TRUCK IDENTIFICATION USING

NEW JERSEY WEIGH IN MOTION DATA

By

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ABSTRACT OF THESIS

Truck Identification using New Jersey

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An algorithm for truck identification based on the truck's axle configuration, arrival time, and gross vehicle weight is proposed. The algorithm is applied between WIM Stations and can further be modified for use in Origin-Destination (O-D) studies for New Jersey State. Truck Origin-Destination study is necessary in order to find out if the roads are being used by local state trucks, or by trucks traveling from out of the state. Truck volumes have incomparably increased since past years in the State of NJ reducing the level of safety of pavement structures and highway bridges.

An extensive database of WIM data was collected from more than 50 fixed stations throughout the State of NJ. The WIM data collected includes gross weight, axle weights, axle spacings, number of axles, speed, length of the vehicle, vehicle classification and counts, lane, date and time of passage and ESAL's to evaluate truck

loading. Truck volumes are highly site specific, depending upon the type of highway and its functionality. Based on the truck's axle spacings, arrival time, and gross vehicle weight, an algorithm is written for monitoring its presence at various WIM Stations. The effect of Weight calibration and other factors on WIM accuracy, and thus on truck identification, are studied. The algorithm was further validated by Spot checking WIM data for the truck presence between stations. Based on the results of this study, it can be concluded that the method followed for truck identification is reliable when applied to stations having accuracy in terms of installation and calibration.

However, a rational approach to the whole process of truck identification between WIM stations and O-D study is provided if visual identification systems, like license plate readers, are also adopted as a supplement with WIM data.

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CHAPTER I

INTRODUCTION

1.1 PROBLEM STATEMENT

The truck traffic volume in New Jersey needs to be monitored and analyzed for in state and out of state traffic since their increasing volumes and weights cause damage to the pavement structures and reduce the safety level of bridges ,deteriorating their performance. It is necessary to know if the damage caused to the roadways due to the heavy flow of trucks is because of trucks traveling inside the state or not. By doing so, it can be concluded whether or not the trucks traveling from out of state avoid tolls bypassing the highways and travel through local roads, participating in impairment of roadway surfaces. As of now, there are about 50 WIM stations installed through out the state for monitoring truck traffic. Mostly, the WIM stations serve the purpose of vehicle classification & counts. An attempt is made to utilize the existing WIM data of trucks to track their path of travel between stations.

1.2 RESEARCH OBJECTIVES AND SCOPE

The main objective of this research is to write an algorithm for locating trucks at various WIM stations in order to find out the truck route followed throughout its journey. Considering the insufficiency of an exact and convenient approach for truck identification at stations, an approximate method which mainly identifies the truck based on truck axle spacings, time of travel, and axle weights is presented. Due to the inherent properties of WIM and the external factors affecting its accuracy, the method seems more reliable when it is tied up with some kind of visual verification system for recognition and confirmation of the truck. This would give us a whole picture of truck traffic flows.

1.3 THESIS ORGANIZATION

This thesis consists of five chapters described briefly as below:

Chapter I covers introduction consisting of problem statement, research objective and scope, and thesis organization.

Chapter II covers the literature review of data collection using weigh-in-motion technology and its advancement over the years, previous works on studying truck load data and O-D surveys and studies. Current research using Automated License Plate Recognition (ALPR) Systems Technology for capturing license plate records for monitoring truck traffic is also discussed.

Chapter III covers the description and principle of weigh-in-motion, WIM system types, WIM properties, factors affecting WIM accuracy and their effect on truck identification process, and the key role played by the calibration factor in the whole process. Various methods to verify, interpret and adjust the calibration accordingly at WIM sites have also been discussed.

Chapter IV covers the details of NJDOT database of permanent WIM stations, including its locations and mile post numbers, and the algorithm followed for truck search (approximate method) program. Observations and results obtained from

FORTRAN program on various case studies is put forth. Suggestions for a more reliable and feasible way of truck identification are also discussed.

Chapter V covers the conclusions and recommendations.

CHAPTER II

LITERATURE REVIEW

2.1 EVOLUTION OF WIM TECHNOLOGY

Over the past years, Weigh-In-Motion (WIM) has evolved to a large extent due the advancement in sensor technology .It has been under development since about 20 years and wide spread research is still going on for further improvements.

Sensors of various types are already in extensive use (Piezo sensors, capacitive mats, load cells, etc.).Integration of sensor technology with electronics has provided suitable and substantial operational systems since the end of the 1980's.

WIM systems enable measurements of axle weights and gross vehicle weights traveling at highway speeds. Several countries have adopted the use of such systems. WIM stations are being used all over the world, mostly in the USA, Europe and Australia.

2.1.1 Bridge WIM (B-WIM)

Bridge WIM was developed in the US by Moses et al. in 1979 but least development had taken place since then. Bridge weigh-in-motion (B-WIM) involves instrumentation of bridges in order to measure the axle weights, axle spacings and gross vehicle weights of trucks traveling at highway speeds. Strain gauges are attached to the underside of the bridge beams or girders using C-clamps for measuring deflections, Strains, and for obtaining lateral distribution factors used for analysis of bridges. Sensors are placed for recording vehicle data. Portable electronic systems are connected for data collection from the strain transducers and sensors. The bridge deck serves as the WIM platform, thus reducing the dynamic effects of the vehicles. However, due to the presence of other vehicles on the bridge during the truck weighing process, the signal noises are affected greatly, reducing the accuracy of load computations based on the bridge's response. B-WIM is considered reliable for short spans where trucks can be isolated during weighing process. It necessitates extensive site set up, calibration, and testing.

A demonstration project was initiated by the Utah Department of Transportation initiated in 1983 for testing, evaluation and implementation of a state-of-the-art Weigh-In-Motion (WIM) technology, namely the Bridge Weigh Systems, Inc. It was a 2 year study involving the BWIM system, and its limitations and applications. They studied the accuracy of the weights measured by the BWIM system which revealed that the gross vehicle weight was the most accurately measured having a deviation of only 4.9% from the static weight. Single and tandem axle weights measured deviated about 14% to 16% from the static weight. Work on the further development of B-WIM was focused primarily on increased accuracy for typical bridges, dynamic analysis of typical bridges and calibration procedures (Gustavo et al., Bridge Weigh-In-Motion Demonstration Project, RTAP Final Report, 1986).

2.2 WIM Technology

Traditionally, static weigh scales are used at weigh stations to measure heavy vehicles traveling at low speeds. Portable weighing pads are placed under the tires of the vehicle. Though the static weigh scales are suitable for measuring heavily loaded trucks, they seldom prove useful and appropriate for continuous traffic data collection. A very small percentage of freight is weighed by the static scales and due to its expensive set up, maintenance and low operation hours. Often the drivers tend to avoid the static weigh station and a major part of the trucks representing the overloaded truck stream usually go undetected.

A high speed WIM system measures vehicles traveling at highway speeds and collects data continuously. Since they do not interfere with the traffic stream, there are a least chances of the drivers avoiding these systems and being recorded. WIM systems can be permanent or portable as per requirements. At permanent sites, the sensors are permanently fixed and the data acquisition system collects data continuously for long durations while at portable sites, data collection is limited to a short period and the sensors along with the equipment can be moved to another location. Weigh-in-motion systems use different sensor types and equipments for data acquisition as described in Chapter 3. However, since the existing WIM systems have not yet achieved 100% accuracy in terms of calibration and durability, further improvements are needed for satisfactory performance.

B-WIM is used in the USA on a smaller scale compared to other European countries where they are further being developed to increase their effectiveness and performance. A number of European countries still support the use of bridge WIM, and

Australia extensively uses a similar system based on the deflection of culverts called the CULWAY, in which, the strain transducers are attached to the bottom side of the culvert instead of bridges. A new concept of multiple-sensor WIM (MS-WIM), introduced a few years ago in UK and France and roughly tested either by numerical simulation or road tests, will be developed and improved, which could solve this issue.

2.3 The WAVE project

In the late 1990's, extensive research was under way in Europe as a part of the WAVE project (Weighing in motion of Axles and Vehicles in Europe).Considerable progress is being made in terms of traffic data collection and analysis. The project was planned for a period of 2 years and various work plans were carried out accordingly. Accuracy in estimating static weights using WIM, WIM data quality and management, durability of WIM systems and the future of optical WIM sensors were addressed. About ten countries (France, UK, Ireland, The Netherlands, Sweden, Belgium, Germany, Switzerland, Finland, and Slovenia) participated in the WAVE and opened up a transition to full scale use of WIM devices. Static weighing was the only way for overload detection until now. Since it had its own limits, it necessities to find new solutions to the existing traffic problems. WIM seemed to be an ideal solution to address these problems, but required high accuracy in estimation of static weights and needed to overcome dynamic effects of vehicles induced on the road profile. Hence, the concept of Multiple Sensor WIM (MS-WIM) was tried, in which, several sensors were placed in succession and data is collected. Though this concept was introduced in the late 80's in the UK, it was enhanced during WAVE.

LCPC (Laboratoire Central des Ponts et Chaussees, France) and CUED (Cambridge University Engineering Department, UK) conducted research on MS-WIM and developed two algorithms and tested on various sites. They found that though the MS-WIM precision needs further improvement for direct enforcement, they could be used to screen vehicles for overloads and weigh them statically, if needed. (Jacob et al.1999)

Another sensor technology that was developed in Switzerland was the Piezo-quartz sensors which were tested in Sweden for harsh climates. In spite of the temperature variations, it was found to give stable results.

Fiber Optic (FO-WIM) sensors were also testes for weighing accuracy .The sensors were tested in a parking area on real pavement and was proven feasible. The research on FO technology and its long term performance is still under progress and yet to introduced in the markets.

The WAVE project also took the B-WIM to a level comparable to other WIM technologies. Analysis of the system's accuracy was studied after full scale field tests, B-WIM's feasibility, and the range of bridge types suitable for instrumentation.

Algorithms were written and new computer models were simulated to take into account the dynamics of vehicles effect on the static axle weights. Field tests showed considerable level of consistency. Free axle detectors (FAD's) were introduced which improved the durability of B-WIM. Theoretical studies and initial field trials showed a promising approach. B-WIM is very useful in assessment and rehabilitation of bridges and hence bridge monitoring. (www.siwim.com)

2.4 IRD WIM Equipment

Intelligent Transportation Systems (ITS) provide technological solutions by combining transportation management systems with electronics, wireless communications, and data processing and control techniques. It works towards providing us with innovative and efficient technologies for the enhancement of highway systems performance.

IRD has a world wide reputation of being a major manufacturer of automated data collection systems including WIM technologies. IRD has about 7 WIM technologies that are being used for traffic data collection.

IRD WIM offers a wide range of data acquisition tools ranging from classifiers/counters (for axle counts) to full scale weigh-in-motion systems (for classification with weight data).The weigh scales are durable and reliable and can be set up for either permanent or portable applications and use various sensor types for specific purposes. WIM finds its applications in traffic data collection weigh stations, portable/permanent operations, bridge assessment and evaluation, virtual weigh stations, toll collection systems, weight limit enforcements, road safety and overall traffic monitoring and management. They also provide data regarding traffic volumes, speeds and truck weight data.

IRD acquired PAT Traffic (German based company) in the year 2003, located in Europe and the United States which also offer WIM systems, traffic data collection systems, portable weigh scales and other related ITS products and services. With the acquisition of the PAT, IRD has now expanded its worldwide presence to over 8225 lanes of equipment (http://www.irdinc.com).

2.5 Origin-Destination (O-D) Study

O-D studies are usually carried out by conducting personal interviews of truck drivers at busy weigh stations, usually for duration of 24 hours or so. Data entry personnel perform a check on each questionnaire and enter into the database for further analysis. This interview procedure is tedious as well as time consuming. However, this survey method is still being followed in some states as a part of O-D study and is carried out only for short durations of time.

Advancement in technology has provided us with novel methods for recording and analyzing vehicle data. Though the Weigh-in-motion data provides all necessary information for evaluating truck loads, due to the absence of an exact way of identification for a truck, is less reliable O-D study. However, an approximate method of truck identification is possible.

The studies made by Dempsey et al. (1996) showed that multiple sensor array and spatial repeatability increase the accuracy in axle weight prediction. Experiments were carried out on a bridge WIM in Dublin, Ireland. Multiple passes of a truck of known static weight was used for calibration purposes. GVW's showed an error of ± 10% and axle weight errors were much more. Static and Dynamic sources of Bridge WIM inaccuracy were studied. Total Gross bending moments are used to calculate the static axle weights and gross weights of the trucks. It as found that an error of 8 % in the first axle of a 5 axle truck resulted in a 100% error in first axle weight, proving the axle weight is highly sensitive to the velocity measured. The four axle spacings were varied proportionally and altered to ±8%.It is seen that significant errors in axle weights resulted from proportional errors in all axle spacings and since velocity is used for axle spacing calculation, such proportional errors could occur due to miscalculation of velocity. In Irish system, the maximum experimental error in axle spacing was found to be ±3% .A Least squares error minimization process is used for fitting purposes. A parametric study of the error effects in axle spacing and velocity on the inferred errors in axle weights and GVW's showed that the velocity component was more critical and led to large errors in weights. The front axle spacings of 5 axle vehicles seemed to be more sensitive to errors than the rear ones. Examination of Truck Dynamics and Bridge Dynamics revealed that for shorter spans, dynamic oscillations lead to significant errors in weights and the axle weight errors was found to be as high as 25%,though the reasons that lead to errors is difficult to be identified and further analysis and modeling is required.

Connor et al. (2005) presented Traffic Flow Simulation Models for determining their appropriateness in bridge assessment using statistical approach. Maximum load effects were determined using WIM data and Monte Carlo Simulation (regenerates traffic records using random variables for any chosen scenario). They studied the extreme load effects and the factors influencing them. The implications of accuracy of recorded data, duration of recording and the sensitivity of the extreme to the predicted method were also investigated. The mixed4, mixed2 and free 4 scenarios were considered which represents majority of traffic flows on bridges. It as noted that for spans<30m, side by side case of two fully loaded vehicles governed during both mixed and free flow conditions whereas for spans >30m, more than two vehicles are present and hence mixed flow governed. The data recorded was over a 7 day period on two carriageways of a main motorway on mainland from Paris to Lille in France. WIM data was recorded on 2 lanes in each direction. A vehicle having GVW of more than 3500 kg was considered a truck. Extremes were predicted by Rice's extrapolation from simulations using WIM data while Gumbell I and Weibull value were form Monte Carlo simulation. The load effects considered were mid span moment on a simply supported beam, continuous support moment on two span beams and total load on the span since they are often govern calibration of traffic load models. The WIM data recorded showed a substantial scatter in the GVW measurements. Implications of WIM accuracy and its influence on characteristic extremes are studied. It was noted that many WIM sensors still give inaccurate static weight estimates due to factors like vehicle dynamics, sensor inaccuracy, weighing station location, site issues, and calibration drift. Hence they all played a significant role in predicted extremes. Recommendation for the accuracy required from WIM data for prediction required a minimum Class C (15),meaning the required number of gross vehicle weight records fall within 15% of the static values for spans<50m, but les accurate data for spans>50m and hence less data. Assessments of time and seasonal patterns and influence of traffic growth were also made.

Kwon et al. (2003) proposed an algorithm for real time estimation of truck traffic volume from single loop detectors as a part of PeMS project (Freeway Performance Measurement System). Large scale deployment of the algorithm was made in Los Angeles County, California comprising of more than 1300 detector locations. The algorithm was achieved by adding spatial filtering and aggregation components. Free way to free way variability and data quality issues were addressed by spatial smoothing and segment based maps. TAADT (Truck Annual Average Daily

Traffic) for different sections of freeway were needed to be estimated. Since most of the methods like AVC (Automatic Vehicle Classifiers) based on WIM technologies and video imaging is not completely error free and incurs high operation costs, estimation of traffic flows and occupancy from the already installed loop detectors are explored. Spatial distribution of total daily truck traffic volume was studied for a period of one week. In the pilot study, the algorithm showed an accuracy of about 6%. The algorithm output is utilized for mobile source emission estimation, freeway crash analysis and pavement management.

The Oak Ridge National Laboratory (ORNL), a center for Transportation Analysis is involved in research work in the heavy Truck Safety area for more than five years. Research involves Field and Track Testing, Modeling and Simulation, Data and Information Analyses, Laboratory Testing, Demonstration Projects and National Program Support. The WIM program aims at reducing the manual process of weighing and mitigates safety and operational concerns. Combine efforts are underway towards WIM technology developments by the ORNL, U.S. Army and Air Force. Brake Performance Correlation, Heavy Vehicle Duty Cycle, and Road Side Testing Laboratory work towards improving safety and security for commercial vehicles. Partners involved in the Heavy Truck Safety Research include U.S.DOT's, U.S.DOE, and U.S.DoD and several other industries.

Romero et al. (2005) studied the influence of variations in suspension & tire characteristics (dynamic responses) and pavement roughness proposed a method for assessing the spatial distribution of potential pavement damage. The study measured the potential pavement damage in terms of the stored strain energy within the pavement due to a measured distribution of heavy vehicle traffic. The traffic on Mexican roads during 24 hour duration was sampled for the distribution of heavy vehicles within real traffic. In-plane models of heavy vehicles were formulated to represent mixed traffic and pavement analytical model. Equations of motion for models were obtained using Newtonian approach .Equations for cumulative stored energy were derived analyzed and correlated with rut depth data and the prediction of damage was reasonable. The Dispersion analysis (peak to peak variation in stored energy along pavement profile normalized with respect to average value and coefficient of variation measures, both expressed as percentages) of the stored energy showed that the spatial variation in road damage ranged from 40 to 50% for rough roads, 9 to 14% for smooth and 18 to 20% for a medium rough pavement. It was found that the effect of suspension and tire characteristics was a function of pavement roughness, within these limits of spatial concentration. It was also observed that for rough pavements, increase in suspension damping led to a reduction in pavement potential damage while increase in tire stiffness led to an increase in the damage. But for medium pavements, increase in suspension damping led to an increase in pavement potential damage. It was concluded that this differential response marked the significance of spectral content characteristics associated with pavement profiles and needs an n open analysis to a wide variety of roughness characteristics.

Papagiannakis et al. explored the feasibility of two procedures for evaluation and calibration of WIM system was carried out using two procedures. The first method involved a combination of test trucks and vehicle simulation models, the other involved traffic stream and vehicles equipped with AVI (Automatic Vehicle Identification) transponders. In the first method, three types of WIM sensors and three test trucks were adopted including 5 axle semi trailer truck. At each WIM site, ten runs were conducted at four different speeds and recorded WIM measurements were plotted as a function of speed. The precision of the systems is indicated by the coefficient of variation from replicate axle passes. Inherent variation in the magnitude of dynamic loads applied because of weaving and other factors provided conservative estimates of errors. Simulation of test trucks was done using VESYMF using pavement roughness parameter as an input. Calibration was carried out by comparing vertical accelerations. WIM error analysis was and procedures for calibration were recommended.

The Heavy Vehicle Electronic License Plate (HELP) program was used to combine WIM with AVI of vehicles. About 5000 trucks were quipped with AVI transponders and was used to compare static weights of particular vehicles by considering the date ad time interval between locations on I-5 corridor: Woodburn (SB) and Ashland (NB).The static axle load data were provided by the Oregon DOT.WIM data and static scale data were input into two separate relational data bases which also included AVI and load data, axle spacing data, classes of vehicles, date and time. FHWA Class 9 trucks were a majority amongst AVI equipped vehicles. FORTRAN algorithms were used to analyze the data for screening in two stages, first by comparing dates and second, by comparing times. Static and WIM loads were compared and errors were analyzed. Calibration factors were developed through linear regression such that the line of the slope is the calibration factor. A Portable AVI system was developed for WIM calibration. Two AVI readers were installed in Minnesota on I-94 in Lake Elmo and the other at WIM system location, situated 3 miles apart. 80 AVI transponders were installed on trucks. WIM data along with static axle load data of AVI equipped vehicles were collected at the truck inspection station and compared. Calibration was achieved by curve fitting using least squares regression method.

Cetin et al. (2006), proposed a new method for quality control of WIM using the gross vehicle weight distributions of class 9 trucks using finite mixture models for numerical characterization. Analysis was done on the data collected in a single lane on I-80/94 near Gary, Indiana, based on the GVW's of Class 9 vehicles only. Mixture models are used to fit a series of normal distributions to the GVW for identification of peak parameters. The data was aggregated by week for three consecutive years .EMMIX software developed by McLachlan et al. was used to fit a mixture of normal components via the EM (expectation maximization) algorithm. EMMIX software was used to determine the optimal number of components in each distribution. Three component mixture models were fit to the data in all three years, hence the best fit to the actual frequency distributions from WIM data. The mean, variances and proportions of the fitted distributions were monitored over time to detect calibration drifts and sensor failure. Graphs of the three components with respect to time were plotted for one year by week between week 30 of 2008 and week 29 of 2003.Futher analysis revealed a sudden and short drastic calibration drift during week 21 and an axle sensor problem during week 28.

Cetin et al. (2006) presented a new approach for matching commercial vehicles crossing adjacent weigh-in-motion stations using the Bayesian method (BM). Finite mixture models that represent probabilities of vehicle attribute data were developed for re-identification at multiple locations. The parameters used in this study included time stamp, axle spacings, axle weights and length of vehicle. Various combinations of the vehicle's axle spacings, axle weights and length, were analyzed from both WIM (9 dimensions) and AVC (Automatic vehicle classification, 5 dimensions) scenarios. Algorithms to automatically match vehicles based on its data were developed. The data for this study was collected on I-70 in Terre Haute, IN for 2 days. The weigh station included a mainline WIM and ramp WIM (2 single load cell sensors) set 0.8miles apart and a static scale was set 0.3 miles from the ramp WIM. The former was used for weight checking of trucks with transponders while the latter served the purpose of screening trucks to bypass around the static scale. Video was collected at 3 locations and along with WIM time stamp records & static scale details', matching was carried out. Class 9 trucks were found to be predominant at this site. Search space with lower bound and upper bound limits for travel times was determined based on travel speed, distance between two stations, traffic flow interruptions. They also developed the nearest neighborhood (NN) or nearest squared distance method and an algorithm for matching were written based on the above method which was used for comparison purposes. Different time windows between two and forty five minutes were chosen arbitrarily that relate to the search space. The test data set consisted of more than 900 samples. Of the three methods (NN, BM without prior, BM with prior) developed, it was found that BM with prior method achieved 5.4% error rate for AVC (Automatic vehicle classification) and 3.0% error rate for WIM scenario utilizing all vehicle attributes compared to the 18% error rate achieved by estimating models for axle 3-4 spacing only. It was also observed that the probability of a mismatch is higher with increasing search space to include more non matching vehicles. The study was found to have its applications in the assessment of WIM sensor accuracy (for axle weights), WIM calibration, travel time estimates and weigh station enforcement applications.

2.6 Automated License Plate Recognition (ALPR) Technology

The most recent development with regards to vehicle identification is the ALPR technology which uses License plate readers for capturing license plates of vehicles for traffic studies and enforcement purposes. ALPR sometimes referred to as ANPR (Automated Number Plate Recognition) is a mass surveillance system that uses OCR (Optical Character Recognition) on images for capturing license plates of vehicles.

ALPR systems have the ability to collect real-time data and helps in enhancing the performance level of transportation management applications. ALPR hardware and software is owned by The Traffic Group Inc. It is found to have various applications ranging from O-D studies, trip surveys, vehicle tracking, traffic monitoring, road safety and control, travel patterns and travel time related studies, HOV lane enforcement, parking lot management, and automated traffic ticketing systems.

Some states like Virginia and South Carolina are currently experimenting on using Cameras and License Plate Readers at various locations, in which case, the truck will be matched based on its license plate information, providing an assurance for the identified truck. Below are the details of recently experimented projects which involved the usage of ALPR technology for capturing the vehicle's license plates. A brief description of the various projects undertaken by the Traffic Group Inc. using ALPR technology is given below (www.trafficgroup.com).

2.6.1 VIRGINIA (2004)

In Virginia state (2003) , more than 50,000 license plates were captured from 6 cameras as a part of O-D study for determining travel patterns of vehicles entering and leaving the Winchester town. The study was carried out for 3 weeks.

In 2004, I-81 project was undertaken by Traffic Group inc. and uses the ALPR technology which is the first of its kind. This project aimed at collecting data for vehicles on Shenandoah Valley and used PIPS technologies (Knoxville, TN and UK). The project was undertaken for a period of one day and valuable information was collected regarding length and O-D of trips along the Inter state highway network in I-81 study area. The observations were made on April 6 from 3am, 2004. More than 46 cameras were installed which collected over 250,000 license plates for duration of 24 hours. The license plate survey was also carried out along I-61, I-66, I-581, I-77 simultaneously in both directions over a 24 hour period. The license plates at various stations were then matched using a computer program. The captured license plate image is processed by OCR (Optical character Recognition) software program. ALPR studies help identify the travel patterns and roadway requirements, alternate routes, and also anticipate present and future traffic patterns.

2.6.2 SOUTH CAROLINA (2005)

The Traffic Group also conducted an O-D study using ALPR in Beaufort County, South Carolina for the assessment and evaluation of the proposed improvement on their roadway system and O-D linkages for trips entering and leaving Port Royal Island in Beaufort. License plate information from all vehicles entering and exiting the port was captured and recorded. Comparisons were made with date collected at six mutually different sites. The data was collected on May 12, 2005 between 6am and 4pm at all locations that provided access to the island allowing for both the quantification of traffic volume and qualification of the traffic by trip type. About 80, 000 plates were captured and the data included time, location and direction of travel onto or off of the island. The data for each vehicle was compared to all other vehicles at all other locations to identify a "match".

Several other projects involving Automated License Plate Recognition were carried out by the Traffic Group Inc. Studies were carried out along I-66 (Fairfax, Virginia) and I-95 (South Washington, DC) for vehicle identification by their license plates and determination of their occupancy for the usage of HOV lanes carrying no passengers. The durations of study were only for a short period. In 2007, along Routes NJ 33, and Chestertown (Maryland), more than 20 cameras collected about 50,000 license plate records for the assessment and evaluation of the proposed roadway networks and further improvements.

CHAPTER III

WEIGH-IN-MOTION DATA

3.1 INTRODUCTION

3.1.1 DEFINITION OF WEIGH-IN-MOTION

"Weigh-in-motion", as defined by the American Society for Testing and Materials (ASTM), is "the process of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle". The in road sensors at a weigh in motion station collects and records the data automatically with out disrupting truck traffic. The collected traffic data for vehicles include axle weights, axle spacings, gross vehicle weight, speed, lane number, year, month, date and time of passage, length, and vehicle classification type. Weigh-in-motion technology uses sensors that can be intrusive, involving access to roadway or non intrusive in which case the sensors are mounted over head or on the side of the roads not interfering with the roadway access. Sensor technologies can be used only for classification of vehicles and counts or for WIM .The systems could be portable or permanent as per requirements. Additionally the data collected can be only for a short duration or over a long period of time.

3.1.2 DATA COLLECTION NEEDS

Traffic load data is the key to design pavement structures, and bridges. Truck volumes and the loading spectra information contribute the key factors for design. WIM data are needed both at geographically diverse locations, and over long periods at some locations to measure seasonal and day-of-week vehicle characteristics. WIM is complicated as it measures the dynamic motion of trucks. Many factors are required to be considered so that the collected data represents the corresponding static axle loads accurately. Gross vehicle and axle weight monitoring also helps in legal truck size, and weight enforcement. For better comparisons, it is also required that continuous data is available for all the sites.

3.1.3 METHODS USED FOR DATA COLLECTION

The type of data collected includes Vehicle Classification/Counts, and Weigh-in-motion. Both of these data types can be collected either for short duration or long duration utilizing specific technology. In common terms, short duration WIM refers to the usage of portable WIM, and long duration to usage of permanent WIM systems.

3.1.3.1 Vehicle Classification/Counts

The most commonly used Portable sensors (Short Duration) for vehicle classification based on FHWA's 13-category system are Road tubes, and piezoelectric sensors. Data is usually collected for a period of one day or two. These sensors are pressure sensitive causing a signal when a vehicle passes over it which is then interpreted into weights. For continuous data collection, in-pavement sensors mostly in the form of Piezo ceramic cables or dual inductance loops are used. They fall under the category of intrusive sensors since they interfere with the pavement structure.

3.1.3.2 Weigh-in-motion Data

Short duration WIM data collection technologies include BL-style Piezo electric sensors, and capacitance mats. These are mounted on top of the pavement surface. Since it involves a dynamic action when a vehicle passes over, it creates a bump when the axle hits the sensor making it viable to inaccurate recordings of weights. Hence, calibration of portable WIM scales becomes utmost necessary in order to achieve the same level of accuracy in the measured weights as of a static scale.

Continuous WIM (Permanent/Long duration) equipment, most commonly include, PiezoCeramic Cable, Inductance loops, Bending plates, and Piezo-quartz sensors.

All the above weight sensors are installed in pavement reducing the effect of bump and hence reasonable weight recordings. They also have long sensor life as the sensors are placed inside the pavement, and are not subjected to wear and tear. However, every system has its own strengths and weaknesses. Temperature sensitivity, site conditions, disturbances to the sensor signal interfere with the performance of WIM systems.

Piezo sensors are placed parallel at a measured distance apart, and perpendicular to the road traffic. The difference in time between the two Piezo sensors is used to compute speeds and hence axle spacings.

Inductance loops detect the presence of vehicle as the sensor inductance generates variation due to the presence of metal in the vehicle .Loops are used in conjunction with Piezo sensors to avoid misclassification of tailgating cars from trucks.

3.1.3.3 Non-Intrusive sensors

These sensors are mounted overhead or to the side of the roadway not interfering with the roadway access. The most widely used Non intrusive sensor technologies include Video Cameras, Radar, and Infrared. The major drawback of non intrusive sensors is their inability to count the vehicles axles accurately, and hence make them classify vehicles by the overall length of the vehicle.

3.2 WIM SYSTEMS

3.2.1 WIM SENSORS

The most commonly used sensors for portable WIM technologies include, piezoelectric sensors (BL-type, and ceramic cable), and capacitance pads. Permanent WIM sensors are usually flushed with the roadway surface avoiding the impact loads, and bumps on the sensors as the vehicle passes over. Most commonly used are Piezo sensors, Loops, and Bending plates.

3.2.1.1 Capacitance mats

Capacitance mats consists of two metal sheets separated by a dielectric material. The sensor is placed on pavement, and a voltage applied across the two plates. As vehicle passes over the system, the distance between the plates decreases, and capacitance increases. Resonant frequency of the system is measured, and axle weights are estimated. They have significant shortcomings in terms of accuracy of the overall system, only one side of passing axles is measured, and because of the thick sensor, the vehicle dynamics is affected creating am impact load on the sensor, and affecting its accuracy.

Figure 3.1 Capacitance mat

3.2.1.2 Piezo sensors

Piezoelectric sensors are basically thin strips of Piezo sensors having flat plate configuration (BL sensor), and unmounted coaxial PiezoCeramic cable. The sensor is about 10 feet in length, and about 1/2-in wide. The state highway agencies use Piezo sensors for collecting high speed portable WIM data, which works on the principle of voltage generation due to the applied mechanical force. The system records the electrical charge created by the sensor, and calculates the dynamic load. The static load is estimated using the measured dynamic load, and calibration parameters.

Roadtrax BL Piezoelectric Sensor

Installed Piezosensor

Figure 3.1 Piezosensor

The Piezo sensors are taped to the roadway, perpendicular to travel lane. Usually two sensors are place at a distance apart, each Piezo measuring about one lane width in length. The time difference between the axle contacts on the two sensor cables is used to determine the speed of the vehicle, and in turn used to determine the axle spacings. It is common to install two inductive loops, and two piezoelectric sensors in each monitored lane. The inductive loops are placed upstream and downstream from the sensor. The upstream loop is used to detect vehicles, and alert the system of an approaching vehicle. The downstream loop is used to determine speed and axle spacings based on timing. A properly installed and calibrated Piezoelectric WIM system can provide gross vehicle weights that are within 15% of the actual vehicle weight for 95% of the measured trucks. The Piezo sensors and loops can be combined into various sensor configurations as follows:

1 Piezo-Piezo (P-P)
2 Piezo-Loop-Piezo (P-L-P)
3 Loop-Piezo-Piezo (L-P-P)
4 Loop-Piezo-Loop (L-P-L)
5 Loop-Piezo-Piezo-Loop (L-P-P-L)
6 Loop-Piezo-Loop-Piezo (L-P-L-P)
7 Loop-Piezo-Loop-Piezo-Loop (L-P-L-P-L)

Other sensors include Bending Plates, Piezo quartz sensors, and hydraulic load cells.

3.2.2 WIM EQUIPMENT

3.2.2.1 IRD TRS WIM

The IRD TRS (Traffic Recording Systems) WIM also provides weigh-in-motion data apart from serving as classifiers, and counters. Data can be collected without any interruptions to the collection process and is widely used for Piezo weigh-in-motion, loops, and tubes. It is user friendly for field operations, and has options of solar panel, and expandable memory. The standard TRS can be used as portable or permanent unit.

(a) (b)

Figure 3.2 IRD WIM systems: (a) TRS (b) TCC-540 WIM

3.2.2.2 IRD TCC 540 WIM

IRD TCC (Traffic Counters/Classifiers) 540 WIM provides all the necessary information regarding vehicle classification, and counts along with weigh-in-motion data. It can be used for both permanent and portable operations. Data recorded includes gross vehicle weights, axle weights, and spacings, speed, length, and time stamp of passage. It has the capability of counting up to 6 lanes, classifying or weighing up to 8 lanes. It allows the user to define time intervals. The data can be retrieved though a telephone modem or downloading directly to the computer. Sensor configurations can range from multiple combinations of loops, Piezo sensors , and road tubes. It also has auto calibration routine. Other equipments include PAT Traffic DAW 300 portable WIM system (for slow speeds), and PAT Bending Plate systems.

3.2.3 ADVANTAGES & DISADVANTAGES OF WIM

ADVANTAGES OF WIM

WIM ensures continuous data processing, and the processing rate is high compared to static scales. Since the trucks are weighed as they travel at highway speeds without disrupting the traffic, there is less chance of an overweight truck avoiding the WIM unlike in static weigh stations.

DISADVANTAGES OF WIM

Truck information such as fuel type, state of registry, year model, loaded or unloaded status, origin, , and destination cannot be obtained with typical WIM systems. Also, WIM accuracy is of high concern as it depends on a number of factors, some of which can be uncontrolled.

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3.3 WIM DATA PROCESSING

3.3.1 WIM DATA FORMAT

The WIM system records data primarily in binary format .This helps in storing enormous quantities of data for long durations since it is in a compressed format. The binary format is then converted to readable ASCII format by using the IRD (*International Road Dynamics*) software. The final ASCII readable format is as shown in Table 3.1. The truck classification is according to the Federal Highway Administration FHWA's 13-category system based on the axle-count, length, and axle-spacing, and weights of the vehicle recorded. The Table 3.2 describes the FHWA's 13-category system.

The typical vehicle configurations for each class are illustrated in Table 3.3. The most prevalent, and dominant truck is typically the Class 9. The Class 9 tractor trailer, also referred to as 3S2 configuration, is indicative of a three axle drive tractor followed by a 2 axle semi-trailer. This is commonly used for long haul freight operations. The most similar configurations seen in the traffic stream are shown in Figure 3.3. Classes 5 , and 6 are usually weigh less than Class 9 truck. Class 7 trucks are dump trucks which carry bulk material. At times, a fourth "drop-axle" that can be lowered if there is payload is present which then classifies itself under lass 7 truck. Passenger vehicles fall under Classes 1 to 4. Class 14 is a code for user defined vehicle type , and Class 15 to any vehicle that is unclassified by the software program. As each vehicle in a traffic stream passes over the WIM system, the number of axles, length, axle spacing, , and axle weights are read to determine its classification. The exact criteria for the FHWA classification scheme are given in ASTM E-1318(02) Specifications (ASTM 2002).

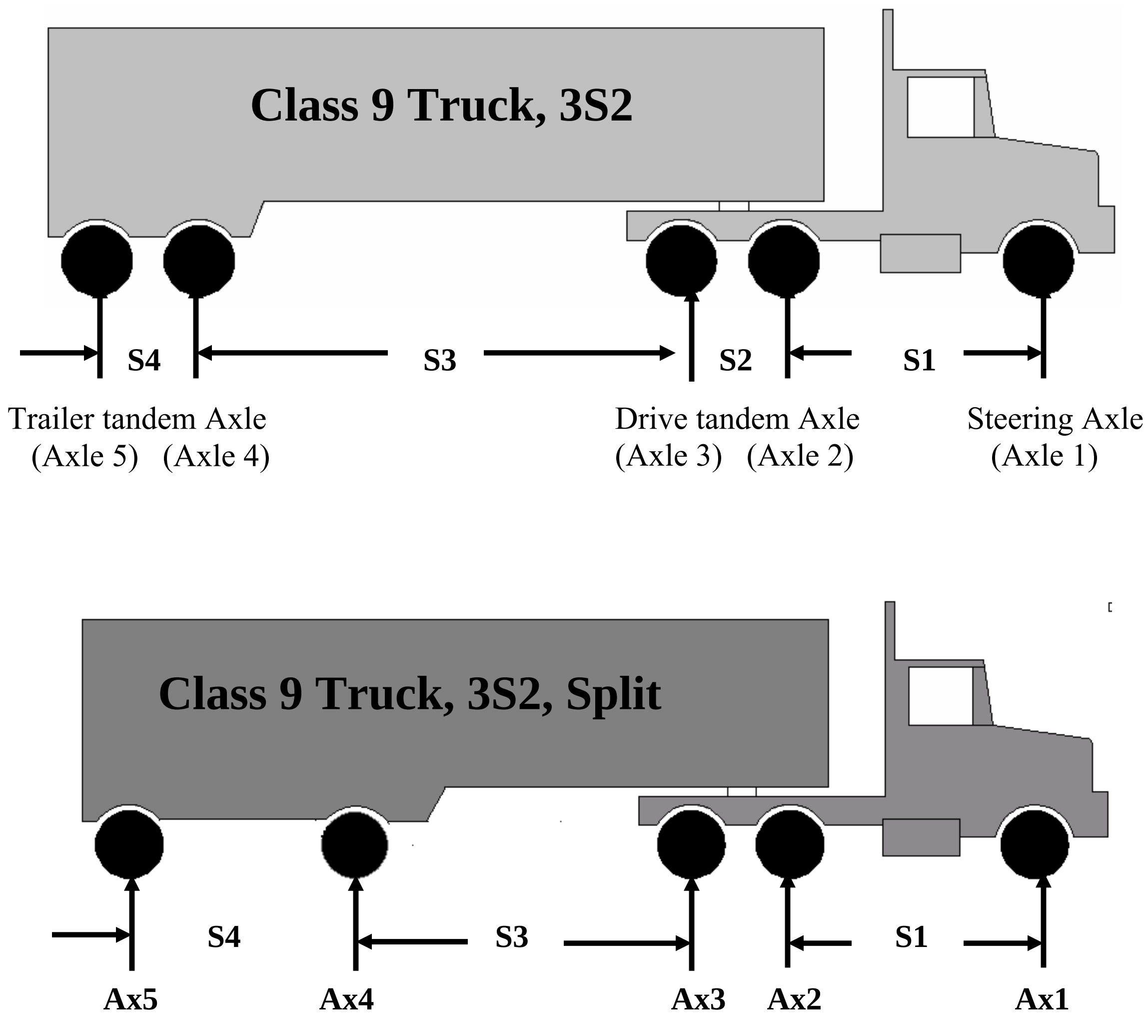
The typical raw data format from NJWIM for a Class 9 truck is shown below,

- 6,8,17,0,4,45,89,0,11,2,49,9,64,77.8,2.707,11.5,20.4,15.5,4.3,15.8,23.4,17.5,10.2,17.4,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,NO_AVI_TAG,32

The format parameters are explained as follows,

Table 3.1 NJWIM Data Format

Raw Data value	Description
6	**Year**
8	**Month**
17	**Day**
0	**Hour**
4	**Minute**
45	**Second**
89	**Hundredth second**
0	**Code**
11	**Code**
2	**Lane**
49	**Speed (miles per hour, mph)**
9	**Vehicle Class**
64	**Length (feet)**
77.8	**Gross Vehicle Weight (kips)**
2.707	**ESAL's**
11.5	**Axle 1 weight (kips)**
20.4	**Axle Spacing 1-2 (feet)**
15.5	**Axle 2 weight (kips)**
4.3	**Axle Spacing 2-3 (feet)**
15.8	**Axle 3 weight (kips)**
23.4	**Axle Spacing 3-4 (feet)**
17.5	**Axle 4 weight (kips)**
10.2	**Axle Spacing 4-5 (feet)**
17.4	**Axle 5 weight (kips)**
0.0	**Spaces and weights up to Axle 14**
NO_AVI_TAG,32	**Code**



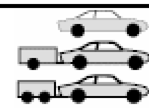
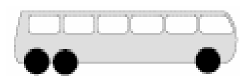
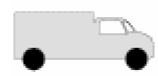
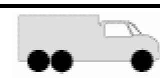
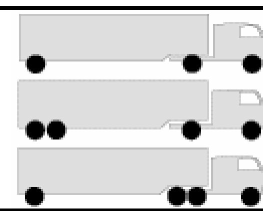
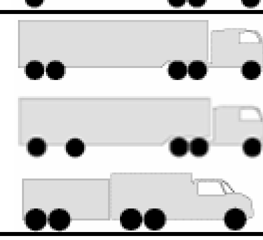
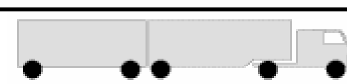
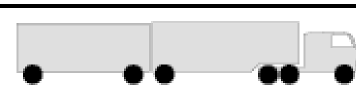
S1=Spacing between Axle 1 & Axle 2 S2=Spacing between Axle 2 & Axle
S3=Spacing between Axle 3 & Axle 4 S4=Spacing between Axle 4 & Axle

Figure 3.3 3S2 Class 9 Truck configurations

Table 3.2 FHWA 13 Category Vehicle Classification Scheme (FHWA, 2001)

Class	Type	Description
1	Motorcycles	All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State
2	Passenger Cars	All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All two-axle, four tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, and carryalls. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. All two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified
5	Two-Axle, Six-Tire, Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels
6	Three-Axle Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles
8	Four or Less Axle Single Trailer Trucks	All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit
9	Five-Axle Single Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit
10	Six or More Axle Single Trailer Trucks	All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit
11	Five or Less Axle Multi-Trailer Trucks	All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit
12	Six-Axle Multi-Trailer Trucks	All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit
13	Seven or More Axle Multi-Trailer Trucks	All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit

Table 3.3 FHWA 13 Category Vehicle Classification Descriptions (FHWA, 2001)

Class	Type	Vehicle	Number of Axles
1	Motorcycles		2
2	Passenger Cars		2 3 4
3	Other Two-Axle, Four-Tire Single Unit Vehicles		2,3,4
4	Buses		2,3
5	Two-Axle, Six-Tire, Single Unit Trucks		2
6	Three-Axle Single Unit Trucks		3
7	Four or More Axle Single Unit Trucks		4
8	Four or Less Axle Single Trailer Trucks		3 4 4
9	Five-Axle Single Trailer Trucks		5
10	Six or More Axle Single Trailer Trucks		6,7
11	Five or Less Axle Multi-Trailer Trucks		5
12	Six-Axle Multi-Trailer Trucks		6
13	Seven or More Axle Multi-Trailer Trucks		7 or more

3.4 PROCEDURE FOLLOWED FOR WIM DATA PROCESSING

- Raw daily files are downloaded to the computer from the WIM data acquisition system which is recorded in the simplest binary format (compressed)
- It is then converted to readable ASCII format by running the IRD (International Road Dynamics Inc.) software program, which gives various options of combining files based on hourly, daily, monthly or yearly basis. Other parameters fed as inputs include site name and vehicle classes. The IRD software has inbuilt site information, and details, which is activated upon entering the name of the site. For the purpose of this study, files were processed on daily basis.
- The IRD output data files contain the ASCII format of the recorded WIM data, as shown in step 6 in the pictorial representation. The typical format of a truck record (Class 9 truck) obtained as output from the IRD program is as shown in Table 3.1
- In this way, the output files for the required origin and destination sites are obtained. Next, the files are run using the FORTRAN program built on the basis of the proposed algorithm. Inputs to the truck search program include the file names of O & D, their lanes corresponding to respective directions of travel, travel time interval, tolerances for spacings, and weights. During the processing, it matches trucks based on the instructions fed in to the program, and spits out the summary, and truck matches as two separate files. The files are then opened using Microsoft Excel for further investigations.

Figure 3.4 Pictorial representation of WIM data processing

Figure 3.5 ….. *Contd.*

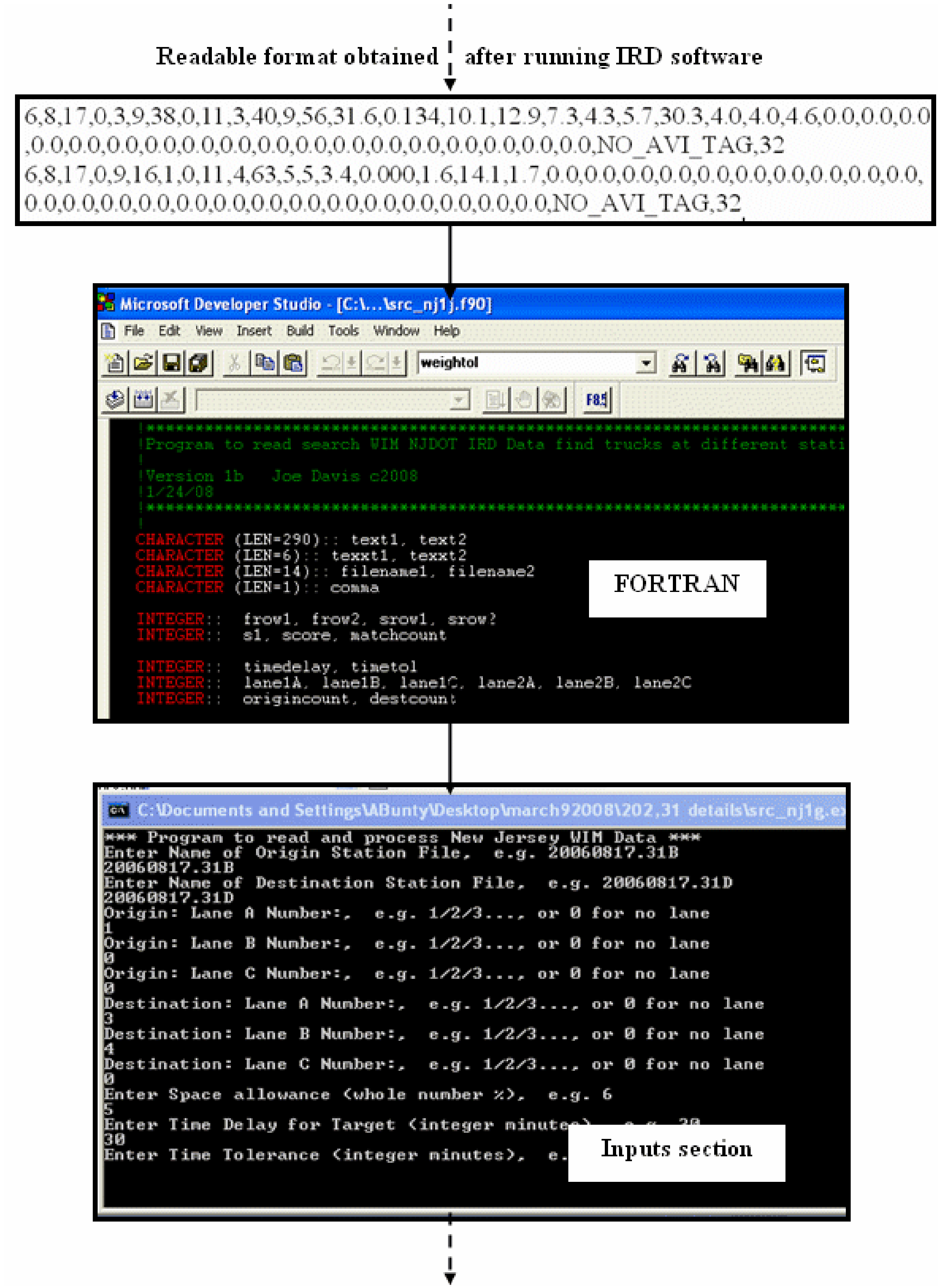
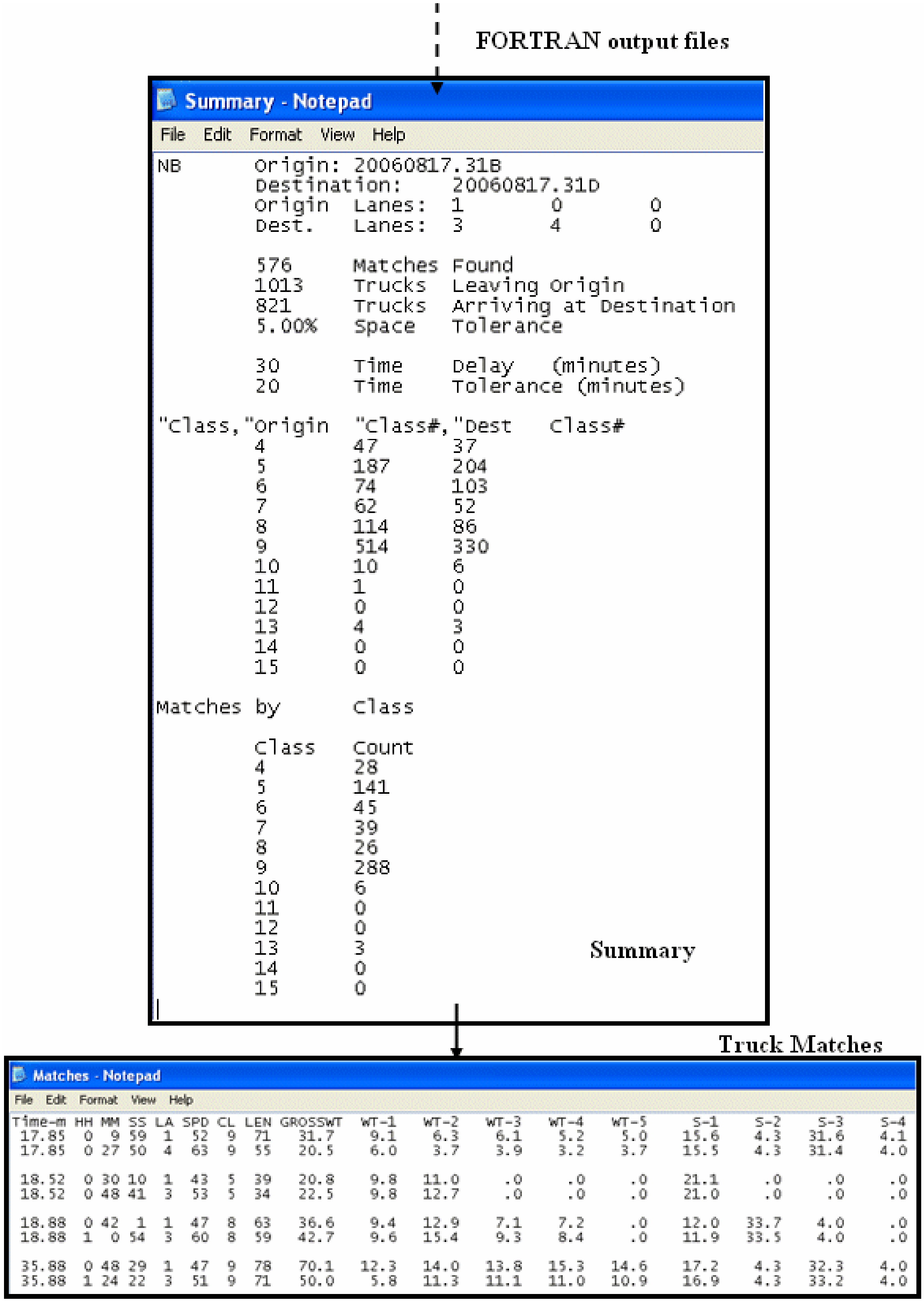


Figure 3.6 ….. *Contd.*



Summary - Notepad

File Edit Format View Help

```
NB         Origin: 20060817.31B
           Destination:    20060817.31D
           Origin  Lanes:  1        0        0
           Dest.   Lanes:  3        4        0

           576     Matches Found
           1013    Trucks  Leaving Origin
           821     Trucks  Arriving at Destination
           5.00%   Space   Tolerance

           30      Time    Delay   (minutes)
           20      Time    Tolerance (minutes)

"Class,"Origin  "Class#,"Dest   Class#
           4       47      37
           5       187     204
           6       74      103
           7       62      52
           8       114     86
           9       514     330
           10      10      6
           11      1       0
           12      0       0
           13      4       3
           14      0       0
           15      0       0

Matches by         Class

           Class   Count
           4       28
           5       141
           6       45
           7       39
           8       26
           9       288
           10      6
           11      0
           12      0
           13      3
           14      0
           15      0
```

Matches - Notepad

File Edit Format View Help

Time-m	HH	MM	SS	LA	SPD	CL	LEN	GROSSWT	WT-1	WT-2	WT-3	WT-4	WT-5	S-1	S-2	S-3	S-4
17.85	0	9	59	1	52	9	71	31.7	9.1	6.3	6.1	5.2	5.0	15.6	4.3	31.6	4.1
17.85	0	27	50	4	63	9	55	20.5	6.0	3.7	3.9	3.2	3.7	15.5	4.3	31.4	4.0
18.52	0	30	10	1	43	5	39	20.8	9.8	11.0	.0	.0	.0	21.1	.0	.0	.0
18.52	0	48	41	3	53	5	34	22.5	9.8	12.7	.0	.0	.0	21.0	.0	.0	.0
18.88	0	42	1	1	47	8	63	36.6	9.4	12.9	7.1	7.2	.0	12.0	33.7	4.0	.0
18.88	1	0	54	3	60	8	59	42.7	9.6	15.4	9.3	8.4	.0	11.9	33.5	4.0	.0
35.88	0	48	29	1	47	9	78	70.1	12.3	14.0	13.8	15.3	14.6	17.2	4.3	32.3	4.0
35.88	1	24	22	3	51	9	71	50.0	5.8	11.3	11.1	11.0	10.9	16.9	4.3	33.2	4.0

3.5 ACCURACY OF WIM DATA

3.5.1 EFFECT OF TEMPERATURE

Temperature affects both the sensitivity of the Piezo-cable itself, and the structural response of the roadway that supports that cable. Piezo sensors use the impulse of the axle loads while recording data .At low pavement temperatures, the sensor is bound to give high values on the readings recorded since it offers more resistance , and at high temperatures, as the asphalt is softer, reduces the sensor reading.

3.5.2 EFFECT OF SITE PROFILE

ASTM specification E 1318 provides specific guidance on the pavement conditions needed for accurate performance of WIM system.

The pavement conditions favorable for installation of WIM are as follows:

- Flat – Grades, and Horizontal or vertical curves are undesirable for a WIM site as they would encourage acceleration or deceleration of vehicles.
- Strong-The pavement surface should be strong to avoid flexing below the WIM sensor underneath.
- Smooth-No bumps or other surface conditions that create vehicle dynamics is favorable. Rough pavement should be avoided.

Ideally, the site chosen for WIM installation must satisfy all the above conditions. Inaccurate sensor location and installation process affect the calculation of the vehicle speed, and axle spacings, and also affects the sensor life (Sensors are subjected to fatigue due to the repeated traffic cycles. Hence, wear, and tear results in sensor degradation deteriorating their performance), providing unreasonable results.

3.5.3 WIM CALIBRATION

WIM calibration includes two steps.

(i) Initial Calibration

(ii) Calibration maintenance over time

The initial calibration is usually done by driving a test truck of known static weight over the WIM sensors repeatedly. The dynamic and static weights are then compared, and adjusted to minimize the error by adjusting the scale factor. This procedure is repeated until the WIM scale measured weight is close to the static weight of the test truck. The ASTM and the FHWA's LTPP (Long Term Pavement Performance Project) recommends the adjustment of the sensor scale by running two test trucks of known weights, and different vehicle characteristics in order to rule out any bias caused by a single test truck. It ensures better calibration quality. However, if that single test truck truly represents the traffic stream, the method seems reasonable.

For ideal conditions, the sensor should be tested under various speeds and temperature conditions since the pavement temperature greatly affects the sensors calibration, and hence the data measured for better quality calibration. Substantiation of WIM equipment for calibration setting is often necessary for the site. The GVW characteristics of FHWA Class 9 vehicles are commonly used for assessing WIM accuracy. They are described as follows,

a) Visual interpretation of Class 9 trucks frequency histograms: The gross vehicle weights distribution of class 9 trucks (mostly five axle tractor semi-trailer trucks) is usually bimodal occurring in the loaded, and unloaded or partially loaded weight ranges, and shows prominent peaks. Consistent peaks are expected to be found, and most sites will show two peaks in the class 9 histogram plots. The unloaded peak for tractor semi-trailers falls between 25,000, and 35,000 lbs. This weight range has been determined from data collected at static scales around the country, and appears to be reasonable for most locations. The loaded peak in the GVW distribution represents the most common loaded vehicle condition at that site, and it most likely occurs in the load range of 70,000 to 80,000 lbs. The location of these peaks within the GVW histogram remains fairly constant, for most of the sites. If a plot shows both peaks shifted from their expected location, the scale is most likely out of calibration. Recalibration of the scale at that site is required. There are several methods to adjust the data to bring it back into calibration. Sometimes, the WIM scale manufacturers provide computer routines to adjust calibrations based on Class 9 trucks characteristics.

b) Logarithmic regressions method, Southgate (2000): Southgate used a logarithmic regression of axle spacing, and weights in order to check WIM calibration. After analyzing approximately 2,000 days of data, it was concluded that this methodology may not be appropriate for data sets having less that 100 VC9records per day. Therefore, this method is not applied to lanes which accommodated less than 100 VC9 per day. These functions use the relationship of the steering axle to the gross weight of a typical five axle tractor trailer (Class 9).It is recommended to limit the sample size to a single day since seasonal temperature changes, and drift will affect the data. The WIM quality control procedure is as follows:

    (1) The data recorded from WIM is first reduced only to Class 9 Trucks

(2) Calibrations plotted are by lane since they vary with lane

(3) The ratio of the steering axle weight (W1) to the first axle spacing (S1) for each truck is calculated,($W1/S1$)

(4) The $\log_{10}(W1/S1)$ is calculated

(5) The $\log_{10}(S1)$ where S1 corresponds to the first axle spacing is calculated

(6) $\log_{10}(S1)$ Versus $\log_{10}(W1/S1)$ is plotted respectively on the x & y axes, and a linear regression is performed from which the slope, M, and the intercept, B are obtained.

(7) Log regression, of each data point is calculated such that $R = 10\wedge(B + M * \log(S1))$

(8) Reference equation is calculated using, the equation, $E = (10\wedge(3.925361 - 0.952182 * \log(S1))$

(9) The upper bound of the regression is calculated, i.e., steering axle weight to spacing ratio (by manufacturers specifications) as $\max\lim = ((12000/S1) + 50) lb/ft$

(10) The lower bound of the regression of the steering axle is calculated as $\min\lim = (10\wedge(3.942369 - 1.07509 * \log(S1))$

(11)The ratio ($W1/S1$), regression equation (R), reference regression equation (E), upper bound ratio (max lim), and the lower bound ratio (min lim) for each data point (truck record) is plotted for every lane.

The results are interpreted by Southgate, and typical patterns are as follows,

- Data sets that fit nearly perfectly between the 12-kip (upper bound line), and Truck Manufacturers Minimum Specification line (lower bound line).The conclusion in this case was that, "if it ain't broke, don't fix it."
- Data sets that nearly fitted between the two criteria lines but the data set was skewed.
- Data points above the 12 kip line (i.e., the upper bound line penetrating too far into the data set) limit indicates that the data sets were too high, , and
- Data points below the Truck manufacturer's minimum limit specification line (or the lower bound line penetrating too far into the data set) limit indicates that the data sets were too low.

c) For FHWA Class 9 trucks, the Steering axle loads range approximately from 6,500 lbs to 12,000 lbs, and Gross vehicle loads range from approximately 25,000 lbs to 80,000 lbs, Southgate (2000), the same range noted with data collected from static weigh scale sites. Hence, a graph of Vehicle gross load v/s steering axle load can be used as a check for calibration quality.

d) The mean front axle weight for loaded FHWA Class 9 trucks: The mean front axle weight falls in the range between 8,000lbs to 12,000lbs, and should fairly remain constant for the site.

e) Mean axle spacing of drive tandems on of class 9 tractors: From the Traffic monitoring guide, it is noted that the truck manufacturers in the United States primarily use 4.25, 4.33, 4.50, and 4.58 foot axle spacing for Class 9 trucks. Since this distribution has not changed much in the past years, it is said that the Class 9 truck population on U.S. highways will a drive tandem axle spacing between 4.25 , and 4.58 feet over 99% of the time. The weighted average in this study was found to be 4.33 feet. It also points that, though this is not true at every site, the maximum error that can be induced with this value is +6.5% in the rare case that all of the trucks at a site had a drive tandem axle spacing of 4.58 feet.

f) An increase in the percentage of overweight vehicles also makes the calibration of that site questionable.

g) Similar loading characteristic of other vehicle classes.

After the initial calibration is done, it needs to be periodically verified for good data quality by field tests, and routine checking of output data. Calibration maintenance over time is a very important practice, and should be investigated for performance of the sensor scale from time to time.

Some WIM systems have an auto calibration feature which adjusts the calibration factor to changing environmental conditions along with software adjustments. However the LTPP tests showed that auto calibration factors were not always successful in maintaining environmentally sensitive sensors. Hence caution must be taken, and various procedures verified on site before adopting auto calibration.

As Calibration plays a key role in setting up the WIM equipment, proper procedures must be followed for installation, and calibration for the sensor to be able to perform well.

3.5.4 OTHER SOURCES OF ERRORS

- Lane Discipline: For the Piezo sensors to record axle weights relatively accurately, the vehicles at the sites should travel at fairly constant speeds, and maintain lane discipline.
- Truck Characteristics /Vehicle Dynamics: Suspension systems, spacings between steering axles to tandem axle (s).
- Manual Settings: At the time of initial setting up of the WIM system, care, and caution must be taken in order to check all the parameters, and set it up rightly. For instance, it was found during these studies that, the time setting on WIM Station I2C of I-295 was that the initial time setting was inaccurate, which led to making necessary adjustment in the time settings.
- Misclassification of vehicles: Sometimes, if the time out setting is too long, the WIM system tends to combine the closely following vehicles, and misclassify. This happens mostly with Class 8 trucks when the system misclassifies two closely following cars as a truck. Hence, care needs to be taken in setting up the right initial features for proper classification.

CHAPTER IV

ALGORITHM FOR TRUCK IDENTIFICATION

4.1 NEW JERSEY WIM (NJWIM) DATA BASE

Over the years, the NJDOT has collected a large database of Weigh-in-motion data from more than 50 permanent WIM sites located all over the state of New Jersey. The collected data includes all the parameters required for evaluation of live load. The data from these sites is used for pavement design, long-term freight planning, and enforcement. The functional classification of the sites ranges from two lane country roads, to urban arterials, to major interstate highways. The duration of available data varies by site depending on the installation date. Typically about five years of data is available for the sites, with some having as much as 13 years of continuous data. As for truck identification, it is favorable to have common data for all sites for a particular duration of time.

4.2 TRUCK IDENTIFCATION CRITERIA

An effort is made to identify trucks on different WIM stations along a Route with the use of weigh-in-motion data. After all the processing of raw data is complete, the files are run on truck search program, using FORTRAN, which follows proposed algorithm, based on the identification criteria explained below. The major factors taken into account for the truck identification criteria are as follows,

4.2.1 AXLE SPACINGS

During the process of identifying a truck between two WIM stations, the primary factor on which the possible matches were listed, was the axle spacings. Since the spacings recorded are determined based on the time difference between axle contacts on the two Piezo sensor cables placed a measured distance apart, the recorded axle spacings are least prone to error.

4.2.2 TIME OF TRAVEL

The secondary factory considered was the time of travel between the two stations based on which a match could be found. A maximum , and minimum time limit was chosen keeping in mind the variation of speeds of vehicles depending on factors like presence of traffic lights, possibility of speeding above limits due to free roads, slowing down if any exits, etc.

Straight line diagrams were referred for this purpose , and time was chosen respectively.

If d =distance between two stations, miles

x = average speed of truck, 50 miles per hour, (50 mph)

t= time taken by the truck (based on 50 mph speed) from origin to destination (min)

Hence, the actual time'‘t’ taken by the truck to reach destination is $((d/x) * 60)$ minutes.

As the distance between any two stations is a constant, the actual time of travel between any two stations is a constant.

Due to the varying speeds of trucks, presence of traffic lights , and exits allowing for slowing down of vehicles, a range must be chosen for searching a match for the truck in the next station which is explained in the section below.

4.2.2.1 TIME DELAY

The term time delay refers to the total time taken to reach the destination station i.e., the sum of the actual time of travel between the two WIM stations (based on average speed of 50 mph) , and extra time allowance for the traffic lights , slowing down ,etc. It is represented symbolically as Δt (min).

4.2.2.2 TIME TOLERANCE

Time tolerance represents the range of time between which the truck is assumed to be present .For example, if the actual time of travel between Station 1 , and station 2 is 25 minutes , and the extra time allowance for traffic lights is 10 minutes, then, Δt= 35minutes.A chosen Time tolerance of 30 minutes means that the range of time that the truck will be checked at the destination will be (5 min to 65 min) which is reasonable.

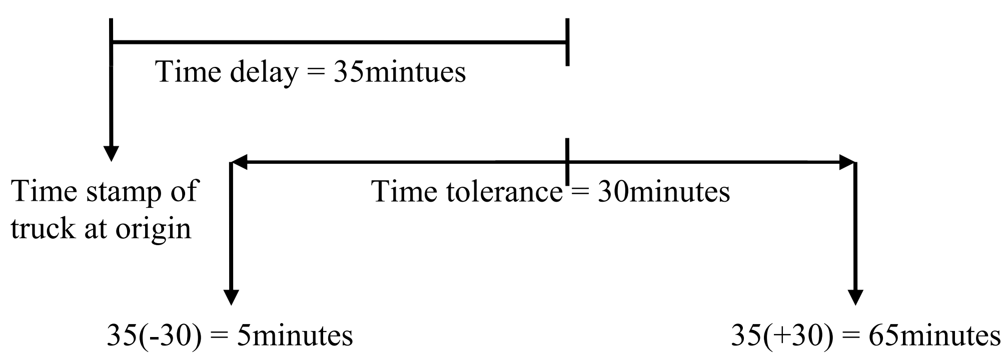


Figure 4.1 Description of the time range selected using, time delay and time tolerance

4.2.3 GROSS VEHICLE WEIGHT (GVW)

The third factor included in the algorithm for truck search process is the GVW of the truck .The GVW's of the trucks at origin , and destination stations are compared , and adjusted for calibration if necessary, to narrow down the number of trucks which could provide us with a suitable match for the reference truck at the origin station. During this step of checking , and comparing the gross vehicle weights, first of all, the calibration at both the stations needs to be checked for quality assurance as it plays a key role in determining the axle weights , and gross vehicle load. For this study, the GVW's obtained from the WIM data are considered as is, only at reasonably well calibrated sites. For sites which are either calibrated too high or too low, GVW's are adjusted for the same after checking from calibration charts , and manual verifications. Other checks include the individual axle weight's , and speeds which may or may not be of much help in determining the identical truck as they could vary a lot depending on other factors.

The NJDOT straight line diagrams (SLD's) give details of the traffic lights, interchanges, exits, county roads , and other highways cutting across between the WIM stations. These factors must also be kept in mind during the search process since they affect the time delay , and time tolerance largely, which in turn affects the truck search process. The search would be more conclusive , and confirmative only when some kind of visual identification system for trucks is attached to the WIM. This would give us a whole picture of the truck traffic population, including weights, , and origin destination.

4.2.4 GVW CALIBRATION

Adjustments in GVW of trucks are made if the charts indicate any calibration drifts. The FORTRAN program includes necessary steps for calibration. Since the calibration changes by lane, it is important to apply the adjustment factor only to the affected lanes, which otherwise, may modify the accurate data , and output unreasonable results. In this study, the factor by which the calibration is adjusted to high or low is done relatively keeping either the origin or destination as the reference. Whichever seems to be well calibrated compared to the other site, is taken as reference since there is no static load data for comparisons, which would be a more reasonable way for adjustments. The FORTRAN program allows for inputting the calibration factor(CF) which either reduces or increases the GVW's of all trucks in that particular direction. For example, if it is observed that a particular site shows its calibration a little too high, then the GVW's of trucks are divided by an adjustment factor, to reduce the GVW's in that particular direction for all lanes. An example cited below is explained as follows, Site I2C shows about 15 % high calibration , and hence an adjustment factor of 1.15 to I2C in the NB direction (Lanes 4, 5 , and 6) reduced the GVW from 101 kips to 88 kips, refining the accuracy. The affect of GVW calibration on Truck search results is discussed later. It is clear that by doing so, the GVW error has decreased to 11%, because of which, refined matches of trucks can be obtained. The calibration factor is chosen after investigating the Class 9 histograms mean values of the loaded , and unloaded peaks. The ratio of the difference in mean values of both stations to that of the reference station where the calibration seems to be reasonable is calculated. For this study, from the manual checks process, some class 9 truck matches were chosen whose errors in GVW were also calculated. An example is cited below showing the reduction in GVW by 15%, from a value of 101 kips to 88 kips. The calibration is adjusted, by comparing with an outside source such as static scale data of known quality.

	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0	21	6	9	60	**101**	14.3	19	20	23.9	23.9	17.4	4.2	32.9	4
0	22	5	9	70	79.5	10.1	16	17.8	18.6	17	17.3	4.2	32.3	4
		Errors		14%	27%						1%	0%	2%	0%

Before GVW Calibration

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0	21	6	9	60	**88**	14.3	19	20	23.9	23.9	17.4	4.2	32.9	4
0	22	5	9	70	79.5	10.1	16	17.8	18.6	17	17.3	4.2	32.3	4
		Errors		14%	11%						1%	0%	2%	0%

After GVW Calibration

Class 9 truck traveling from I2C towards 295, on 12/18/2006

However, since there is no static data available for the sites considered for this study, an adjustment factor was chosen, based on the Class 9 histograms Mean values. Also, the truck matches obtained from manual checks were used to calculate GVW errors , and a reasonable factor was selected for calibration adjustment.

4.3 PROCESSING ALGORITHM

The algorithm was programmed using FORTRAN for truck matches between weigh-in-motion stations. The program was run on the following sites , and the observations , and results obtained are reported under case studies for the respective sites.

- NJ 31, I-295, US 202

Figure 4.2 Algorithm used for Truck Search Process

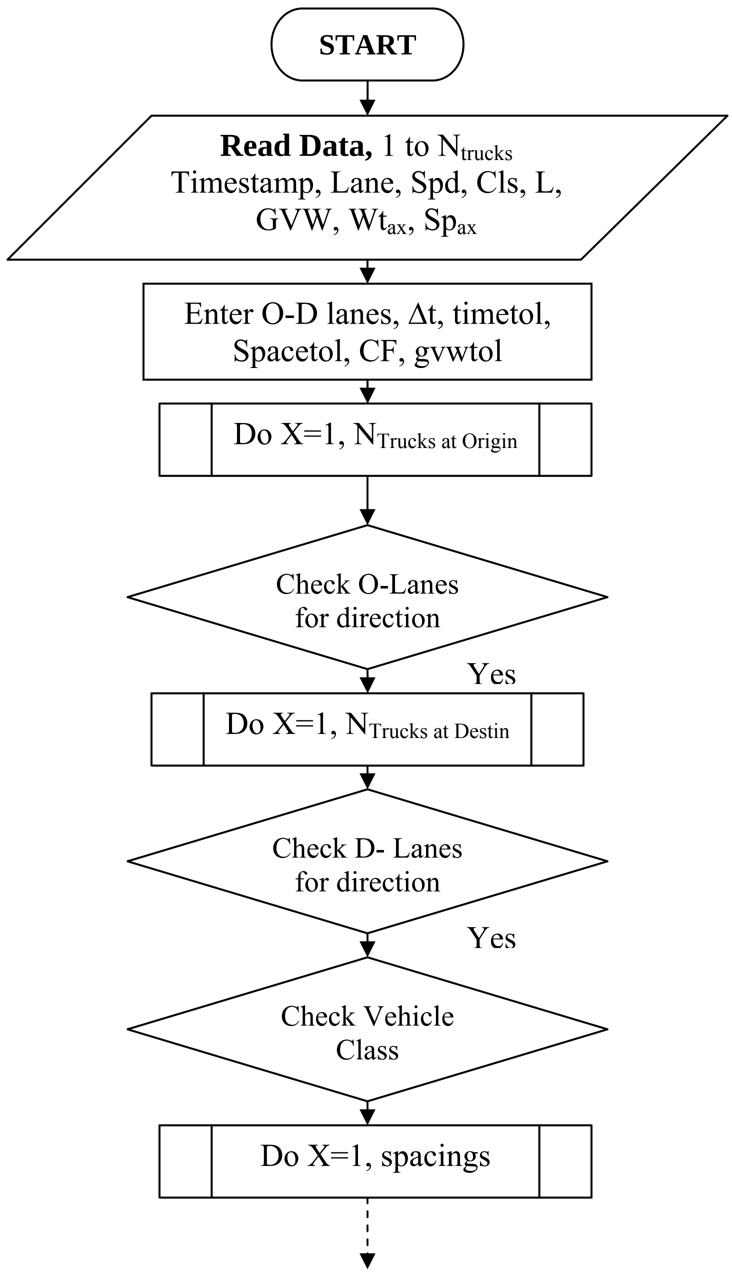
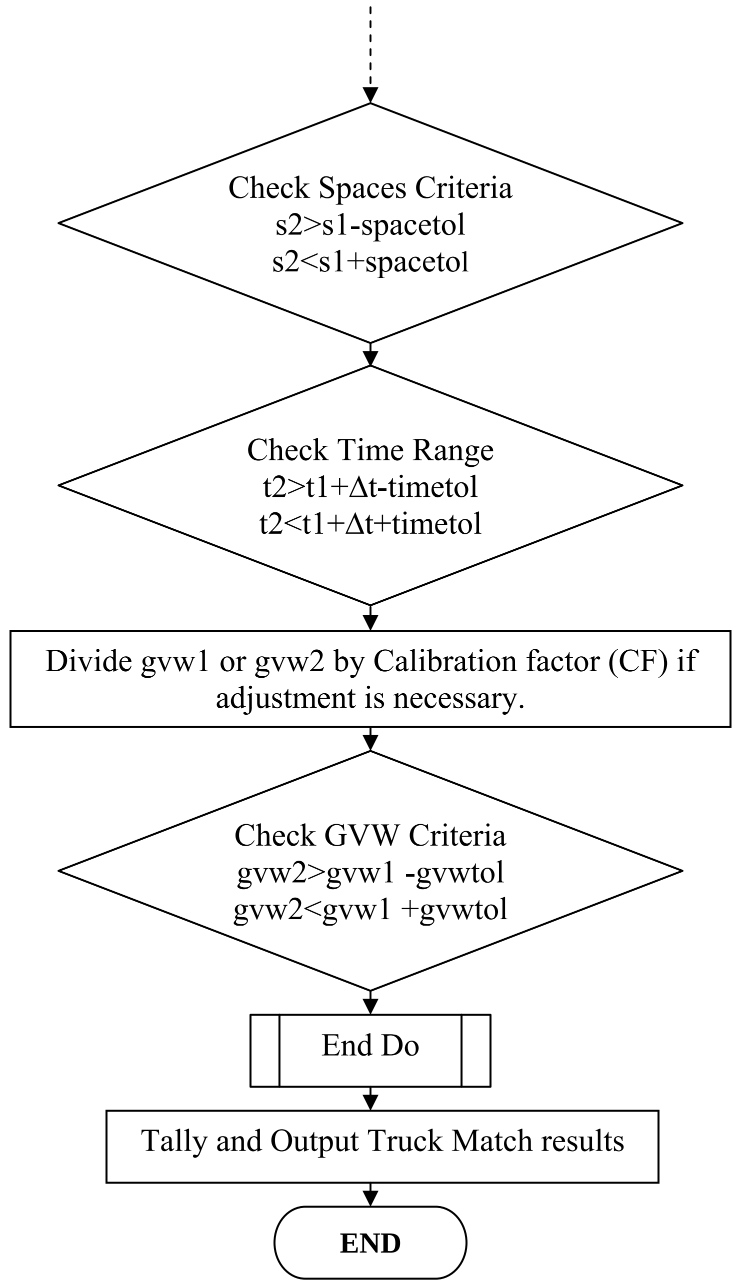


Figure 4.3….. *Contd.*



The parameters included in FORTRAN are explained as below,

N_{trucks} =Number of Trucks

Wa_x = Axle Weight's (kips)

Sa_x = Axle Spacings (feet)

Δt ='time delay' or the travel time between two stations, (minutes)

Timetol = the maximum, and minimum tolerances (allows for extra time of travel - due to presence of traffic lights, slow speeds, etc), (minutes)

Spacetol = the maximum, and minimum tolerances for axle spacings in %

Gvwtol = the maximum, and minimum tolerances for gross vehicle weight in %

t1 = time stamp of truck at origin, minutes

t2 = time stamp of truck at destination, minutes

s1 = axle spacings of truck at origin, feet

s2 = axle spacings of truck at destination, feet

s1, s2 vary from (1 to (number of axles -1)) according to the program

gvw1 = gross vehicle weight of truck at origin, kips

gvw2 = gross vehicle weight of truck at destination, kips

1 refers to the parameter recorded at the Origin (O) station

2 refers to the parameter recorded at the Destination (D) station

The following table shows the permanent weigh-in-motion sites installed by the NJDOT in the state of New Jersey.

Table 4.1 NJDOT Weigh-In-Motion System Sites (2007)

ROUTE	# LANES	MILE POST	MUNICIPALITY	COUNTY	SITE NAME	SENSOR CONFIGURATION
Co-539	NB/SB (2)	29.3	Plum stead Twp	Ocean	539	(L-P-L-P)
Co-551	NB/SB (2)	6.8	UpperPittsgroveTwp	Salem	C51	(L-P-P-L)
Co-653	NB (2)	2.6	Secaucus Town	Hudson	CLR	(L-P-P-L)
DorAve	NB/SB (2)	2.3	Newark City	Essex	DRM	(L-P-L-P-L)
I-195	EB/WB (4)	4.0	Hamilton Twp.	Mercer	19B	(L-P-P-L)
I-195	EB/WB (4)	10.2	Upper Freehold	Monmouth	195	(L-P-P-L)
I-280	WB (3)	5.1	Roseland Boro	Essex	280	(L-P-P-L)
I-287	NB (3)	31.7	Harding Twp	Morris	A87	(L-P-P-L)
I-287	NB/SB (4)	61.7	Franklin LakeBoro	Bergen	287	(L-P-P-L)
I-295	NB/SB (6)	35.7	Cherry Hill Twp	Camden	I2C	(L-P-L-P)
I-295	NB/SB (6)	39.6	Mt. Laurel Twp	Burlington	295	(L-P-L-P)
I-78	EB/WB (6)	25.7	Readington Twp	Hunterdon	78D	(L-P-L-P)
I-78	WB (4)	34.5	Bernard's Twp	Somerset	78B	(L-P-L)
I-80	EB/WB(6,6)	66.2	S. Hackensack	Bergen	SHE/W	(L-P-L-P-L)
NJ-124	EB/WB(4)	7.6	Summit City	Union	124	(L-P-L-P-L)
NJ-138	EB/WB (4)	2.6	Wall Township	Monmouth	138	(L-P-L-P-L)
NJ-15	NB/SB (4)	7.1	Jefferson Twp	Morris	015	(L-P-P)
NJ-168	NB/SB (3)	1.3	Gloucester Twp	Camden	168	(L-P-P)
NJ-18	NB/SB (4)	16.0	Colts Neck Twp	Monmouth	18B	(L-P-L-P-L)
NJ-18	NB/SB (4)	26.6	Marlboro Twp	Monmouth	018	(L-P-L-P)
NJ-18	NB/SB (3,2)	44.6	Piscataway Twp	Middlesex	18D	(L-P-L-P-L)
NJ-23	NB/SB (4)	23.8	West Milford Twp	WestMilford	23	(L-P-L-P-L)
NJ-31	NB/SB (2)	13.0	East Amwell Twp	Hunterdon	31B	(L-P-L-P-L)
NJ-31	NB/SB (4)	26.4	Readington Twp.	Hunterdon	31D	(L-P-L-P-L)
NJ-31	NB/SB (2)	40.4	Washington Twp	Warren	31C	(L-P-L)
NJ-33	EB/WB (5)	23.5	Manalapan Twp	Monmouth	033	(L-P-P-L)
NJ-34	NB/SB (4)	0.6	Wall Township	Monmouth	034	(L-P-L-P-L)
NJ-34	NB/SB (4)	5.7	Wall Township	Monmouth	34B	(L-P-L-P)
NJ-55	SB (2)	27.4	Vineland City	Cumberland	55C	(L-P-L)
NJ-55	NB/SB (4)	57.9	Deptford Twp	Gloucester	552	(L-P-P)
NJ-68	NB/SB (2)	2.4	Springfield Twp	Burlington	068	(L-P-P)
NJ-68	NB/SB (4)	7.0	Mansfield Twp	Burlington	68A	(L-P-L)
NJ-72	EB/WB (2)	2.1	Woodland Twp	Burlington	072	(L-P-P-L)
NJ-73	NB/SB (4)	11.9	Winslow Twp	Camden	073	(L-P-P)
NJ-94	NB/SB (2)	33.8	Hardyston Twp	Sussex	094	(L-P-L)
NJTPK	NB (2)	0.8	Carneys Point Twp	Salem	NJT	(L-P-P-L)
US-1	NB/SB (6)	12.9	Plainsboro Twp	Middlesex	001	(L-P-L-P-L)

Table 4.2 NJDOT Weigh-In-Motion System Sites (2007) ….. Contd.

US-1	NB/SB (4)	18.0	S. Brunswick Twp	Middlesex	01A	(L-P-L-P-L)
US-130	NB/SB (4)	57.0	Bordentown Twp	Burlington	13B	(L-P-P-L)
US-130	NB/SB (4)	70.6	Cranbury Twp	Middlesex	13A	(L-P-L-P)
US-202	NB/SB (4)	3.5	West Amwell Twp	Hunterdon	202	(L-P-P)
US-202	NB/SB (4)	19.2	Branchburg Twp	Somerset	02B	(L-P-L-P-L)
US-22	EB/WB (4)	26.6	Readington Twp	Hunterdon	022	(L-P-P-L)
US-22	EB/WB (4)	32.3	Bridgewater Twp	Somerset	22B	(L-P-P-L)
US-322	EB/WB (4)	27.5	Monroe Twp	Gloucester	322	(L-P-L-P-L)
US-40	EB/WB (4)	3.0	Carneys Point Twp	Salem	40A	EB:(L-P-L-PL) WB:(L-P-P-L)
US-40	EB/WB (2)	28.4	Franklin Twp	Gloucester	040	(L-P-P)
US-40	EB/WB (4)	61.6	Egg Harbor Twp	Atlantic	40B	(L-P-L)
US-46	EB/WB (4)	25.2	Mount Olive Twp	Morris	046	(L-P-L-P-L)
US-9	NB/SB (4)	111.8	Freehold Twp	Monmouth	09A	(L-P-P)
I-295	NB/SB (4)	2.9	Carneys Point	Salem	I2S	(L-BP-BP-L)
US-130	NB/SB (2)	3.4	Penns Grove Boro	Salem	130	(L-BP-BP-L)
NJ-72	EB/WB (4)	25.0	Stafford Twp	Ocean	72B	(L-P-L-P)
US-1&9	SB (7)	48.1	Newark City	Essex	01C	(L-P-L-P-L)
I-78	EB (3)	5.0	Greenwich Twp	Warren	78E	(P-L-P)
I-78	WB (3)	7.9	Bethlehem Twp	Hunterdon	78W	(P-L-P)
I-676	NB/SB (4)		Camden City	Camden	676	(L-P-L-P-L)
I-80	EB/WB (6)	32.4	Roxbury	Morris	80B	(L-P-L-P)
I-80	EB/WB (8)	38.1	Rockaway	Morris	80C	(L-P-L-P)
I-80	EB/WB(4,3)	8.3	Knowlton	Warren	80A	(L-P-L-P)
I-95	NB/SB (6)	1.2	Ewing	Mercer	095	(L-P-L-P)
I-95	NB/SB (6)	6.3	Lawrence Twp	Mercer	95B	(L-P-L-P)
NJ-55	NB/SB (4)	37.0	Vineland City	Cumberland	551	(L-P-L-P)
NJ-57	EB/WB (4)	3.5	Greenwich Twp	Warren	57A	(P-L-P)
NJ-70	EB/WB (2)	10.3	Evesham Twp	Burlington	551	(L-P-L-P-L)
NJ-173	EB/WB (4)	2.4	Greenwich Twp	Warren	173	(P-L-P)
I-78	EB/WB (6)	14.5	Union	Hunterdon	78A	(L-P-P)
I-95	NB (2)	2.1	Ewing	Mercer	952	(L-BP-L)
NJ-17	SB (3)	25.5	Mahwah	Bergen	017	Bending Plates
NJ-31	NB/SB (4)	30.1	Clinton	Hunterdon	031	(L-P-P)
NJ-52	NB/SB (4)	1.6	Ocean City	Cape May	052	(L-P-L)
NJ-440	NB/SB (4)	21.4	Bayone City	Hudson	169	Bending Plates
US-1&9	SB (2) Ex	47.2	Newark City	Essex	01B	(L-P-L-P-L)
US-206	NB/SB (2)	22.0	Southampton	Burlington	206	(L-P-P)

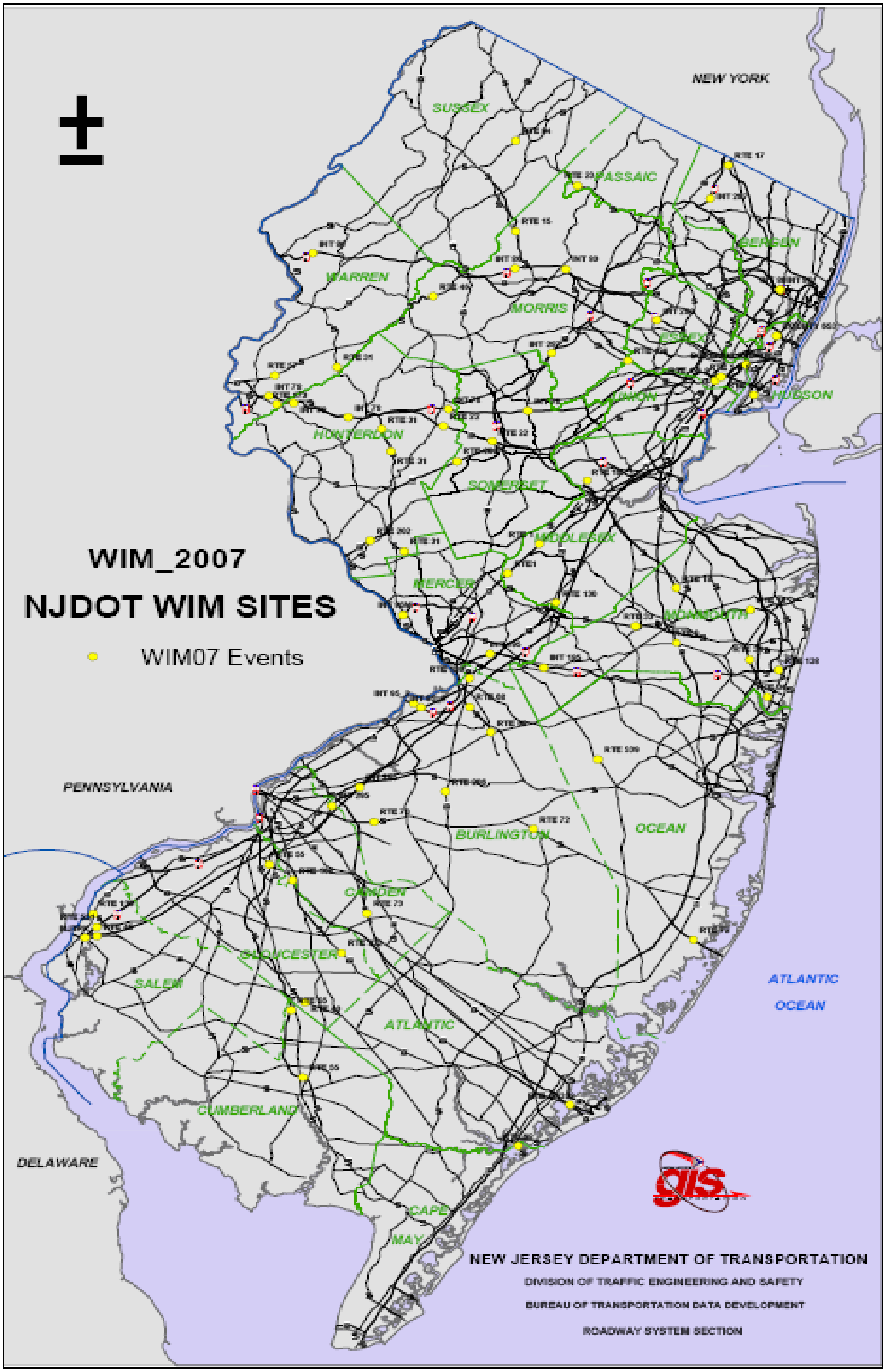


Figure 4.4 New Jersey WIM Sites (NJDOT 2007, http://www.state.nj.us)

4.4 VARIOUS CASE STUDIES CONSIDERED

4.4.1 CASE ONE: LINK WITH TWO NODES (NJ ROUTE 31)

NJDOT WIM Sites 31B and 31D are located along NJ Route 31 state highway at mile posts 13.0, and 26.4. Most of NJ-31 is a two-lane country road except for six miles in Hunterdon County, where it is concurrent with U.S. Route 202.In some places, the two lanes became four eliminating the shoulders along the road side. Major intersections between 31B, and 31D sites are US 202, and NJ 12. Sites 31C and 031 are not considered for the study due to unavailability of required data. Major intersections between 31C and 031 include I-78, and US 22. Along Route 31 are installed four weigh-in-motion stations, out of which three are currently active and collecting data. The sites and their locations are as follows,

Route No.	No. of Travel Lanes	Mile Post	Municipality (Township)	County	Site Name	WIM System Status
NJ-31	NB/SB(2)	13.0	East Amwell	Hunterdon	31B	Active
NJ-31	NB/SB(4)	26.4	Readington	Hunterdon	31D	Active
NJ-31	NB/SB(2)	40.4	Washington	Warren	31C	Active
NJ-31	NB/SB(4)	30.1	Clinton	Hunterdon	031	Not active

Table 4.3 Route NJ-31, Details of WIM Stations

The WIM layout is a Loop-Piezo-Loop-Piezo-Loop configuration for both 31B , and 31D sites. Since the configuration involves the usage of two axle sensors at a distance apart, the axle spacings determined from the vehicle speed is less prone to errors , and ensures good data quality. The site layout, and lane directions are shown in Figure 4.5 below.

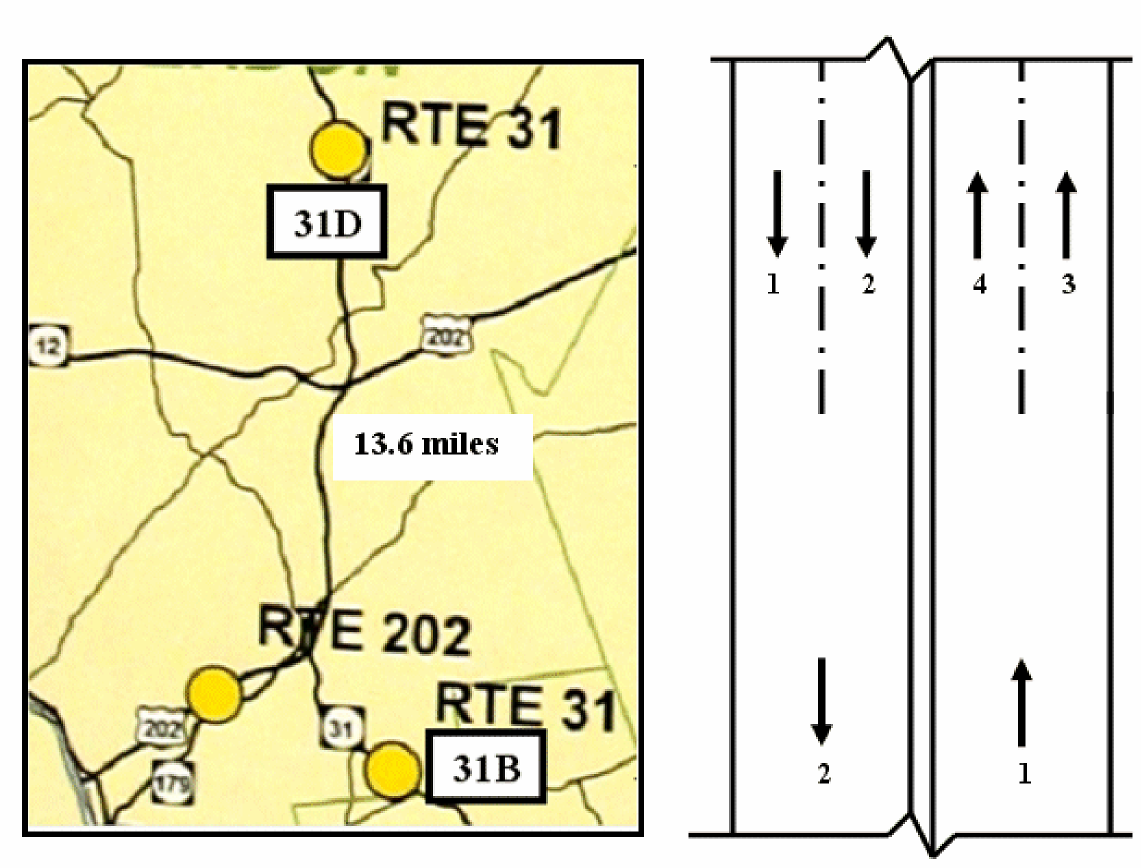
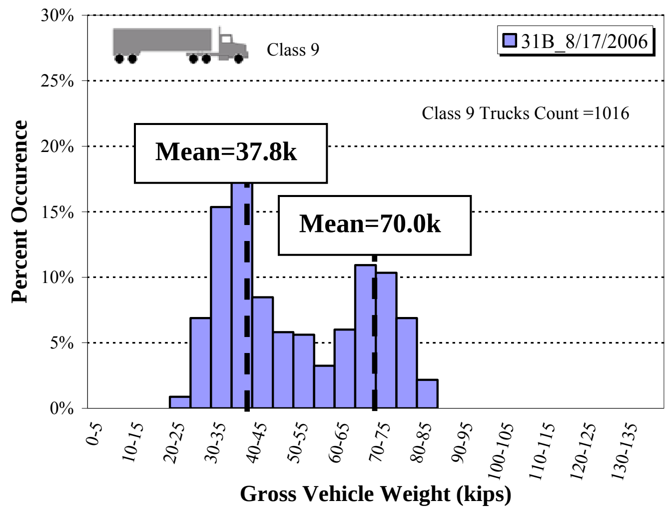


Figure 4.5 WIM stations 31B, 31D, and 31C and, Lane layout along NJ-31

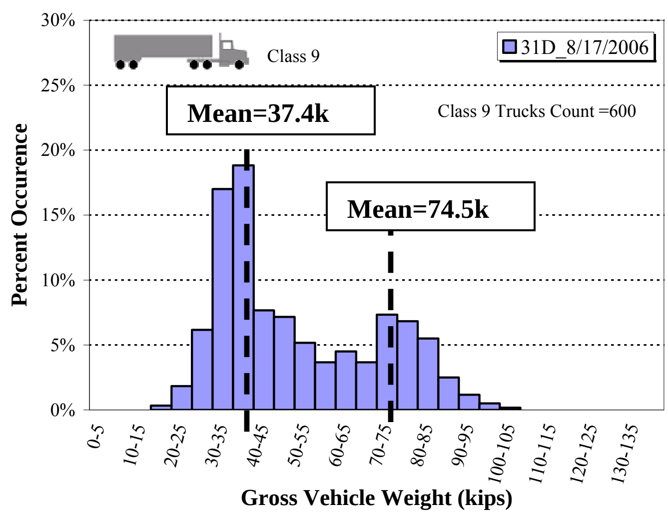
4.4.1.1 Histograms of Class 9 Truck Frequency

The study was primarily emphasized on FHWA's Class 9 trucks since they typically dominate the truck traffic. Foremost, the calibration quality had to be verified to understand if the WIM data collected truly represents the vehicle axle weights or needed an adjustment for the same. The visual interpretation of Class 9 trucks histograms serve as an initial check for calibration. For the plotting of Class 9 histograms, a separate program which filters bad data is run. The filters include Class 9 trucks with front axle weight greater than 12.5 kips , and length of vehicle greater than 50ft with gross vehicle weight lesser than 20 kips. Hence, the Class 9 truck count number provided on histograms is lesser than the truck search output summary results.

As stated earlier, previous studies have shown that, mostly empty trucks approximately weigh in the range of 25 kips to 35 kips, and the heavy trucks in the range of 70 kips to 80 kips. Any shift from this range indicates calibration drifts.



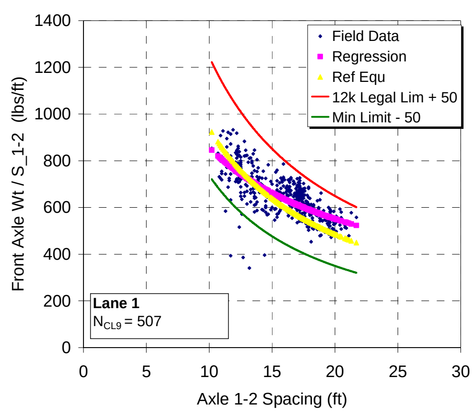
(a) Site 31B



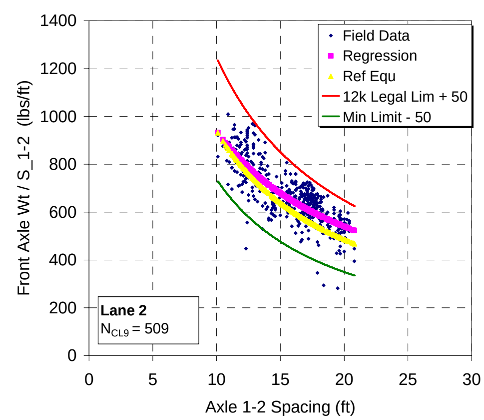
(b) Site 31D

Figure 4.6 Class 9GVW Histograms, 31B, and 31D, 08/17/06

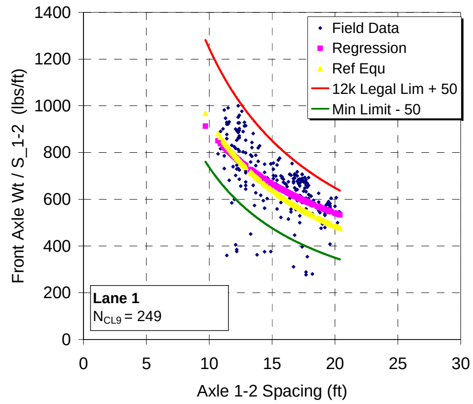
The histograms of Class 9 trucks plotted in Figure 4.6 for 31B and 31D show distinctly two normal distributions corresponding to the lightly loaded trucks, and heavily loaded trucks. The lightly loaded trucks peaked in the range of 35 kips to 40 kips, and the heavily loaded trucks peaked in the range of 70 kips to 80 kips. This provides us with an initial check. However, the calibration was also verified for quality assurance of weigh-in-motion data by using the regression method developed by Herbert. F. Southgate (2000) as described in the previous chapter and the calibration charts were obtained as in Figure 4.7. The plot of steering axle spacing vs. the ratio of the first axle weight to the steering axle spacing should produce a smooth logarithmic decay as the reference equation curve. As seen from the graphs, all the data points are well within the maximum, and minimum limits are compact with no much scatter. Calibration Charts –logarithmic regression method



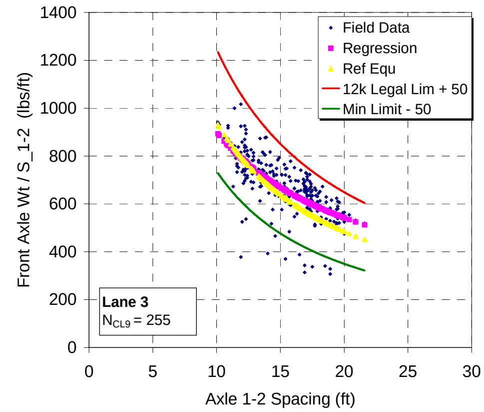
(a) Site 31B, Lane 1



(b) Site 31B, Lane 2



(c) Site 31D, Lane 1



(d) Site 31D, Lane 3

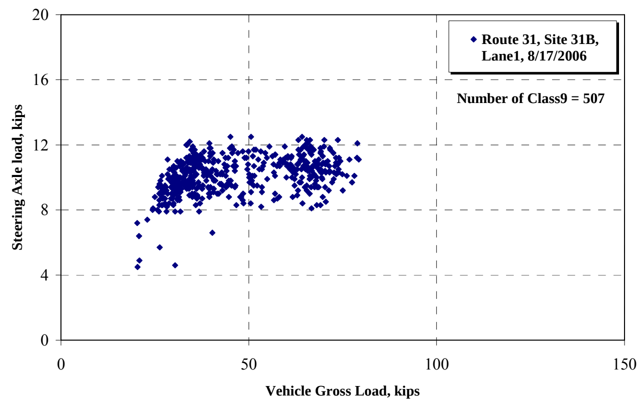
*Note: Lanes 2, and 4 for 31D are not shown as the Class 9 truck volume was lower than 50

Figure 4.7 NJ-31 WIM data Quality assurance using Logarithmic-regressions method, (Southgate, 2001) for 08/17/06

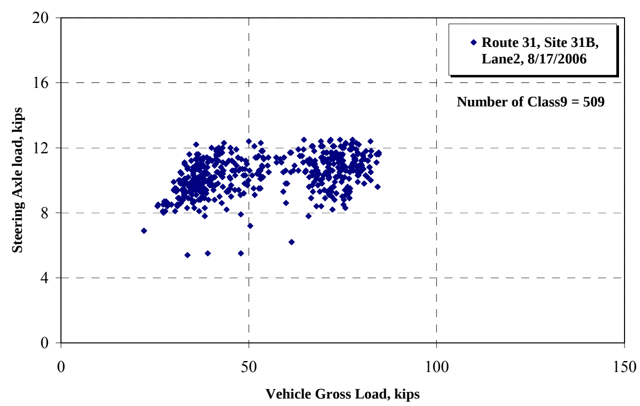
From the above plots, we can say that the calibration for 31B , and 31D sites is reasonably good, since the fit of the WIM data for all lanes shows low divergence from the reference curve , and hence can be concluded that the weights recorded by WIM very closely represents the static weight of axle loads of the traffic stream. As calibration plays an important role in truck identification between sites, Route 31 was chosen to check manually the presence of identical truck on sites 31B, and 31D located 13.6 miles apart as explained in Section 4.4.2.

4.4.1.2 Vehicle Gross load v/s Steering Axle load

Further, the vehicle Gross load was compared to Steering Axle load, and the plotted graphs showed the following for 31B, Steering axle loads range from approximately 8,000lbs to 12,500lbs, and Gross loads Range from approximately 25,000lbs to 85,000lbs which fall in the range of reasonable limits.31D has lower volume of Class 9's compared to 31B , and shows the range for Gross load up to about a 100 kips.

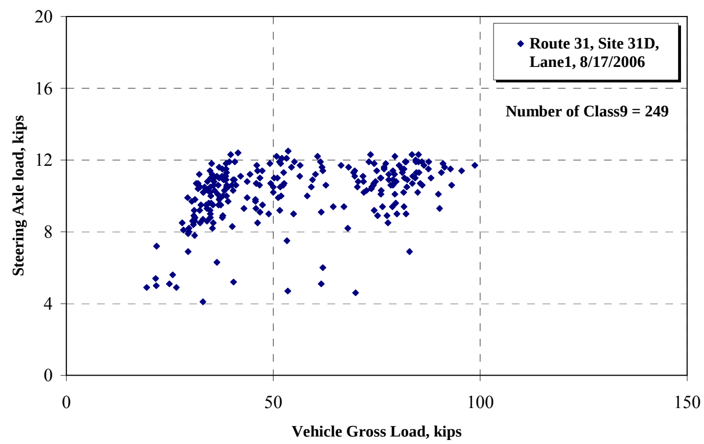


(a) Site 31B, Lane 1

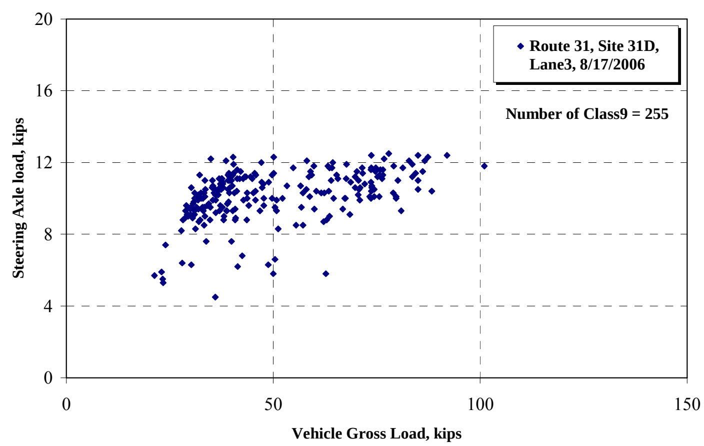


(b) Site 31B, Lane 2

Figure 4.8 gross loads compared to Steering Axle Weight (Front Axle) for Site 31B on 08/17/2006



(c) Site 31D, Lane 1



(d) Site 31D, Lane 3

Figure 4.9 Vehicle gross loads compared to Steering Axle Weight (Front Axle) for Site 31D on 08/17/2006

As a case study, for finding an identical FHWA Class 9 truck along Route 31 between stations 31B , and 31D, check for identical trucks was first done by manual method , and then by the truck identification criteria .

4.4.2 MANUAL PROCEDURE FOLLOWED

Firstly, the time window is calculated as follows. The maximum acceptable driving time was established based on the minimum recorded time assuming a driving speed of 40mph, plus an allowance of 2 to 3 minutes for every traffic stop delay during driving. The minimum travel time was used instead of the actual time difference between WIM stations .The time allowance is calculated from the actual distance between adjacent WIM locations assuming a driving speed of 70 mph. For example, 31B, and 31D sites are located 13.6 miles apart. Hence, the minimum, and maximum limits during manual check was ((13.6/70)*60) = 11 minutes, and ((13.6/40)*60) = 20 minutes. The time range for station 31D to check for truck A was taken as 20 minutes from the minimum time limit of 11 minutes. An additional 10 minutes was considered for any delays during traffic. Therefore, in site 31D, all the class 9 trucks occurring after 6:31 am, for a period of 30 minutes is recorded for the searching process. Accordingly, the truck should be spotted during this time range as per our assumptions in the destination site.

After limiting the number of trucks falling within the time range, the axle spacings are compared, and errors are calculated. Reasonable results were obtained for truck search at sites 31 B, and 31 D in the B direction. Following are two examples to show the matching of trucks between 31B, and 31D manually using excel program.

- The first table in Table 4.4 shows the details of the reference truck at origin i.e., WIM station 31B.
- The second table shows the details of all Class 9 trucks observed between the set time ranges at WIM station 31D.

- The third table compares the truck at 31B , and the suitable match found at 31D showing the calculated errors in axle spacings, gross vehicle weight , and axle weights , and also shows the time taken to travel from 31B to 31D in the Northbound direction.

TRUCK A

Truck A at Station 31B traveling North Bound to 31D situated 13.4 miles apart

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	20	1	9	50	35.6	10.7	8	8.1	4.5	4.3	20.4	4.3	37.7	4.2

Trucks observed between the set time ranges at 31D , and the found suitable match

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	34	4	9	63	26.2	8.6	5	5	3.7	3.8	12.8	4.3	30.2	4
6	39	4	9	65	39	12.1	8.8	8.8	4.9	4.4	20.3	4.3	37.3	4.1
6	51	3	9	55	41.2	10.4	9.2	9.6	6.2	5.8	17.9	4.2	35.2	4
6	57	4	9	62	27.9	9.8	4.9	5.9	3.6	3.8	12.5	4.3	30.4	4
6	59	3	9	58	79.7	10	16.9	16.9	17.4	18.4	18.9	4.3	27.9	4

Calculated %errors for the 'matched truck B' between two stations 31B , and 31D

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	20	1	9	50	35.6	10.7	8	8.1	4.5	4.3	20.4	4.3	37.7	4.2
6	39	4	9	65	39	12.1	8.8	8.8	4.9	4.4	20.3	4.3	37.3	4.1
	19	**min**			**10%**	**13%**	**10%**	**9%**	**9%**	**2%**	**0%**	**0%**	**1%**	**2%**

Table 4.4 Truck A on Day 08/17/2006 on Stations 31B & 31D

The truck A occurred at 31B at 6:20 am weighing 35.6 kips having a 3S2 configuration. The same truck was identified at 31D traveling North Bound at 6:39am weighing 39 kips, and the same 3S2 configuration for axle spacings with less than 2.5% error. During the manual search process, firstly the time stamp of a truck at origin is referred to, and all the class 9 trucks occurring for the time range of 30 minutes from minimum time limit is chosen. All the Class 9 trucks are then compared to the reference truck at the origin. The axle spacings are compared, and the closest match is found thereby. In the following example, it is clearly seen that the steering axle spacing (S1) of truck A at origin has a length of 20.4 feet. In the destination site, the steering axle spacing (S1) of all trucks in the time range is compared, and the closest appears to be the truck arriving at 6:39 am. Next, the axle spacing between Axle 3 and Axle 4 (S3) is compared. Since it happens to match the spacings of the reference truck very closely, , and has no other competitor, it is confirmed that this truck is the same as that at origin which traveled a distance of 13.4 miles , and reached site 31D.For further confirmations of the match, the GVW of the trucks is compared , and errors calculated. The error in GVW measurements between the two stations is about 10% which is reasonable, and can be accounted for the good calibration on both sites. Hence, it can be confirmed that Truck A occurred at both stations. The axle spacings have an error much below the specified limit of ±5%, and so does the vehicle gross load error, the limit being ±10%.A travel time of 19 minutes between stations is also justifiable assuming there was no traffic delays since it occurred in the morning hours.

Similar case of another Class 9 truck is shown .The truck B occurs at 6:36 am, and weighs 26.3 kips. Here, it is seen that the truck B at origin has found more than one match that has axle spacings close to the reference value. Therefore, the two trucks at destination are compared now for GVW with that of the truck at origin. Since, the second truck at the destination suits the one at origin the closest, in terms of S1, S3, and GVW; this is confirmed to be the most suitable match for Truck B at origin.

TRUCK B

Truck B at Station 31B traveling North Bound to 31D situated 13.4 miles apart

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	36	1	9	48	26.3	9.6	5	4.5	3.6	3.6	12.5	4.3	30.6	4

Trucks observed between the set time ranges at 31D, and the found suitable match

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	51	3	9	55	41.2	10.4	9.2	9.6	6.2	5.8	17.9	4.2	35.2	4
6	57	4	9	62	27.9	9.8	4.9	5.9	3.6	3.8	12.5	4.3	30.4	4
6	59	3	9	58	79.7	10	16.9	16.9	17.4	18.4	18.9	4.3	27.9	4
7	1	3	9	56	47.3	10.6	8.7	9.5	9.2	9.4	12.2	4.2	30	4
7	1	3	9	63	47.7	9.6	11.5	10.9	7.9	7.9	19.1	4.3	28.7	10.4

Calculated %errors for the 'matched truck B' between two stations 31B, and 31D

H	M	Ln	Cl	Spd	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
6	36	1	9	48	26.3	9.6	5	4.5	3.6	3.6	12.5	4.3	30.6	4
6	57	4	9	62	27.9	9.8	4.9	5.9	3.6	3.8	12.5	4.3	30.4	4
	21	**min**			**6%**	**2%**	**2%**	**31%**	**0%**	**6%**	**0%**	**0%**	**1%**	**0%**

Table 4.5 Truck B on Day 08/17/2006 on Stations 31B & 31D

It was noted during the manual search process that, during non-peak hours, the number of trucks occurring in the time range at destination varied between 3 to 7, out of which those having configuration similar to the reference truck rarely exceeded 3.However, during peak hours, the number of trucks occurring in the time range increased, but every class 9 truck had its own, unique finger printing of axle spacings S1, and S3 in its 3S2 configuration, which made the identification process quite simple. Also, since the volume of class 9 trucks on this site was not too high, the number of trucks being available for comparisons was low. In this way, the manual search was carried out at various sites when needed. This process seemed to be tedious, and time consuming. Hence, an algorithm was written based on the truck's axle spacings, time of travel, and GVW which was programmed using FORTRAN, and used for further purposes.

4.4.3 FORTRAN Truck search results for sites 31B, and 31D

The Truck search program is run on sites 31B, and 31D along NJ Route 31 for Day 08/17/2006(Thursday).The input parameters for various cases are shown in the table headings respectively. The tables summarize the output obtained from the truck search program. It should be noted that the program was run for all trucks without application of any filters, since it was assumed that any error caused due to non-application of filters would repeat as errors on other stations too. Analysis was carried out for two different cases in either direction, namely;

(i) time delay = 30 min; time tolerance = 20 min; spacings tolerance = 5%

(ii) time delay = 30 min; time tolerance = 20 min; spacings tolerance = 5%; GVW tolerance =20% & 25%

Matches Summary-NB , Day 08/17/2006					
Class	**31B**	**31D**	**#Match**	**%Origin**	**%Destination**
4	47	37	28	60%	76%
5	187	204	141	75%	69%
6	74	103	45	61%	44%
7	62	52	39	63%	75%
8	114	86	26	23%	30%
9	514	330	288	56%	87%
10	10	6	6	60%	100%
11	1	0	0	0%	0%
12	0	0	0	0%	0%
13	4	3	3	75%	100%

Table 4.6 NJ-31 NB, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%

Matches Summary-NB								
GVW tolerance			20%			25%		
Class	31B	31D	#Match	%Org	%Dest	#Match	%Org	%Dest
4	47	37	20	43%	54%	23	49%	62%
5	187	204	66	35%	32%	79	42%	39%
6	74	103	23	31%	22%	26	35%	25%
7	62	52	20	32%	38%	29	47%	56%
8	114	86	20	18%	23%	22	19%	26%
9	514	330	188	37%	57%	217	42%	66%
10	10	6	6	60%	100%	6	60%	100%
11	1	0	0	0%	0%	0	0%	0%
12	0	0	0	0%	0%	0	0%	0%
13	4	3	2	50%	67%	3	75%	100%

Table 4.7 NJ-31 NB, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%; GVW tolerances = 20% & 25%

The following observations were made for case (i), in the NB direction corresponding to trucks traveling from WIM site 31B to 31D,

- From the Summary Table 4.6 it is seen that 514 Class 9 trucks leave the Origin (31B) while 330 trucks arrive at the destination (31D), indicating that a part of the truck population, about a third, is leaving between these two stations. On examining the NJDOT SLD's (Refer APPENDIX B), it is found that a major intersection of NJ 31 with US 202 is present, wherein the trucks are assumed to exit or enter in either direction. Care should also be taken while determining the time range limits for allowances in time delay due to the presence of traffic lights, and slowing down of vehicles.
- More than 50 % of VC9 trucks have seen to be found a suitable match at the destination. However, a major problem confronted is the phenomenon of 'Multiple Hit Criteria' or in simple words, a truck finding more than one suitable matches at its destination within the limits of all parameters. This

proves a concern to the study but is unavoidable. It is mainly due to the of Class 9 trucks in large volumes in the traffic stream , and high similarity in axle configurations; though some Class 9 trucks show unique finger prints in their axle spacings S1 , and S3.

- Class 13 trucks are unique, and 3 out of 4 trucks are found to occur in the destination site. Later, it is seen that the one Class 13 truck traveled towards site 02B along Route US 202, which makes all Class 13 trucks identified.
- Increasing the time tolerance limit increases the number of matches found since it widens the time range limit, which encourages the multiple hit criteria.

Case (ii) analysis in the NB direction showed the following results,

- It is obvious that, by having a weight tolerance factor, the number of class 9 trucks is bound to reduce, owing to the refined results obtained. The process eliminates unreasonable mismatches, and refines the truck search process.
- Each Class 10 truck arriving at the destination proved a genuine, suitable match with respect to the origin.
- It is seen that for 20% GVW tolerance, only 50% of class 13 trucks is successfully identified. On increasing the tolerance to 25%, we find that the other class 13 truck is also included.
- It is found later in the study that the fourth class 13 truck traveling from 31B site is spotted at 02B in the NB direction.
- Having GVW factor in the truck search process, no doubt, helps in the filtering and validation of trucks by weight, but at times, this may prove unreasonable if the calibration drifts vary by lane.

Similar study was carried out in the SB direction, for trucks traveling from 31D to 31B, and the output results are shown below.

Matches Summary-SB , Day 08/17/2006					
Class	31D	31B	#Match	%Origin	%Destination
4	30	37	19	63%	51%
5	192	196	138	72%	70%
6	91	72	39	43%	54%
7	70	51	46	66%	90%
8	85	118	40	47%	34%
9	305	525	243	80%	46%
10	6	12	5	83%	42%
11	3	2	1	33%	50%
12	0	1	0	0%	0%
13	0	2	0	0%	0%

Table 4.8 NJ-31 SB, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%

Matches Summary-SB								
GVW tolerance			20%			25%		
Class	31D	31B	#Match	%Org	%Dest	#Match	%Org	%Dest
4	30	37	14	47%	38%	14	47%	38%
5	192	196	71	37%	36%	78	41%	40%
6	91	72	26	29%	36%	27	30%	38%
7	70	51	41	59%	80%	44	63%	86%
8	85	118	39	46%	33%	39	46%	33%
9	305	525	182	60%	35%	192	63%	37%
10	6	12	4	67%	33%	4	67%	33%
11	3	2	1	0%	0%	1	33%	0%
12	0	1	0	0%	0%	0	0%	0%
13	0	2	0	0%	0%	0	0%	0%

Table 4.9 NJ-31 NB, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%; GVW tolerances = 20% & 25%

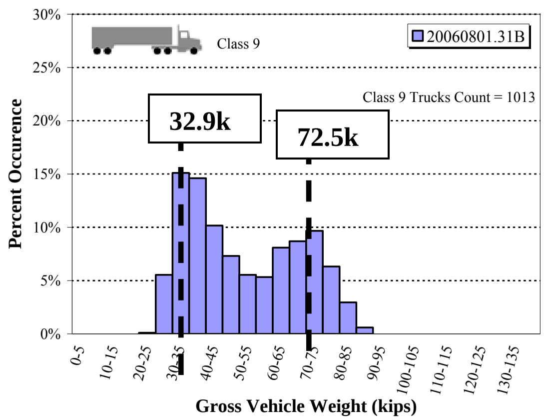
The observations made in the SB direction for case (i) are as follows,

- The truck population arriving at destination has increased due to trucks entering in between the stations. This is noted even for Class 10 trucks.
- About 80% of the Class 9 trucks have found suitable matches.

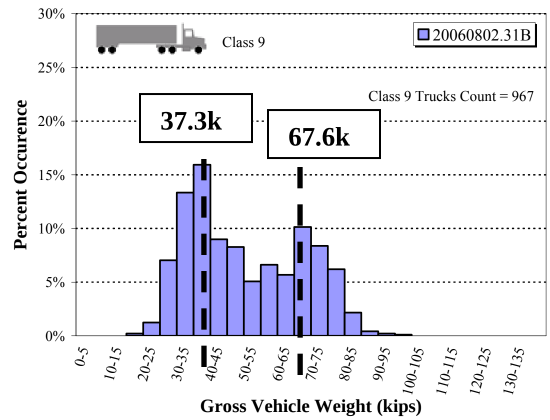
Of all the matched trucks, further analysis can be made in order to eliminate the multiple hits based on the vehicle's GVW. Hence, case (ii) is analyzed.

- The number of matches obtained from case (i), is always high. However, it may have included in itself, more than one match for a single truck with respect to the origin.
- Inclusion of GVW tolerance of 20% showed about 20% decrease in class 9 trucks match number with respect to origin. The results from 25% GVW tolerance showed almost the same percentage of matches.
- Five class 10 trucks are matched from case (i), whereas only four from the case (ii) criteria. On referring to the Appendix A for truck matches obtained, it is found that the truck that was not matched from case (ii) had an error in GVW above 50%.

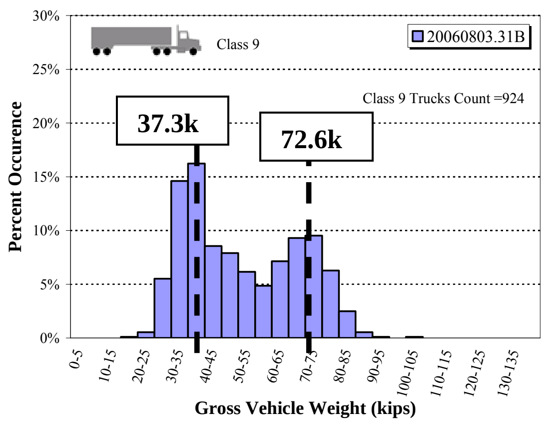
On further analysis of the match results obtained, it is also seen that a truck at origin can have more than one suitable mach after all the other necessary criteria are fulfilled, in which case, it becomes almost impossible to conclude the 'matched truck'. The truck matches obtained in the output are shown in Appendix A. However, the identification of truck classes 10, 11, & 13 is not as difficult for class 9 trucks since they possess a unique configuration in their axle spacings, and are present in a lesser volume compared to the class 9 trucks. In the NB direction, 100% matches are obtained for classes above 9, and are confirmative. The identified' suitable matches' are shown in Appendix A for reference. Further analysis was carried out for a period of five consecutive days from 08/01/2006 (Tuesday) up to 08/05/2006 (Saturday) for more conclusive results. Histograms were plotted, and load ranges were determined to see the bi-modal distributions, and compare calibration on daily basis, checking for drifts.



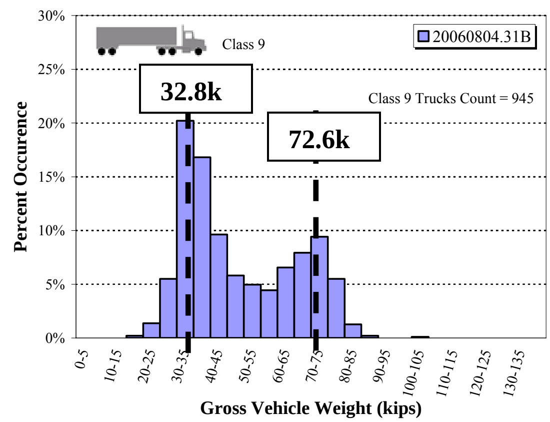
(a) Site 31B , 08/01/06, Tuesday



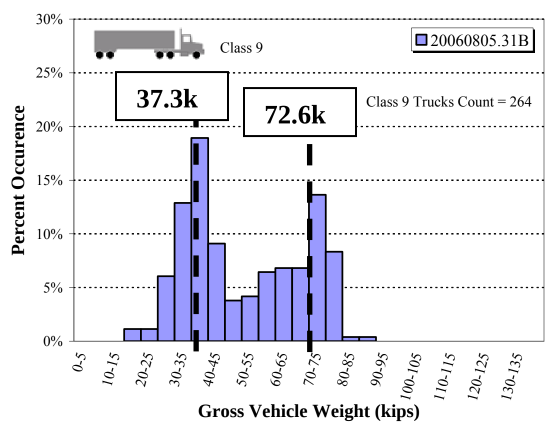
(b) Site 31B, 08/02/06, Wednesday



(c) Site 31B, 08/03/06, Thursday

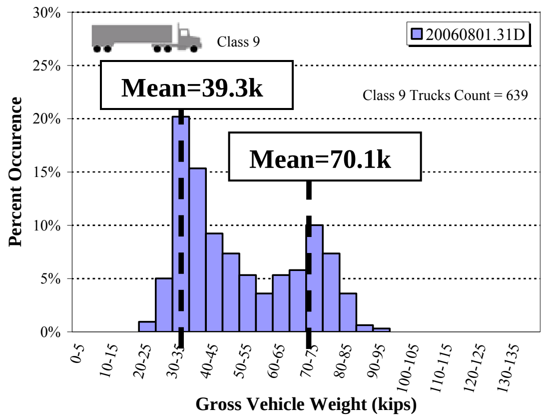


(d) Site 31B, 08/04/06, Friday

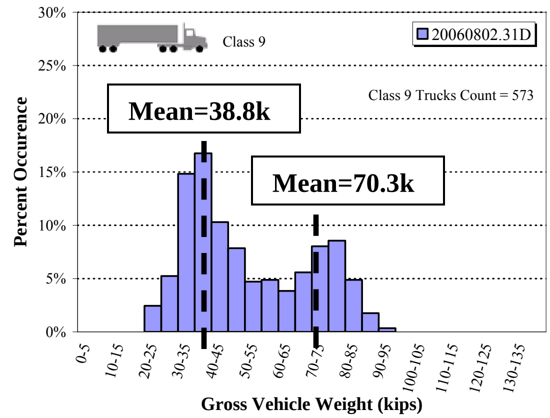


(e) Site 31B, 08/05/06, Saturday

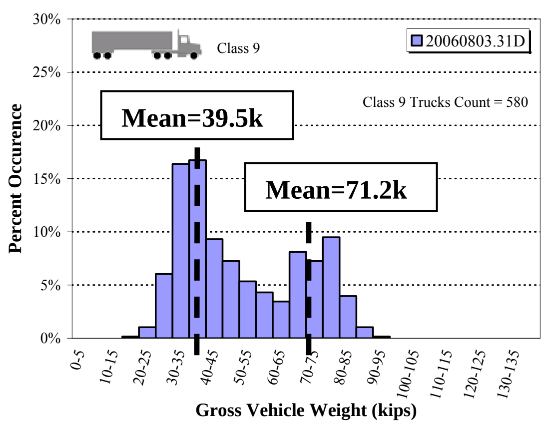
Figure 4.10 Class 9 GVW Histograms, 31B, Days 08/01/06 to 08/05/06



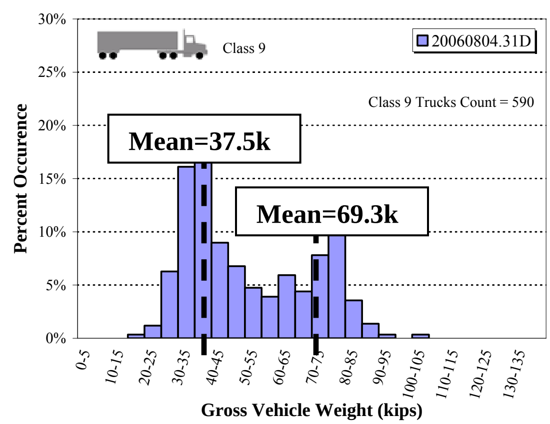
(a) Site 31D, 08/01/06, Tuesday



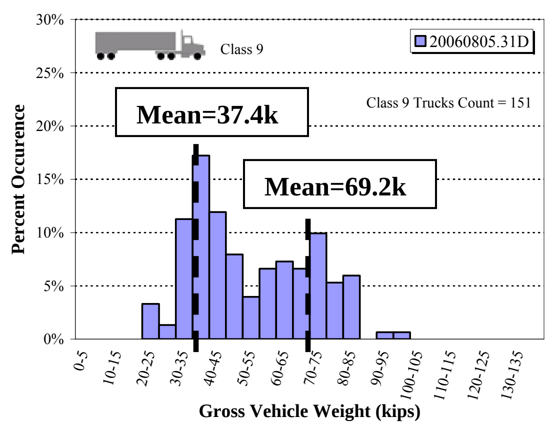
(b) Site 31D, 08/02/06, Wednesday



(c) Site 31D, 08/03/06, Thursday



(d) Site 31D, 08/04/06, Friday



(e) Site 31D, 08/05/06, Saturday

Figure 4.11 Class 9 GVW Histograms, 31D, Days 08/01/06 to 08/05/06

The Class 9 GVW histograms show that the mean values for lightly/partially loaded distribution ranges between 32 kips , and 38 kips, while that of loaded distribution ranges between 72 kips , and 78 kips except for that on Wednesday at site 31B, shows a peak at 67 kips. However, comparing the loaded peak range to site 31D, on the same day, an error of 15% is calculated. It is to be noted that the histograms plotted take into account all the class 9 truck volume for that particular site on a particular day. For calibration by lane, the calibration charts plotted from Southgate method (2000) is to be referred. The following tables show the summary of matches obtained from FORTRAN truck search program for NJ 31 in the NB, and SB directions for the period 08/01/06 to 08/04/06 respectively. The optimum time delay was chosen as 30 minutes, time tolerance as 20 minutes, spacings tolerance limit as 5%, and GVW tolerance limit as 20%.

Matches Summary-SB, Day 08/01/06					
Class	**31D**	**31B**	**#Match**	**%Origin**	**%Destination**
9	508	307	186	37%	61%
10	1	3	1	100%	33%
11	0	0	0	0%	0%
12	1	0	0	0%	0%
13	2	0	0	0%	0%

Tuesday

Matches Summary-SB, Day 08/02/06					
Class	**31D**	**31B**	**#Match**	**%Origin**	**%Destination**
9	522	303	182	35%	60%
10	1	4	0	0%	0%
11	0	1	0	0%	0%
12	1	1	1	100%	0%
13	2	0	0	0%	0%

Wednesday

Matches Summary-SB, Day 08/03/06					
Class	31D	31B	#Match	%Origin	%Destination
9	507	320	184	36%	58%
10	5	7	2	40%	29%
11	0	0	0	0%	0%
12	2	0	0	0%	0%
13	0	1	0	0%	0%

Thursday

Matches Summary-SB, Day 08/04/06					
Class	31D	31B	#Match	%Origin	%Destination
9	453	310	160	35%	52%
10	4	2	1	25%	50%
11	1	1	0	0%	0%
12	1	0	0	0%	0%
13	0	0	1	0%	0%

Friday

Table 4.10 NJ-31, NB, 08/01/06 to 08/05/06, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%; GVW tolerance= 20%

The following observations are made:

- About 60% of Class 9 trucks by volume arrived at the destination site, 31D.
- 80% of Class 9 trucks arriving at the destination site proved suitable matches for trucks at the Origin. Some matches are genuine while some are multiple matches.
- The problem faced is multiple hits of trucks, which can only be prevented by means of utilizing a visual identification system.

Similar analysis in the South Bound direction gave the following output results,

Matches Summary-SB, Day 08/01/06					
Class	31D	31B	#Match	%Origin	%Destination
9	355	608	292	82%	48%
10	3	3	1	33%	33%
11	1	2	1	100%	50%
12	1	3	1	100%	33%
13	2	5	2	100%	40%

Tuesday

Matches Summary-SB, Day 08/02/06					
Class	**31D**	**31B**	**#Match**	**%Origin**	**%Destination**
9	315	579	251	80%	43%
10	7	11	5	71%	45%
11	1	2	1	100%	50%
12	0	1	0	0%	0%
13	3	2	2	67%	100%

Wednesday

Matches Summary-SB, Day 08/03/06					
Class	**31D**	**31B**	**#Match**	**%Origin**	**%Destination**
9	298	579	247	83%	43%
10	6	9	1	17%	11%
11	2	4	2	100%	50%
12	0	1	0	0%	0%
13	0	0	0	0%	0%

Thursday

Matches Summary-SB, Day 08/04/06					
Class	**31D**	**31B**	**#Match**	**%Origin**	**%Destination**
9	311	508	240	77%	47%
10	5	10	2	40%	20%
11	1	3	1	100%	33%
12	0	1	0	0%	0%
13	0	0	0	0%	0%

Friday

Table 4.11 NJ-31, NB, 08/01/06 to 08/05/06, time delay = 30 minutes; time tolerance = 20 minutes; spacings tolerance = 5%

The observations made in the South Bound direction are listed below,

- The volume of class 9 trucks in 31B is more than one half times as that of 31D.A reasonable assumption of an entry point(s) in between sites can be made.
- More than 80% of class 9 trucks have been identified as suitable matches between Origin (31D), and Destination (31B).

- It seems from the graphs that site 31D weighs a little more. This is conformed from the GVW v/s Front Axle weight graph for 31D, Figure 4.9, where in the data points plotted indicated trucks greater than 80k kips, accounted for the calibration being a little high. However, this does not affect the process of truck search to a great extent.
- Overall, the sites 31B, and 31D provided reasonable results during the truck search process, and served as a good example for the application of the proposed algorithm.

4.4.4 CASE TWO: LINK WITH TWO NODES (ROUTE I-295)

Along interstate I-295 are located adjacent WIM sites I2C & 295 at Mile posts 35.7, and 39.6, in Camden, and Burlington Counties respectively. The lane layout is as shown below. The sites are located 3.9 miles apart.

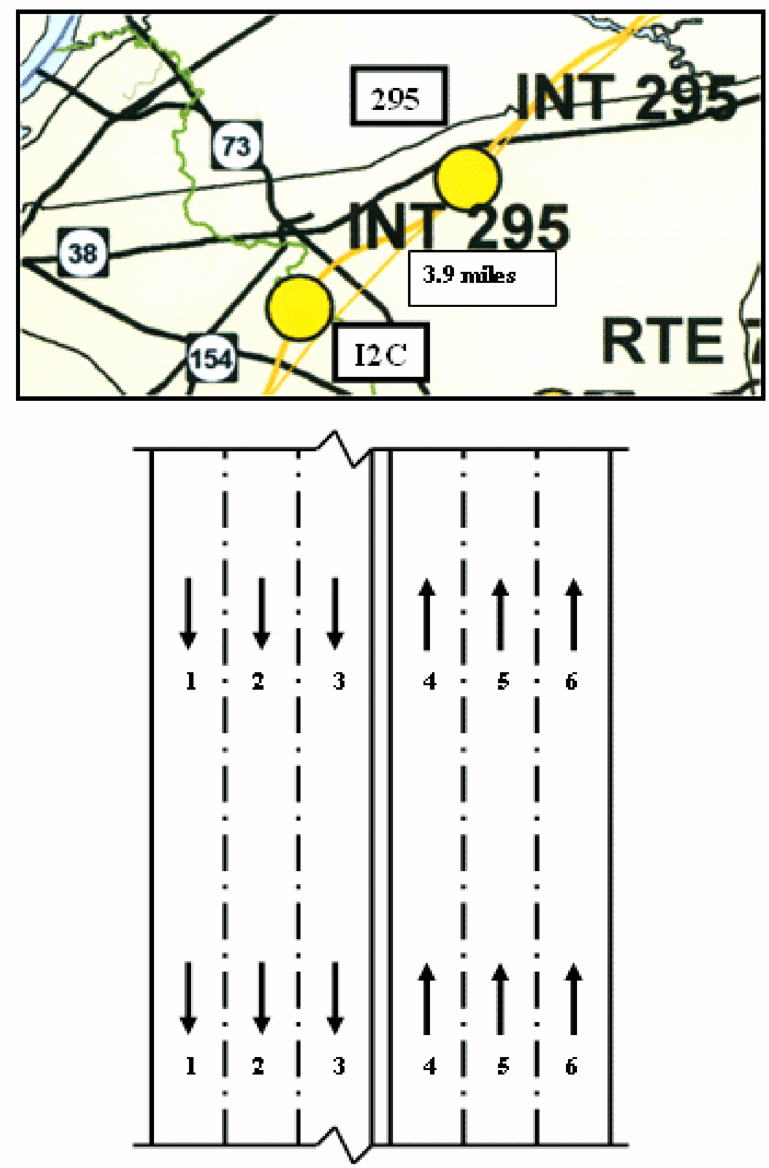
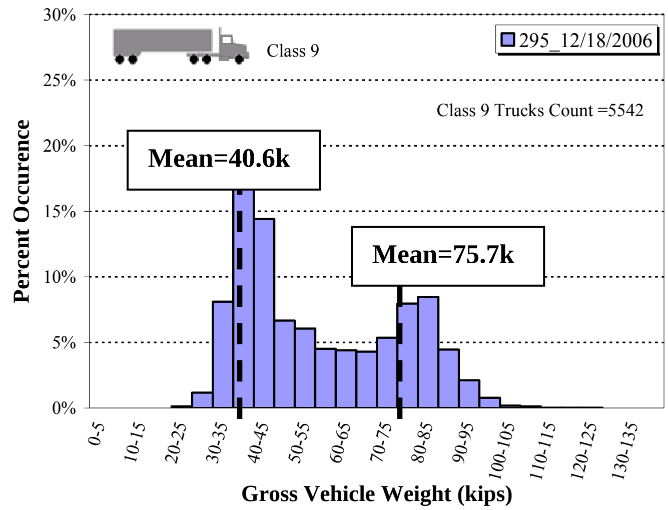


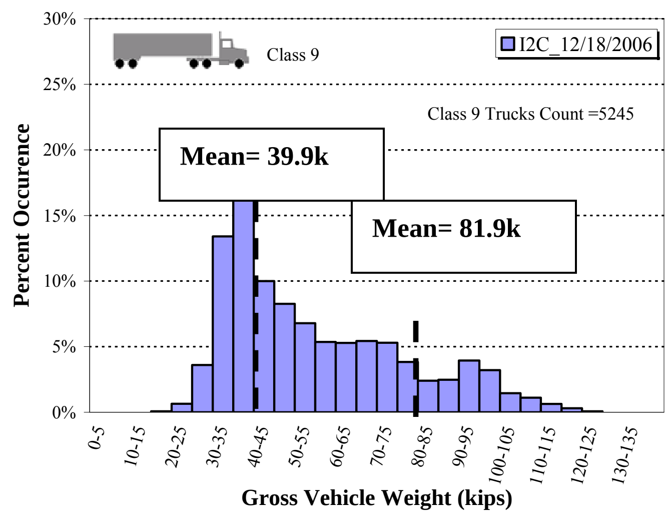
Figure 4.12 WIM stations I2C & 295, and Lane layout along I-295

4.4.4.1 Histograms of Class 9 Truck Frequency

The Class 9 GVW histograms plotted for sites I2C , and 295show that at site I2C , the heavily loaded peak distribution shows a mean value of 92 kips which is high since the weight limit for class 9 trucks is about 80 kips. This is a relative error of about 12 %.



(a) Site 295

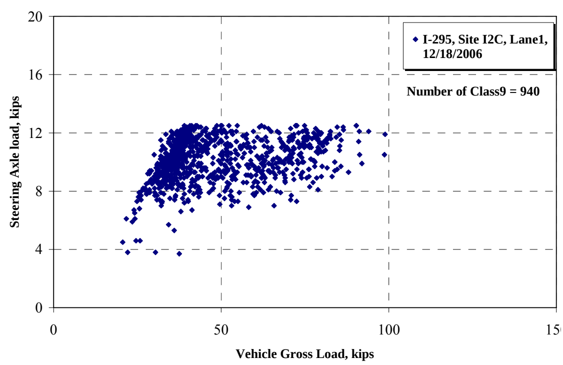


(b) Site I2C

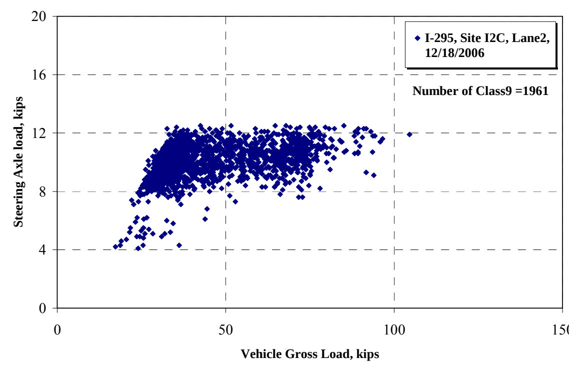
Figure 4.13 Class 9 gross vehicle weight histograms for Sites I2C & 295.

4.4.4.2 Vehicle Gross load v/s Steering Axle load

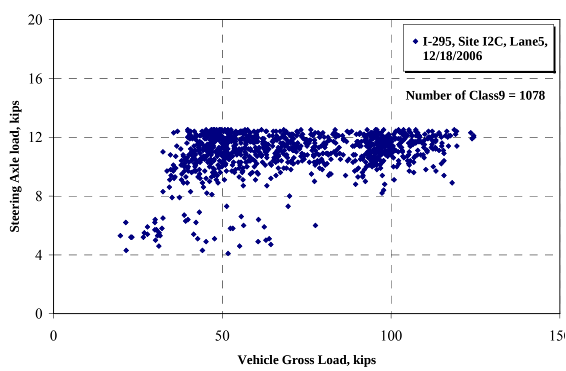
A plot of the GVW's of all class 9 trucks occurring in the NB lane (Lanes 4,5 , and 6) for I2C, on the day 12/18/2006 is shown in Figure 4.14 , and is seen that a reduction of 15% in its GVW is reasonable. The line indicates the 80 kips maximum enforced weight limit.



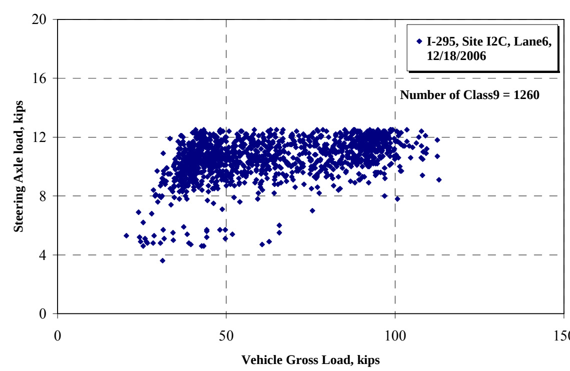
(a) Site I2C, Lane 1



(b) Site I2C, Lane 2



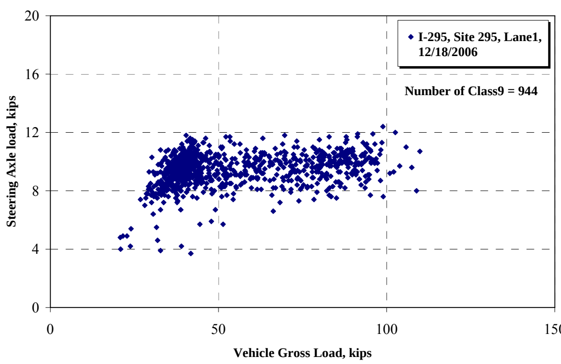
(c) Site I2C, Lane 5



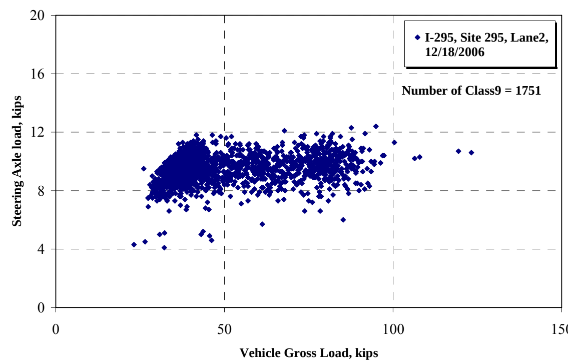
(d) Site I2C, Lane 6

Figure 4.14 Vehicle gross loads compared to Steering Axle Weight (Front Axle) for Site I2C on 12/18/2006

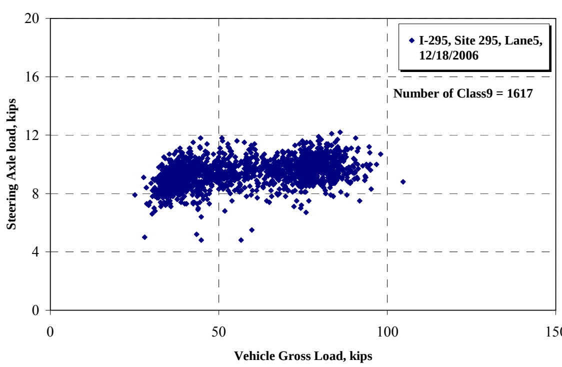
The graphs in Figure 4.14 for lanes 5, and 6 shows a spread above 100 kips sounding a little unreasonable. Hence, in the NB direction, an adjustment factor of 1.15 is fed in the input section, and results are obtained. Figure 4.15 show the graphs for site 295.Exept a few outliers, the calibration seems reasonable, and ready to use for comparisons.



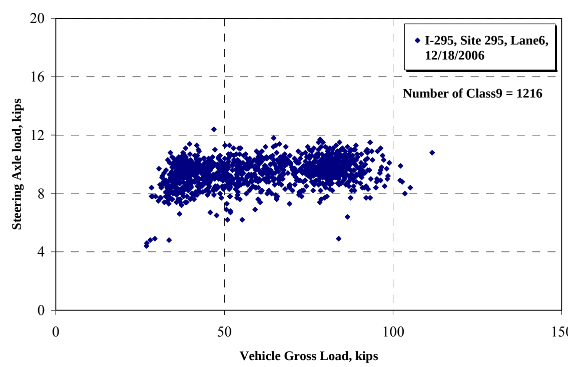
(a) Site 295, Lane 1



(b) Site 295, Lane 2

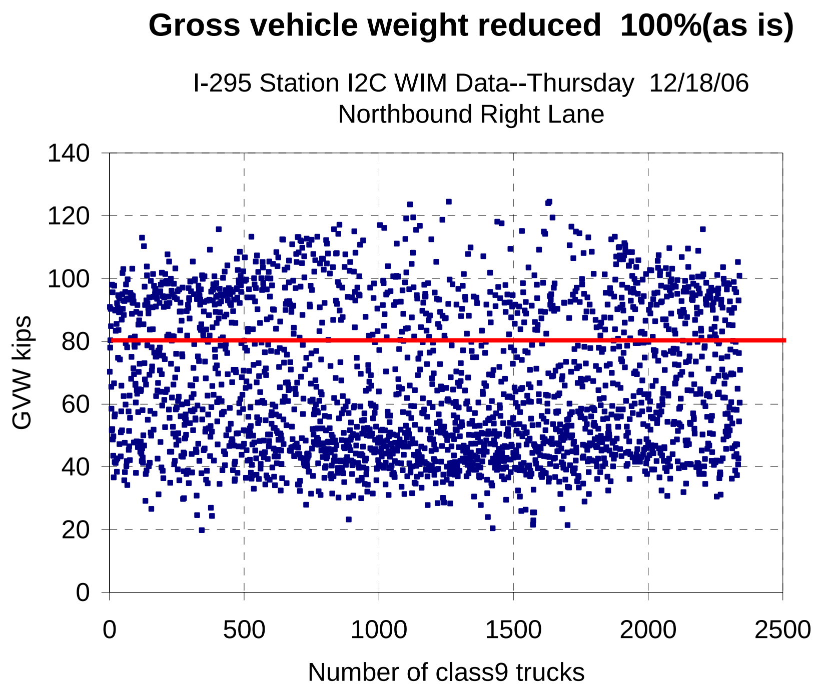


(c) Site 295, Lane 5



(d) Site 295, Lane 6

Figure 4.15 Vehicle gross loads compared to Steering Axle Weight (Front Axle) for Site 295 on 12/18/2006



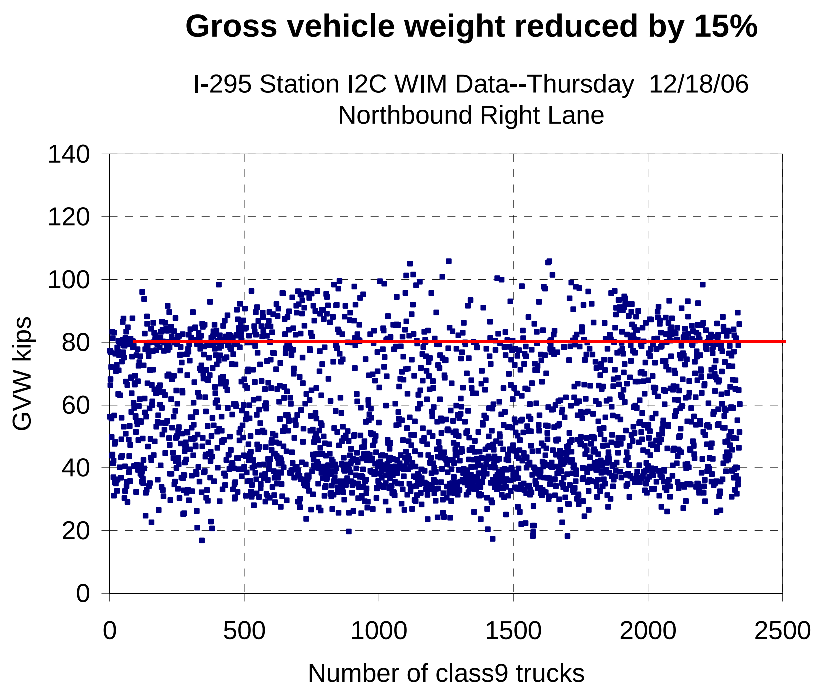
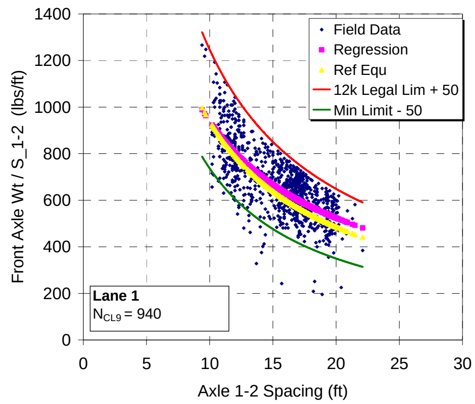
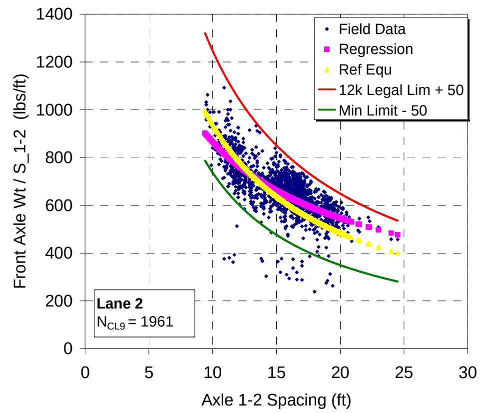


Figure 4.16 Gross Vehicle weights reduced by a factor of 15% on site I2C

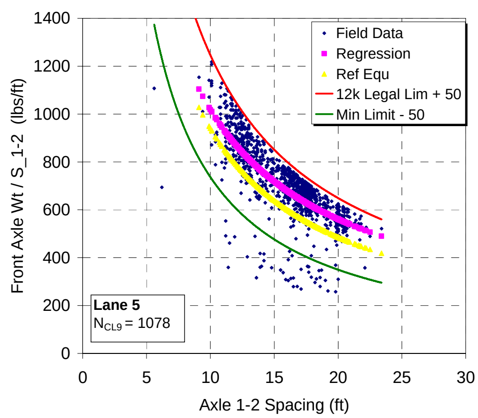
4.4.4.3 Calibration Charts –logarithmic regression method



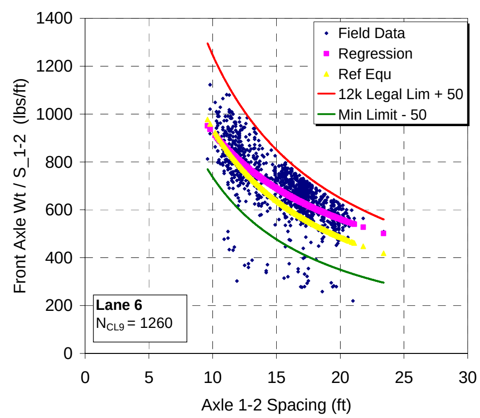
(a) Site I2C, Lane 1



(b) Site I2C, Lane 2



(c) Site I2C, Lane 5

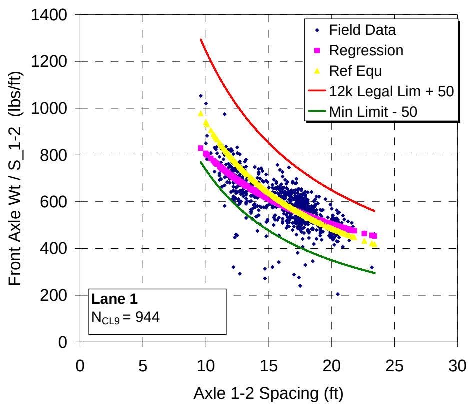


(d) Site I2C, Lane 6

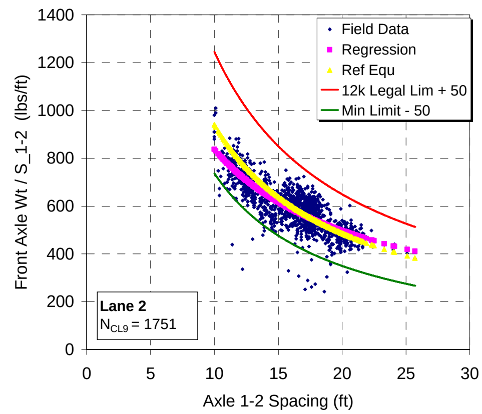
*Note: Lanes 3, and 4 for both site s is not shown as the number of trucks was less than 10

Figure 4.17 WIM Quality Control, logarithmic regressions of axle weight, and spaces for NJ Site I2C on 12/18/06

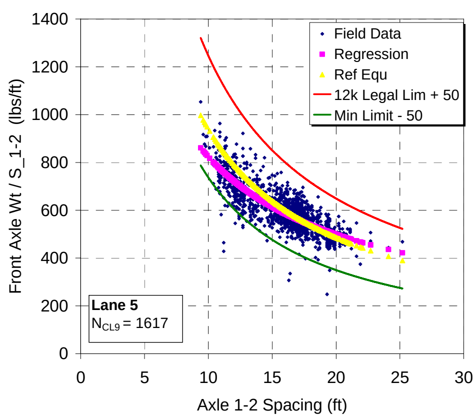
A closer look at the calibration charts by lane proves that Lanes 5 and 6 are calibrated towards a higher side. We can see the shift since all the data points are shifted towards the maximum limit. Also, Figure 4.17 indicates the same for lanes 5, and 6 of I2C.Hence, it is necessary to adjust for calibration at I2C in the NB direction using the FORTRAN program for screening mismatches in the truck identification process. The calibration charts of site 295 show the quality of calibration is good. Since all the data



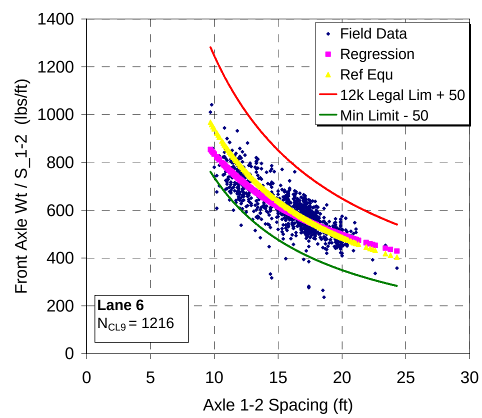
(a) Site 295, Lane 1



(b) Site 295, Lane 2



(c) Site 295, Lane 5



(d) Site 295, Lane 6

*Note: Lanes 3, and 4 for both sites is not shown as the number of trucks was less than 10

Figure 4.18 WIM Quality Control, logarithmic regressions of axle weight, and spaces for NJ Site 295 on 12/18/06

points are well within the defined limits, and are compact by nature, showing very low divergence from the reference curve, it can be concluded that the calibration on this site is very good.

A manual check was carried out before the program could be run. Significant discrepancies in times at site I2C was noted in both NB and SB directions, which could be attributed to improper clock settings of the system. In the NB direction, for trucks traveling from sites I2C to 295, it was observed during the manual check process that the truck at destination arrived at destination after only a minute's travel from the origin. This was concluded based on the observations of Class 11 trucks since they appeared to occur frequently at reasonable time interval. Also, in the SB direction, the truck seemed to take longer to reach its destination after considering all travel time factors. The speeds of trucks were taken in to account, and max, and min time limits were calculated, and it was found that an assumption of 4 to 5 minutes delay was quite reasonable. Hence, 5 minutes should be subtracted in both directions for all trucks on site I2C. In order to eliminate these discrepancies; input parameters in FORTRAN were adjusted for time factor to obtain reasonable results. The FORTRAN output results in the NB direction i.e., for trucks traveling from site I2C to 295 for Day 12/18/2006 are obtained as below.

Matches Summary-NB , Day 12/18/06					
Class	**I2C**	**295**	**#Match**	**%Origin**	**%Destination**
9	3269	2843	1688	52%	59%
10	43	40	5	12%	13%
11	33	19	9	0%	0%
12	3	1	0	0%	0%
13	2	2	1	50%	50%

Table 4.12 I-295 NB, time delay=5 min, time tolerance=4 min, spacings tolerance=5%

The first trial was run based on a time delay of 5 min, and time tolerance of 4 min, having time range from 1 min to 9 min for the truck search at destination. It was noted that some trucks go unrecorded as suitable matches because of the variables in the time window. Next trial was run for a time delay of 2 min, and time tolerance of 2 min, therefore, searching in the range from 0 min to 4 min, which in reality is illogical. But due to the time discrepancies, the FORTRAN program parameters were adjusted to suit accordingly. It was found to give the expected results after comparing with the manual results. Hence, these parameters were chosen for further study. Table 4.13 shows the results for the same.

Matches Summary- NB , Day 12/18/06					
Class	I2C	295	#Match	%Origin	%Destination
9	3269	2843	2161	66%	76%
10	43	40	25	58%	63%
11	33	19	18	0%	0%
12	3	1	1	0%	0%
13	2	2	2	100%	100%

Table 4.13 I-295 time delay=2min, time tolerance=2min, spacings tolerance=5%

Matches Summary- NB , Day 12/18/06					
Class	I2C	295	#Match	%Origin	%Destination
9	3269	2843	812	25%	29%
10	43	40	15	35%	38%
11	33	19	12	0%	0%
12	3	1	0	0%	0%
13	2	2	2	100%	100%

Table 4.14 I-295 NB time delay=2min, time tolerance=2min, spacings tolerance=5%; weight tolerance=20%

Matches Summary- NB , Day 12/18/06					
Class	I2C	295	#Match	%Origin	%Destination
9	3269	2843	1718	53%	60%
10	43	40	22	51%	55%
11	33	19	17	0%	0%
12	3	1	0	0%	0%
13	2	2	2	100%	100%

Table 4.15 I-295 NB time delay=2min, time tolerance=2min, spacings tolerance=5%; weight tolerance=20%; calibration factor = 1.15 at I2C

The following were observed for the run without any tolerance for GVW,

a) **No GVW tolerance**: About 65% of Class 9 trucks were suitably matched .However, on investigating the matches, it is found that some trucks have a huge difference in their GVW's. But, for classes 11, 12, and 13 the matches found were reasonably good, and confirmative.

b) **GVW tolerance of 20%:** Next, a GVW tolerance of 20% was added as an additional filter criterion after the axle spacings, and time windows matched. It was found that the results only outputted trucks from (a) except that the GVW difference between that of the origin truck, and destination truck was below 20% tolerance limit.

c) **Adjustment factor of 1.15 at I2C, and GVW tolerance of 20%:** A more refined way of identifying trucks would be to add an adjustment factor after deciding its value from the calibration charts, histograms, and manual verifications. The same was done at site I2C wherein, all the class 9 trucks GVW was reduced by a factor of 1.15 to achieve accurate results. The truck matches for a period of 15 minutes is shown in the Appendix A, for the NB direction (I2C to 295). Also, for comparison purposes, the same is shown also for (a) having a total of 48 truck cases occurring between 10:00 am, and 10:15 am. When the Calibration was adjusted by a factor of 1.15, the numbers of class 9 truck matches were 38, , and as seen from the tables, it is clear that this is the best case scenario since it adjusted for the calibration , and also survived the GVW tolerance limit.

d) By doing so, the process of truck search can be refined, and proves the most reasonable way of going about the identification process.

Matches Summary-SB , Day 12/18/06					
9	2709	3076	2078	77%	68%
10	30	36	13	43%	36%
11	12	28	8	0%	0%
12	3	4	1	0%	0%
13	4	5	3	75%	60%

Table 4.16 I-295, SB, Day 12/18/2006 time delay=10min, time tolerance=4min, spacings error=6%

Matches Summary- SB , Day 12/18/06					
Class	**295**	**I2C**	**#Match**	**%Origin**	**%Destination**
9	2709	3076	1622	60%	53%
10	30	36	13	43%	36%
11	12	28	5	42%	18%
12	3	4	0	0%	0%
13	4	5	3	75%	60%

Table 4.17 I-295, SB, Day 12/18/2006 time delay=10min, time tolerance=4min, spacings error=6%; GVW tolerance 20%

Matches Summary- SB , Day 12/18/06					
Class	**295**	**I2C**	**#Match**	**%Origin**	**%Destination**
9	2709	3076	1316	49%	43%
10	30	36	11	37%	31%
11	12	28	5	42%	18%
12	3	4	0	0%	0%
13	4	5	3	75%	60%

Table 4.18 I-295, SB, Day 12/18/2006 time delay=10min, time tolerance=4min, spacings error=6%; GVW tolerance 15%

The truck matches in the SB direction as shown in Table 4.16 from the manual checking process, it was found that an error of 6 5 in axle spacings is reasonable, and due to the time discrepancies on site I2C, adjustments had to be made in order to obtain accurate results. Since the calibration on lanes 1, and 2 for both sites I2C, and 295 show compactness, and low divergence from the reference equation, it is reasonable to compare the data as is for the truck search process.

Analysis on hourly truck volumes for classes 9 and above trucks were made and summarized in the following tables for NB and SB directions respectively.

NB, # trucks	Class 9			Class 10			Class 11			Class 12			Class 13		
Time by Hour	I2C	295	#M	I2C	295	#M	I2C	295	#M	I2C	295	#M	I2C	295	#M
12:00am-1:00am	57	51	12	-	-	-	-	-	-	-	-	-	-	-	-
1:00am - 2:00am	55	45	3	-	-	-	1	-	-	-	-	-	-	-	-
2:00am - 3:00am	96	80	18	1	-	-	-	-	-	-	-	-	-	-	-
3:00am - 4:00am	99	101	20	-	-	-	1	1	1	-	-	-	-	-	-
4:00am- 5:00am	137	116	17	1	1	-	1	-	-	-	-	-	-	-	-
5:00am- 6:00am	136	123	35	2	1	-	1	-	-	-	-	-	-	-	-
6:00am - 7:00am	128	97	18	3	3	-	-	-	-	-	-	-	-	-	-
7:00am - 8:00am	32	111	3	-	1	-	-	1	-	-	-	-	-	-	-
8:00am- 9:00am	157	130	99	3	5	3	-	-	-	-	-	-	-	-	-
9:00am - 10:00am	257	190	168	5	6	4	-	-	-	1	-	-	-	-	-
10:00am - 11:00am	247	209	162	-	3	-	1	-	-	-	-	-	-	-	-
11:00am- 12:00pm	248	190	131	2	1	-	3	1	1	-	-	-	-	-	-
12:00pm - 1:00pm	247	197	115	7	6	3	3	1	1	-	-	-	-	-	-
1:00pm - 2:00pm	191	166	104	5	3	3	2	2	2	1	1	-	1	1	1
2:00pm - 3:00pm	189	154	117	4	4	3	2	1	-	-	-	-	1	1	1
3:00pm - 4:00pm	174	154	115	2	1	1	-	-	-	-	-	-	-	-	-
4:00pm - 5:00pm	166	152	116	2	2	2	1	1	1	-	-	-	-	-	-
5:00pm - 6:00pm	126	118	78	2	1	1	-	-	-	-	-	-	-	-	-
6:00pm - 7:00pm	104	86	66	-	-	-	-	-	-	1	-	-	-	-	-
7:00pm - 8:00pm	91	81	68	-	-	-	2	1	1	-	-	-	-	-	-
8:00pm - 9:00pm	67	59	49	-	-	-	3	1	1	-	-	-	-	-	-
9:00pm - 10:00pm	77	64	58	1	-	-	2	1	1	-	-	-	-	-	-
10:00pm - 11:00pm	94	87	74	3	2	2	8	8	8	-	-	-	-	-	-
11:00pm - 12:00pm	95	82	72	-	-	-	2	-	-	-	-	-	-	-	-

Table 4.19 Volumes and Matches by hour on day 12/18/2006, North Bound; axle spacings tolerance-5%, Calibration adjustment factor at I2C= 1.15, GVW tolerance= 20%

Discrepancy was noted during the hour 7:00am to 8:00am on site I2C, since the WIM data showed records only up to 7:15 am and hence that low volume. The numbers of matches shown in these tables are for a GVW tolerance of 20%. It is to be noted that the calibration was carried out for all lanes in the NB direction for all trucks. In cases where only the heavy trucks need calibration, it is important to adjust only the heavy truck stream, not giving a chance to over or under estimate the partially loaded truck weights. The number of multiple matches is very low as the GVW tolerance is increased. Hence, the ultimate goal is to output the number of right matches rather than the numbers by volume. The results of the analysis made in the south bound direction, where no calibration adjustments were needed is shown in the table below. A GVW tolerance of 20% was applied .From both the tables, it is clear that there are exits and entries in-between sites and hence the results can be justified.

SB, # trucks	Class 9			Class 10			Class 11			Class 12			Class 13		
Time by Hour	**295**	**I2C**	**#M**	**295**	**I2C**	**#M**	**295**	**I2C**	**#M**	**295**	**I2C**	**#M**	**295**	**I2C**	**#M**
12:00am-1:00am	16	27	9	-	-	-	-	-	-	-	-	-	-	-	-
1:00am - 2:00am	27	29	12	-	-	-	-	1	-	-	-	-	-	-	-
2:00am - 3:00am	25	30	12	-	-	-	1	1	-	1	1	-	-	-	-
3:00am - 4:00am	41	48	16	-	-	-	-	-	-	-	-	-	-	-	-
4:00am- 5:00am	41	53	15	-	-	-	-	1	-	-	-	-	-	-	-
5:00am- 6:00am	74	76	35	1	2	-	-	-	-	-	-	-	-	-	-
6:00am - 7:00am	115	131	69	2	3	1	-	1	-	-	-	-	-	-	-
7:00am - 8:00am	150	41	13	6	2	2	1	-	-	-	-	-	-	-	-
8:00am- 9:00am	142	181	88	1	1	1	1	1	1	-	-	-	1	-	1
9:00am - 10:00am	189	255	144	5	5	4	2	2	1	-	-	-	1	2	1
10:00am - 11:00am	224	273	150	-	3	-	-	1	-	1	-	-	-	-	-
11:00am- 12:00pm	242	282	179	4	5	3	-	-	-	-	-	-	-	-	-
12:00pm - 1:00pm	233	292	174	1	4	-	1	1	1	-	-	-	1	2	-
1:00pm - 2:00pm	197	246	128	2	5	-	-	1	-	-	-	-	-	-	-
2:00pm - 3:00pm	193	240	131	2	3	-	-	-	-	-	-	-	-	-	-
3:00pm - 4:00pm	134	172	96	4	1	1	1	2	-	-	-	-	-	-	-
4:00pm - 5:00pm	121	138	86	-	1	-	1	1	1	-	-	-	-	-	-
5:00pm - 6:00pm	100	67	16	1	-	-	-	1	-	-	1	-	-	-	-
6:00pm - 7:00pm	104	127	67	1	1	1	1	-	-	1	-	-	1	-	1
7:00pm - 8:00pm	68	79	43	-	-	-	2	4	1	-	-	-	-	1	-
8:00pm - 9:00pm	92	95	51	-	-	-	-	1	-	-	1	-	-	-	-
9:00pm - 10:00pm	73	81	39	-	-	-	-	-	-	-	-	-	-	-	-
10:00pm - 11:00pm	56	65	31	-	-	-	-	2	-	-	-	-	-	-	-
11:00pm - 12:00pm	52	48	18	-	-	-	1	7	-	-	1	-	-	-	-

Table 4.20 Volumes and Matches by hour on day 12/18/2006, South Bound; axle spacings tolerance-6%, GVW tolerance= 20%

4.4.5 INTERSECTION ROUTE 31 & ROUTE 202 (THREE NODE)

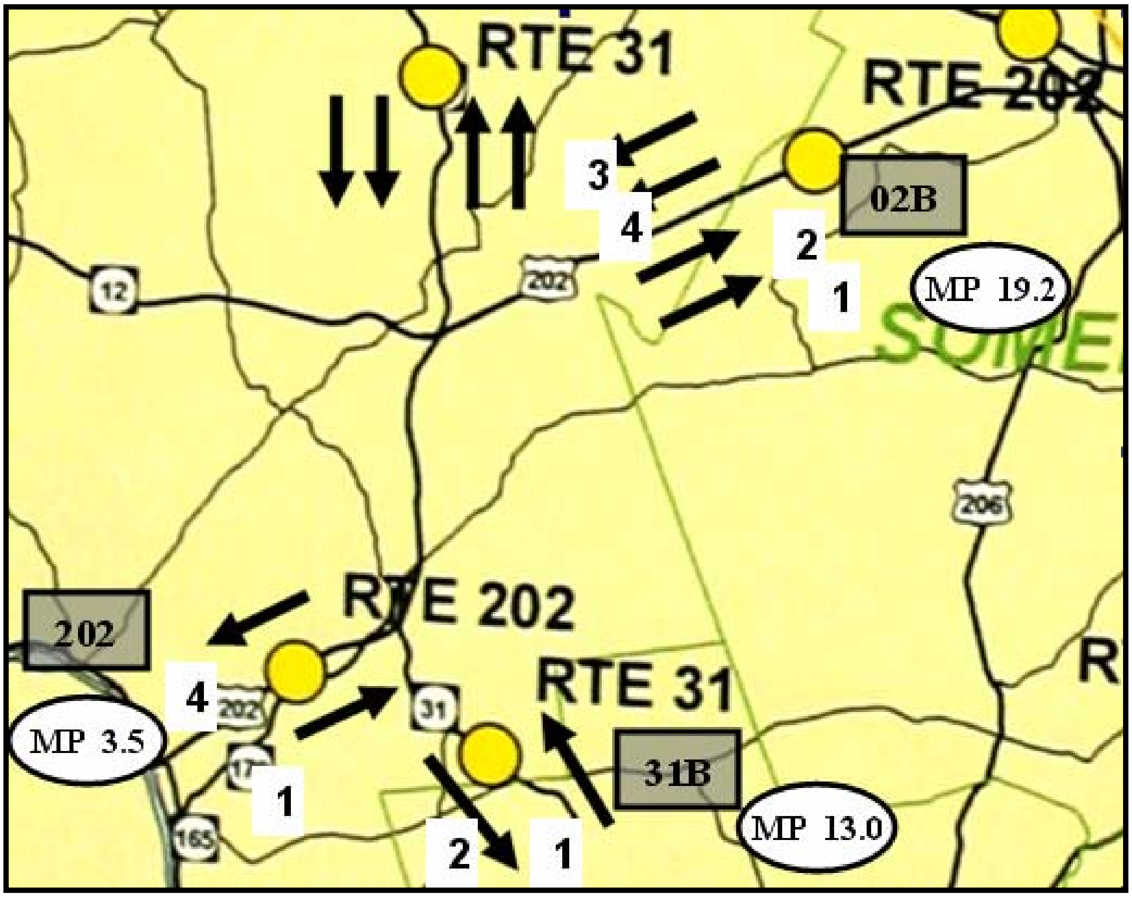


Figure 4.19 Map of Route NJ 31, US 202 intersection

A study considering three node links was done with the existing WIM sites. Route 31/202 intersections were considered. Sites 31B, 31D, and 02B were checked for matches. The FORTRAN program was run for Day 08/17/2006, and from Days 08/01/2006 to 08/04/2006.The results obtained are as shown in Table 4.17 , and Table 4.18.

Matches Summary-NB/EB on day 08/17/06					
Class	31B	02B	#Match	%Origin	%Destination
4	47	56	21	45%	38%
5	187	358	160	86%	45%
6	74	98	41	55%	42%
7	62	32	6	10%	19%
8	114	165	35	31%	21%
9	514	466	312	61%	67%
10	10	9	2	20%	22%
11	1	2	0	0%	0%
12	0	0	0	0%	0%
13	4	1	1	25%	100%

Matches Summary-SB Direction on Day 08/17/2006					
Class	31B	31D	#Match	%Origin	%Destination
4	47	37	28	60%	76%
5	187	204	141	75%	69%
6	74	103	45	61%	44%
7	62	52	39	63%	75%
8	114	86	26	23%	30%
9	514	330	288	56%	87%
10	10	6	6	60%	100%
11	1	0	0	0%	0%
12	0	0	0	0%	0%
13	4	3	3	75%	100%

Table 4.21 Summaries of Matches obtained along Route NJ 31/US 202, from site 31B to 31D/02B on 08/17/06

An interesting fact was noted when a Class 13 truck traveling north bound from site 31B was spotted at 02B on 08/17/2006.It is pretty clear that the truck traveled from 31B as it can be seen from maps that 31B has an exit point which enters route 202 making a confirmation of the above. Hence, there are chances that other class trucks also follow this route, and be spotted at site 02B.But since the Class 9 truck volume is very high; the process just by using WIM data becomes difficult for confirmation. Also, since the data on lanes 2, and 3 were unavailable in the recorded WIM data, it is possible that some important data may have been missed. It is very significant to the truck search process that complete data is available for accurate analysis.

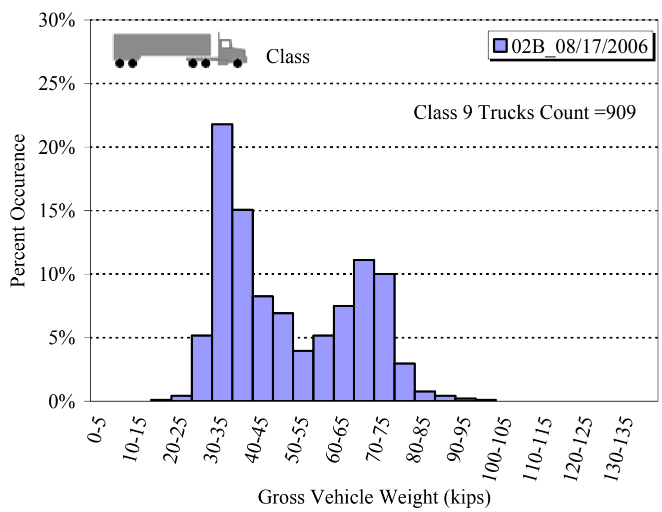
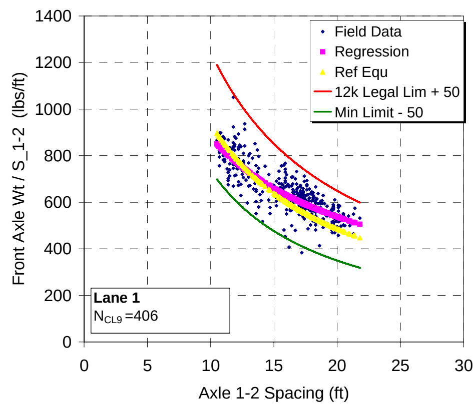
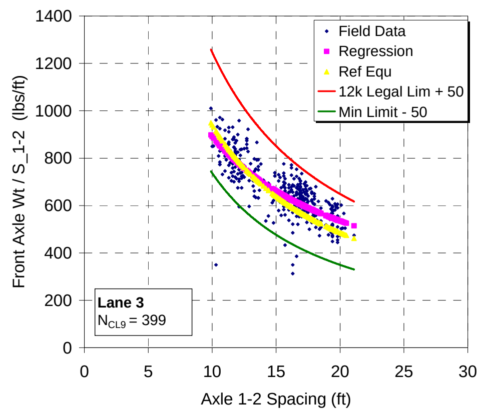


Figure 4.20 Class 9 Histograms for stations 202 & 02B along Route US 202 on 08/17/2006



(c) Site 02B, Lane 1



(b) Site 02B, Lane 3

*Note: Lanes 2, and 4 for both site s is not shown as the number of trucks was less than 55

Figure 4.21 Route U.S.202 WIM data Quality assurance using Logarithmic-regressions method, (Southgate, 2000) for Day 05/18/2001

Matches Summary-NB, 08/01/06, Tuesday					
Class	31B	02B	#Match	%Origin	%Destination
9	508	397	183	36%	46%
10	1	9	0	0%	0%
11	0	2	0	0%	0%
12	1	2	1	100%	50%
13	2	2	1	50%	50%

Tuesday

Matches Summary-NB, 08/01/06, Wednesday					
Class	31B	02B	#Match	%Origin	%Destination
9	522	418	180	34%	43%
10	1	18	0	0%	0%
11	0	0	0	0%	0%
12	1	0	0	0%	0%
13	2	1	1	50%	100%

Wednesday

Matches Summary-NB, 08/01/06, Thursday					
Class	31B	02B	#Match	%Origin	%Destination
9	507	410	175	35%	43%
10	5	16	1	20%	6%
11	0	0	0	0%	0%
12	2	3	1	50%	33%
13	0	0	0	0%	0%

Thursday

Matches Summary-NB, 08/01/06, Friday					
Class	31B	02B	#Match	%Origin	%Destination
9	453	383	137	30%	36%
10	4	10	1	25%	10%
11	1	0	0	0%	0%
12	1	2	1	100%	0%
13	0	1	0	0%	0%

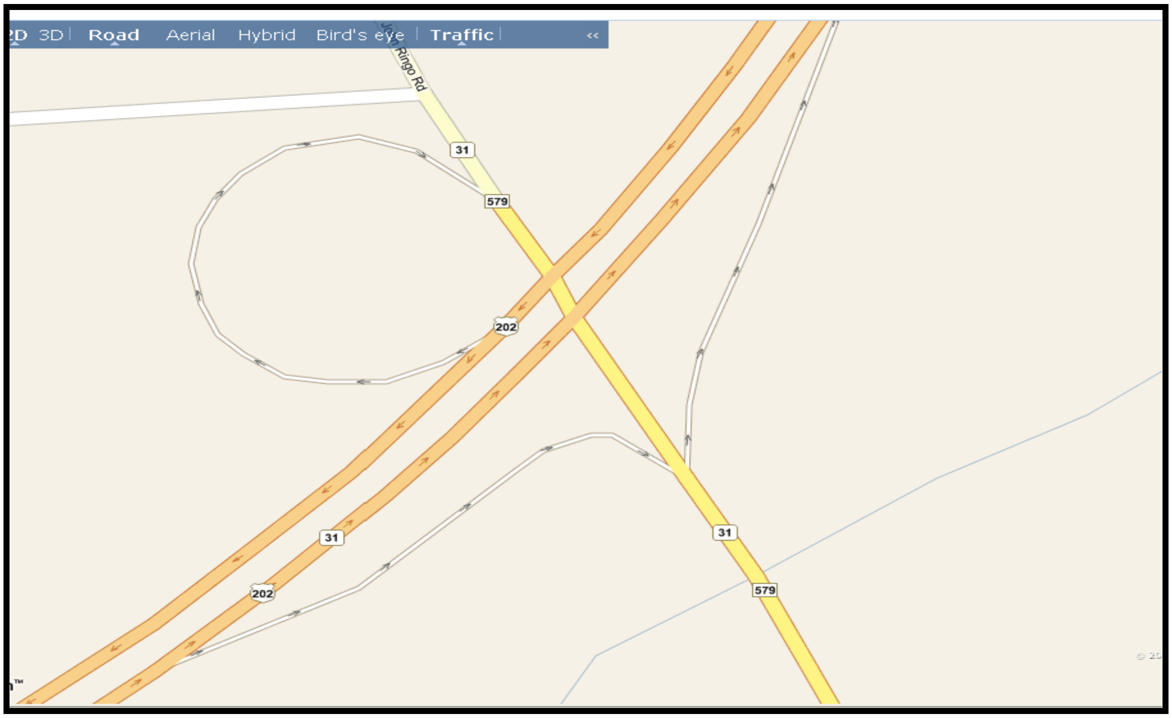
Friday

Table 4.22 31B & 02B, NB; Days 08/01/06 to 08/04/06, time delay =30 minutes; time tolerance =20 minutes; spacings tolerance =5%; GVW tolerance= 20%

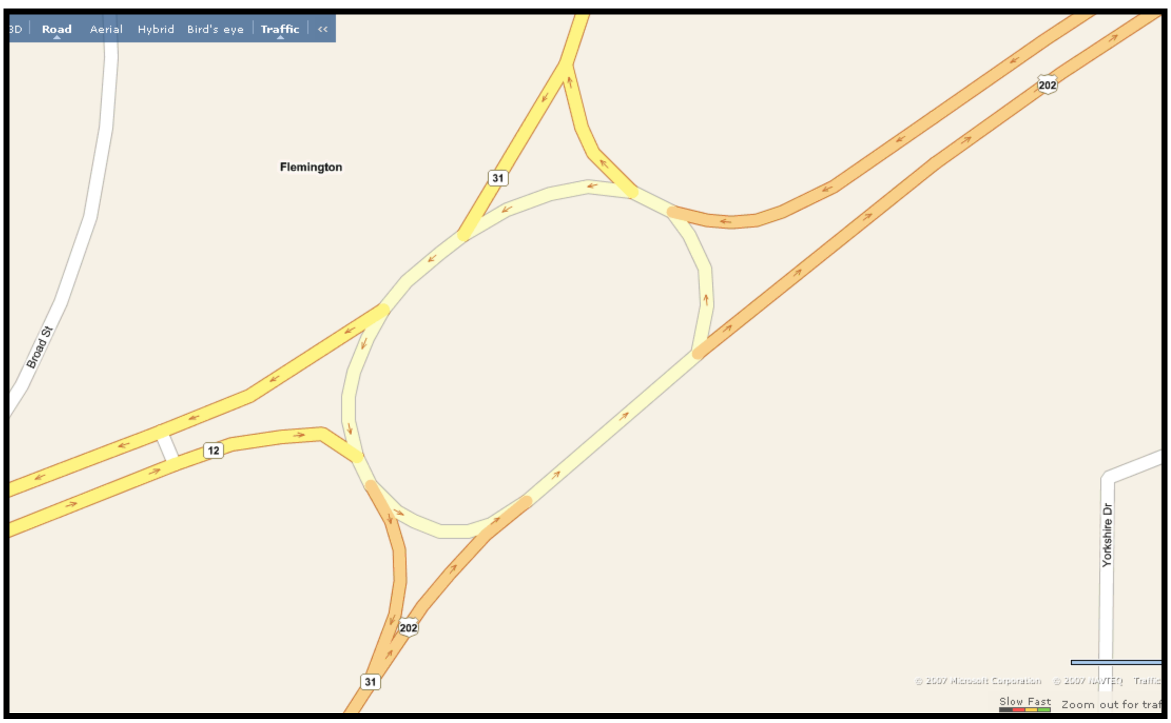
It is seen that Class 12 trucks traveled from site 31B to 02B on Thursday, and Friday. Assumptions can be made of the same for Class 9 trucks. Some of the Class 9 trucks may have traveled from site 31B to 02B.Since the data from site 202 was missing lanes 2 , and 3, not much can be concluded on the same. However, this shows that there is a possibility of trucks from 31B being spotted a 02B, located approximately about 15 miles apart. On referring the SLD's, some major intersections that support the obtained results are found. The pictures are shown

Figure 4.22 NJ 31 & 202 Junction

Figure 4.23 Map of WIM sites along NJ 31 & US 202



(A)



(B)

Figure 4.24 NJ 31 & 202 Junction

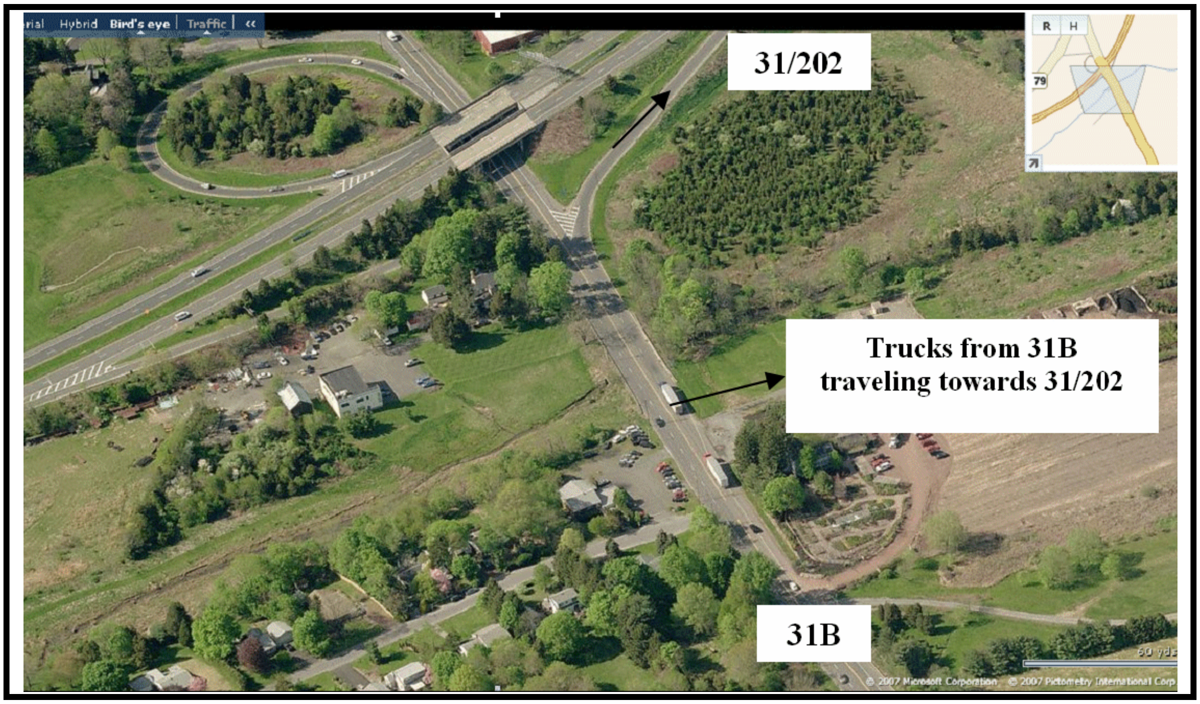


Figure 4.25 NJ 31 & 202

CHAPTER V

CONCLUSIONS & RECOMMENDATIONS

5.1 CONCLUSIONS

Truck traffic will always have to be monitored in the United States, and often checked due to factors involved in affecting pavement, roadways, bridges, for, its volume gradually increases by the year, and necessary steps need to be taken to prevent any damage it incurs.

The routes followed by trucks could be local, in state or out of state trucks which pick up or deliver goods from the national network to customers. Monitoring the Origin Destination of Trucks will help the Department of Transportation to keep a check on Truck activities , and their load spectra , illegal operations incase of exceeding the maximum load carrying limits, measuring percentage of out of state , and in state truck traffic, tax paying regularities, , and plays a key role in the design of pavement , and bridge structures.

From this study, the following conclusions are made,

- The WIM Data being collected needs to be checked for Calibration from time to time for quality assurance, and necessary adjustments need be made.
- The truck identification at various stations along a route will provide accurate results when the calibration is good, and the source of manual errors like initial

equipment installation, and time setting is at its least. Hence, the Truck Identification using the Match Criteria method proves to be reasonable after all the parameters are checked for accuracy and adjusted accordingly.

- FHWA Truck Classes 10, 11, 12, 13 can be easily identified due to their uniqueness in axle spacings configuration.
- FHWA Class 9 trucks dominate the truck traffic. Though the Class 9 trucks Axle spacings (1-2) , and (3-4) have genuine finger prints, their presence in large volumes in the traffic stream , and similarity in axle configurations, makes it difficult to find a perfect match at all times. Since there is no exact way to confirm the truck identity, the approximate method used to identify based on the three key factors of time of travel, axle spacings, and axle weights is less reliable in terms of Class 9 truck volumes.
- Since the trucks can get out at exit points, interchanges, , and major junctions in between the WIM stations, there is a high probability that some trucks might leave in between , and fails in providing accurate results. This is a major concern to the truck search study using only WIM data.
- The gross vehicle weight factor should be adjusted using calibration factor if the sites show drifts in the GVW's of trucks. Utilizing GVW's as one of the key factors in FORTRAN helps refine the truck search process. If it is not applied in a right way, it affects the other lanes since calibration changes by lane, and hence care should be taken.

5.2 RECOMMENDATIONS

- It becomes almost impossible to identify a truck between stations if the data available is not continuous for the required period of time. WIM data must be available for all stations under study to monitor O-D of trucks.
- The installations of WIM stations must be done keeping in mind the entry/exit points, interchanges, and major junctions. A precise study of the area under consideration needs to be carried out prior to the installation process.
- As the truck identification method described in this study is an approximate one, an exact and justifiable way of confirming the truck needs to be performed. This can be accomplished by installing License Plate Readers, Cameras, EZ Pass Readers, and other Optical Sources.
- The WIM Data along with LPR/EZ Pass will prove useful in providing information on load spectra, volume of trucks, and its Origin and Destination, provided the WIM, LPR/EZ Pass are installed at suitable locations along with timely calibration checks and maintenance. Hence, it is recommended that EZ Pass Readers and Automated License Plate Readers (ALPR) be used in conjunction with Weigh-in-motion (WIM).

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APPENDIX A

ROUTE NJ 31 NB Direction traveling from 31B to 31D site Truck Matches on Day 08/17/2006

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
18.3	1	18	1	9	27.7	8.7	5.7	6	2.8	4.6	13.6	4.3	30.6	4
18.3	1	36	3	9	29.3	9.1	6.4	5.8	3.3	4.8	13.5	4.3	30.4	4
26.3	2	15	1	9	49.4	11.2	12.5	12.1	6.5	7.1	16.2	4.3	26	4.1
26.3	2	41	3	9	58.1	12.1	15.3	15.7	7.1	8	16.1	4.2	25.8	4
34.8	3	3	1	9	69.2	11.6	13.5	13.2	15.2	15.8	17.8	4.3	33	4.1
34.8	3	38	3	9	64.4	12	12.6	12.1	14	13.7	17.1	4.2	32.7	4
21.7	3	16	1	9	64.2	12.5	13	12.6	13.4	12.6	17.2	4.2	33	4
21.7	3	38	3	9	64.4	12	12.6	12.1	14	13.7	17.1	4.2	32.7	4
21.7	3	47	1	9	73.6	10.3	14.7	14.6	17.8	16.2	15.4	4.4	29.6	10.1
21.7	4	8	3	9	86.1	11.5	15.6	17.8	20	21.2	15.4	4.3	29.5	10
17.8	3	55	1	9	54.9	9.9	13	12.3	10.4	9.2	10.9	4.4	34.9	4.1
17.8	4	12	3	9	58.8	10.1	14	13.7	10.5	10.5	10.9	4.3	34.7	4
28.2	3	57	1	9	71	11	15.3	14.8	16.2	13.8	19	4.3	31.2	4
28.2	4	25	3	9	62.7	5.8	14.7	14.2	15.5	12.6	18.9	4.3	30.9	4
22.1	4	3	1	9	70.3	10.4	15.4	16.2	13.9	14.4	19.5	4.3	32	4.1
22.1	4	25	3	9	62.7	5.8	14.7	14.2	15.5	12.6	18.9	4.3	30.9	4
35.8	4	12	1	9	74.4	11	15.4	15.4	16.6	15.9	16.8	4.2	32.3	4.1
35.8	4	48	3	9	87.4	12.3	18.2	18	19.5	19.5	16.6	4.2	32.2	4.1
18.7	4	30	1	9	74	11.2	15.6	14.7	16.1	16.4	13.5	4.3	29.2	4.1
18.7	4	48	3	9	81.3	11.7	17.3	16.8	17.7	17.8	13.4	4.3	29	4.1
19.4	6	20	1	9	35.6	10.7	8	8.1	4.5	4.3	20.4	4.3	37.7	4.2
19.4	6	39	4	9	39	12.1	8.8	8.8	4.9	4.4	20.3	4.3	37.3	4.1
20.6	6	36	1	9	26.3	9.6	5	4.5	3.6	3.6	12.5	4.3	30.6	4
20.6	6	57	4	9	27.9	9.8	4.9	5.9	3.6	3.8	12.5	4.3	30.4	4
23.8	8	39	1	9	29.4	9	6.2	5.4	4.8	4	12	4.3	23.2	4.2
23.8	9	3	4	9	31.9	10.1	6.3	6.1	4.7	4.7	11.9	4.3	22.9	4.1
26.1	8	48	1	9	66.2	9	15.4	14.8	13.3	13.7	13.3	4.4	27.5	4.1
26.1	9	14	3	9	79	10.3	17.9	16.9	16	17.8	13.3	4.3	27.3	4
24	9	8	1	9	34.6	10.9	7	7	4.7	5	18.2	4.3	31	10.1
24	9	32	3	9	35.2	10.6	7	6.6	5.3	5.7	18.1	4.3	30.9	10

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
30.8	9	28	1	9	66.4	10.5	15	14.8	12.9	13.2	19.3	4.3	28.8	4.1
30.8	9	59	3	9	79.7	10.1	17.7	18.1	16.8	17.1	19.2	4.3	28.6	4
23	9	40	1	9	69.4	10	12.1	10.7	18.1	18.6	13.9	4.3	22.2	10.1
23	10	3	3	9	73.3	10.1	11.7	11.7	19.7	20.1	13.9	4.2	22.1	10
23.2	10	15	1	9	39.5	12.1	8.9	9	4.7	4.8	21.7	4.3	31.6	10
23.2	10	38	3	9	43.1	11.2	10.4	10.6	5.3	5.6	21.6	4.3	31.5	9.9
14.4	10	20	1	9	30.3	9.4	6.7	6.3	4	4	17.4	4.3	31.4	4.1
14.4	10	35	4	9	30.3	10.3	6.7	6.3	3.5	3.5	17.8	4.2	30.6	4
26	10	44	1	9	29.8	10.5	5.9	6	3.6	3.7	17.4	4.5	26.7	10.1
26	11	10	3	9	30.2	10.6	6	5.9	3.7	4	17.3	4.5	26.4	10.1
25.1	10	45	1	9	61.7	8.8	13	12.5	12.9	14.5	12.4	4.3	29.1	10
25.1	11	10	3	9	62.2	8.7	13.9	13.2	12.3	14	12.3	4.3	28.9	9.9
23.8	11	34	1	9	30.8	9.2	6.4	6.6	4.1	4.5	16.6	4.3	29.9	10.1
23.8	11	58	4	9	33.4	10.7	6.8	7.2	4.4	4.4	16.5	4.3	29.6	10
28.7	11	46	1	9	64.3	8.4	14.8	14.4	13.4	13.3	14.3	4.4	30.3	8.1
28.7	12	15	3	9	68.7	10.9	16.2	14.9	13.6	13.2	14.3	4.3	30.2	8.1
25.9	12	6	1	9	50.6	9.1	11.1	12.9	8.3	9.3	14.5	4.1	30.3	8.1
25.9	12	32	3	9	51.2	8.3	11.9	11.4	8.9	10.8	14.4	4.1	30.1	8.1
25.9	12	21	1	9	71.7	11.7	15.5	15.6	13.6	15.2	19.5	4.3	22.9	10.1
25.9	12	47	3	9	86.6	12.1	20	19.8	16.7	18	19.4	4.3	22.8	10
46.2	13	22	1	9	63.1	9.2	14.2	13.3	12.2	14.2	17.9	4.3	33.1	4
46.2	14	8	3	9	69.8	10.6	15	14.7	14.7	14.8	17.8	4.3	33.4	4
24	13	31	1	9	32.6	10.8	6.9	6.3	4.3	4.4	18.4	4.3	30.7	10.1
24	13	55	3	9	35.4	10.7	7.6	7.2	4.8	5.2	18.2	4.3	30.6	10
25.9	13	33	1	9	61.5	10.6	12.7	11.8	13.7	12.6	14.9	4.3	28.4	10.2
25.9	13	59	3	9	67.4	10	14.1	13.7	15.5	14.2	14.8	4.3	28.2	10.1
31.7	**13**	**36**	**1**	**9**	**64.6**	**10.7**	**12.6**	**11.6**	**12.6**	**17.1**	**17.1**	**4.3**	**32.9**	**3.9**
31.7	**14**	**8**	**3**	**9**	**69.8**	**10.6**	**15**	**14.7**	**14.7**	**14.8**	**17.8**	**4.3**	**33.4**	**4**
30	**13**	**38**	**1**	**9**	**42.4**	**10.2**	**11**	**9.6**	**6**	**5.6**	**17.2**	**4.3**	**32**	**4.1**
30	**14**	**8**	**3**	**9**	**69.8**	**10.6**	**15**	**14.7**	**14.7**	**14.8**	**17.8**	**4.3**	**33.4**	**4**
24.8	13	55	1	9	62.2	9.9	12	12.2	13.6	14.4	18.2	4.2	30.8	10.1
24.8	14	20	3	9	66.8	9.4	13.2	13.9	14.7	15.5	18.2	4.2	30.5	9.9

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
14.8	14	0	1	9	46	11.7	10.6	9.7	7.1	6.9	17	4.3	31.5	4.1
14.8	14	15	3	9	44.5	11.2	9.4	8.9	7.5	7.5	17	4.3	30.8	4
20.8	14	13	1	9	30.2	10.3	6.3	5	4.1	4.4	16.5	4.3	27.4	4.3
20.8	14	34	3	9	32.5	10.3	6.3	6.2	4.6	5	16.4	4.2	27.3	4.3
26.8	14	32	1	9	73.9	10.3	17.3	17	15.4	14	13.6	4.3	30.3	4.1
26.8	14	59	3	9	76.8	12.2	15.8	15.8	17.6	15.4	13.9	4.3	30	4.1
41.2	**14**	**54**	**1**	**9**	**68.9**	**10.4**	**14**	**12.8**	**16**	**15.8**	**17.1**	**4.4**	**29.4**	**4.1**
41.2	**15**	**35**	**4**	**9**	**72.4**	**11.9**	**14.1**	**13.1**	**16.7**	**16.7**	**17**	**4.4**	**29.2**	**4**
41	**14**	**55**	**1**	**9**	**69.1**	**11.8**	**13.3**	**12.1**	**16**	**15.8**	**16.8**	**4.4**	**30**	**4.1**
41	**15**	**35**	**4**	**9**	**72.4**	**11.9**	**14.1**	**13.1**	**16.7**	**16.7**	**17**	**4.4**	**29.2**	**4**
30.1	14	58	1	9	45.9	10.7	9.1	8.9	8.3	9	13.4	4.3	30.1	4
30.1	15	28	3	9	50.8	9.9	10.4	10.5	9.5	10.5	13.3	4.3	29.9	4
26	15	6	1	9	65.4	12.3	12.9	12.2	14.5	13.5	17	4.3	26.4	10.1
26	15	32	4	9	63.3	11.8	12.1	11.8	14.4	13.3	16.9	4.3	26.2	10.1
24.4	15	21	1	9	73.2	10.9	14.9	13.9	15.9	17.7	17.8	4.3	23.6	10
24.4	15	46	3	9	68.5	9.1	14.2	13.5	15.3	16.4	17.7	4.3	23.5	9.9
23.7	15	23	1	9	37.7	9.5	7.9	8	6	6.4	19.2	4.3	28.9	10.5
23.7	15	47	4	9	33.8	10	6.9	6.6	5.2	5.1	19.1	4.3	28.5	10.4
24	15	55	1	9	57.5	10.7	12.5	12	11	11.3	20.8	4.3	30.3	11
24	16	19	4	9	56.8	10.9	12.4	11.4	11.3	10.9	20.7	4.3	30.2	10.9
26.7	16	33	1	9	49.6	10.5	9.1	9.3	10.6	10.1	19.6	4.3	29.9	10.1
26.7	17	0	3	9	53.3	10.7	9.8	10.7	10.9	11.2	19.5	4.3	29.6	10
29.7	**16**	**36**	**1**	**9**	**60.4**	**11.3**	**13.6**	**12.8**	**11.6**	**11.1**	**17**	**4.3**	**34.5**	**4.1**
29.7	**17**	**6**	**3**	**9**	**77.9**	**12.5**	**13.3**	**13.6**	**19.3**	**19.2**	**17.3**	**4.2**	**33.8**	**4**
28	**16**	**38**	**1**	**9**	**67.3**	**11.7**	**11.3**	**11.2**	**16**	**17**	**17.4**	**4.2**	**34**	**4**
28	**17**	**6**	**3**	**9**	**77.9**	**12.5**	**13.3**	**13.6**	**19.3**	**19.2**	**17.3**	**4.2**	**33.8**	**4**
26.4	17	26	1	9	17.2	5	6.6	2.1	1.9	1.6	13.2	32.8	2.8	2.8
26.4	17	52	3	9	19.3	4.7	7.2	2.9	2.6	2	13.2	32.6	2.8	2.8
23.6	20	30	1	9	64.6	10.7	13	13	13.8	14	19.5	4.2	34	4.1
23.6	20	53	3	9	64.6	10	13.2	13.2	14	14.1	19.4	4.2	34	4
22	21	27	1	9	34.6	10.1	7.3	7.2	4.8	5.2	16.9	4.3	29.8	10.1
22	21	49	3	9	39.1	11	7.9	8.5	5.6	6.1	16.9	4.2	29.6	10

ıss 10 trucks spotted in the NB direction traveling from 31B to 31D on Day 08/17/2006

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	W6	S1	S2	S3	S4	S5
22.05	15	43	1	10	72	9	13.1	12.8	7.7	15.3	14.5	12.8	4.3	18.6	5.4	4
22.05	16	5	3	10	76.6	9	13.2	12.8	8.6	15.6	17.1	12.8	4.3	18.5	5.3	4
25.1	14	20	1	10	75.7	10	14.2	14.1	9.1	13.7	14.5	12.9	4.2	18.2	5.4	4.1
25.1	14	45	3	10	85.5	11	15.9	15.9	11.2	15.4	16.5	12.8	4.2	18.1	5.4	4.1
20.18	6	44	1	10	68.3	9	15.5	16	9.3	8.9	9.4	11.5	4.3	33.4	4.1	4.1
20.18	7	5	3	10	71.6	10	16.3	15.9	10.2	9	10.5	11.4	4.3	33.1	4.1	4.1
24.92	11	21	1	10	91.8	8	21.5	19.9	14.6	14.1	13.8	13.5	4.2	33.1	4.5	4.5
24.92	11	46	3	10	92.1	9	19.8	20.4	14.6	14.3	13.6	13.4	4.1	32.9	4.5	4.5
24.72	12	23	1	10	72.2	11	11.7	12.5	7.2	15.6	14.7	16.2	4.4	19.2	4.1	4.1
24.72	12	48	3	10	79.2	11	14.1	13.3	8.6	16.4	16	16.1	4.4	19.1	4	4.1
34.72	12	38	1	10	36.4	9	6.7	6.6	4.8	4.6	4.5	15.9	4.3	31.9	2.8	2.8
34.72	13	13	4	10	40.6	10	6.7	7	5.4	5.4	5.8	15.8	4.3	31.8	2.7	2.7

Class 13 trucks spotted in the NB direction traveling from 31B to 31D on Day 08/17/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	W7	S1	S2	S3	S4	S5	S6
37	15	20	1	105.4	10.6	19.3	17.1	17.1	13.2	14.5	13.6	16.7	4.5	4.5	38	4.2	4.6
37	15	57	3	105.2	9.4	19	17	16.7	14.4	14.1	14.6	16.6	4.5	4.5	37.6	4.1	4.5

Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	W7	W8	W9
12	53	1	126	12	15.4	15.7	13	13	14.9	14.9	13.7	13.5
13	22	4	99	6.9	12.3	12.2	11	12	10.8	13.3	10.9	9.6

S1	S2	S3	S4	S5	S6	S7	S8
19.7	4.5	13.3	4.5	35.1	4.6	14	4.5
19.5	4.4	13.1	4.5	34.9	4.4	14	4.5

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
25	10	53	1	84.5	11.4	13.3	14.3	4.4	4.4	4.3	5.2	5.4	6	5.2	5.4	5.3
25	11	18	3	94.4	12.3	13.2	14.3	5.2	5.4	4.7	6	6.5	6.4	6.7	6.9	6.8

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
17.2	4.4	11.7	5	5.1	15.2	5.1	10.2	5.2	5	5.1
17.1	4.4	11.6	5	5	15	5	10.1	5.1	5	5.1

Class 13 trucks spotted in the NB direction traveling from 31B to 02B on Day 08/17/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	W7	S1	S2	S3	S4	S5	S6
32	11	27	1	100.5	6	16.4	17.5	18.6	14.6	13.1	14.3	13.8	4.3	4.5	37.5	4.2	4.1
32	11	59	1	103.3	4.7	17.6	18.6	20.4	15.1	13.3	13.5	13.8	4.3	4.5	37.9	4.2	4.2

ROUTE NJ 31 SB Direction traveling from 31D to 31B site Truck Matches on Day08/17/2006

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
20.1	0	30	1	9	52.1	12.1	9.5	10.4	10.3	9.8	17.7	4.4	32.9	4.1
20.1	0	50	2	9	53.8	11.4	10.3	9.8	10.9	11.4	17.6	4.3	32.9	4
48.8	0	36	1	9	66.4	11.7	14.2	13.9	13.5	13.2	17.3	4.2	30.6	4
48.8	1	24	2	9	69.2	12.4	14.3	13.6	14.7	14.2	17.3	4.2	30.6	4
15.6	1	17	1	9	75.9	11	16.4	16.1	16.5	16	12.3	4.3	30.3	4
15.6	1	33	2	9	75.9	10.6	17	17.3	15.9	15.2	12.3	4.3	30.3	4.1
16.6	1	17	1	9	36.7	10.6	7.4	7.2	5.9	5.7	17.2	4.2	36	4.1
16.6	1	34	2	9	36.2	11	6.8	6.8	5.6	6.1	17.3	4.2	36	4.1
16.9	1	29	1	9	85.5	10.7	17	18.9	18.9	19.9	15.3	4.6	33.4	4
16.9	1	46	2	9	74.8	10.2	16.7	16.7	15.5	15.6	15.3	4.6	33.5	4
16	1	30	1	9	47.4	9.5	8.7	8.7	10.5	10.1	11.9	4.3	30.8	4
16	1	46	2	9	42.8	8.6	7.7	7.5	8.6	10.3	12	4.3	30.8	4
13.3	1	33	1	9	73.8	10.5	17	14.4	16.1	15.8	15.4	4.4	32.9	4.1
13.3	1	46	2	9	74.8	10.2	16.7	16.7	15.5	15.6	15.3	4.6	33.5	4
30.5	2	18	1	9	78.9	11.4	17.2	17.5	18.5	14.3	20	4.2	28.1	4.1
30.5	2	49	2	9	75.1	10.9	16.3	16.6	16.3	14.9	20	4.2	28.1	4.1
14.4	2	24	1	9	38.2	11.1	7.7	8.1	5.5	5.7	18	4.2	22.3	10.1
14.4	2	38	2	9	36.3	10.7	7.7	6.7	5.5	5.6	18	4.2	22.2	10.2
15	2	37	1	9	77.9	12.7	14.6	14.2	19.5	16.7	17.2	4.3	32.4	4.1
15	2	52	2	9	63.6	11.5	11.9	12.1	13.4	14.7	17.2	4.2	32.4	4
15.6	3	19	1	9	83.7	11.1	18	19.1	17.8	17.7	12.4	4.3	30.4	4
15.6	3	35	2	9	80.1	10.9	15.7	19.2	17.1	17.3	12.4	4.3	30.4	4
18	3	20	1	9	78.4	10.6	19.2	18.5	15.2	14.8	17.3	4.5	26.6	10.1
18	3	38	2	9	77.6	12.5	16.6	16.6	16.1	15.7	17.3	4.5	26.6	10.1
17.8	3	26	1	9	84.4	12	18.7	16.9	18.4	18.4	17.4	4.4	33.2	4
17.8	3	44	2	9	82.4	12.4	18.3	17	17.2	17.5	17.4	4.4	33.2	4.1
16.4	3	28	1	9	81.7	11	18.6	19	16.7	16.4	12.3	4.3	30.8	4
16.4	3	44	2	9	80.4	11.5	17.8	18.3	15.7	17.1	12.4	4.3	30.8	4
15.8	3	53	1	9	90.6	11.3	20.5	21.5	19.3	17.9	19.5	4.2	28.6	4.4
15.8	4	9	2	9	82.5	10	19.1	19.5	16.8	17.1	19.6	4.2	28.7	4.3
29.7	4	4	1	9	61.8	11.6	12.5	12.6	13.5	11.7	16.4	4.2	30.1	4.1
29.7	4	34	2	9	61.2	10.5	12.7	12.4	12.9	12.8	16.4	4.2	30.1	4.1

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
16.8	4	25	1	9	89.9	10.1	20.5	20.8	20	18.5	13.3	4.3	31.2	4
16.8	4	42	2	9	80.7	9.8	18.2	19.3	16.9	16.5	13.3	4.3	31.3	4
13.5	6	17	1	9	77.9	11.2	16.7	17.1	16.7	16.3	12.4	4.3	30.3	4
13.5	6	30	2	9	74.9	12	14.7	15.3	16.4	16.5	13	4.2	31.8	4
16.7	6	17	1	9	36.4	11.1	7.6	7	5.8	5	18.1	4.3	31.8	10.1
16.7	6	34	2	9	41.4	11.6	9	8.8	5.9	6.1	18.1	4.3	31.9	10.1
18	6	34	2	9	41.2	11.6	7.6	7.6	6.9	7.5	17.8	4.2	30.9	4
18	6	52	2	9	45.1	12	8.5	8.7	6.7	9.3	18	4.3	31.3	4
19.2	7	12	1	9	80.4	11.7	18.4	16.1	16.9	17.4	17.1	4.4	33.6	4.1
19.2	7	31	2	9	79.9	11	16.8	15.8	17.9	18.4	17.2	4.3	33.7	4.2
19.6	**7**	**49**	**1**	**9**	**86**	**10.6**	**21.3**	**18.4**	**20.4**	**15.2**	**12.3**	**4.3**	**31.9**	**4.1**
19.6	**8**	**8**	**2**	**9**	**84.6**	**11.6**	**19.5**	**18.5**	**17.1**	**18**	**12.4**	**4.4**	**30.8**	**4.1**
19.6	**7**	**49**	**1**	**9**	**82.4**	**10.9**	**17.8**	**20**	**17.4**	**16.4**	**12.3**	**4.3**	**30.9**	**4**
19.6	**8**	**8**	**2**	**9**	**84.6**	**11.6**	**19.5**	**18.5**	**17.1**	**18**	**12.4**	**4.4**	**30.8**	**4.1**
19.3	8	26	2	9	79.8	12.2	18.7	16.9	16.5	15.5	13.3	4.3	30	4.1
19.3	8	45	2	9	77.7	12	18.8	17.1	14.7	15.1	13.3	4.3	30.2	4
18.5	8	55	1	9	74.4	9.2	17.8	17	15.6	14.8	16.5	4.3	29.8	10
18.5	9	14	2	9	75.4	10.9	16.3	16.3	16.1	15.8	16.5	4.3	29.8	10.1
21.3	9	11	1	9	87.6	11.9	19.9	18.5	16.5	20.9	17.7	4.4	31.2	3.9
21.3	9	32	2	9	81.1	12.6	18.1	17.1	15.6	17.6	17.7	4.4	31.1	4
18	9	12	2	9	71.3	9.9	16.9	16.1	15.3	13.1	13.2	4.3	30.8	4.1
18	9	30	2	9	69.8	11.2	15.9	15.5	13.6	13.6	13.3	4.3	30.9	4
47.3	9	24	1	9	33.1	10.2	6.6	6.5	4.9	4.9	17.4	4.3	33.3	4
47.3	10	11	2	9	34.1	9.6	6.9	7.6	5.2	4.7	18	4.3	33.1	4.1
32.1	9	40	1	9	30.9	9.2	6.7	5.7	4.8	4.6	19.2	4.3	28.1	4
32.1	10	12	2	9	35.4	9.4	7.4	7.7	4.9	6	19.2	4.3	28.1	4.1
19.2	9	40	2	9	71.4	10.1	15.2	16.4	15.3	14.3	15.7	4.3	29.2	4.4
19.2	10	0	2	9	73.5	10.2	16.9	15.4	15.4	15.7	15.7	4.3	29.3	4.4
21	9	52	1	9	44.4	11.2	8.1	8.1	8.5	8.5	16.7	4.3	37	4
21	10	13	2	9	47.1	12.7	9	8.2	8.6	8.6	16.7	4.3	37.4	4
22.2	10	28	1	9	71.7	11.1	13.1	16.3	15.7	15.3	20.3	4.2	30.8	10
22.2	10	50	2	9	69.7	12.1	13.5	13.1	15.1	15.9	20.3	4.1	30.9	10

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
21.3	10	49	1	9	71.8	10.8	14.6	15.3	14.8	16.3	12.4	4.3	28.7	4
21.3	11	10	2	9	71.8	11.7	14.4	15.8	15.3	14.6	12.4	4.3	28.7	4.1
21.1	**11**	**11**	**1**	**9**	**79.6**	**9.6**	**19.3**	**17.2**	**17.4**	**16**	**12.8**	**4.3**	**30.4**	**4**
21.1	**11**	**32**	**2**	**9**	**74.9**	**9**	**17.3**	**17.9**	**15.8**	**14.8**	**12.8**	**4.3**	**31.9**	**4.1**
20	**11**	**12**	**2**	**9**	**69.8**	**9.6**	**15.5**	**16.9**	**14.2**	**13.6**	**12.8**	**4.3**	**31.8**	**4.1**
20	**11**	**32**	**2**	**9**	**74.9**	**9**	**17.3**	**17.9**	**15.8**	**14.8**	**12.8**	**4.3**	**31.9**	**4.1**
20.1	14	48	2	9	71.6	9.2	15.4	14.3	16.9	15.8	13.3	4.3	32.8	4
20.1	15	8	2	9	75.7	9.4	15	15.3	18	17.9	13.3	4.2	33	4.1
19.3	14	51	1	9	31.1	8.8	6.4	6.7	4.2	5	14.6	4.2	30.1	8
19.3	15	10	2	9	32.8	9	7.4	8.1	3.7	4.6	14.6	4.1	30.3	8.1
15.5	16	9	2	9	32.1	11	6.6	6.2	4.3	4	19.6	4.3	29.7	10.1
15.5	16	25	2	9	38.1	10.1	9.2	8	5.5	5.3	19.7	4.3	30.4	10.1
10.9	16	28	2	9	28.2	8.1	5.7	5.6	4.4	4.4	14.1	4.3	30.2	4.1
10.9	16	39	2	9	27.2	8.5	5.1	5.8	3.7	4.1	14.3	4.3	29.8	4.1

Class 10 truck spotted traveling SB from 31D to 31B on Day 08/17/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	S1	S2	S3	S4	S5
22	11	18	1	79.5	9.7	18.1	16.6	11	12.1	11.8	18	4.5	33.1	4.3	4.3
22	11	40	2	72	10.2	16.1	15.4	9.9	9.8	10.6	18.1	4.5	33.2	4.3	4.3
18	14	9	1	46.3	9.7	9.3	9.2	6.1	6.1	5.8	13.6	4.1	32.9	4.5	4.5
18	14	27	2	46	8.1	9.3	10.5	5.5	6	6.6	13.7	4.1	33	4.5	4.4
22	14	20	1	23.3	4.9	5.8	5.7	2.6	2.3	1.9	18.5	4.6	32.7	5.1	5.1
22	14	42	2	35.6	5.8	8.3	9.1	4.3	4.9	3.2	18.4	4.5	32.4	5.1	5.1
23	14	53	1	116.3	15.7	19.4	18.8	21.9	20.8	19.6	16.8	4.5	39	4.2	4.2
23	15	16	2	107.2	14.7	20.3	18.1	17.9	17.7	18.6	16.8	4.5	39.2	4.1	4.1
22	21	22	1	105	12.2	24.5	23.9	15.6	14.8	14	14.1	4.5	35.1	4.5	4.5
22	21	44	2	97.2	11.2	23.6	23.7	13	12.7	12.9	14.2	4.5	35.3	4.4	4.6

Class 11 truck spotted traveling SB from 31D to 31B on Day 08/17/2006

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
19	7	29	1	11	34.9	4.3	11.9	7.7	6.2	4.8	13.2	32.7	2.8	2.8
19	7	48	2	11	30.9	5	10.2	6.1	5.3	4.3	13.2	32.6	2.9	2.9

Class 9 trucks spotted traveling NB from I2C to 295 on Day 12/18/2006-(No calibration factor) between 10:00am and 10:15 am; # Class 9 trucks= 43

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.65	10	0	5	9	69.2	11.8	16.1	15.8	12.1	13.4	16.9	4.3	30.1	4.4
0.65	10	1	6	9	54.1	8.8	13.5	13.2	9.7	8.8	16.5	4.2	29.4	4.3
0.63	10	0	5	9	50	10.7	11.8	7.9	9.2	10.4	12.7	4.5	33.8	4.1
0.63	10	1	5	9	34.2	7.2	7.1	6	7.2	6.7	12.4	4.3	33.1	4
0.55	10	1	6	9	82.1	10.2	20.9	19.2	15.8	16.1	14	4.3	32.3	4
0.55	10	1	5	9	33.7	7.8	6.2	6.6	6.4	6.6	14.1	4.3	33.5	4
0.63	10	1	5	9	57.1	13.8	12.5	12.5	8.8	9.5	18.8	4.3	35.8	4.1
0.63	10	2	5	9	40.8	10.3	8.7	9.1	6.7	6.1	18.3	4.2	34.9	4
0.67	10	1	6	9	31.5	9.1	6.6	5.1	5.4	5.4	16.2	4.2	36	3.9
0.67	10	2	5	9	37	9.5	7.4	8	6	6.1	16.2	4.2	36.1	3.9
0.52	10	1	5	9	50.5	11	10.1	11	9	9.4	13.6	4.4	25.5	10.3
0.52	10	2	5	9	40.4	8.4	8	8.4	7.2	8.5	13.4	4.3	24.6	10
0.47	10	1	5	9	73.2	12.9	19.3	20.7	10.7	9.6	19.9	4.4	31.5	4.2
0.47	10	2	5	9	56.2	10	15.5	15.1	7.8	7.8	19.3	4.3	30.6	4
0.77	10	3	5	9	59.6	10.4	16.3	12.6	9.7	10.6	11.2	4.4	35.1	4.1
0.77	10	4	6	9	47.2	8.4	10.5	14.3	7	7	11	4.2	34.4	4.1
0.8	10	4	5	9	115	12.6	27.4	28.5	22.3	23.9	17	4.3	29.4	4.1
0.8	10	5	5	9	85.3	9.8	17.6	18.3	19.8	19.8	16.5	4.2	28.5	4.1
0.28	10	4	5	9	93.8	11.4	23.5	21.2	18.9	18.9	11.5	4.4	35.9	4.1
0.28	10	4	6	9	47.2	8.4	10.5	14.3	7	7	11	4.2	34.4	4.1
0.85	10	5	6	9	45.4	11.5	9.9	9.5	6.8	7.7	16.9	4.3	12.8	4
0.85	10	6	5	9	43.8	9.9	9.4	8.2	7.6	8.7	16.9	4.3	12.8	4
0.68	10	5	5	9	44.6	11.3	10.2	10	5.6	7.4	18	4.3	29.9	10.4
0.68	10	6	5	9	35.6	9.3	7.7	7.3	5.7	5.7	17.5	4.2	29.2	10.2
3.08	10	5	6	9	57.2	11.4	14.4	14.8	8.1	8.5	17.1	4.2	32.7	4
3.08	10	8	5	9	36.4	9.7	7.8	7.5	5.5	5.9	16.5	4.3	31.1	4
0.68	10	5	6	9	79.7	10.2	18.7	18.8	15.1	16.9	19.5	4.3	37.1	4.1
0.68	10	6	6	9	82	11	17.9	17.8	17.3	17.9	19.5	4.3	37.3	4.1
1	10	6	6	9	35.7	11.7	8.6	7.3	3.9	4.3	18.7	4.3	30.2	10
1	10	7	6	9	34.8	10	7.6	7.2	5.1	4.9	18.8	4.3	30.3	10

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.83	10	6	5	9	48.6	10.8	11.1	11.2	7.7	7.8	16.9	4.5	29.4	4.1
0.83	10	7	5	9	40.1	8.8	8	9	6.3	7.9	16.5	4.3	28.5	3.9
0.12	10	6	5	9	45.6	12.2	10.8	10.2	5.4	7	20	4.4	36.6	4.1
0.12	10	6	6	9	82	11	17.9	17.8	17.3	17.9	19.5	4.3	37.3	4.1
0.72	10	6	5	9	52.8	12.3	12	11.6	8	8.9	19.9	4.4	34	4.4
0.72	10	7	5	9	40.2	9.5	8.7	8.6	7.1	6.3	19.3	4.3	33.1	4.3
2.07	10	6	5	9	44.9	12.6	10.1	9.7	6.3	6.2	17.3	4.5	35.2	4.1
2.07	10	8	5	9	79	9.7	17.4	17	17.9	17	16.8	4.3	34.1	4
0.77	10	7	5	9	92.8	15.5	22.7	25.7	14.7	14.2	18.2	4.3	28.5	4.1
0.77	10	8	5	9	67.4	10.8	17.1	19.6	9.7	10.2	17.7	4.2	27.6	4.1
0.82	10	7	6	9	39.5	11	7.6	7.9	6.5	6.5	16.5	4.3	31.2	4
0.82	10	8	5	9	36.4	9.7	7.8	7.5	5.5	5.9	16.5	4.3	31.1	4
2.45	10	8	6	9	39.4	11	8	7.7	7	5.7	15.8	4.2	33.4	4.1
2.45	10	10	5	9	34.8	8.7	6.9	7.7	5.3	6.1	16.5	4.3	34.5	4
0.57	10	8	5	9	119	13.8	25.9	25	26.2	28	17.3	4.4	35.2	4.1
0.57	10	8	5	9	79	9.7	17.4	17	17.9	17	16.8	4.3	34.1	4
0.77	10	8	6	9	90.4	11.5	19.1	17.6	21.9	20.3	11.3	4.3	34.9	4
0.77	10	9	6	9	75.6	9.2	16.8	14.7	18.2	16.7	11.3	4.4	34.9	4
0.7	10	9	5	9	49.5	13.1	10.2	9	9.3	8	16.9	4.4	35.3	4.2
0.7	10	10	5	9	34.8	8.7	6.9	7.7	5.3	6.1	16.5	4.3	34.5	4
0.58	10	10	5	9	73.9	14.3	18.7	19.5	8.7	12.7	20	4.4	29.5	4
0.58	10	10	5	9	54.9	10.5	14.2	15.8	6.4	8.1	19.4	4.2	28.6	4
0.67	10	10	5	9	47.6	12.5	9.6	7.9	8.7	8.7	16.2	4.4	33.5	4.1
0.67	10	11	6	9	35.7	9.3	7.5	7.4	5.8	5.8	15.9	4.3	32.8	4
0.83	10	10	6	9	70.9	12.9	16.9	17	13.1	11	19.4	4.2	28.9	4
0.83	10	11	6	9	60	10.2	14.8	14	11.3	9.7	19.6	4.3	29.1	4.1
0.68	10	10	5	9	51.2	12.8	10	8.5	8.4	11.5	18	4.4	31.2	4.1
0.68	10	11	6	9	34.7	9.8	6.6	6.3	6	6	17.7	4.3	30.4	4
0.72	10	11	6	9	42.1	10.9	7.9	7.8	8.5	7.1	11	4.3	30.1	4.1
0.72	10	12	5	9	37.2	8.8	7.1	7.5	7.3	6.4	11	4.2	30.1	4
0.7	10	12	5	9	49.1	12.3	10.6	9.9	8.6	7.7	17.9	4.3	34.1	4.2
0.7	10	12	5	9	38.2	9	7.2	7.7	7	7.3	17.5	4.2	33.4	4

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.52	10	12	6	9	40.6	10.7	7.6	8.4	6	7.9	17.8	4.3	34.4	4
0.52	10	12	5	9	38.2	9	7.2	7.7	7	7.3	17.5	4.2	33.4	4
0.72	10	12	5	9	111	13.1	19.8	21.1	28.5	28	19.1	4.4	30.9	10.4
0.72	10	13	5	9	74.5	9.7	13.9	13.3	18.6	19	18.6	4.3	30.1	10.1
0.45	10	12	6	9	77.2	12.4	18.3	18.6	13.9	14	17	4.2	32.3	4
0.45	10	12	5	9	38.2	9	7.2	7.7	7	7.3	17.5	4.2	33.4	4
0.7	10	12	5	9	59.9	13.9	12.9	11.3	10.2	11.5	15.7	4.4	33.2	4.2
0.7	10	13	5	9	42.7	9.9	9	7.8	8.1	7.9	15.2	4.3	32.3	4.1
0.68	10	13	5	9	111	13.9	25.5	24.8	24.4	22.3	19.9	4.4	31.5	4.2
0.68	10	13	5	9	75.3	9.6	17	16.4	16.3	16.1	19.4	4.3	30.6	4
3.93	10	13	6	9	58	12.7	11.5	11.3	11.1	11.5	17.4	4.3	32.6	4
3.93	10	17	6	9	34.4	8.5	7	6.7	6.2	6	16.8	4.3	33.6	4.1
0.63	10	14	5	9	113	13.7	24.6	24.1	25	25.4	17.9	4.3	36.7	4.1
0.63	10	15	5	9	78	9.9	15.6	15.5	18.8	18.2	17.3	4.2	35.5	4
0.88	10	14	6	9	49.3	11.8	11.8	11.5	7.4	6.6	17.6	4.2	27.4	4
0.88	10	15	5	9	44.9	10	11.2	10.8	6.8	6.1	17.5	4.2	27.3	4
0.58	10	14	5	9	117	11.4	27.9	26.5	26.5	24.7	14.5	4.4	31.2	4.2
0.58	10	15	6	9	88.5	9.6	20.5	20.2	19.2	19	14.2	4.3	30.7	4.1
0.55	10	15	6	9	48.2	12.5	10.1	10.1	7.9	7.5	15.7	4.3	33.1	4
0.55	10	15	5	9	37.6	9.8	8.2	7.7	5.6	6.3	15.7	4.3	33.1	4
1.05	10	15	6	9	40.4	10.3	9	8.1	5.7	7.3	11.8	4.3	34.5	4
1.05	10	16	5	9	36.9	8.8	9.3	7.7	5.9	5.3	11.7	4.3	34.2	4
0.73	10	15	5	9	51.6	12.3	10.9	10.7	8.5	9.3	18.5	4.4	36.9	4.1
0.73	10	16	5	9	41.2	9.5	9.8	9.5	6.4	5.9	18	4.3	35.9	4

Class 9 trucks spotted traveling NB from I2C to 295 on Day 12/18/2006- calibration factor 1.15 applied to reduce GVW at site I2C between 10:00am and 10:15 am; #Class 9 trucks= 38

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.65	10	0	5	9	60.2	11.8	16.1	15.8	12.1	13.4	16.9	4.3	30.1	4.4
0.65	10	1	6	9	54.1	8.8	13.5	13.2	9.7	8.8	16.5	4.2	29.4	4.3
0.63	10	0	5	9	43.5	10.7	11.8	7.9	9.2	10.4	12.7	4.5	33.8	4.1
0.63	10	1	5	9	34.2	7.2	7.1	6	7.2	6.7	12.4	4.3	33.1	4
0.63	10	1	6	9	71.4	10.2	20.9	19.2	15.8	16.1	14	4.3	32.3	4
0.63	10	2	5	9	71.4	8.9	17.7	15.7	15.3	13.8	14	4.3	32.3	4.1
0.63	10	1	5	9	49.7	13.8	12.5	12.5	8.8	9.5	18.8	4.3	35.8	4.1
0.63	10	2	5	9	40.8	10.3	8.7	9.1	6.7	6.1	18.3	4.2	34.9	4
0.52	10	1	5	9	43.9	11	10.1	11	9	9.4	13.6	4.4	25.5	10.3
0.52	10	2	5	9	40.4	8.4	8	8.4	7.2	8.5	13.4	4.3	24.6	10
0.47	10	1	5	9	63.7	12.9	19.3	20.7	10.7	9.6	19.9	4.4	31.5	4.2
0.47	10	2	5	9	56.2	10	15.5	15.1	7.8	7.8	19.3	4.3	30.6	4
0.77	10	3	5	9	51.8	10.4	16.3	12.6	9.7	10.6	11.2	4.4	35.1	4.1
0.77	10	4	6	9	47.2	8.4	10.5	14.3	7	7	11	4.2	34.4	4.1
0.8	10	4	5	9	99.7	12.6	27.4	28.5	22.3	23.9	17	4.3	29.4	4.1
0.8	10	5	5	9	85.3	9.8	17.6	18.3	19.8	19.8	16.5	4.2	28.5	4.1
0.78	10	4	5	9	81.6	11.4	23.5	21.2	18.9	18.9	11.5	4.4	35.9	4.1
0.78	10	5	5	9	66.2	8.6	16.1	15.7	13.1	12.7	11.3	4.2	34.8	4
0.85	10	5	6	9	39.5	11.5	9.9	9.5	6.8	7.7	16.9	4.3	12.8	4
0.85	10	6	5	9	43.8	9.9	9.4	8.2	7.6	8.7	16.9	4.3	12.8	4
0.68	10	5	5	9	38.8	11.3	10.2	10	5.6	7.4	18	4.3	29.9	10.4
0.68	10	6	5	9	35.6	9.3	7.7	7.3	5.7	5.7	17.5	4.2	29.2	10.2
0.68	10	5	6	9	69.3	10.2	18.7	18.8	15.1	16.9	19.5	4.3	37.1	4.1
0.68	10	6	6	9	82	11	17.9	17.8	17.3	17.9	19.5	4.3	37.3	4.1
1	10	6	6	9	31	11.7	8.6	7.3	3.9	4.3	18.7	4.3	30.2	10
1	10	7	6	9	34.8	10	7.6	7.2	5.1	4.9	18.8	4.3	30.3	10
0.83	10	6	5	9	42.3	10.8	11.1	11.2	7.7	7.8	16.9	4.5	29.4	4.1
0.83	10	7	5	9	40.1	8.8	8	9	6.3	7.9	16.5	4.3	28.5	3.9

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.78	10	6	5	9	39.7	12.2	10.8	10.2	5.4	7	20	4.4	36.6	4.1
0.78	10	7	5	9	35.9	9.3	7.6	7.9	5.1	6	19.5	4.3	35.5	4
0.72	10	6	5	9	45.9	12.3	12	11.6	8	8.9	19.9	4.4	34	4.4
0.72	10	7	5	9	40.2	9.5	8.7	8.6	7.1	6.3	19.3	4.3	33.1	4.3
3.95	10	6	5	9	39	12.6	10.1	9.7	6.3	6.2	17.3	4.5	35.2	4.1
3.95	10	10	5	9	34.8	8.7	6.9	7.7	5.3	6.1	16.5	4.3	34.5	4
0.77	10	7	5	9	80.7	15.5	22.7	25.7	14.7	14.2	18.2	4.3	28.5	4.1
0.77	10	8	5	9	67.4	10.8	17.1	19.6	9.7	10.2	17.7	4.2	27.6	4.1
0.82	10	7	6	9	34.3	11	7.6	7.9	6.5	6.5	16.5	4.3	31.2	4
0.82	10	8	5	9	36.4	9.7	7.8	7.5	5.5	5.9	16.5	4.3	31.1	4
2.45	10	8	6	9	34.3	11	8	7.7	7	5.7	15.8	4.2	33.4	4.1
2.45	10	10	5	9	34.8	8.7	6.9	7.7	5.3	6.1	16.5	4.3	34.5	4
0.77	10	8	6	9	78.6	11.5	19.1	17.6	21.9	20.3	11.3	4.3	34.9	4
0.77	10	9	6	9	75.6	9.2	16.8	14.7	18.2	16.7	11.3	4.4	34.9	4
0.7	10	9	5	9	43	13.1	10.2	9	9.3	8	16.9	4.4	35.3	4.2
0.7	10	10	5	9	34.8	8.7	6.9	7.7	5.3	6.1	16.5	4.3	34.5	4
0.58	10	10	5	9	64.3	14.3	18.7	19.5	8.7	12.7	20	4.4	29.5	4
0.58	10	10	5	9	54.9	10.5	14.2	15.8	6.4	8.1	19.4	4.2	28.6	4
0.67	10	10	5	9	41.4	12.5	9.6	7.9	8.7	8.7	16.2	4.4	33.5	4.1
0.67	10	11	6	9	35.7	9.3	7.5	7.4	5.8	5.8	15.9	4.3	32.8	4
0.83	10	10	6	9	61.7	12.9	16.9	17	13.1	11	19.4	4.2	28.9	4
0.83	10	11	6	9	60	10.2	14.8	14	11.3	9.7	19.6	4.3	29.1	4.1
0.68	10	10	5	9	44.5	12.8	10	8.5	8.4	11.5	18	4.4	31.2	4.1
0.68	10	11	6	9	34.7	9.8	6.6	6.3	6	6	17.7	4.3	30.4	4
0.72	10	11	6	9	36.6	10.9	7.9	7.8	8.5	7.1	11	4.3	30.1	4.1
0.72	10	12	5	9	37.2	8.8	7.1	7.5	7.3	6.4	11	4.2	30.1	4
0.7	10	12	5	9	42.7	12.3	10.6	9.9	8.6	7.7	17.9	4.3	34.1	4.2
0.7	10	12	5	9	38.2	9	7.2	7.7	7	7.3	17.5	4.2	33.4	4
0.52	10	12	6	9	35.3	10.7	7.6	8.4	6	7.9	17.8	4.3	34.4	4
0.52	10	12	5	9	38.2	9	7.2	7.7	7	7.3	17.5	4.2	33.4	4
0.72	10	12	5	9	96.1	13.1	19.8	21.1	28.5	28	19.1	4.4	30.9	10.4
0.72	10	13	5	9	74.5	9.7	13.9	13.3	18.6	19	18.6	4.3	30.1	10.1

Time	Hr	Min	Ln	Cls	GVW	W1	W2	W3	W4	W5	S1	S2	S3	S4
0.7	10	12	5	9	52.1	13.9	12.9	11.3	10.2	11.5	15.7	4.4	33.2	4.2
0.7	10	13	5	9	42.7	9.9	9	7.8	8.1	7.9	15.2	4.3	32.3	4.1
0.68	10	13	5	9	96.4	13.9	25.5	24.8	24.4	22.3	19.9	4.4	31.5	4.2
0.68	10	13	5	9	75.3	9.6	17	16.4	16.3	16.1	19.4	4.3	30.6	4
0.63	10	14	5	9	98.1	13.7	24.6	24.1	25	25.4	17.9	4.3	36.7	4.1
0.63	10	15	5	9	78	9.9	15.6	15.5	18.8	18.2	17.3	4.2	35.5	4
0.88	10	14	6	9	42.9	11.8	11.8	11.5	7.4	6.6	17.6	4.2	27.4	4
0.88	10	15	5	9	44.9	10	11.2	10.8	6.8	6.1	17.5	4.2	27.3	4
0.58	10	14	5	9	102	11.4	27.9	26.5	26.5	24.7	14.5	4.4	31.2	4.2
0.58	10	15	6	9	88.5	9.6	20.5	20.2	19.2	19	14.2	4.3	30.7	4.1
0.55	10	15	6	9	41.9	12.5	10.1	10.1	7.9	7.5	15.7	4.3	33.1	4
0.55	10	15	5	9	37.6	9.8	8.2	7.7	5.6	6.3	15.7	4.3	33.1	4
1.05	10	15	6	9	35.1	10.3	9	8.1	5.7	7.3	11.8	4.3	34.5	4
1.05	10	16	5	9	36.9	8.8	9.3	7.7	5.9	5.3	11.7	4.3	34.2	4
0.73	10	15	5	9	44.9	12.3	10.9	10.7	8.5	9.3	18.5	4.4	36.9	4.1
0.73	10	16	5	9	41.2	9.5	9.8	9.5	6.4	5.9	18	4.3	35.9	4

Class 10 trucks spotted traveling NB from I2C to295 on Day 12/18/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	S1	S2	S3	S4	S5
0.93	8	28	6	39.4	9.7	7.3	7.1	3.1	5.2	7	15.9	4.3	14.7	4.4	4.4
0.93	8	29	6	35.7	8.7	6.7	6.1	3.5	4.6	6	15.9	4.3	14.8	4.5	4.5
1.08	8	35	6	66.6	12.3	16.1	13.9	7.7	7.9	8.8	15.7	4.5	34.6	4.5	4.5
1.08	8	36	6	62.7	11.9	17.2	13.7	6.9	6.1	7.1	15.7	4.6	34.6	4.5	4.5
0.67	8	52	5	45.5	11.9	6.3	7.7	6.2	6.2	7.2	17.3	4.4	18.9	4.5	4.6
0.67	8	53	5	37.9	8.9	7.1	5.4	5.4	5.3	5.9	16.8	4.3	18.4	4.3	4.4
0.72	9	20	5	51.3	12.8	8.3	7.7	8	7	7.5	17.1	4.3	13	5.1	5.1
0.72	9	21	5	36.6	9.1	6.5	5.1	5.7	5.4	4.8	16.7	4.3	12.7	5	5
0.72	9	20	5	49	11.8	7.7	8.5	6.8	6.4	7.7	17.8	4.3	18.9	4.5	4.5
0.72	9	21	5	38.6	8.8	6.1	6.4	5.2	5.3	6.9	17.4	4.2	18.5	4.3	4.4
0.93	9	35	6	51.6	12.3	10.5	11.6	5.7	4.6	6.9	13.4	5	33.8	4.1	4.1
0.93	9	36	6	47.4	10	9.6	10.1	4.9	6.8	6.1	13.4	5	34.1	4.1	4.2
0.9	9	44	5	49.6	13.6	9.8	10.3	4.5	4.3	7.1	17.3	4.4	24.2	5.1	5.1
0.9	9	45	5	38.6	9.9	7.7	8	4	4.4	4.5	16.8	4.3	23.5	4.9	5
1.15	11	5	6	40.4	7.5	8.2	7.9	5.6	5.2	6	12.5	4.3	26.6	3.9	3.9
1.15	11	7	6	47.8	7.2	8.3	8.5	8.6	7	8.2	12.6	4.4	26.7	4	3.9
0.63	12	19	5	133	15.5	24.6	28	18.9	21.8	24	20.3	4.4	20.5	4.2	4
0.63	12	19	5	84.1	10.1	15.5	16.2	13.2	14	15.1	19.7	4.3	19.9	4	4
0.7	12	52	6	103	11.5	11.9	12	22.4	22.9	22.6	19.1	4.3	30.8	4.5	4.5
0.7	12	52	5	85.4	9.1	12.1	10.6	18.3	17.1	18.2	19.1	4.3	30.9	4.5	4.4
0.68	12	52	6	79.4	8.7	18.8	18.6	8.6	11.5	13.2	18.4	4.3	30.5	5	5
0.68	12	52	5	70.9	8.3	16.2	16.5	8.8	9.7	11.5	18.3	4.3	30.5	5	5
0.68	12	52	6	79.8	10.9	17.6	16	12.9	11.9	10.4	15.3	4.2	31	4.5	4.4
0.68	12	52	5	65.9	10	13	12.5	11.3	10.2	8.9	15.3	4.2	30.9	4.5	4.4
1.38	13	8	6	95.7	9.1	23.6	25.8	12.3	12.8	12.1	11.6	4.6	34.4	4.1	5.2
1.38	13	10	6	84.7	8	25.4	20.7	10.8	9.6	10.2	11.7	4.7	34.5	4.2	5.2
1.67	13	41	6	83.3	8.9	17.8	18.7	12.8	13.3	11.8	12.3	4.3	32.9	4.1	4.1
1.67	13	43	6	77.8	8.4	17.9	18.4	11.5	11	10.6	12.4	4.3	33.1	4.2	4.1
0.92	13	46	6	80.4	11.1	18	17.3	13.8	11.7	8.6	19.5	4.3	31	4.5	4.6
0.92	13	47	6	72.2	9.4	15.2	16.8	13.2	9.3	8.3	19.5	4.2	31.1	4.5	4.5

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	S1	S2	S3	S4	S5
0.83	14	14	6	125	10.3	26.8	27.7	20.1	18.9	20.8	12.7	4.3	37.5	4.1	4.1
0.83	14	15	6	107	8.8	22.8	23.4	17	16.9	17.9	12.7	4.3	37.7	4.1	4.1
0.72	14	30	5	59.4	12	12.2	17	4.5	5.1	8.6	15.2	4.2	20.4	4.2	4.1
0.72	14	31	5	46.9	8.9	11.3	9.7	5.2	5.2	6.6	14.8	4.1	19.7	4.1	4
0.77	14	39	5	72.3	15.7	15.3	13	11	11	6.4	21.3	4.5	37.8	4.1	4.2
0.77	14	39	6	48.4	11.1	10.6	9.9	5.4	6.8	4.7	20.8	4.3	36.8	4	4
0.6	14	41	5	51.9	10.8	11.2	11.3	6	5.3	7.3	16.5	4.6	19.6	4.2	4.1
0.6	14	42	6	40.4	8.3	7.5	8.5	4.3	5.4	6.4	16.2	4.5	19.2	4	4
1.08	15	24	5	81.2	10.7	18.6	20.7	10.3	11.3	9.5	12.1	4.8	35.3	4.2	5.4
1.08	15	25	5	60.1	8.7	15.3	14.2	7.6	7.3	6.9	11.6	4.6	34.3	4.1	5.2
0.8	16	23	5	48.9	9.6	9.8	9.4	7.2	7.4	5.6	12	4.4	25.3	4.5	4.6
0.8	16	24	5	41.3	8	8.8	9.1	5.5	5.9	4	11.7	4.2	24.7	4.4	4.6
0.73	16	45	5	62.6	12.4	13.1	12	7.4	8.2	9.5	15.2	4.5	37	4.6	4.6
0.73	16	46	6	43.6	9.3	10	9.2	4.9	6.4	3.7	14.9	4.3	36.1	4.5	4.6
0.9	17	50	5	112	12.4	21.6	21.3	17.3	19.5	19.8	17.6	4.4	22.2	4.1	4.2
0.9	17	51	5	81.9	9.3	17.3	17	11.1	13.6	13.6	17.1	4.3	21.6	4	4.1
0.68	22	41	6	44	12.9	7.9	7.7	6.3	5.3	4	16.7	4.3	22.7	3.9	4.1
0.68	22	42	6	41.3	10.4	8	7.6	6.1	5.6	3.5	16.7	4.3	22.8	3.9	4.1
0.67	22	41	6	48.1	12.1	9.9	9.5	4.8	5.2	6.6	19.5	4.3	24.5	4.1	4.2
0.67	22	42	6	41.1	9.3	9.3	7.5	3.9	6.1	4.9	19.6	4.3	24.7	4.1	4.2

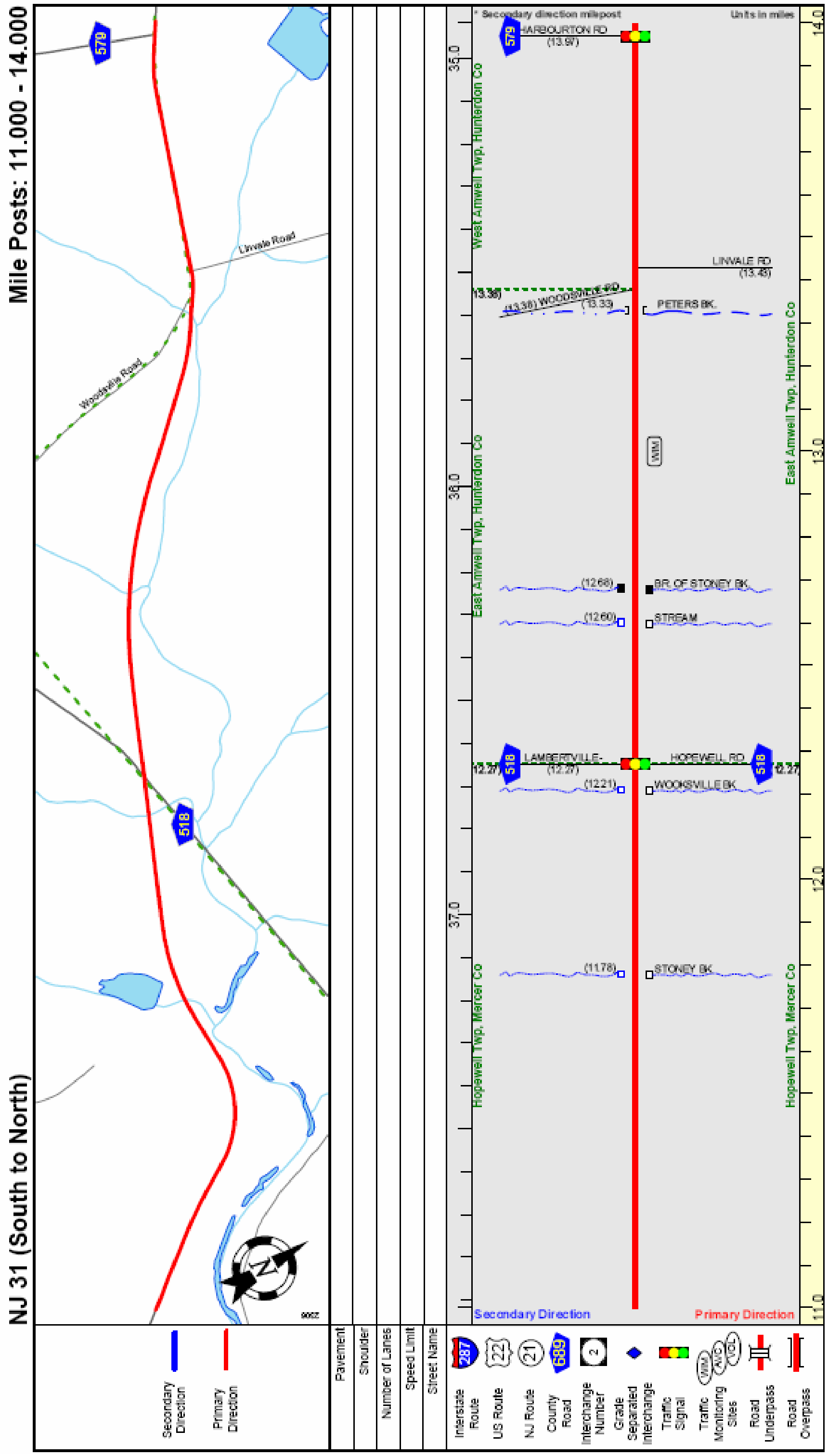
Class 12 truck spotted traveling NB from I2C to295 on Day 12/18/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	S1	S2	S3	S4	S5
0.7	13	19	5	120	14.4	23	22.3	19.5	18.8	21.4	18.6	4.4	27.3
0.7	13	20	6	77.7	8.8	14.7	14.3	13.7	12.9	13.2	18.2	4.3	26.8

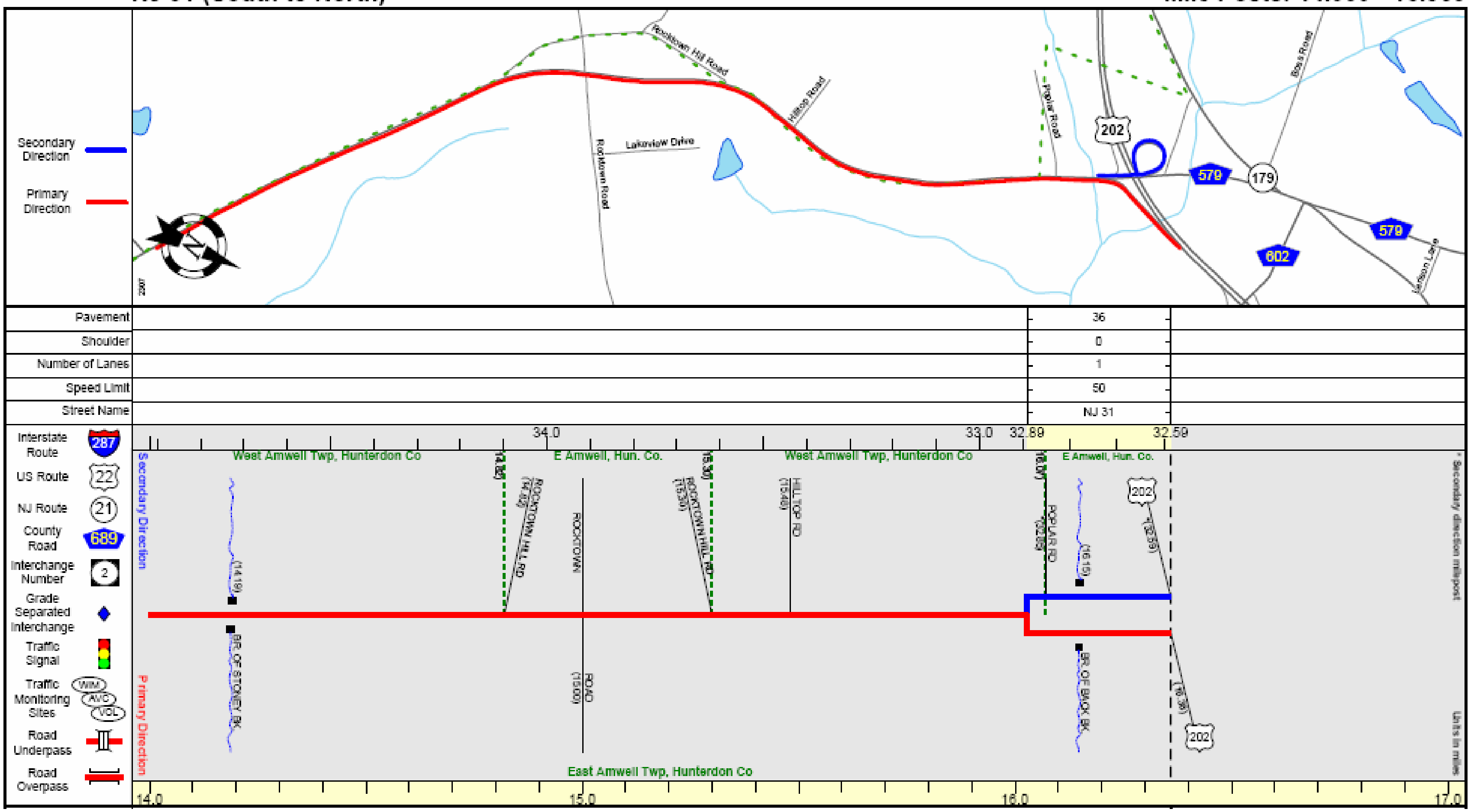
Class 13 trucks spotted traveling NB from I2C to295 on Day 12/18/2006

Time	Hr	Min	Ln	GVW	W1	W2	W3	W4	W5	W6	W7	S1	S2	S3	S4	S5	S6
1.35	13	34	6	167	8.5	15.9	25.6	31.1	30.1	27.3	28.3	11.5	4.1	4.6	33.5	4	4.1
1.35	13	35	6	156	7.8	16.4	27.7	30.4	24.8	23.8	24.8	11.5	4.1	4.6	33.7	4.1	4.1
0.92	14	16	6	153	8.1	19.7	26.1	26	24.2	23.9	24.6	14.8	4.4	4.3	35.2	4.2	4.1
0.92	14	17	5	126	7.1	18.4	20.7	20.6	19.6	19.4	20.5	14.8	4.5	4.3	35.2	4.1	4.1

APPENDIX B: STRAIGHT LINE DIAGRAMS
(http://www.state.nj.us)

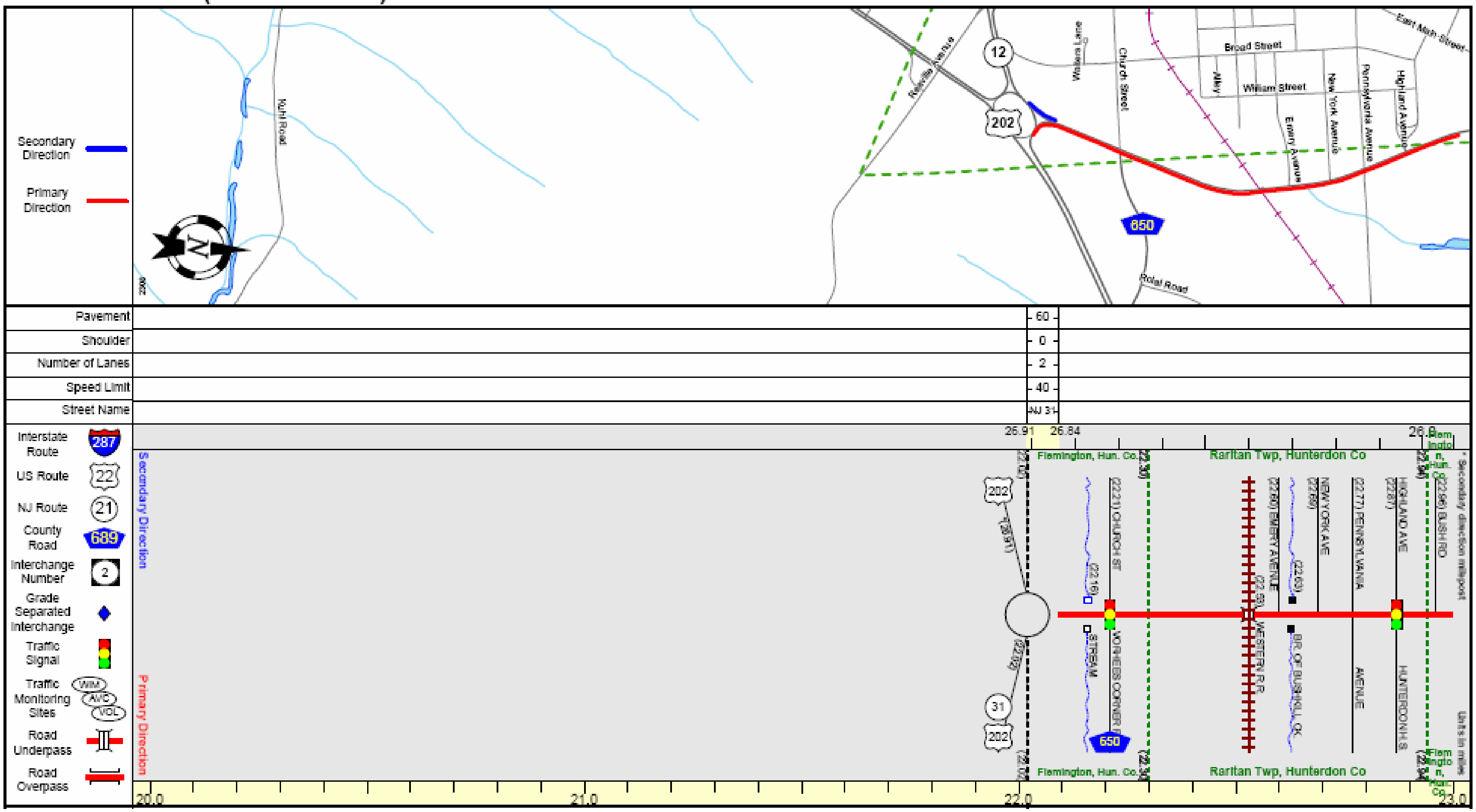


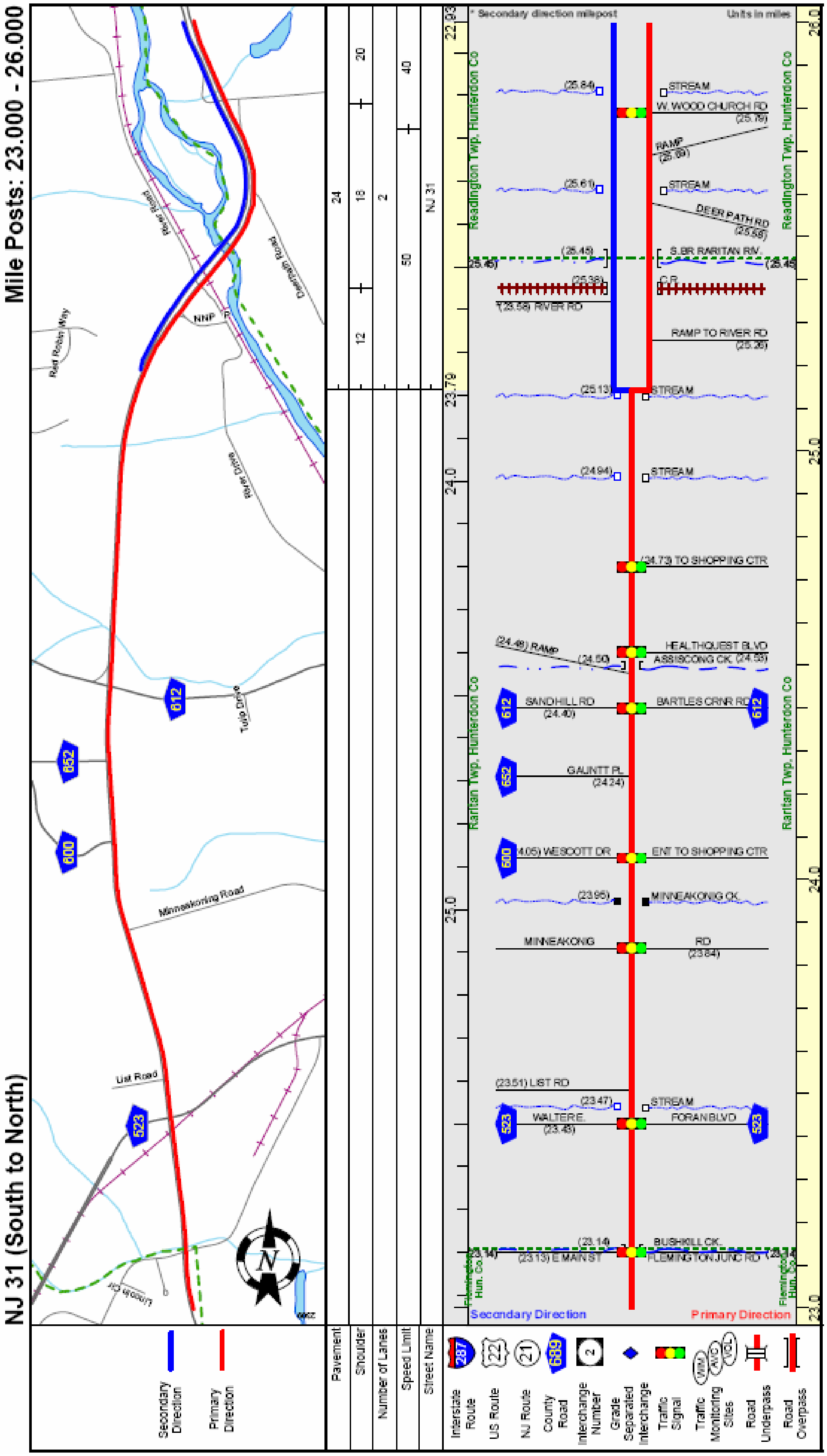
NJ 31 (South to North) Mile Posts: 14.000 - 16.360



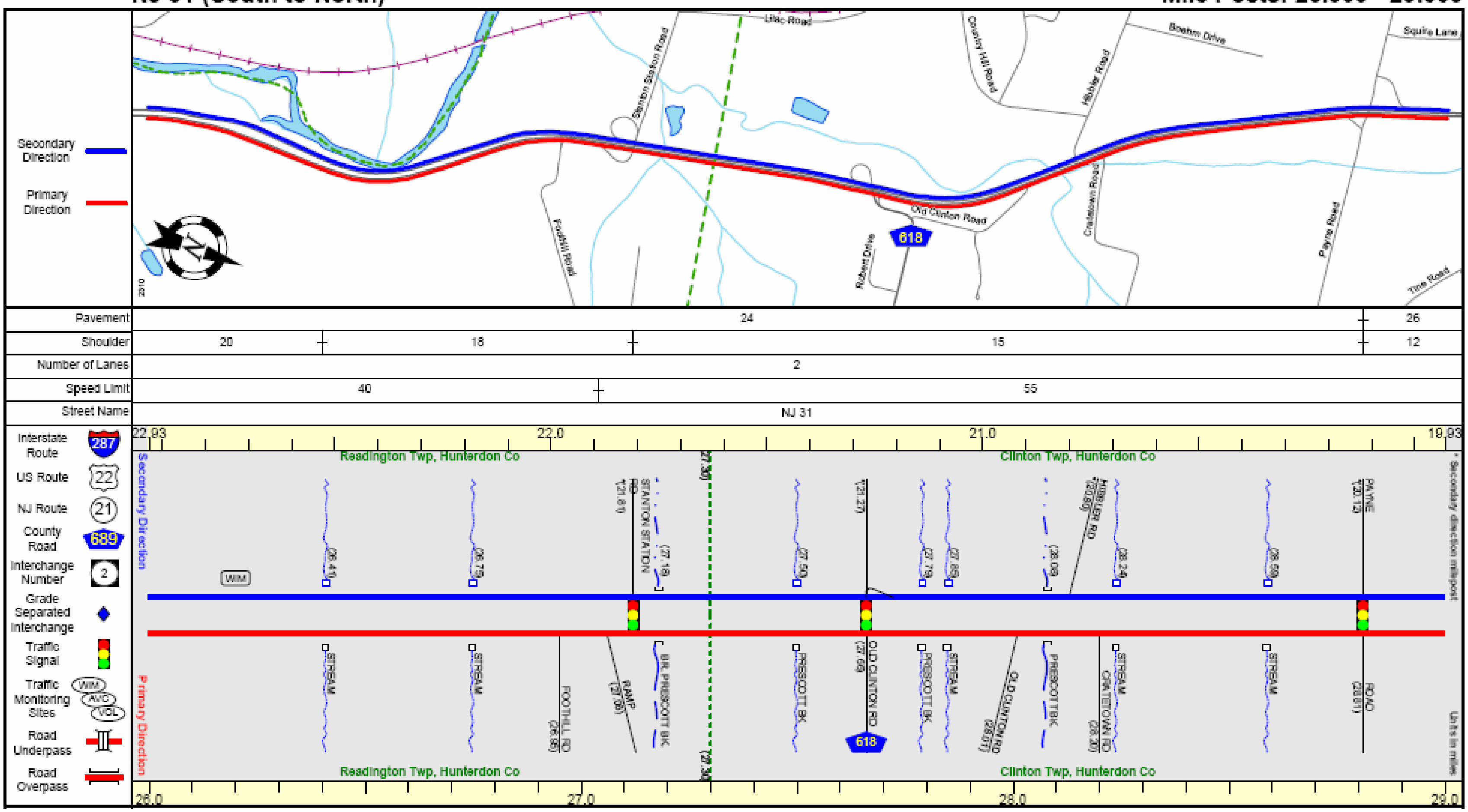
NJ 31 (South to North)

Mile Posts: 22.020 - 23.000



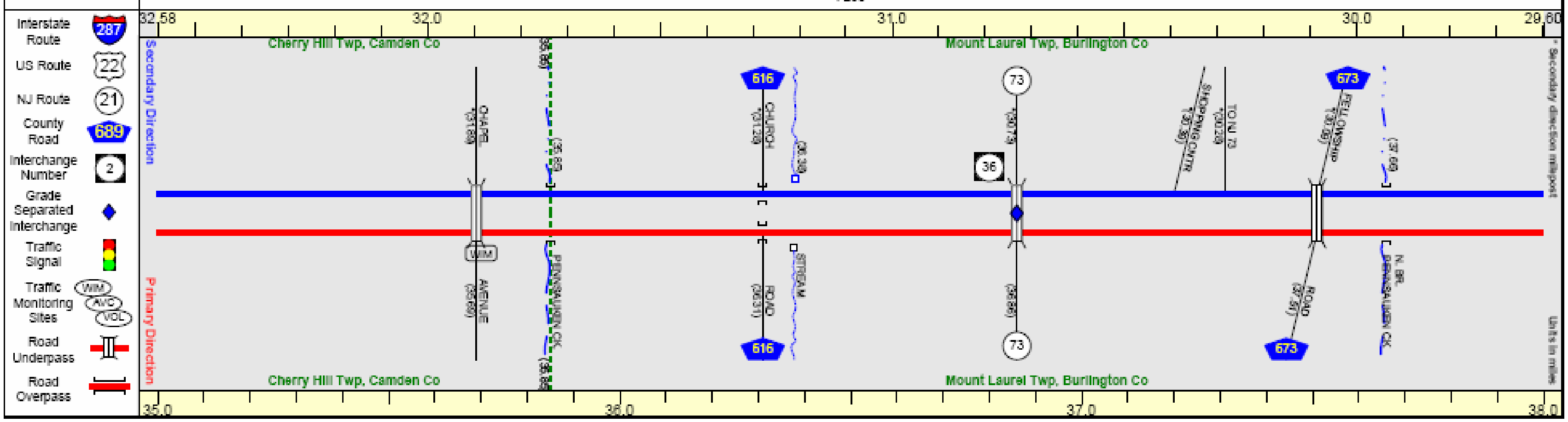

NJ 31 (South to North)
Mile Posts: 23.000 - 26.000
Secondary Direction
Primary Direction
Pavement
Shoulder
Number of Lanes
Speed Limit
Street Name
Interstate Route
US Route
NJ Route
County Road
Interchange Number
Grade Separated Interchange
Traffic Signal
Traffic Monitoring Sites
Road Underpass
Road Overpass
* Secondary direction milepost
Units in miles
NJ 31
Raritan Twp, Hunterdon Co
Readington Twp, Hunterdon Co
(23.13) E MAIN ST
FLEMINGTON JUNC RD
BUSHKILL CK
WALTER E.
FORAN BLVD
(23.51) LIST RD
MINNEAKONIG RD
MINNEAKONIG CK
(24.05) WESCOTT DR
ENT TO SHOPPING CTR
GAUNTT PL
SANDHILL RD
BARTLES CRNR RD
HEALTHQUEST BLVD
ASSISCONG CK
(24.73) TO SHOPPING CTR
STREAM
RAMP TO RIVER RD
(25.58) RIVER RD
S.BR RARITAN RIV.
DEER PATH RD
W. WOOD CHURCH RD
Minneakoning Road
List Road
Tulip Drive
River Drive
River Road
Dreahook Road
Red Robin Way
Lincoln Cir

NJ 31 (South to North) **Mile Posts: 26.000 - 29.000**

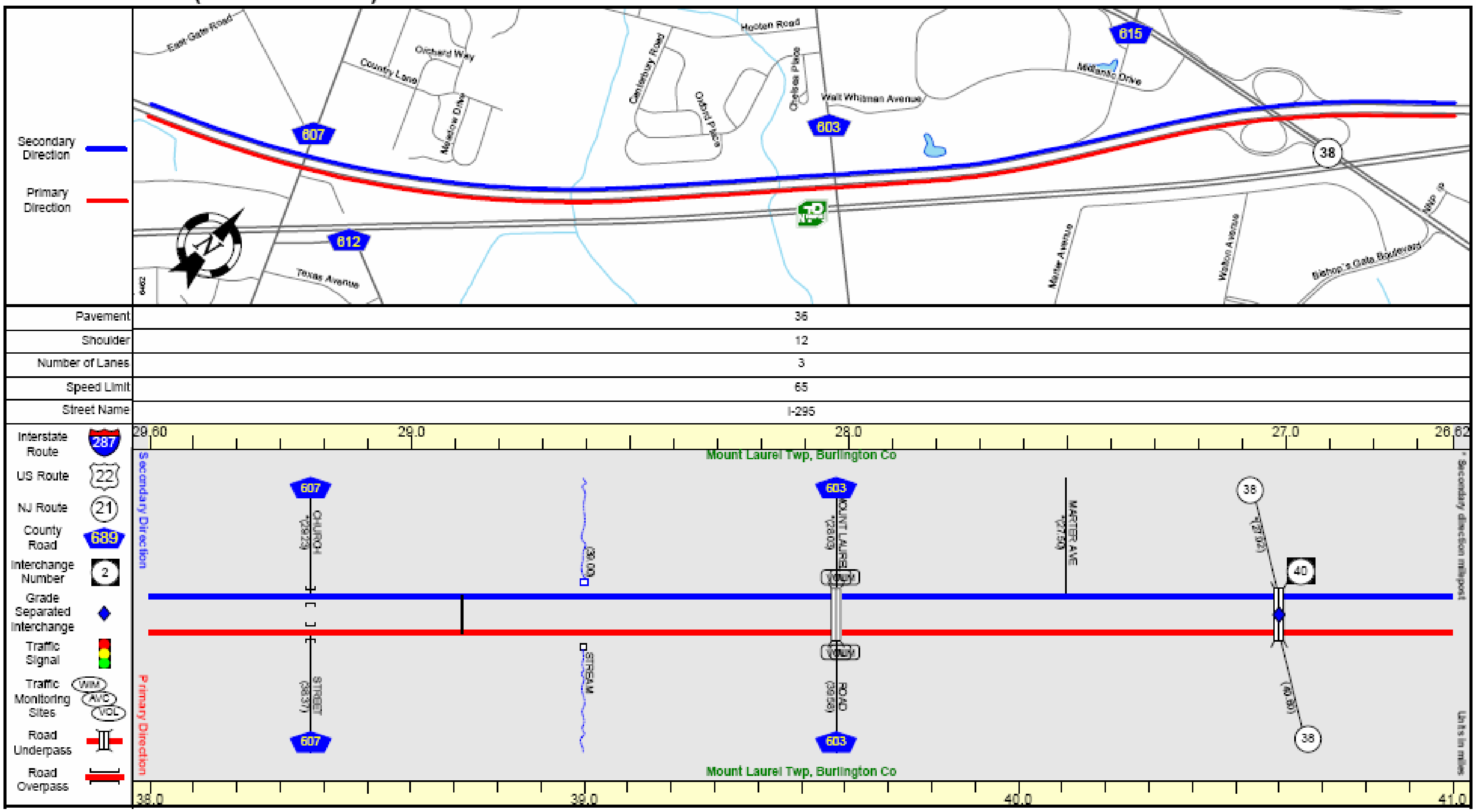


I-295 (South to North) — Mile Posts: 35.000 - 38.000

Pavement	36
Shoulder	12
Number of Lanes	3
Speed Limit	55 / 65
Street Name	I-295

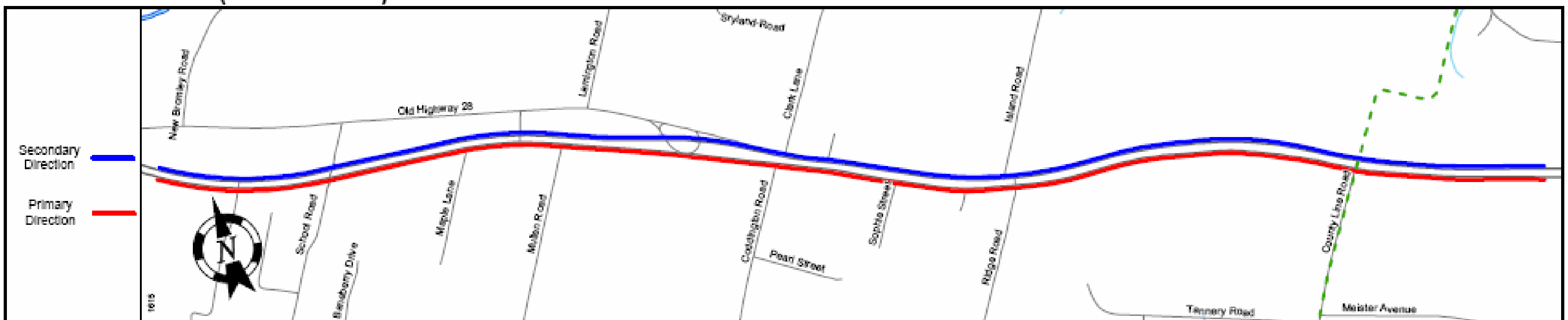


I-295 (South to North) Mile Posts: 38.000 - 41.000

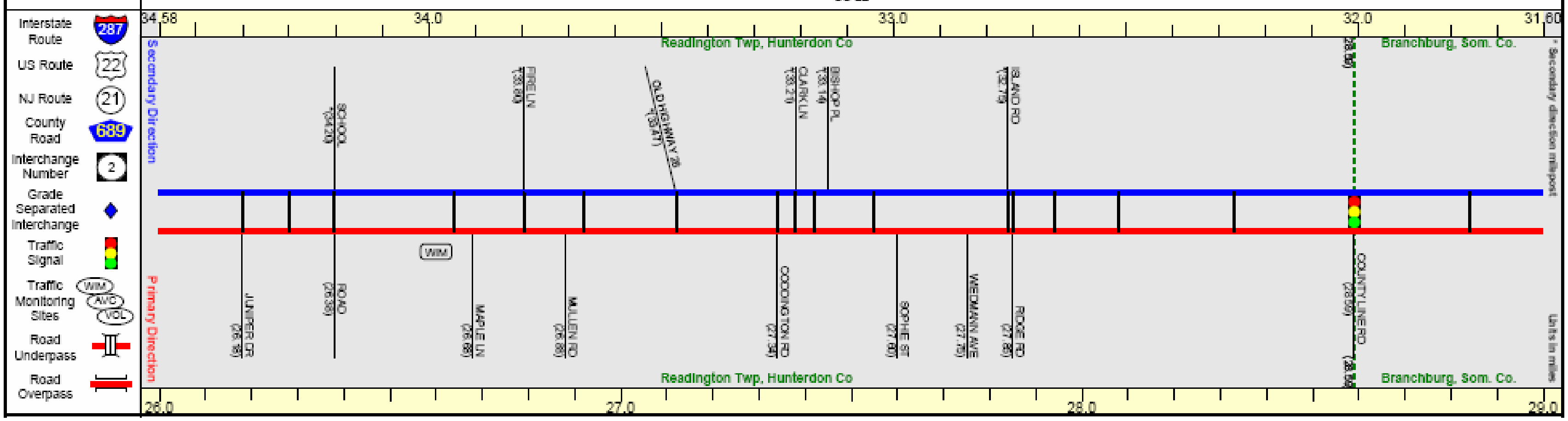


US 22 (West to East)

Mile Posts: 26.000 - 29.000

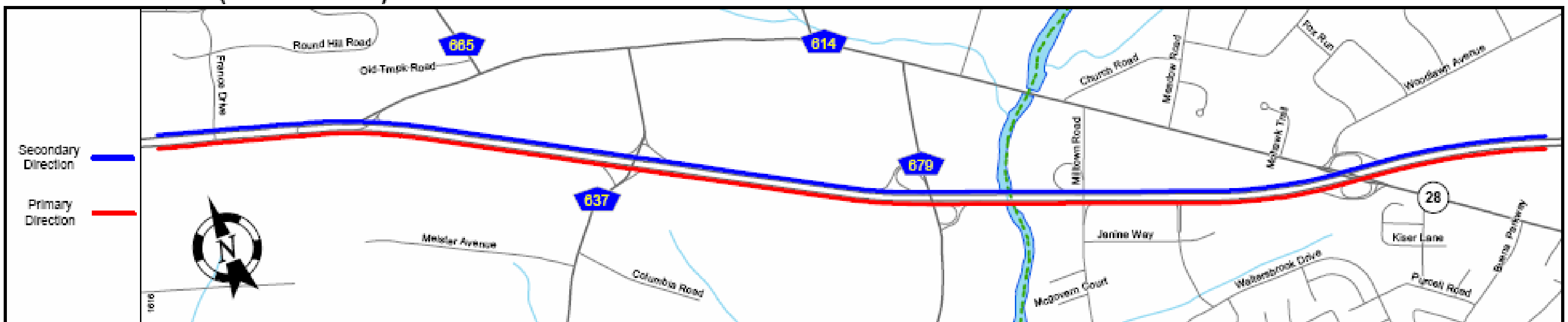


Pavement	24
Shoulder	10
Number of Lanes	2
Speed Limit	55
Street Name	US 22

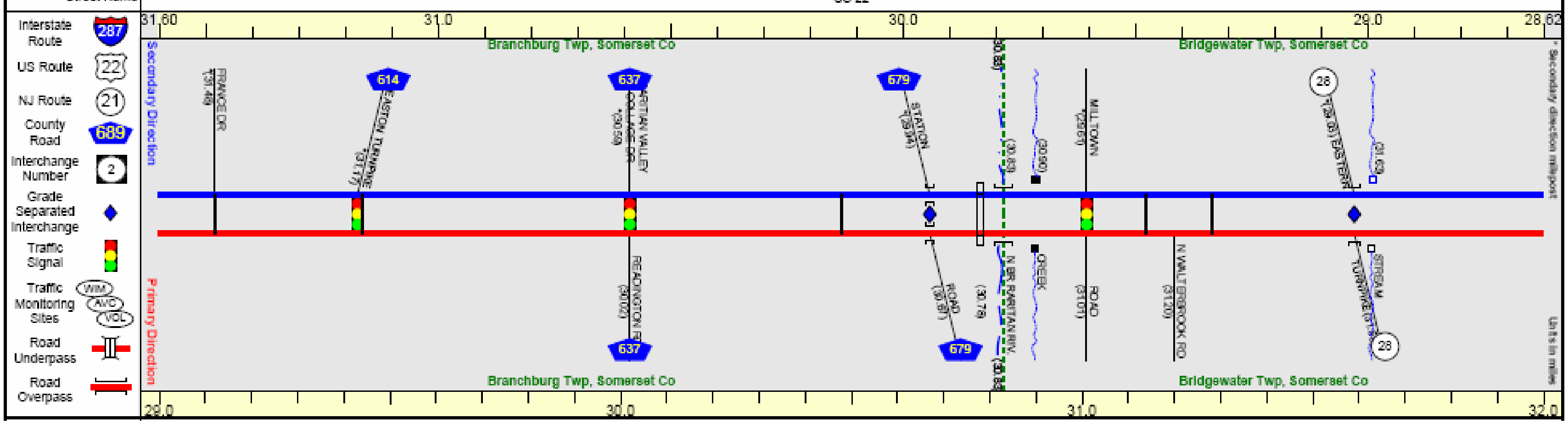


US 22 (West to East)

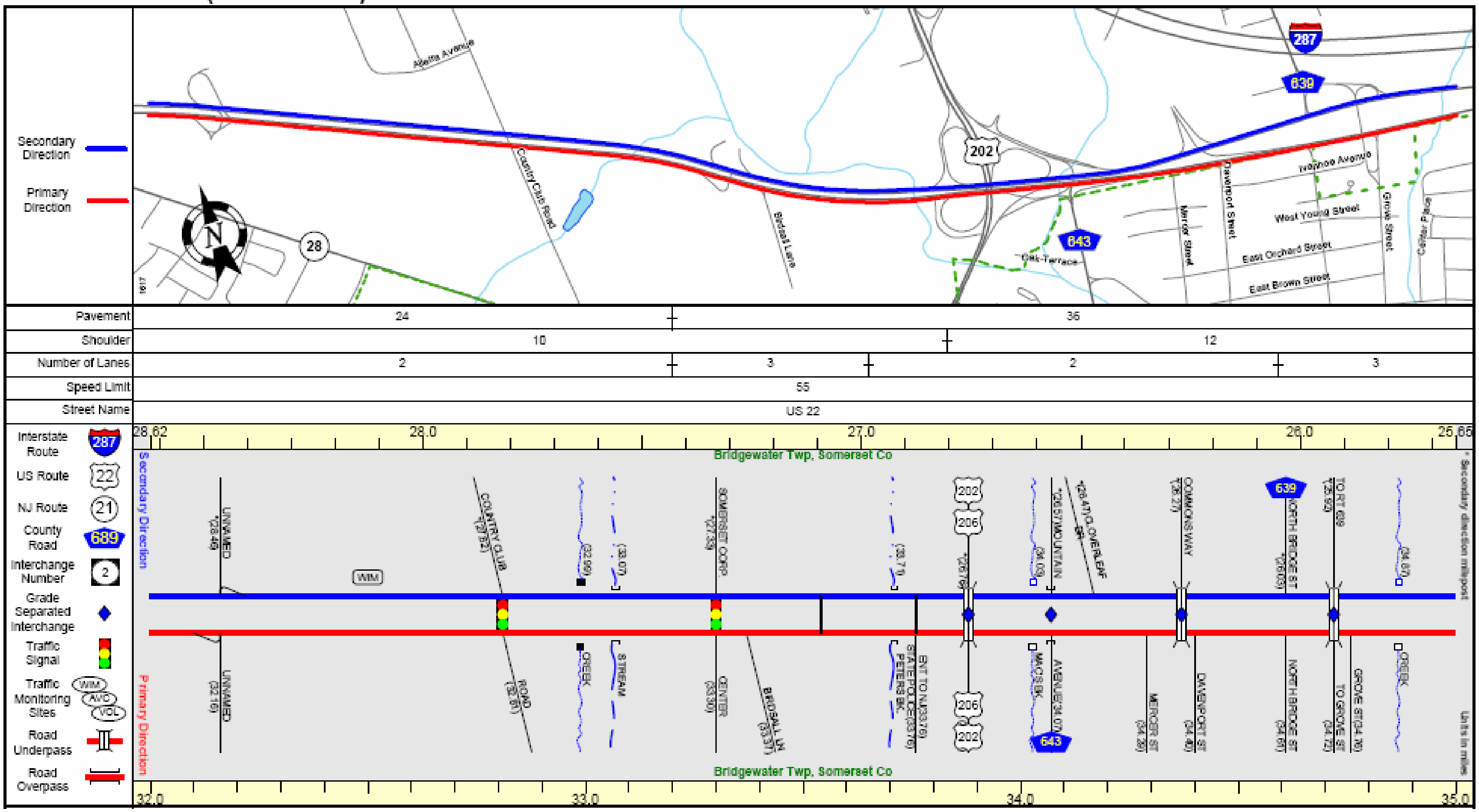
Mile Posts: 29.000 - 32.000



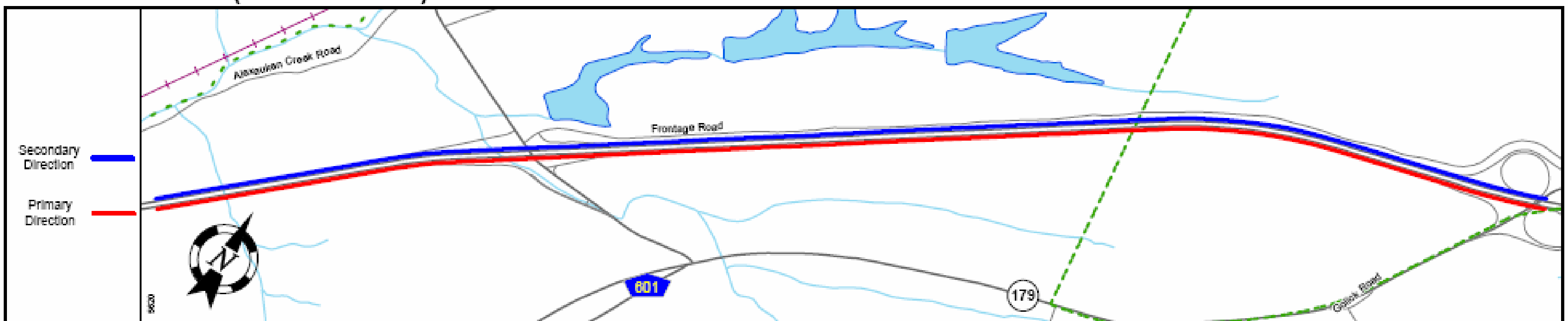
Pavement	24
Shoulder	10
Number of Lanes	2
Speed Limit	55
Street Name	US 22



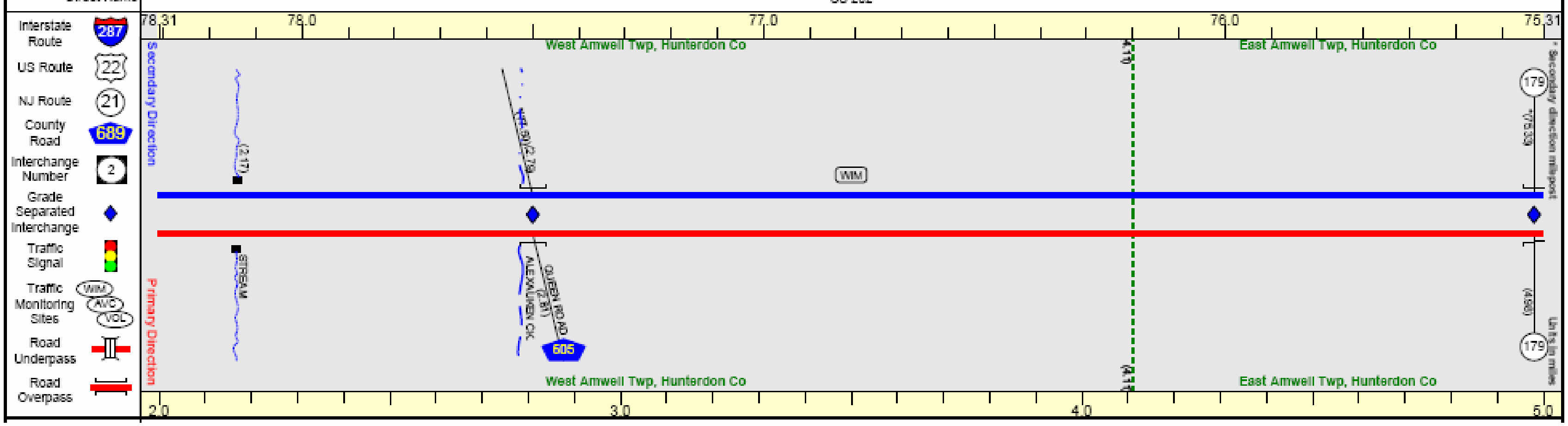
US 22 (West to East) — Mile Posts: 32.000 - 35.000



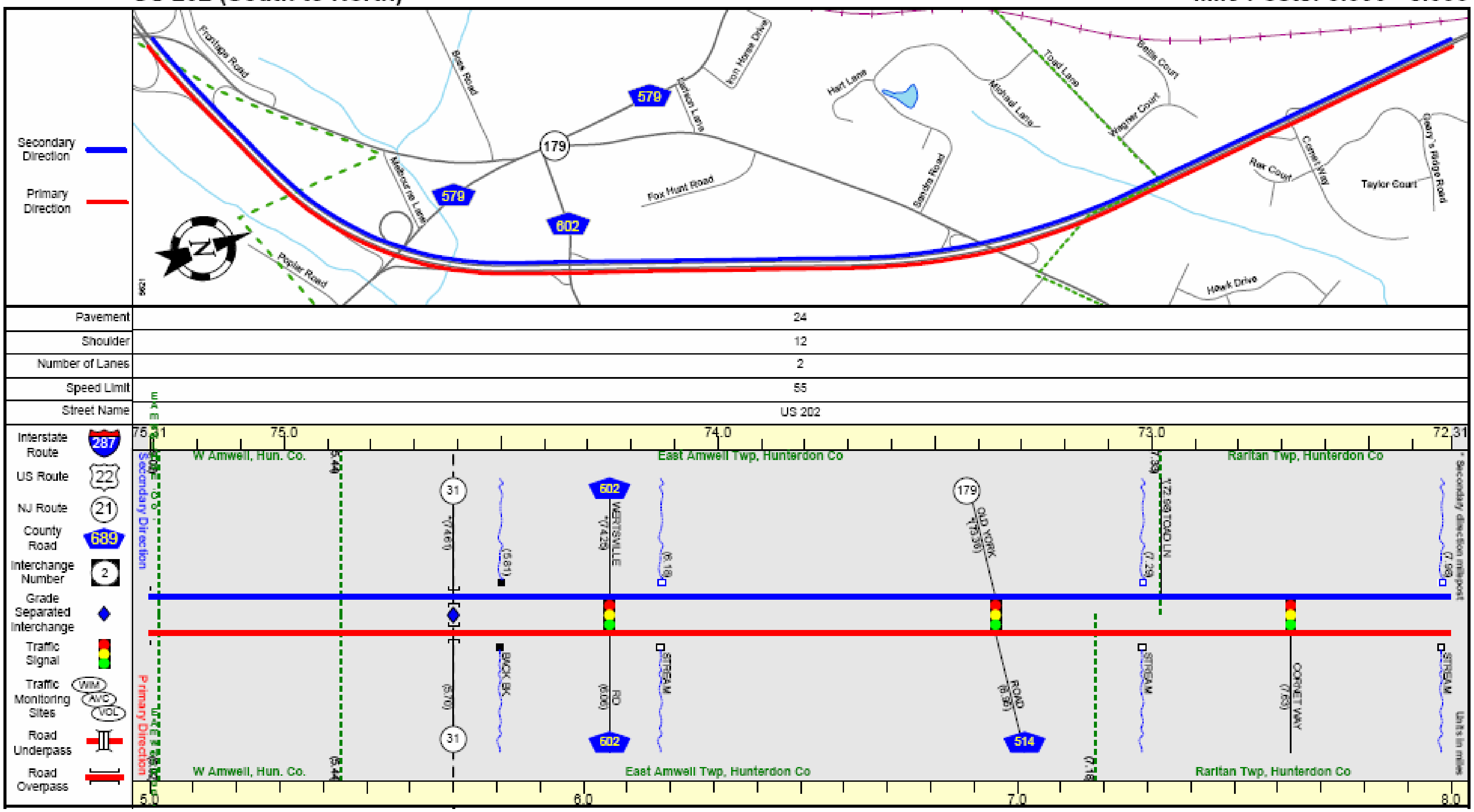
US 202 (South to North) Mile Posts: 2.000 - 5.000



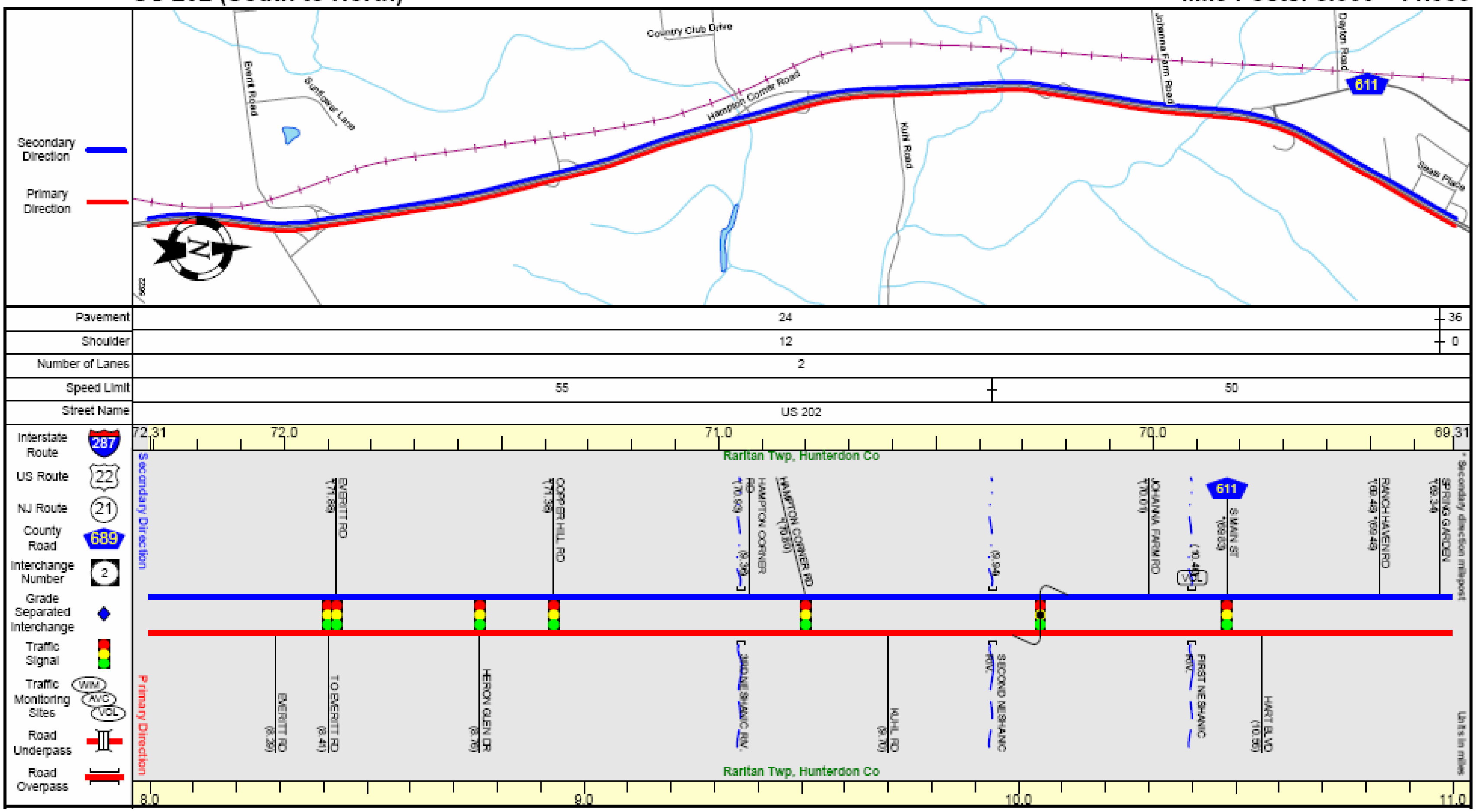
Pavement	24
Shoulder	12
Number of Lanes	2
Speed Limit	55
Street Name	US 202



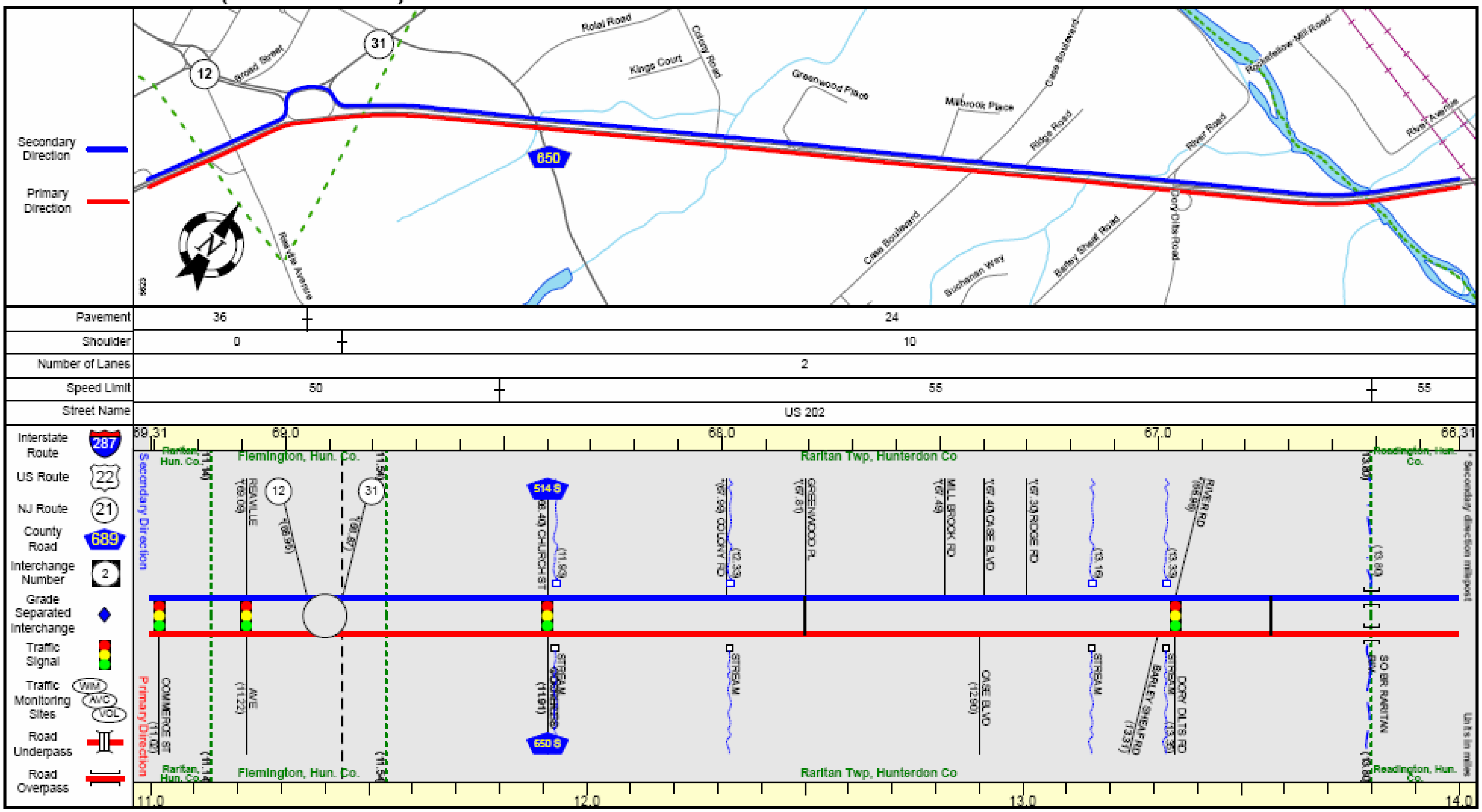
US 202 (South to North) — Mile Posts: 5.000 - 8.000



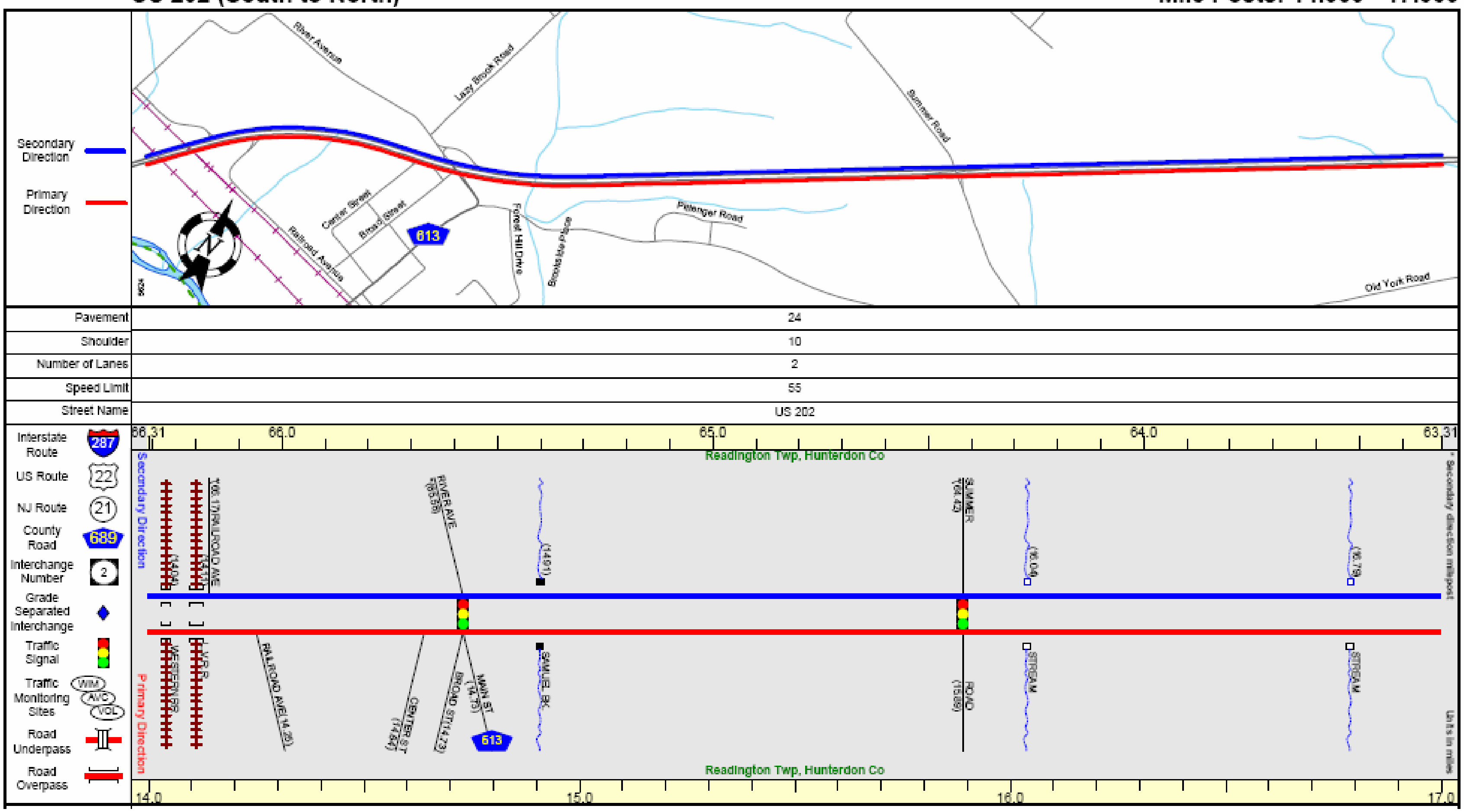
US 202 (South to North) **Mile Posts: 8.000 - 11.000**



US 202 (South to North) — Mile Posts: 11.000 - 14.000



US 202 (South to North) — Mile Posts: 14.000 - 17.000



US 202 (South to North) — Mile Posts: 17.000 - 20.000