70	YES	68.78	2.77	-3.00	47.83	yes	379.99	328.42	323.80	0.00	0.0	56.20	2688.0
101+53705	6.39	3/1/2021	0:30	71.5	71	70	NO	69.07	2.76	0.88	47.83		321.53	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	0:45	75.5	71	70	NO	67.70	2.80	2.79	47.83		304.50	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	1:00	69.17	69	70	NO	68.02	1.91	0.60	36.50		332.36	328.42	333.18	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	1:15	64.07	69	70	NO	69.68	2.68	-2.10	36.50		358.82	328.42	333.18	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	1:30	63.6	69	70	NO	68.47	3.69	-1.32	36.50		361.47	328.42	333.18	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	1:45	39.47	69	70	YES	67.43	6.43	-4.35	36.50	yes	582.46	328.42	333.18	4.76	173.7	249.27	9097.3
101+53705	6.39	3/1/2021	2:00	63	65	70	NO	65.78	11.11	-0.25	37.20		364.91	328.42	353.68	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	2:15	66.54	65	70	NO	68.79	1.69	-1.33	37.20		345.50	328.42	353.68	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	2:30	68.25	65	70	NO	68.67	1.98	-0.21	37.20		336.84	328.42	353.68	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	2:45	64.98	65	70	NO	68.83	2.52	-1.53	37.20		353.79	328.42	353.68	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	3:00	61.67	69	70	YES	68.05	3.20	-2.00	35.79	yes	372.78	328.42	333.18	4.76	170.3	39.60	1417.2
101+53705	6.39	3/1/2021	3:30	70	69	70	NO	68.10	1.42	1.34	35.79		328.42	328.42	333.18	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	3:45	68.61	69	70	NO	68.38	1.87	0.12	35.79		335.08	328.42	333.18	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	4:00	65.31	71	70	NO	68.36	1.98	-1.54	60.23		352.01	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	4:15	70.65	71	70	NO	69.96	1.66	0.42	60.23		325.40	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	4:30	67.27	71	70	NO	69.95	2.83	-0.95	60.23		341.75	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	4:45	69.27	71	70	NO	68.87	1.34	0.30	60.23		331.88	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	5:00	68.24	70	70	NO	69.48	1.44	-0.86	81.85		336.89	328.42	328.42	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	5:15	68.61	70	70	NO	69.15	1.45	-0.37	81.85		335.08	328.42	328.42	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	5:30	68.31	70	70	NO	69.10	1.76	-0.45	81.85		336.55	328.42	328.42	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	5:45	69.63	70	70	NO	69.15	1.58	0.31	81.85		330.17	328.42	328.42	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	6:00	68.99	71	70	NO	69.38	1.41	-0.28	140.31		333.23	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	6:15	69.65	71	70	NO	69.84	2.05	-0.09	140.31		330.07	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	6:30	69.93	71	70	NO	70.45	1.47	-0.35	140.31		328.75	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	6:45	70.31	71	70	NO	68.97	2.86	0.47	140.31		326.97	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	7:00	70.31	71	70	NO	69.50	1.97	0.41	215.43		326.97	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	7:15	71.64	71	70	NO	69.47	2.73	0.79	215.43		320.90	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	7:30	72.62	71	70	NO	69.74	3.57	0.81	215.43		316.57	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	7:45	70.66	71	70	NO	69.61	2.03	0.52	215.43		325.35	328.42	323.80	0.00	0.0	0.00	0.0
101+53705	6.39	3/1/2021	8:00	68.63	69	70	NO	69.31	1.62	-0.42	202.32		334.98	328.42	333.18	0.00	0.0	0.00	0.0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
101+05049	3.04	3/31/2021	23:15	66.62	67	72	NO	68.48	3.27	-0.57	52.69		164.22	151.96	163.30	0.00	0.0	0.00	0.0
101+05049	3.04	3/31/2021	23:30	69.45	67	72	NO	68.65	2.64	-0.30	52.69		157.90	151.96	163.30	0.00	0.0	0.00	0.0
101+05049	3.04	3/31/2021	23:45	69.45	67	72	NO	68.65	2.64	0.30	52.69		157.54	151.96	163.30	0.00	0.0	0.00	0.0

Table 22: Sample delay calculation spreadsheet for the Southbound segments on the weekdays

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
TMC_code	**Length (miles)**	**Date**	**Raw time**	**Average speed (mph)**	**Historical average _speed (mph)**	**Reference _speed (mph)**	**Congestion condition**	**Weekday avg (mph)**	**Std. Dev.**	**SND**	**15-min vol (veh)**	**NRC Present?**	**Average travel time (s)**	**Free flow travel time (s)**	**Historical average travel time (s)**	**Average recurrent delay (-s)**	**Total recurrent delay (veh-s)**	**Average non-recurrent delay (-s)**	**Total non-recurrent delay (veh-s)**
101-05050	2.12	3/1/2021	0:00	59.98	65	72	YES	66.94	3.03	-2.30	34.11	yes	127.31	106.06	117.48	11.42	389.6	9.83	335.3
101-05050	2.12	3/1/2021	0:15	66.96	65	72	NO	65.37	9.61	0.17	34.11		114.04	106.06	117.48	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	0:30	65.93	65	72	NO	66.72	2.56	-0.31	34.11		115.82	106.06	117.48	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	0:45	67.76	65	72	NO	67.94	4.98	-0.04	34.11		112.69	106.06	117.48	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	1:00	70.5	66	72	NO	68.09	3.10	0.78	24.99		108.31	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	1:15	68.47	66	72	NO	65.95	6.35	0.40	24.99		111.52	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	1:30	69.21	66	72	NO	69.82	3.21	-0.19	24.99		110.33	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	1:45	61.58	66	72	YES	66.13	9.30	-0.49	24.99	no	124.00	106.06	115.70	17.94	448.5	0.00	0.0
101-05050	2.12	3/1/2021	2:00	65.47	66	72	NO	65.68	5.86	-0.04	30.28		116.63	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	2:15	68.24	66	72	NO	66.46	6.67	0.27	30.28		111.90	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	2:30	70.31	66	72	NO	68.11	3.71	0.59	30.28		108.61	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	2:45	68.5	66	72	NO	65.75	4.02	0.68	30.28		111.48	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	3:00	66.32	66	72	NO	66.35	6.36	0.00	39.69		115.14	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	3:15	66.79	66	72	NO	67.23	2.15	-0.20	39.69		114.33	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	3:30	68.02	66	72	NO	67.84	2.73	0.07	39.69		112.26	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	3:45	69.93	66	72	NO	67.87	2.31	0.89	39.69		109.20	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	4:00	65.97	66	72	NO	66.79	4.80	-0.17	66.45		115.75	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	4:15	68.6	66	72	NO	66.14	3.72	0.66	66.45		111.31	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	4:30	65.91	66	72	NO	66.54	2.73	-0.23	66.45		115.86	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	4:45	67.75	66	72	NO	68.87	1.53	-0.73	66.45		112.71	106.06	115.70	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	5:00	72.29	68	72	NO	68.17	2.23	1.85	130.84		105.63	106.06	112.30	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	5:15	71.08	68	72	NO	67.28	2.84	1.34	130.84		107.43	106.06	112.30	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	5:30	65.29	68	72	NO	66.80	5.45	-0.28	130.84		116.96	106.06	112.30	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	5:45	66.59	68	72	NO	68.60	2.00	-1.01	130.84		114.67	106.06	112.30	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	6:00	70.8	67	72	NO	69.09	2.91	0.59	198.17		107.85	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	6:15	70.63	67	72	NO	69.11	2.74	0.55	198.17		108.11	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	6:30	66.88	67	72	NO	68.86	1.66	-1.19	198.17		114.18	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	6:45	69.29	67	72	NO	68.97	1.97	0.16	198.17		110.20	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	7:00	69.27	67	72	NO	68.97	1.87	0.16	246.10		110.24	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	7:15	70.25	67	72	NO	68.99	4.24	0.30	246.10		108.70	106.06	113.97	0.00	0.0	0.00	0.0
101-05050	2.12	3/1/2021	7:30	70.64	67	72	NO	69.10	2.89	0.53	246.10		108.10	106.06	113.97	0.00	0.0	0.00	0.0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
101-05049	6.32	3/31/2021	23:15	68.96	67	72	NO	68.00	1.86	0.52	56.53		329.72	315.80	339.36	0.00	0.0	0.00	0.0
101-05049	6.32	3/31/2021	23:30	67.6	67	72	NO	67.65	2.21	-0.02	56.53		336.35	315.80	339.36	0.00	0.0	0.00	0.0
101-05049	6.32	3/31/2021	23:45	70.28	67	72	NO	68.89	2.71	0.51	56.53		323.53	315.80	339.36	0.00	0.0	0.00	0.0

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Overview

This chapter contains the assessment of the results obtained from the calculations performed as shown in Chapter 3. The results were broken down into the weekdays and weekends for the Northbound and Southbound for the I-65 road segments; and the East and Westbound on the I-565 road segments. The values for the Recurrent and Non-recurrent delays calculated based on the procedure described in Chapter 3 helped to identify the road segments that experience congestion issues. Moreover, the delay data helped identify the times of day that the TMC segments experience congestion.

To draw more inference, the dollar value of these delays was computed after the delays were added up for the different days of the month of March 2021. It is pertinent that these monetary implications be considered because they lay out how much is being lost at any time on a particular segment due to congestion-induced delays. The data obtained from Regional Integrated Transportation Information System (Ritis, 2022) contained the truck percentages, from which the passenger car percentages were also computed. These percentages were factored in to get the dollar value of congestion for both the truck and passenger cars users. The different tables and charts shown in this chapter illustrate the contributions and impacts of the different car and truck percentages to the recurrent and non-recurrent delays and associated costs.

4.2 Value of delay time estimates for passenger vehicles and trucks

Ellis stated that the value of delay time is an estimate of the differential cost of the extra travel time due to congestion (Ellis, 2017). This congestion cost is often considered as a function of costs associated with the time spent and the fuel used while the driver is stuck in congested traffic. According to Ellis, the value of travel time and delay time for passenger vehicles now uses as a base the median hourly wage rate for all occupations as produced by the Bureau of Labor Statistics (BLS) (Ellis, 2017). The commercial value of travel time (for trucks) is now based on the American Transportation Research Institute (ATRI) annual survey modified by the speed, vehicle type and vehicle occupancy. Ellis also stated that it is more appropriate to exclude the cost of fuel in calculating the dollar value of delay. Following those recommendations, this study considered \$17.81 per hour as the value of delay time based upon hourly wage rates for delays encountered by passenger cars. The value for the truck congestion cost per hour considered was \$54.35 according to the ATRI (American Transportation Research Institute, 2021). This value covers the truck/trailer lease or purchase payments, repair and maintenance, the truck insurance premiums, permits and licenses, tires tolls, driver wages and benefits.

The Recurrent congestion dollar values were calculated as shown in Equ. 10.

$$\frac{Sum\ of\ total\ recurrent\ delay}{3600}\ ([truck\ fraction * \$54.35] + [car\ fraction * \$17.81]) \qquad (10)$$

The Non- Recurrent congestion dollar values were calculated as shown in Equ. 11.

$$\frac{Sum\ of\ non{-}total\ recurrent\ delay}{3600}\ ([truck\ fraction * \$54.35] + [car\ fraction * \$17.81]) \qquad (11)$$

The binary values in the last column of Table 23 show the status of ASAP patrol teams with 0 representing the absence and 1 showing presence.

4.2.1 Weekday congestion quantification along I-65 study segments

The Northbound and Southbound sections of I-65 have comparatively higher percentages of trucks than the I-565. This is because of large freight movements along the I-65 corridor that runs from Indiana all the way to the Gulf of Mexico, passing through Huntsville. There are also large expanses of farm areas very close to I-65 heading North to Tennessee. The high percentage of trucks contributes significantly to the congestions on these roadways.

Table 23 and Table 24 summarize the recurrent and non-recurrent congestion (dollar values) for weekdays for March 2021 for the Northbound and Southbound study segments of I-65 respectively. Visual depictions of the recurrent and non-recurrent congestion (dollar values) per TMC code for those two study corridors are available in Figure 3 and Figure 4.

The displayed results help identify the segments that lost the most money due to congestion over the study period. For example, as shown in Table 21, when considering Non-Recurrent Congestion Dollar Values, one can see that segments corresponding to TMC codes 101+05047, 101+05042, 101+05043, and 101+53705 (in Cullman, Morgan, and Limestone counties) are the ones that experienced the heaviest cost due to non-recurrent congestion among all Northbound segments of I-65 considered. It is also worth noting that some of the TMC segments that have high dollar values of Non-Recurrent Congestion (including 101+05042, 101+05043, and 101+53705) have no presence of ASAP Patrol teams.

Table 23: Dollar value of recurrent and non-recurrent congestion. Northbound Study Segments of I-65; Weekdays; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-sec)	Sum of Total Non-Recurrent Delay (veh-sec)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101+05042	659059	5633717	32.00	68.00	0.32	0.68	5401	46170	0
101+05043	446227	1543853	31.00	69.00	0.31	0.69	3613	12497	0
101+05044	91415	318422	19.68	80.32	0.20	0.80	255	737	0
101+05045	100775	244452	30.00	70.00	0.30	0.70	329	805	0
101+05046	200652	217974	30.00	70.00	0.30	0.70	2506	2723	1
101+05047	567862	4083300	27.00	73.00	0.27	0.73	7311	52567	1
101+05048	84911	142770	39.00	61.00	0.39	0.61	947	1592	0
101+05049	102322	108002	44.00	56.00	0.44	0.56	963	1017	0
101+05050	74761	94618	44.00	56.00	0.44	0.56	703	890	0
101+05051	75539	73657	37.00	63.00	0.37	0.63	514	501	0
101+05052	22095	24995	37.00	63.00	0.37	0.63	150	170	0
101+05053	374590	75708	40.00	60.00	0.40	0.60	2354	476	0
101+53705	1435896	1149101	39.00	61.00	0.39	0.61	14674	11742	0
101P05043	43184	70611	25.25	74.75	0.25	0.75	324	530	0
101P05044	34894	60508	25.30	74.70	0.25	0.75	109	178	0
101P05045	31965	42268	30.00	70.00	0.30	0.70	106	140	0
101P05046	81912	676644	28.95	71.05	0.29	0.71	1034	8537	1
101P05047	57771	59355	32.31	67.69	0.32	0.68	661	679	1
101P05048	40643	21731	40.93	59.07	0.41	0.59	422	225	0
101P05049	42361	30392	44.00	56.00	0.44	0.56	435	312	0
101P05050	30393	15708	40.82	59.18	0.41	0.59	245	127	0
101P05051	24494	16934	37.00	63.00	0.37	0.63	167	115	0
101P05052	23558	16764	38.28	61.72	0.38	0.62	155	110	0
101P05053	153699	5829	40.00	60.00	0.40	0.60	966	37	0
101P53705	687990	341182	39.00	61.00	0.39	0.61	7033	3488	0

Results displayed in Table 24 and Figure 4 confirm that traveling Southbound on I-65 on the weekdays, TMC Codes 101-05042, 101-05045, 101-05046, 101-05047 101N05043, 101N05047 and 101-53705 (also in Cullman, Morgan, and Limestone counties) showed high level of non-recurrent congestions with 101-05046 being the only segment with ASAP patrol team. Thus, the results from the data analysis performed in this study and summarized in tables similar to Tables 23 and 24 and Figures 3 and 4 provide valuable insights that can help local authorities to prioritize segments for ASAP deployment and improve ASAP resource allocations.

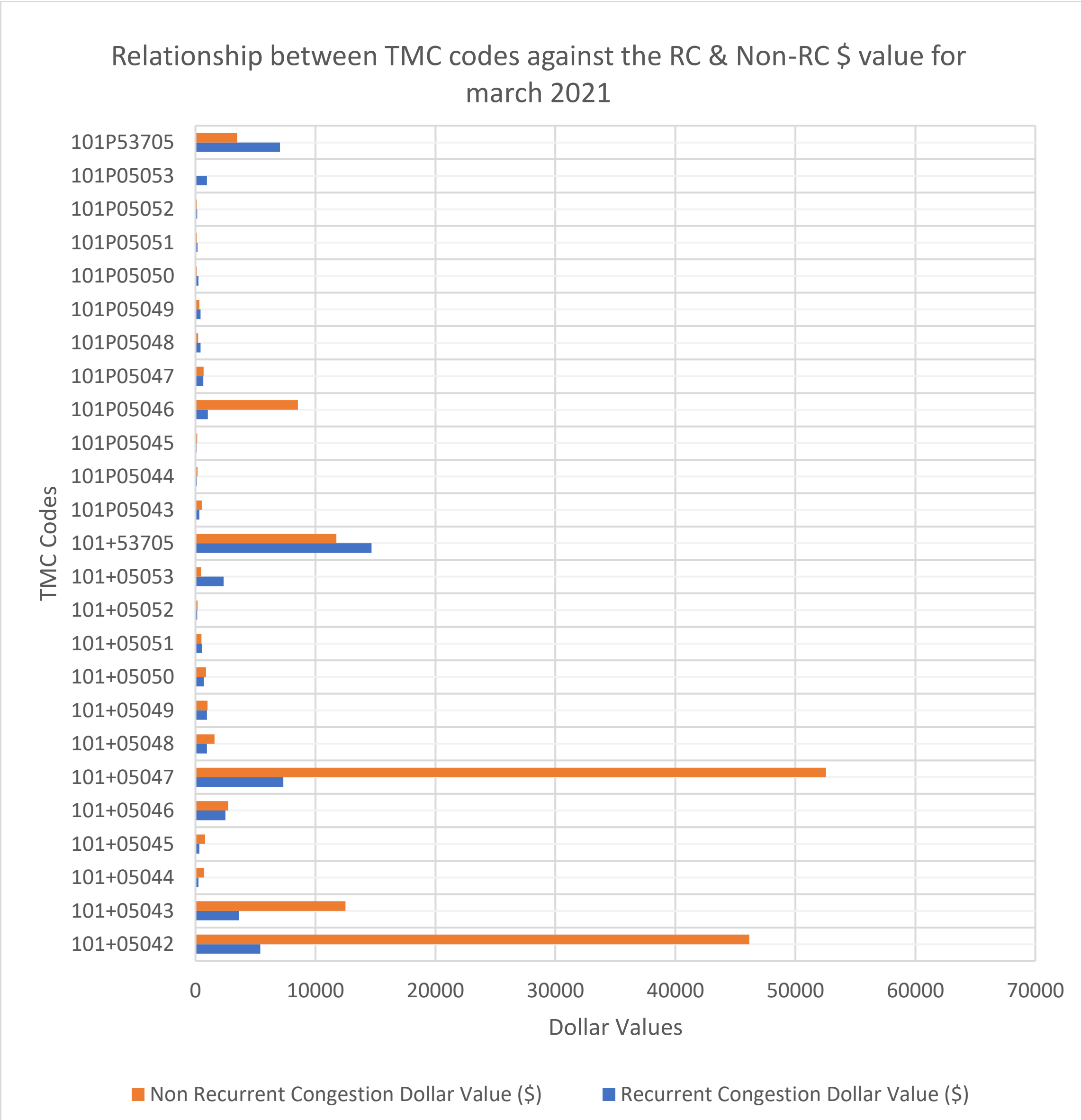

Figure 3: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Northbound Segments of I-65; Weekdays; March 2021

Table 24: Dollar value of recurrent and non-recurrent congestion. Southbound Study Segments of I-65; Weekdays; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay (veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101-05042	629311	8714643	31.0	69.0	0.31	0.69	6383	93784	0
101-05043	150457	320671	19.7	80.3	0.20	0.80	1515	7749	0
101-05044	75071	112196	30.0	70.0	0.30	0.70	897	4104	0
101-05045	180103	396006	30.0	70.0	0.30	0.70	2313	13398	0
101-05046	533084	2896714	27.0	73.0	0.27	0.73	10738	101293	1
101-05047	88074	70037	39.0	61.0	0.39	0.61	2235	47126	1
101-05048	140701	59378	44.0	56.0	0.44	0.56	1413	613	0
101-05049	163793	146158	44.0	56.0	0.44	0.56	1896	1621	0
101-05050	184364	186114	37.0	63.0	0.37	0.63	1858	2346	0
101-05051	155278	77944	37.0	63.0	0.37	0.63	1668	1234	0
101-05052	198346	31197	40.0	60.0	0.40	0.60	1913	337	0
101-53705	112091	619954	39.0	61.0	0.39	0.61	1468	8522	0
101N05043	123511	677706	25.3	74.7	0.25	0.75	1130	11543	0
101N05044	31291	40691	25.4	74.6	0.25	0.75	325	628	0
101N05046	51201	46146	28.2	71.8	0.28	0.72	1042	4370	1
101N05047	273581	460526	32.2	67.8	0.32	0.68	4681	20649	1
101N05048	30748	7394	41.6	58.4	0.42	0.58	351	130	0
101N05049	26412	25208	44.0	56.0	0.44	0.56	289	254	0
101N05050	17894	10138	41.2	58.8	0.41	0.59	230	145	0
101N05051	29950	21301	37.0	63.0	0.37	0.63	345	292	0
101N05052	120932	17905	38.3	61.7	0.38	0.62	1168	221	0
101N05053	161164	4532	40.0	60.0	0.40	0.60	1662	46	0
101N53705	277668	274995	39.0	61.0	0.39	0.61	3808	4528	0

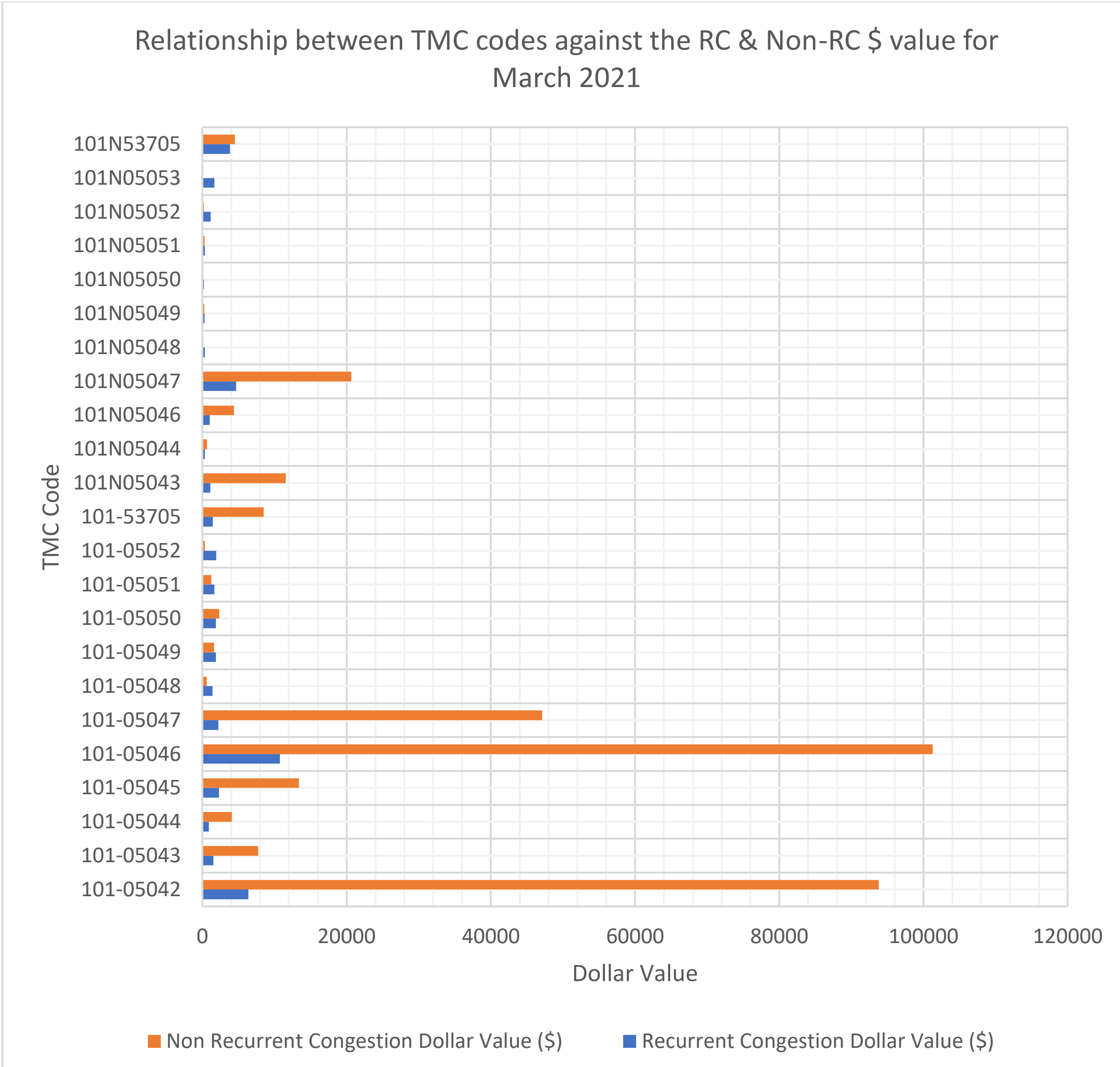

Figure 4: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Southbound Segments of I-65; Weekdays; March 2021

In addition, Tables 23 and 24, and Figures 3 and 4 above show the contrasts in recurrent and non-recurrent congestion. The TMC codes 101+05047, 101-05047, 101N05047, 101N05043, 101-05046, 101+53705 all fall into segment A (between exits 354 and 361) while some of the TMC codes fall into segment D (between exits 310 and 318). Segment A, which contains exits that are close to the Alabama-Tennessee border, serves large stores that include Publix, Lowe’s, Walmart, Dollar general stores and asphalt plants. This might explain the presence of high non-recurrent congestion.

Considering the times of day when congestion occurred, the graphs displayed in Figure 5 through Figure 10 show the value of congestion cost over time for select TMCs that have high non-recurrent congestion. These segments serve as corridors that lead to the University of North Alabama, some restaurants, grocery shops and offices thus attracting traffic for daily activities. It can be seen that the highest costs of Non-Recurrent congestion typically occur from 7:30am to 3:00pm on the weekdays. Also, Figure 6 through Figure 10 show that the cost for Non-Recurrent Congestion is higher than that of Recurrent Congestion over the same time period considered.

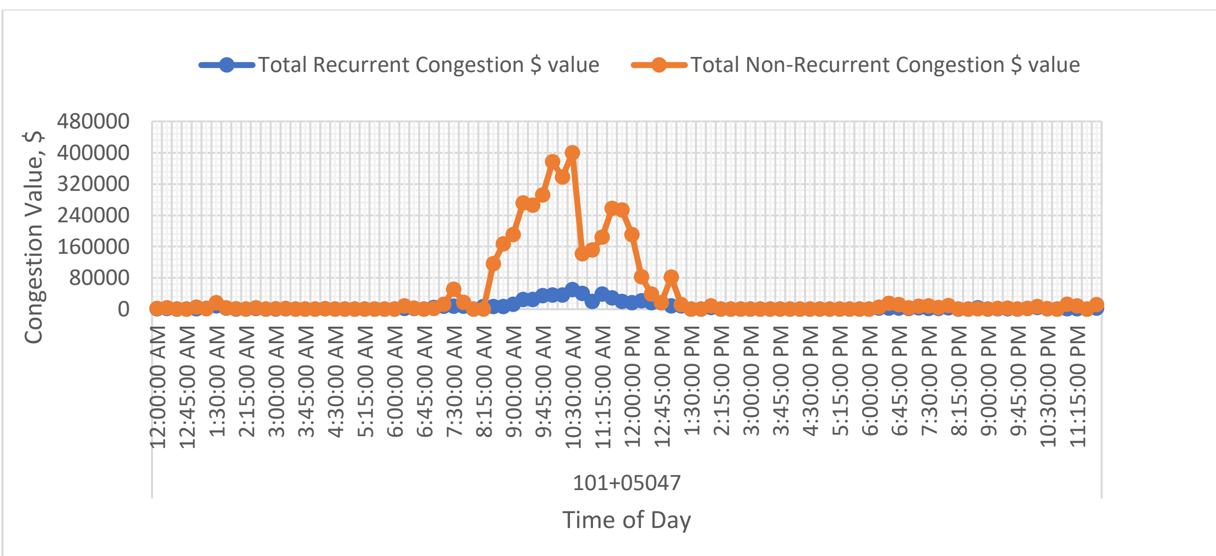

Figure 5: Congestion $ Values over Time. TMC code 101+05047; Weekdays; March 2021

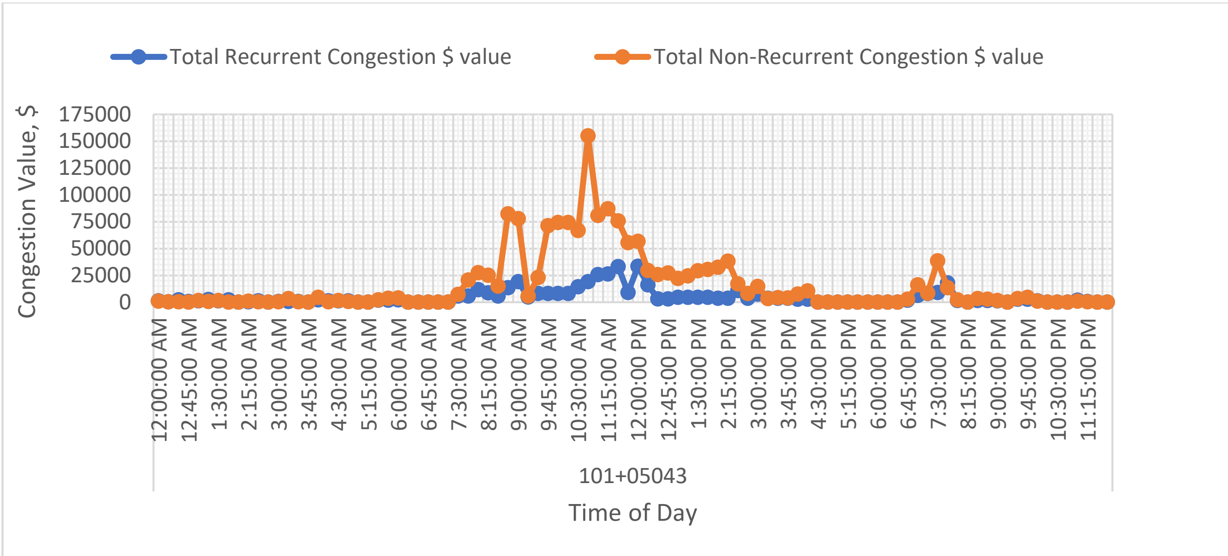

Figure 6: Congestion $ Values over Time. TMC code 101+05043; Weekdays; March 2021

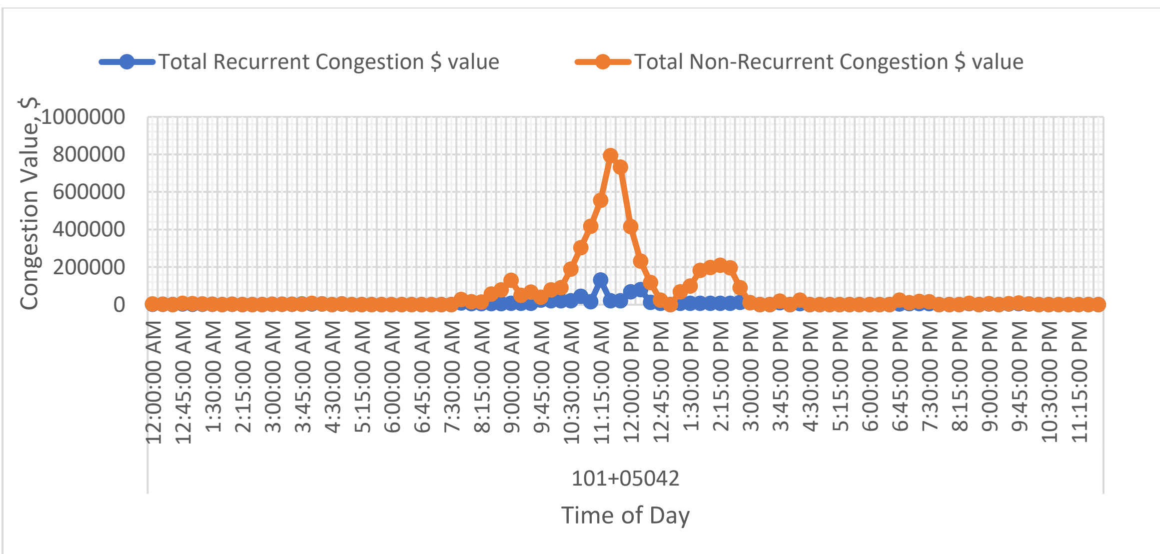

Figure 7: Congestion $ Values over Time. TMC code 101+05042; Weekdays; March 2021

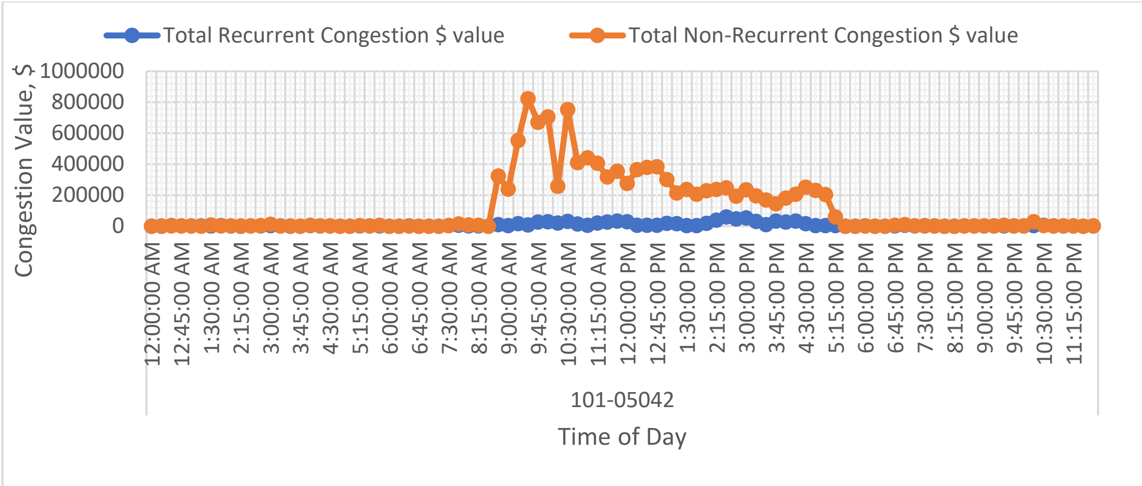

Figure 8: Congestion $ Values over Time. TMC code 101-05042; Weekdays; March 2021

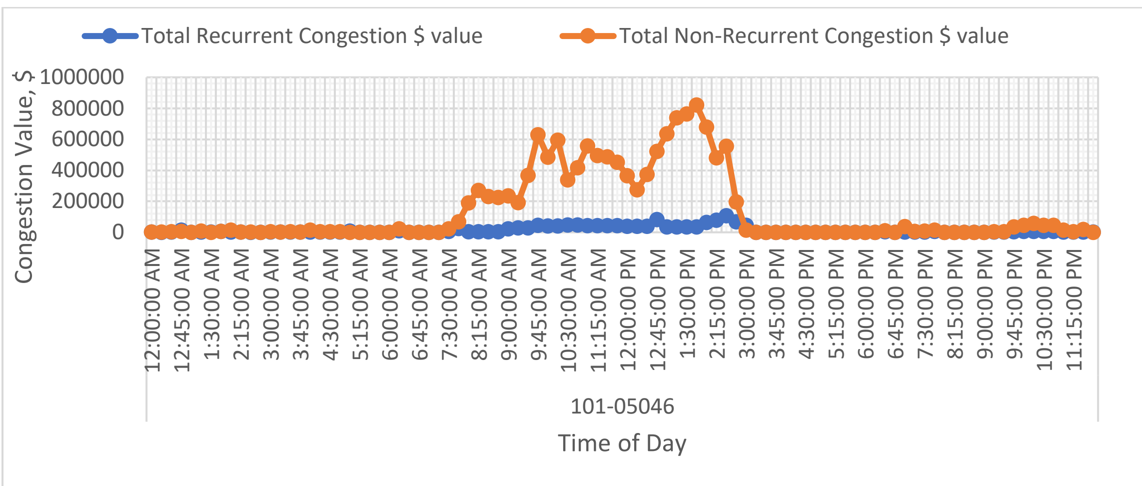

Figure 9: Congestion $ Values over Time. TMC code 101-05046; Weekdays; March 2021

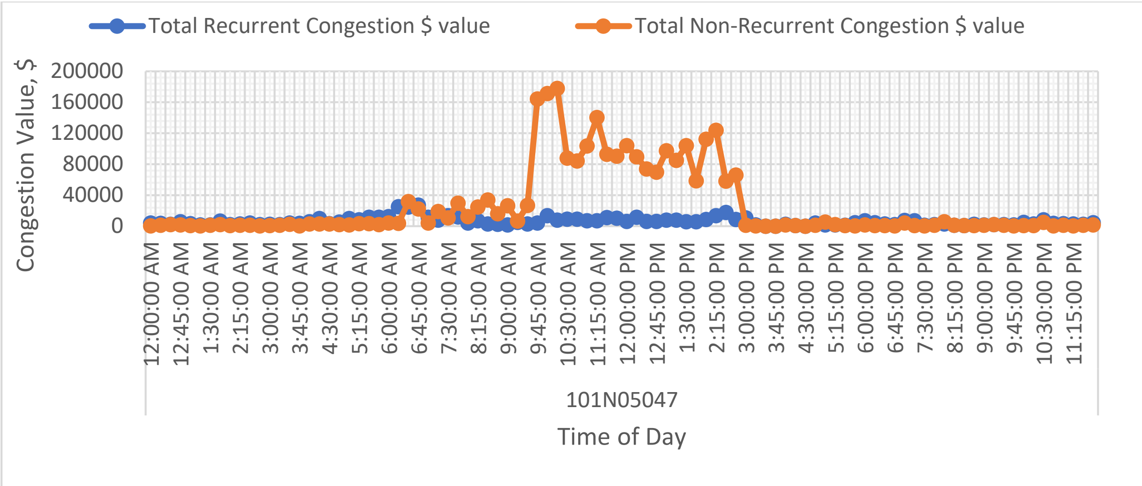

Figure 10: Congestion $ Values over Time. TMC code 101N05047; Weekdays; March 2021

4.2.2 Weekend congestion quantification along I-65 study segments

As shown in Table 25 and Figure 11 the weekends, the Northbound study segments of I-65 had high non-recurrent congestion along TMC Codes 101P05044, 101+05044, 101+05045, and 101+05048. There is no presence of ASAP patrol along any of those TMCs. Results summarized in Table 26 and Figure12 for I-65 Southbound confirm that on weekends high non-recurrent congestion occurs along TMC codes 101-05046, 101-05047 and 101-05042. Comparison of the results further shows that during weekends, congestion delays and associated costs are far higher in the Southbound direction than the Northbound according to the data analyzed in this study.

Figure 13 through Figure 18 show the distribution of the congestion dollar values over time of day for several of the segments noted already for weekends. The highest delays and associated costs on weekends occurred mostly between 10:00am and 12:00 noon.

Table 25: Dollar value of recurrent and non-recurrent congestion. Northbound Study Segments of I-65; Weekends; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay (veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101+05042	16146	13483	32.00	68.00	0.32	0.68	132	111	0
101+05043	10633	10080	31.00	69.00	0.31	0.69	86	82	0
101+05044	25296	95188	19.68	80.32	0.20	0.80	174	655	0
101+05045	23367	93089	30.00	70.00	0.30	0.70	187	744	0
101+05046	8089	2767	30.00	70.00	0.30	0.70	101	35	1
101+05047	9545	29866	27.00	73.00	0.27	0.73	123	385	1
101+05048	17920	43846	39.00	61.00	0.39	0.61	200	489	0
101+05049	21732	13361	44.00	56.00	0.44	0.56	205	126	0
101+05050	18360	13314	44.00	56.00	0.44	0.56	173	125	0
101+05051	13399	10817	37.00	63.00	0.37	0.63	91	74	0
101+05052	4542	3746	37.00	63.00	0.37	0.63	31	26	0
101+05053	52730	9515	40.00	60.00	0.40	0.60	332	60	0
101+53705	4560	27824	39.00	61.00	0.39	0.61	47	284	0
101P05043	3608	5636	25.25	74.75	0.25	0.75	27	42	0
101P05044	8571	159855	25.30	74.70	0.25	0.75	64	1197	0
101P05045	3729	3560	30.00	70.00	0.30	0.70	31	29	0
101P05046	2530	1227	28.95	71.05	0.29	0.71	32	15	1
101P05047	8656	7176	32.31	67.69	0.32	0.68	99	82	1
101P05048	9666	2842	40.93	59.07	0.41	0.59	100	29	0
101P05049	8975	5949	44.00	56.00	0.44	0.56	92	61	0
101P05050	5084	1255	40.82	59.18	0.41	0.59	41	10	0
101P05051	5283	10113	37.00	63.00	0.37	0.63	36	69	0
101P05052	3494	1563	38.28	61.72	0.38	0.62	23	10	0
101P05053	37174	1329	40.00	60.00	0.40	0.60	234	8	0
101P53705	1760	8402	39.00	61.00	0.39	0.61	18	86	0

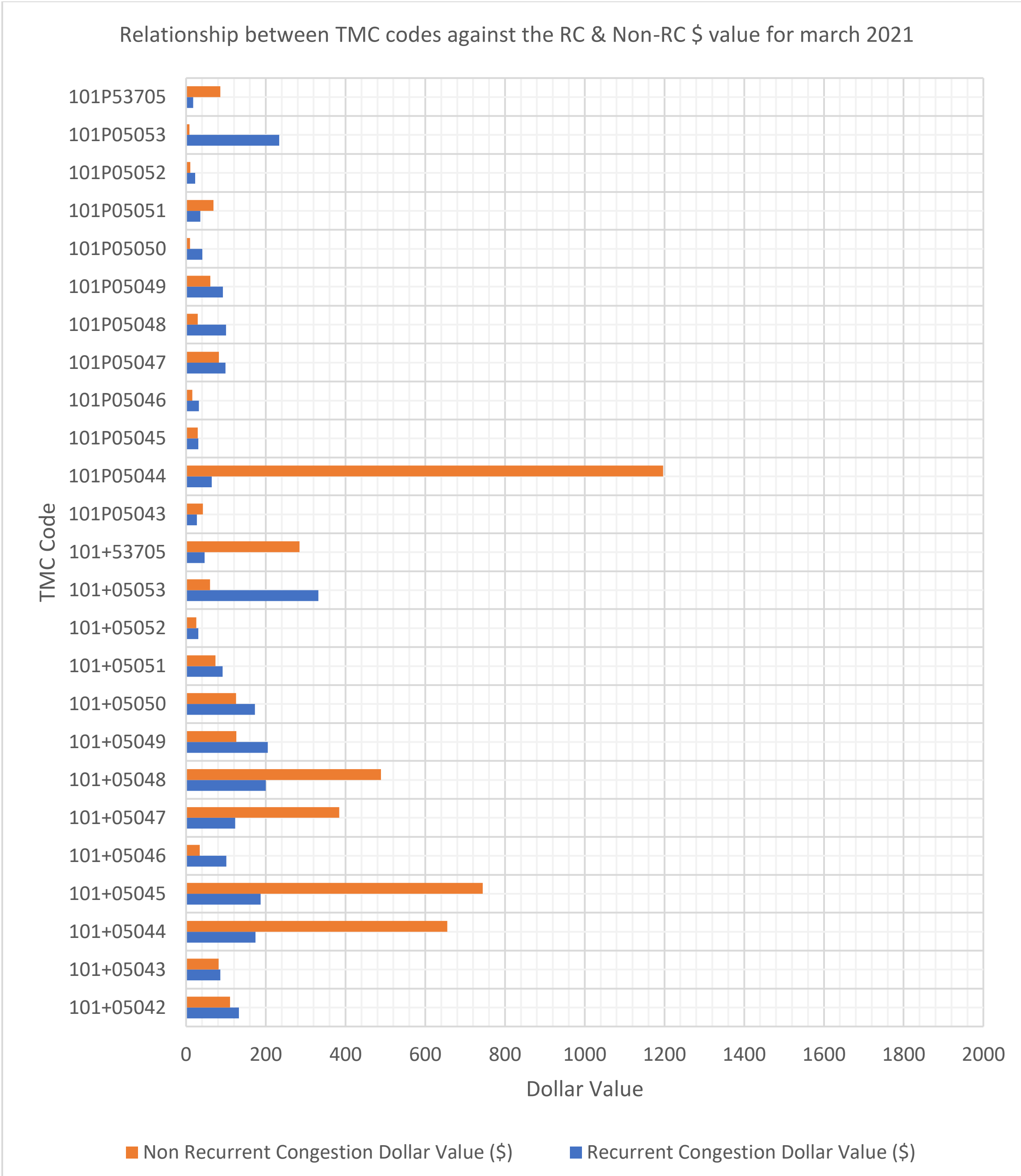

Figure 11: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Northbound Segments of I-65; Weekends; March 2021

Table 26: Dollar value of recurrent and non-recurrent congestion. Southbound Study Segments of I-65; Weekends; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay (veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101-05042	86398	4326885	31.0	69.0	0.31	0.69	699	35021	0
101-05043	82200	1150686	19.7	80.3	0.20	0.80	571	7992	0
101-05044	40383	534532	30.0	70.0	0.30	0.70	323	4272	0
101-05045	117849	1666051	30.0	70.0	0.30	0.70	942	13316	0
101-05046	226005	3043868	27.0	73.0	0.27	0.73	3718	50077	1
101-05047	76720	3557643	39.0	61.0	0.39	0.61	1002	46468	1
101-05048	25168	11453	44.0	56.0	0.44	0.56	217	99	0
101-05049	33689	21955	44.0	56.0	0.44	0.56	317	207	0
101-05050	23605	82353	37.0	63.0	0.37	0.63	205	717	0
101-05051	31578	60708	37.0	63.0	0.37	0.63	275	528	0
101-05052	35169	8680	40.0	60.0	0.40	0.60	282	70	0
101-53705	1131	26000	39.0	61.0	0.39	0.61	15	340	0
101N05043	26111	1286731	25.3	74.7	0.25	0.75	196	9664	0
101N05044	15548	53340	25.4	74.6	0.25	0.75	117	401	0
101N05046	10963	195009	28.2	71.8	0.28	0.72	178	3169	1
101N05047	59097	954176	32.2	67.8	0.32	0.68	866	13990	1
101N05048	6855	8590	41.6	58.4	0.42	0.58	64	80	0
101N05049	6541	1773	44.0	56.0	0.44	0.56	58	16	0
101N05050	3671	3482	41.2	58.8	0.41	0.59	39	37	0
101N05051	7545	11403	37.0	63.0	0.37	0.63	66	99	0
101N05052	16226	5553	38.3	61.7	0.38	0.62	136	47	0
101N05053	40123	1168	40.0	60.0	0.40	0.60	322	9	0
101N53705	1264	74259	39.0	61.0	0.39	0.61	17	970	0

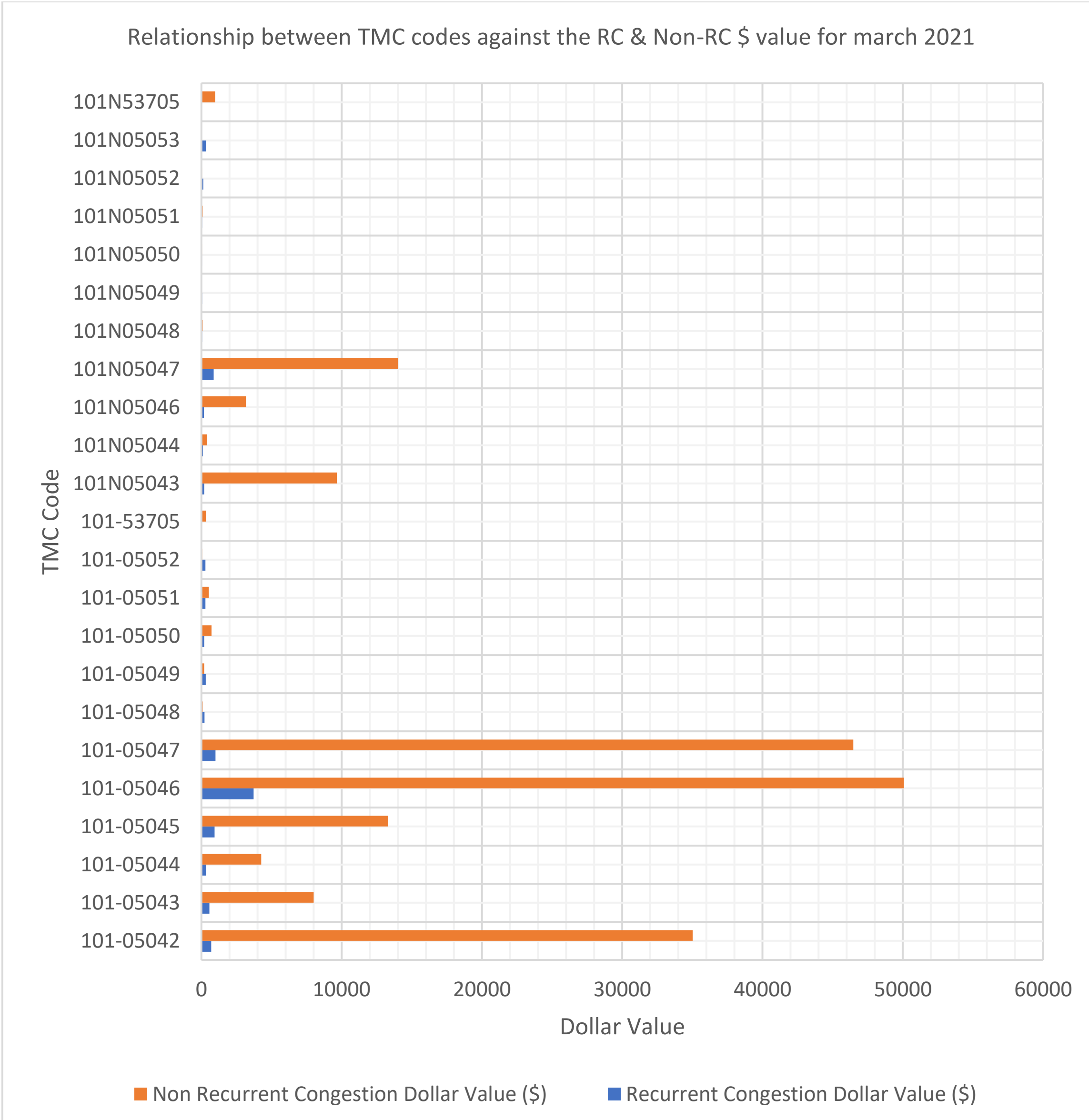

Figure 12: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Southbound Segments of I-65; Weekends; March 2021

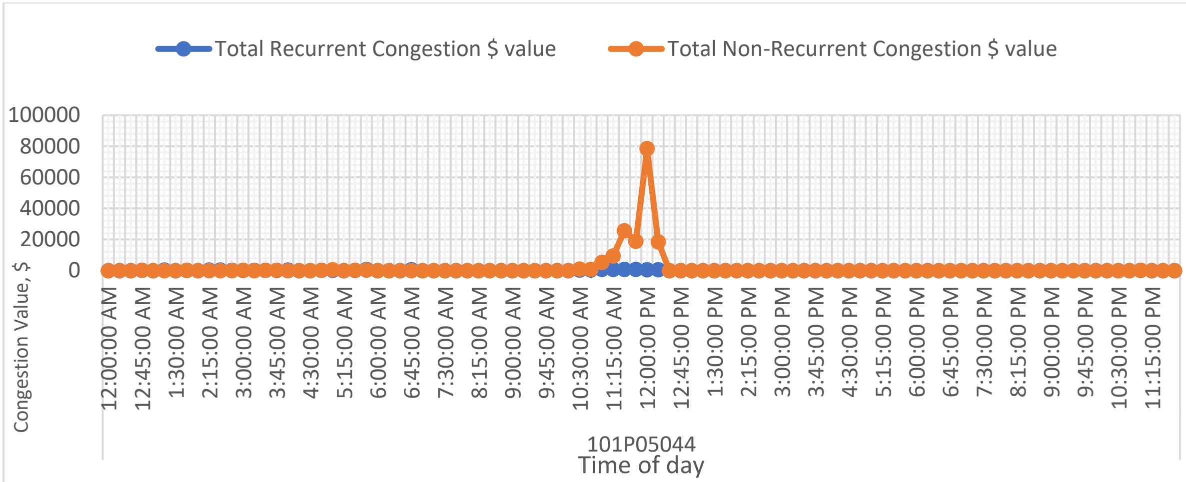

Figure 13: Congestion $ Values over Time. TMC code 101P05044; Weekends; March 2021

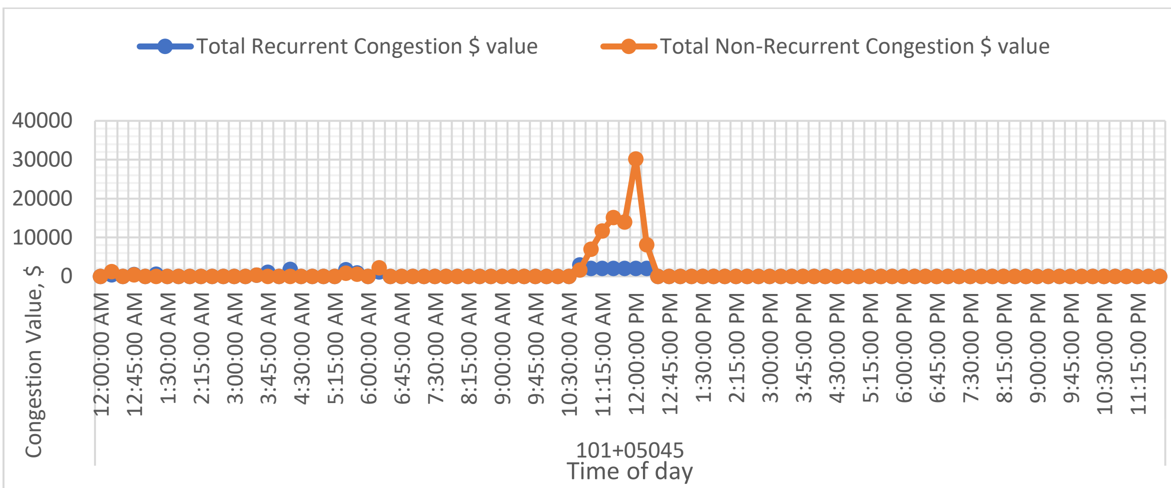

Figure 14: Congestion $ Values over Time. TMC code 101+05045; Weekends; March 2021

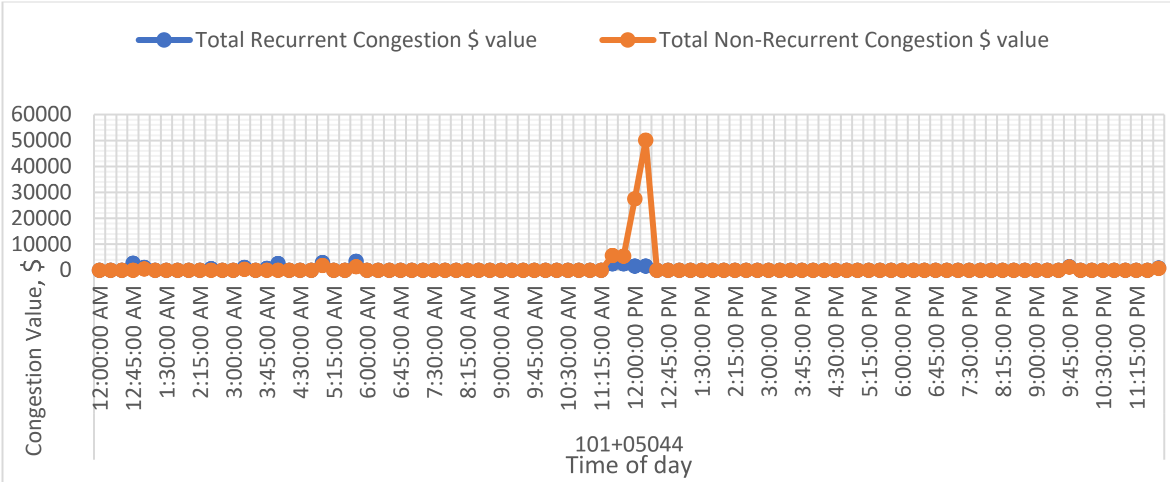

Figure 15: Congestion $ Values over Time. TMC code 101+05044; Weekends; March 2021

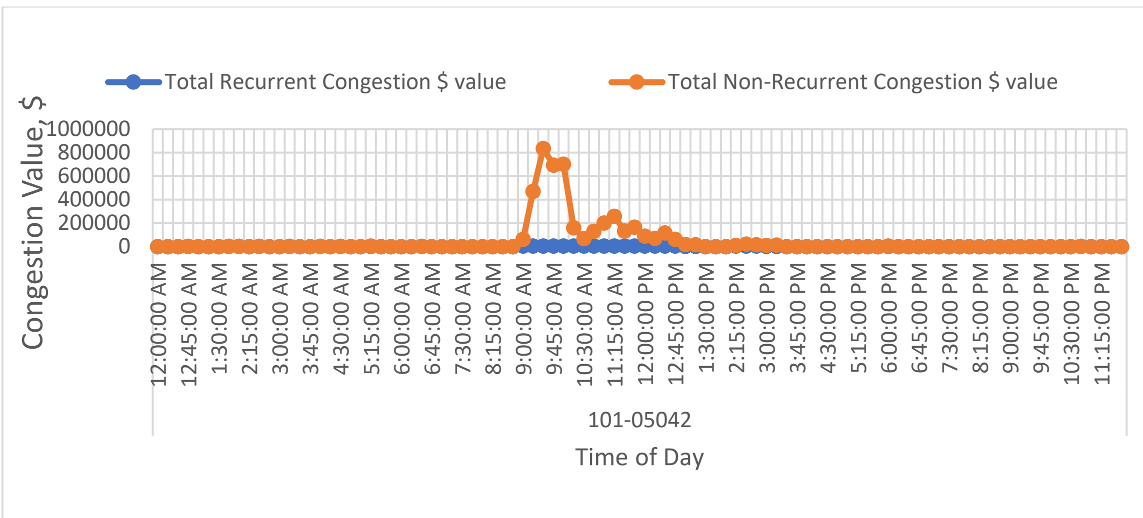

Figure 16: Congestion $ Values over Time. TMC code 101-05042; Weekends; March 2021

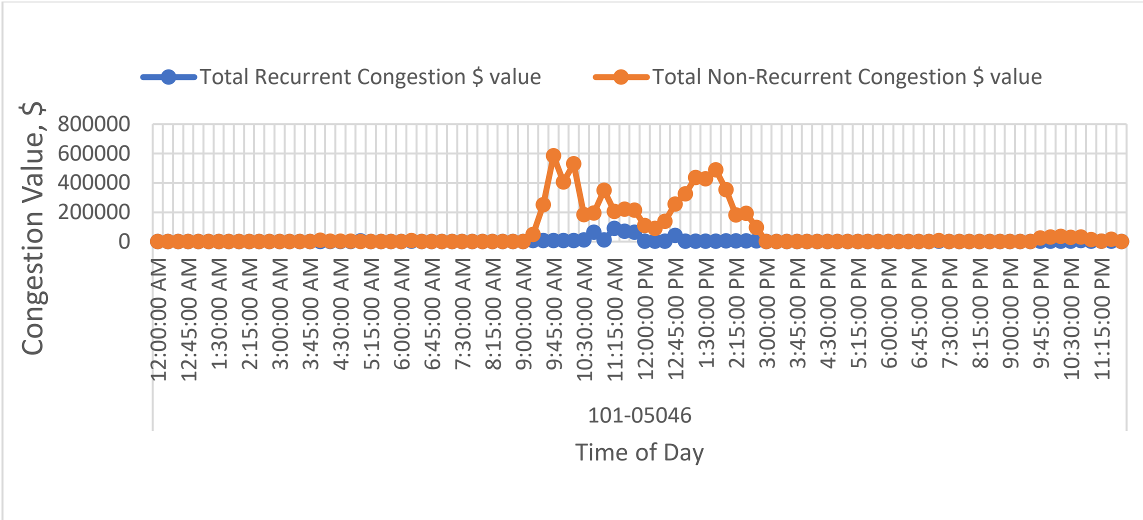

Figure 17: Congestion $ Values over Time. TMC code 101-05046; Weekends; March 2021

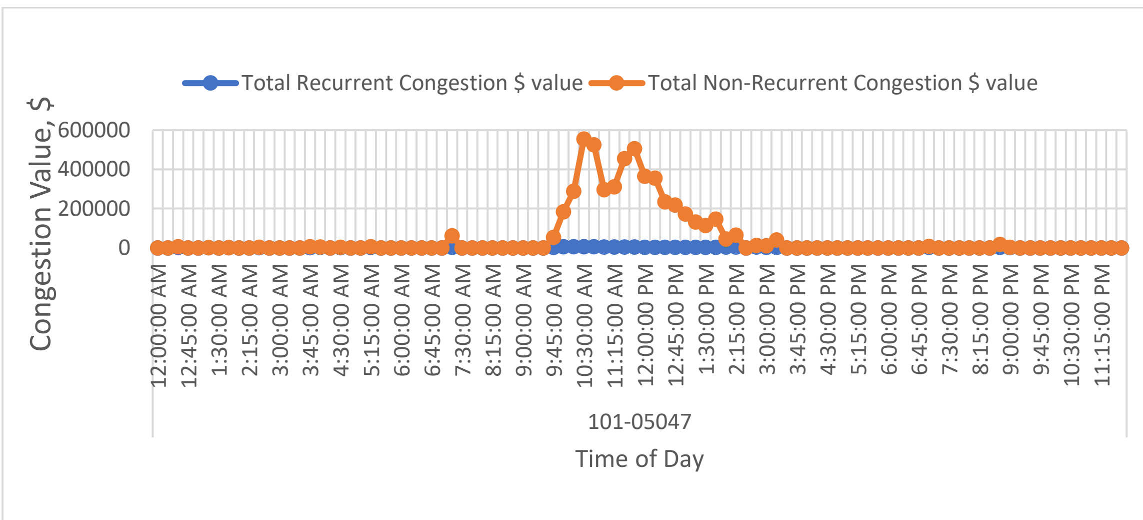

Figure 18: Congestion $ Values over Time. TMC code 101-05047; Weekends; March 2021

4.2.3. Weekday congestion quantification along I-565 study segments

I-565 being a major freeway connects different areas in the heart of the rapidly growing city- Huntsville. The I-565 road corridor has lots of interchanges located in close proximity to each other, and serves a variety of land uses including stores, hotels and rest areas, and the Redstone Arsenal which serves as a garrison for various tenants across NASA, Department of Defense and Department of Justice.

Close examination of the values of the recurrent and non-recurrent delays on the eastbound segments of I-565 during weekdays (see Table 27, and Figure 19) indicates that almost all the TMC codes on eastbound segments have higher values of recurrent delays than non-recurrent delays.

Results displayed in Table 28 and Figure 20 show that the westbound segment of the route with TMC Code 101N04501 had significantly higher delays and associated dollar losses than the rest of the segments. This may be due to the delays on the exit ramp that connects Hwy 20 and Al-72. Other TMC codes that displayed impacts of non-recurrent congestion included 101-04501, 101-04500, and 101-04503. The ASAP patrol team currently serves all segments of the Intersatate-565 so the non -recurrent congestions might be efficiently attended to along the entire segment.

Table 27: Dollar value of recurrent and non-recurrent congestion. Eastbound Study Segments of I-565; Weekdays; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay(veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101+04499	3631745	1395882	12.00	88.00	0.12	0.88	24504	9108	1
101+04500	7247483	6377834	10.00	90.00	0.10	0.90	47634	50788	1
101+04501	8971464	4471919	8.00	92.00	0.08	0.92	55992	33614	1
101+04502	4596011	551955	8.80	91.20	0.09	0.91	28655	3842	1
101+04503	2045895	270413	10.00	90.00	0.10	0.90	13397	2082	1
101+04504	1312569	1970068	8.00	92.00	0.08	0.92	8018	11613	1
101+04505	2485090	190485	7.00	93.00	0.07	0.93	14613	1269	1
101+04506	7376604	754922	7.00	93.00	0.07	0.93	50840	6638	1
101+04507	2181347	242241	7.00	93.00	0.07	0.93	15154	2007	1
101+04508	5522997	816345	7.00	93.00	0.07	0.93	37872	7663	1
101+04509	10958068	3150531	6.00	94.00	0.06	0.94	69734	19207	1
101+04510	463948	73367	7.00	93.00	0.07	0.93	1781	317	1
101+04511	56935	4825	7.00	93.00	0.07	0.93	212	22	1
101+04512	1560830	158964	7.00	93.00	0.07	0.93	10568	1185	1
101P04498	4470446	1564541	9.00	91.00	0.09	0.91	30645	10924	1
101P04499	2646053	1324801	11.12	88.88	0.11	0.89	17816	14463	1
101P04500	2516160	3223731	9.02	90.98	0.09	0.91	16484	27203	1
101P04501	538926	69360	8.00	92.00	0.08	0.92	3467	518	1
101P04502	1089649	314752	9.46	90.54	0.09	0.91	6967	2101	1
101P04503	1129702	483453	9.01	90.99	0.09	0.91	7140	3051	1
101P04504	1498806	160758	7.00	93.00	0.07	0.93	9894	1133	1
101P04505	3538903	604715	7.00	93.00	0.07	0.93	23184	4167	1
101P04506	2263530	211756	7.00	93.00	0.07	0.93	15680	1830	1
101P04507	2675076	286786	7.00	93.00	0.07	0.93	18412	2550	1
101P04508	3436307	874785	6.48	93.52	0.06	0.94	22827	6355	1
101P04509	2950423	514154	6.15	93.85	0.06	0.94	18388	3603	1
101P04510	2775867	233075	7.00	93.00	0.07	0.93	10527	1092	1
101P04511	1429008	111197	7.00	93.00	0.07	0.93	5311	511	1
101P04512	2403007	1178954	7.00	93.00	0.07	0.93	16076	6930	1
101P04513	2103735	768442	6.66	93.34	0.07	0.93	13920	4914	1

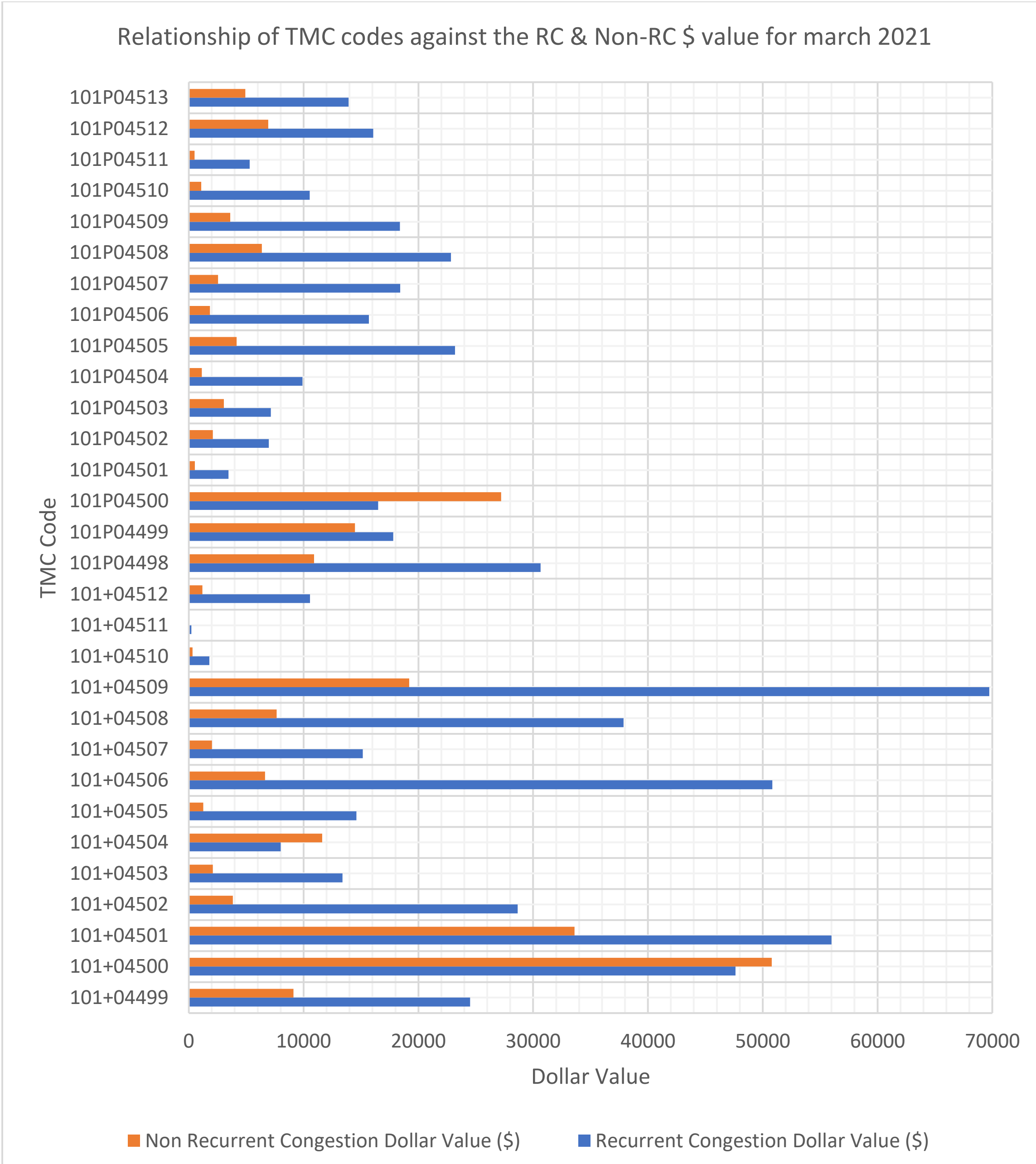

Figure 19: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Eastbound Segments of I-565; Weekdays; March 2021

Table 28: Dollar value of recurrent and non-recurrent congestion. Westbound Study Segments of I-565; Weekdays; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP
101-04498	3548334	698291	12.00	88.00	0.12	0.88	21877	4305	1
101-04499	13407577	5122567	10.00	90.00	0.10	0.90	79940	30542	1
101-04500	23724220	17190753	8.00	92.00	0.08	0.92	136638	99010	1
101-04501	5308404	26702210	9.03	90.97	0.09	0.91	31125	156566	1
101-04502	1778299	7888912	10.00	90.00	0.10	0.90	10636	47184	1
101-04503	5940219	15683195	7.88	92.12	0.08	0.92	34134	90127	1
101-04504	3831794	393287	7.00	93.00	0.07	0.93	21679	2225	1
101-04505	3312676	686130	7.00	93.00	0.07	0.93	18743	3882	1
101-04506	1657461	399034	7.00	93.00	0.07	0.93	9376	2257	1
101-04507	2604429	693415	7.00	93.00	0.07	0.93	14661	3903	1
101-04508	7622996	1352547	6.00	94.00	0.06	0.94	42355	7515	1
101-04509	437711	92853	7.00	93.00	0.07	0.93	2476	525	1
101-04510	225629	45585	7.00	93.00	0.07	0.93	1277	258	1
101-04511	2849567	377851	7.00	93.00	0.07	0.93	16122	2138	1
101-04512	4341358	716066	7.00	93.00	0.07	0.93	24563	4051	1
101N04499	4036957	1237936	10.98	89.02	0.11	0.89	24472	7504	1
101N04500	6343340	2871711	8.80	91.20	0.09	0.91	37049	16773	1
101N04501	13770480	38404481	8.65	91.35	0.09	0.91	80341	224061	1
101N04502	1955655	8923016	10.00	90.00	0.10	0.90	11697	53369	1
101N04503	2093610	12562744	8.61	91.39	0.09	0.91	12186	73126	1
101N04504	1823763	473125	7.00	93.00	0.07	0.93	10318	2677	1
101N04505	5092155	869240	7.00	93.00	0.07	0.93	27825	4750	1
101N04506	1414204	372558	7.00	93.00	0.07	0.93	8001	2108	1
101N04507	1949112	500801	7.00	93.00	0.07	0.93	10972	2819	1
101N04508	2693114	1009652	6.35	93.65	0.06	0.94	15060	5646	1
101N04509	1740164	479364	6.27	93.73	0.06	0.94	14478	3988	1
101N04510	1814829	347406	7.00	93.00	0.07	0.93	10268	1966	1
101N04511	2107270	388713	7.00	93.00	0.07	0.93	11922	2199	1
101N04512	1878724	270118	7.00	93.00	0.07	0.93	10630	1528	1
101N04513	2407559	308284	7.00	93.00	0.07	0.93	13622	1744	1

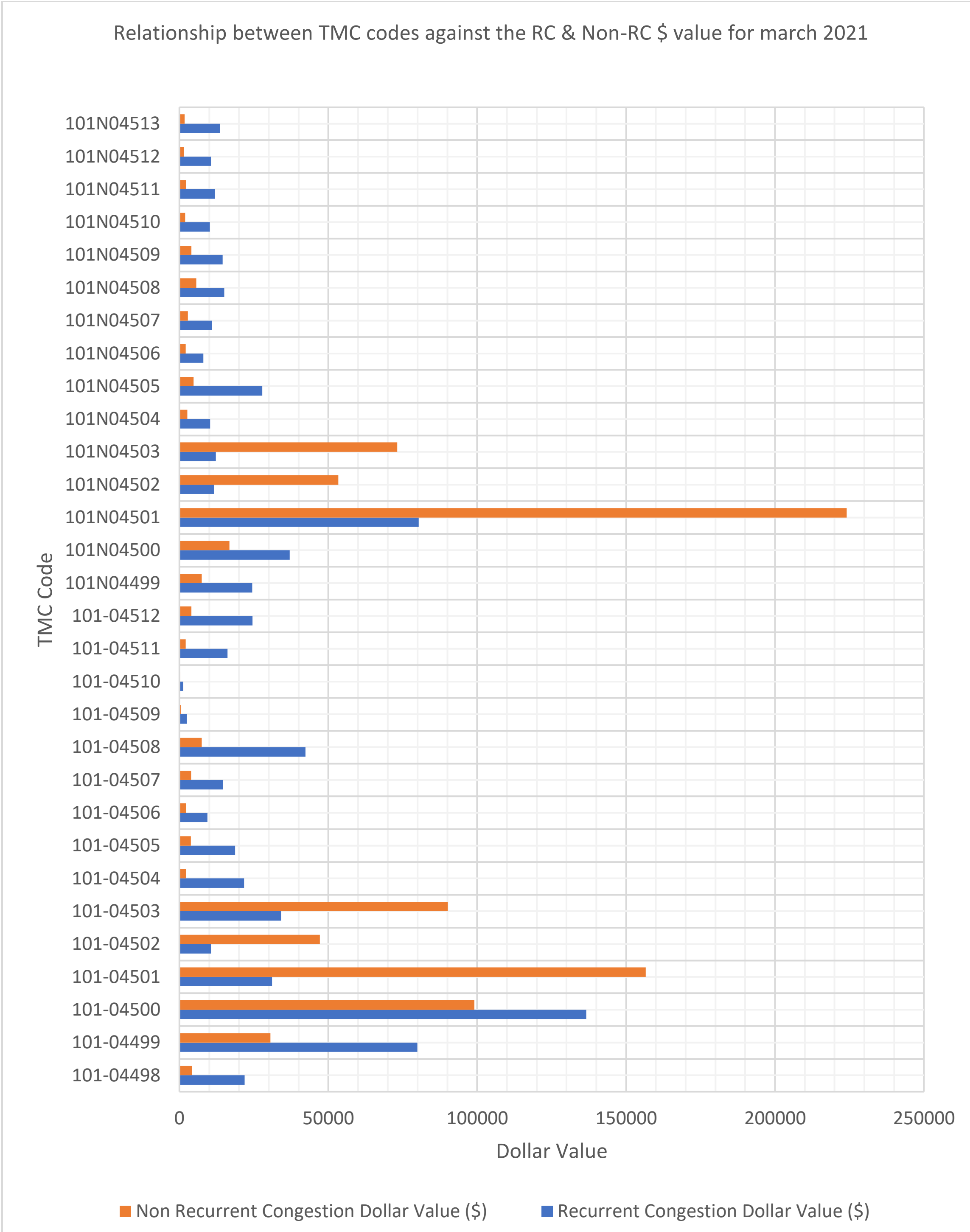

Figure 20: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Westbound Segments of I-565; Weekdays; March 2021

4.2.4. Weekend congestion quantification along I-565 study segments

On the weekends, there are significant contrasts in dollar values for recurrent and non-recurrent congestions. As seen in Table 29 and Figure 21, the Eastbound I-565 corridor has higher levels of non-recurrent congestion dollar losses as most TMC segments have non-recurrent delays. On the I-565, the TMC with the highest non recurrent delay occurrence was 101N04501, followed by TMC codes 101-04500 and 101-04501. Comparison of Figure 20 and Figure 21 further shows that while many TMCs experience non-recurrent congestion during weekends along the Eastbound segments of I-565, the severity of the non-recurrent congestion is moderate resulting in Non-Recurrent Congestion dollar Values with all but one being below $22,000. On the contrary, the majority of the Westbound segments of I-565 show low non-recurrent congestion, however, the 3 segments that are congested show Non-Recurrent Congestion dollar values that range from $71,276 to $14,413.

Table 29: Dollar value of recurrent and non-recurrent congestion. Eastbound Study Segments of I-65; Weekends; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay (veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101+04499	86552	206780	12.00	88.00	0.12	0.88	534	1275	1
101+04500	1506230	397565	10.00	90.00	0.10	0.90	8981	2370	1
101+04501	911337	437820	8.00	92.00	0.08	0.92	5249	2522	1
101+04502	99541	217079	8.80	91.20	0.09	0.91	579	1263	1
101+04503	53526	150427	10.00	90.00	0.10	0.90	319	897	1
101+04504	34573	63114	8.00	92.00	0.08	0.92	199	363	1
101+04505	48476	258127	7.00	93.00	0.07	0.93	247	1317	1
101+04506	246745	1267474	7.00	93.00	0.07	0.93	1396	7171	1
101+04507	73200	375730	7.00	93.00	0.07	0.93	414	2125	1
101+04508	314191	854320	7.00	93.00	0.07	0.93	1778	4834	1
101+04509	317620	1056664	6.00	94.00	0.06	0.94	1765	5871	1
101+04510	15361	81380	7.00	93.00	0.07	0.93	87	460	1
101+04511	1246	8308	7.00	93.00	0.07	0.93	7	47	1
101+04512	35173	199690	7.00	93.00	0.07	0.93	199	1130	1
101P04498	144165	654083	9.00	91.00	0.09	0.91	845	3833	1
101P04499	910885	172058	11.12	88.88	0.11	0.89	5534	1045	1
101P04500	919983	181145	9.02	90.98	0.09	0.91	5393	1062	1
101P04501	20889	36644	8.00	92.00	0.08	0.92	120	211	1
101P04502	36742	61981	9.46	90.54	0.09	0.91	216	365	1
101P04503	38361	55909	9.01	90.99	0.09	0.91	225	328	1
101P04504	35422	140589	7.00	93.00	0.07	0.93	200	795	1
101P04505	118661	556650	7.00	93.00	0.07	0.93	633	2970	1
101P04506	63208	395942	7.00	93.00	0.07	0.93	358	2240	1
101P04507	90836	463527	7.00	93.00	0.07	0.93	511	2609	1
101P04508	152068	463974	6.48	93.52	0.06	0.94	852	2600	1
101P04509	130796	537923	6.15	93.85	0.06	0.94	729	2997	1
101P04510	62840	457403	7.00	93.00	0.07	0.93	356	2588	1
101P04511	30069	203813	7.00	93.00	0.07	0.93	170	1153	1
101P04512	35611	285347	7.00	93.00	0.07	0.93	201	1614	1
101P04513	57016	262857	6.66	93.34	0.07	0.93	321	1478	1

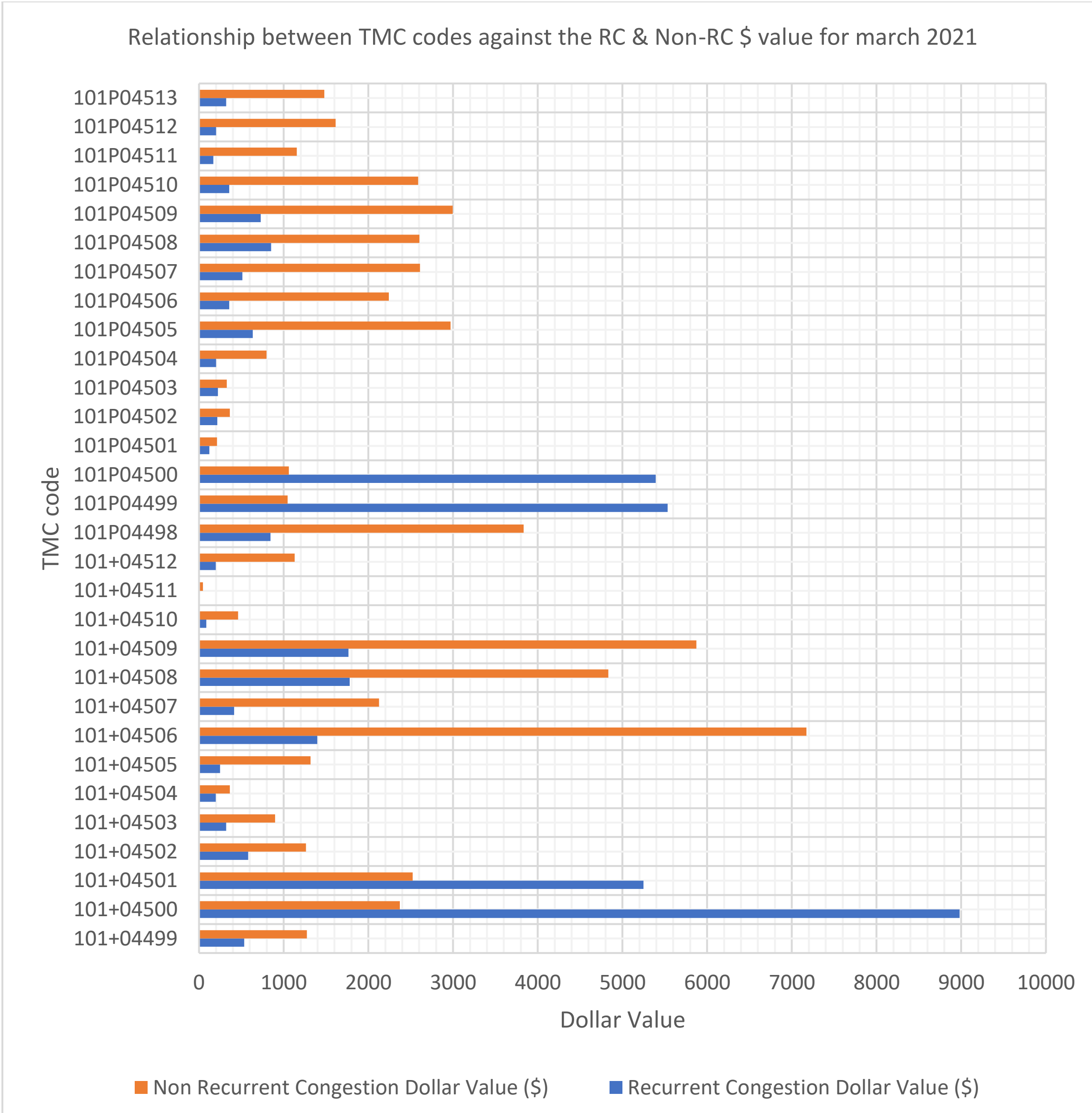

Figure 21: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Eastbound Segments of I-565; Weekends; March 2021

Table 30: Dollar value of recurrent and non-recurrent congestion. Westbound Study Segments of I-565; Weekends; March 2021

TMC Code	Sum of Total Recurrent Delay (veh-s)	Sum of Total Non-Recurrent Delay (veh-s)	Truck %	Car %	Truck fraction	Car fraction	Recurrent Congestion Dollar Value ($)	Non-Recurrent Congestion Dollar Value ($)	ASAP Presence
101-04498	271939	55486	12.00	88.00	0.12	0.88	1677	342	1
101-04499	915856	237348	10.00	90.00	0.10	0.90	5461	1415	1
101-04500	1753986	3732529	8.00	92.00	0.08	0.92	10102	21497	1
101-04501	258524	2458059	9.03	90.97	0.09	0.91	1516	14413	1
101-04502	122712	54772	10.00	90.00	0.10	0.90	734	328	1
101-04503	350734	244607	7.88	92.12	0.08	0.92	2016	1406	1
101-04504	539403	66781	7.00	93.00	0.07	0.93	3052	378	1
101-04505	388297	92703	7.00	93.00	0.07	0.93	2197	524	1
101-04506	195523	91977	7.00	93.00	0.07	0.93	1106	520	1
101-04507	293384	170736	7.00	93.00	0.07	0.93	1651	961	1
101-04508	878611	258072	6.00	94.00	0.06	0.94	4882	1434	1
101-04509	60789	11072	7.00	93.00	0.07	0.93	344	63	1
101-04510	28362	6905	7.00	93.00	0.07	0.93	160	39	1
101-04511	328280	44465	7.00	93.00	0.07	0.93	1857	252	1
101-04512	497791	136165	7.00	93.00	0.07	0.93	2816	770	1
101N04499	341761	67467	10.98	89.02	0.11	0.89	2072	409	1
101N04500	438244	108890	8.80	91.20	0.09	0.91	2560	636	1
101N04501	363077	12216604	8.65	91.35	0.09	0.91	2118	71276	1
101N04502	114443	56949	10.00	90.00	0.10	0.90	684	341	1
101N04503	160882	88525	8.61	91.39	0.09	0.91	936	515	1
101N04504	235581	33072	7.00	93.00	0.07	0.93	1333	187	1
101N04505	683982	157339	7.00	93.00	0.07	0.93	3737	860	1
101N04506	196495	79081	7.00	93.00	0.07	0.93	1112	447	1
101N04507	228388	113632	7.00	93.00	0.07	0.93	1286	640	1
101N04508	398436	255533	6.35	93.65	0.06	0.94	2228	1429	1
101N04509	230750	59651	6.27	93.73	0.06	0.94	1920	496	1
101N04510	227601	44289	7.00	93.00	0.07	0.93	1288	251	1
101N04511	253231	50931	7.00	93.00	0.07	0.93	1433	288	1
101N04512	196419	30689	7.00	93.00	0.07	0.93	1111	174	1
101N04513	278863	49646	7.00	93.00	0.07	0.93	1578	281	1

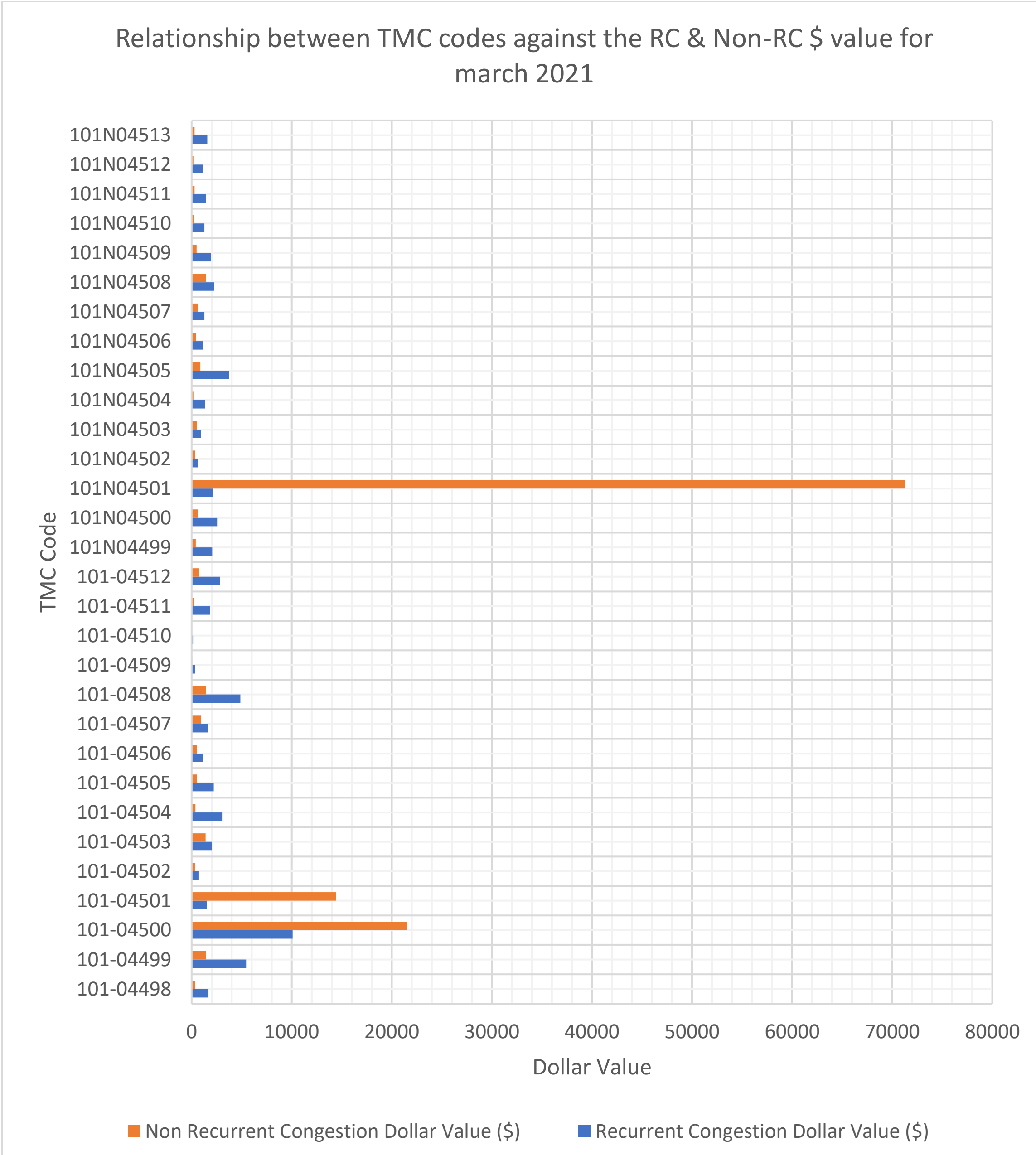

Figure 22: TMC codes and corresponding Recurrent Congestion & Non-Recurrent Congestion dollar values; Westbound Segments of I-565; Weekends; March 2021

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Traffic congestion is an issue of concern in many urban and rural parts of the United States of America resulting in traffic delays, driver frustration, increased fuel consumption, pollution, and negative economic impacts. Traffic congestion is classified as either recurrent- or non-recurrent congestion. Recurrent congestion refers to congestion due to bottlenecks or poor signal timing and it occurs at around the same locations and times day after day. On the other hand, non-recurrent congestion is due to events like incidents, debris on the roadway, weather issues, special events, and work zones that often occur with a defined pattern and frequency. Therefore, under non-recurrent congestion conditions, commuters experience unexpected delays, as they cannot reasonably predict the location and timing so that they can plan ahead of time.

This research work has successfully applied a methodology to (a) categorize the congestion into recurrent and non-recurrent using segments along two interstate corridors in North Alabama as a case study and (b) quantify the cost of congestion by segment and time period. Traffic data obtained from RITIS (Ritis, 2022) provided travel time details over 15-minute aggregation periods that were used in calculating the delays. AADTs were made available through the ALDOT and GIS data were used to match TMC codes with location of the count stations. The corridors used for this study along I-65 and I-565 have variations in traffic demand and geometric characteristics, including differences in truck and car percentages, lengths of segments, AADTs and ADTs, average speeds at different times and presence or absence of ASAP patrol teams.

The methodology developed for this research allowed to: (a) identify roadway segments that experienced congestion; (b) differentiate the two congestion types encountered on the congested roadway segments (i.e., recurrent versus non-recurrent); (c) quantify the monetary value of recurrent and non-recurrent congestion taking under consideration passenger vehicle and truck costs and traffic composition; (d) prioritize the segments with the highest non-recurrent congestion impacts; and (e) identify locations and times where services of ASAP patrol teams are needed.

The analysis showed that several study segments of I-65 that experience high level of non-recurrent congestion do not currently provide ASAP patrols. Better allocation of available ASAP patrol teams and/or expansion of ASAP services to these segments has the potential to reduce the extent and cost of non-recurrent congestion at these I-65 locations in the future. Results from I-565 show that the entire corridor experiences high levels of both recurrent and non- recurrent congestion. The congestion cost calculated for each TMC code as part of the study can provide valuable information to decision makers as they develop plans for deploying the ASAP patrol teams along the I-565 corridor and reallocating ASAP resources from I-565 to other locations that have greater non-recurrent congestion management needs.

The cost implication of these delays was used to highlight the financial impact of non-recurrent congestion. ALDOT can use this methodology to identify times during the day and locations that urgently need presence of ASAP patrol teams in order to improve incident management and minimize non-recurrent congestion costs. In the short run, this knowledge can lead to optimization of allocation of available resources, and in the long run it could support planning decision making related to deployment of ASAP patrol services to address future needs.

The study shows that different segments experienced different levels of recurrent and/or non-recurrent congestion based on analysis of one month's data. It is important to note that variations in data from season to season are expected. Thus, it is recommended that the data set is expanded to account for seasonal variations and the results are updated prior to implementing changes in the ASAP deployment plans along the study corridors.

The proposed congestion assessment process for prioritizing locations and times for deployment of ASAP patrols shows some level of ascendancy over the Incident Factor (IF) equation currently used by ALDOT, as it encompasses more factors than the IF equation. The IF equation only considers the AADT and number of prior crashes on a particular segment in deploying service patrols. This makes the allocation of ASAP patrols reactive rather than proactive. The newly developed methodology considers factors that relate to the operational effects of congestion, rather than historical crash records. One of the reasons is that crashes are rear events and positioning ASAP units at locations were prior crashes took place does not guarantee an optimal resource allocation. Besides, traffic crashes are not the only cause of non-recurrent congestion. Non-recurrent congestion is often the result of work zone presence, special events, and inclement weather, thus over relying on historical crash records for ASAP patrol allocation may not lead to an optimal solution. It is recommended that the analyses be repeated periodically and be considered as a continuous process rather than an one time decision-making exercise. Before and after studies will further allow transportation agencies to determine if reallocating ASAP patrols to different segments has an impact on congestion presence at the original location, thus mitigating the imbalance from one location to another.

The methodology developed in this study makes use of historical average speed/travel time values and the reference speed values to identify areas that need ASAP services. This will help ASAP patrol teams cover areas that have a history of non-recurrent congestion issues. Moreover, the implementation of this proposed congestion assessment process is expected to yield better results as it considers differences in patrolling need during weekdays (versus weekend) and for various times during the day as the analysis was performed for 15-minute intervals. Furthermore, the lengths of different segments played an important role in the calculation of the travel times making the methodology length dependent. Overall, the new methodology is expected to provide a valuable tool for improving the decision-making process related to allocation of ASAP patrol units to roadway segments that need them the most. This, in turn, will enhance the incident management efficiency and help reduce non-recurrent congestion costs and impacts including reducing traffic delays, improving productivity, saving millions of gallons of gas, reducing vehicle emissions, promoting a healthier environment, and increasing transportation users' satisfaction, safety and convenience.

5.2. RECOMMENDATIONS FOR FUTURE WORK

The scope of this study was limited to demonstrating a new methodology for quantifying the cost of non-recurrent congestion and using the findings to guide decisions on ASAP deployment. If this research methodology is to be implemented by the Alabama Department of Transportation (ALDOT) for managing the ASAP patrol vehicle deployment, further studies are recommended to include more extensive datasets and covering more roadway facilities. Along these lines, the following recommendations are offered for future work.

1. This research considered data from one month (March 2021). Further studies can incorporate a year's worth of data to capture better the monthly variations in travel times and delays.
2. This research analyzed data from two interstate corridors in the Huntsville area. Presently, there are other corridors covered by ASAP patrol service in all major cities in Alabama such as the Birmingham, Tuscaloosa, Montgomery, and Mobile areas. Further work can be done along corridors in these areas to determine if presence of ASAP patrols is warranted or needed based on the severity of non-recurrent congestion presence by location, time of the day, and type of day (weekday versus weekend).
3. Future studies can incorporate additional factors to the decision making process including the presence/absence of shoulders, occurrence of special events such as concerts, football games, and determine if those factors make a difference in the optimal allocation of ASAP patrol teams.
4. It is also recommended that more traffic count stations can be set up along major interstate corridors in order to improve the quality of data used to calculate the ADTs and thus the accuracy of the results.
5. Future studies can include additional criterion that incorporates the crash history can be added to act as another weighting factor for the deployment of ASAP patrol teams.

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