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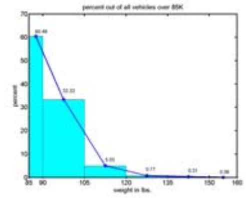

Probabilistic Assessment of Bridge Loading Concurrent with Permit Vehicles

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16. Abstract

The presence of a single permit vehicle on a bridge in addition to the loads from standard weight vehicles is arguably accounted for implicitly in the multi-presence factors in the AASHTO code. However, the presence of multiple permit vehicles may conceivably exceed the capacity of the bridge. This study provides guidance for determining the loads that should be considered concurrent for the purpose of calculating appropriate bridge operating ratings.

The study presents a statistical analysis of permit vehicles (vehicles that exceed 80,000 lbs.) traveling in close proximity to each other over bridges within the State of Florida. The objective is to find the likelihood of exceeding various combined weights of concurrent permit vehicles on a bridge. The source of data for this study are the weigh in motion (WIM) records from 37 WIM stations in Florida, collected between January 1998 and August 2003. The study presents results from the four most heavily traveled WIM stations.

A concurrent permit vehicle occurrence is defined as two or more permit vehicles that are within close enough proximity to each other as to span a total distance no longer than the average length of all bridges within a 15-mile radius of the given WIM station. In this manner, the probability of concurrent vehicles exceeding various weight thresholds is extrapolated from the actual measurement location (WIM station) to those bridges within 15 miles of the station and along the same route. It is shown that, within any given month, there is a high probability of more than one permit vehicle concurrently crossing bridges along major traffic routes. Further, there is an appreciable likelihood that the combined weight of these concurrent permit vehicles will exceed 250,000 lbs. within any given month. The specific probabilities are quantified within the report for the four WIM stations analyzed.

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Weigh in motion, permit vehicles, multi-presence factor, bridge loading, probability modeling	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA, 22161

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Purpose
This document is a companion to the research presented in the Master's Thesis authored by Matthew Crim, adds additional material necessary to support the findings of this study, and presents the final product of the research.

Problem Statement and Outcome Summary
The study is a statistical analysis of multiple permit vehicles traveling in close proximity to each other within the State of Florida, where a permit vehicle is defined as exceeding 80,000 lbs. The specific problem is to find the likelihood that the combined weight of concurrent vehicles on a bridge will exceed a given threshold within a given length of time. The study will provide a statistical prediction of the probability of a bridge experiencing heavy vehicle induced weights that exceed various values at least once within a one-month period. The source of data for this study is the weigh in motion (WIM) records from 37 WIM stations in Florida. The dates of available data differ among WIM stations, with a maximum possible span of January 1998 through August 2003. The presence of non-permit vehicle traffic on the bridge is not modeled.

The final products from this study are a chart and graph indicating the probability of the combined weight of concurrent permit vehicles on a bridge exceeding various threshold values at least once over a one-month period. A concurrent permit vehicle occurrence is defined as two or more permit vehicles that are within close enough proximity to each other as to span a total distance no longer than the average length of all bridges within a 15-mile radius of the given WIM station and along the same route. In this manner, the probability of concurrent vehicles exceeding various weight thresholds is extrapolated from the actual measurement location (WIM station) to those bridges within 15 miles of the station and along the same route.

The final graph and table are provided for four WIM stations (9913, 9926, 9932, 9936), each located along a major truck route with high traffic volume, and is geographically separated from the other three (see Figure 5-2). The final chart and table are provided at the end of this document following a report on the methods used to produce them.

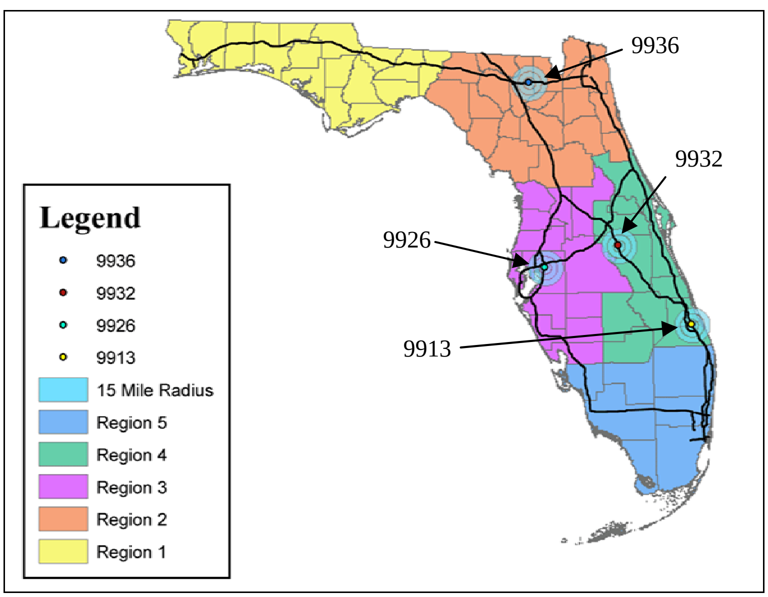

Figure 5-2 from thesis. Locations of the four WIM sites selected for analysis.

Solution Procedure

The solution procedure will begin with a specific example of the problem statement:

> At WIM station 9913, what is the probability of observing at least one occurrence of concurrent permit vehicles with a combined weight that exceeds 220,000 lbs within a one-month time frame?

A procedure to solve the above problem statement is outlined below. This procedure is then applied to a simple coin-flipping problem to illustrate the methodology. Finally the procedure is applied to the concurrent permit vehicle problem, and the final graph and table are presented.

The following is the procedure for determining the probability of a particular outcome of an event occurring at least once during a chosen time frame:

1) Define the event
2) Define the possible outcomes of that event
3) Model a probability distribution of the possible outcomes
    a. Create a histogram from observed event outcomes
    b. Fit an appropriate probability distribution to the histogram and determine the probability of occurrence of the event outcome of interest.
4) Define a time frame of interest
5) Define how many times the event will occur in that chosen time frame
6) Determine the probability that a particular outcome of that event will occur at least once in the chosen time frame (using the binomial distribution)

Example Application of Procedure: Predicting the Outcomes of a Coin Flipping Experiment

This procedure will be demonstrated first by walking through a simple coin flipping example. The goal is to determine the probability of obtaining a 'heads' outcome at least once after flipping the coin a specific number of times.

<u>1) Define the event:</u>

A fair coin is flipped.

<u>2) Define the possible outcomes of that event:</u>

The outcome of a single event is either 'heads' or 'tails'.

<u>3) Model a probability distribution of the possible outcomes:</u>

In this case the obvious answer is heads = 50% and tails = 50%, but the formal procedure based on observation will be demonstrated.

<u>3-a. Create a histogram from observed event outcomes</u>

Flip the coin 100,000 times. Count the number of times heads occurs and the number of times tails occurs. Let's say that we observe 50,500 heads and 49,500 tails. Thus the histogram would be .505 for heads and .495 for tails.

<u>3-b. Fit an appropriate probability distribution to the histogram</u>

Since we expect both events to have equal probability, we use the uniform distribution to model the histogram. The fitted model would take the average probability of the 2 outcomes, which produces the 50/50 heads/tails.

4) Define a time frame of interest:

Five minutes.

5) Define how many times the event will occur in that chosen time frame:

The coin will be flipped once per minute, so five events will occur in the chosen time frame of five minutes

6) Determine the probability that a particular outcome of that event will occur at least once in the chosen time frame (use binomial distribution):

Part 3 of the procedure determined the probability of heads occurring as the outcome of a single event. We now use this information to consider the probability of one or a series of outcomes over multiple events. The *binomial probability distribution* can provide the probability of observing exactly y outcomes of heads (e.g., exactly 1 heads, exactly 2 heads, etc.) when the coin is tossed n times. The binomial distribution provides the answer to the following situation.

Given the following information:

p: the probability of an outcome occurring in a single event (the probability of a coin flip coming up heads is $p = 0.5$)
n: The number of events to be considered (flip the coin $n = 5$ times)
y: The precise number of times out of n trials that we want to calculate the probability of the outcome heads occurring.
n and y must be integers

The distribution that describes the probability that we will observe exactly y occurrences of the outcome (that has a probability of p for a single event) out of n trials is the *binomial distribution*:

$$P(y) = b(y; n, p) = \frac{n!}{y!(n-y)!} p^y (1-p)^{n-y} \tag{1}$$

For example, flip a coin $n = 5$ times, each time the probability of heads is $p = 0.5$.
The probability of observing exactly 3 heads out of the 5 tosses is

$$P(y=3) = b(3;5,0.5) = \frac{5!}{3!(5-3)!} 0.5^3 (1-0.5)^{5-3} = 31.25\ \% \tag{2}$$

Interpretation of this result: The experiment consists of flipping a coin 5 times and observing how many heads come up among those 5 flips. If this experiment is performed many thousands of times (each experiment consists of 5 flips), then we expect that exactly 3 out of 5 flips will be heads to occur in 31.25% of those experiments.

Additional examples:

The probability of observing *less than* 3 occurrences of heads (out of 5 flips) is the combined probability of observing exactly 0, 1, and 2 heads

$$\begin{aligned} P(y<3) &= P(0)+P(1)+P(2) \\ &= 3.125\% + 15.625\% + 31.25\% \\ &= 50.0\ \% \end{aligned} \tag{3}$$

Note that the probability of observing less than 3 heads is equivalent to 1 minus the probability of observing 3 or more heads, or $P(y<3) = 1 - P(y \geq 3) = 1 - P(3) + P(4) + P(5)$. This equivalence will be applied in the next example.

The probability of tossing *at least* 1 heads in a five-minute period (1 flip per minute for 5 minutes) is 1 minus the probability of observing exactly 0 heads

$$P(y>0) = 1 - b(0;5,0.5) = 1 - \frac{5!}{0!(5-0)!}0.5^{0}(1-0.5)^{5-0} = 96.875\ \% \tag{4}$$

If a coin is flipped 5 times, the probability that we observe at *least one* heads in 96.875%.

Application of Procedure for Predicting Concurrent Permit Vehicle Weight

We now apply the above procedure to the concurrent vehicle problem.
Let's define the following situation:

WIM station	9913
Concurrent weight threshold =	220,000 lbs.
Time frame of interest =	1 month

Goal: Determine the probability of observing at least one occurrence of concurrent permit vehicles at WIM station 9913 with a combined weight that exceeds 220,000 lbs. within a one-month time frame

1) Define the event:

The event is that WIM station 9913 observes a single occurrence of concurrent permit vehicles. Concurrent occurrence is defined as two or more vehicles arriving at the WIM station within a given short distance of each other. This distance is determined by the average length of the bridges within 15 miles of, and along the same route as, the WIM station. Thus concurrent vehicles at the WIM station can be reasonably extrapolated to the potential for concurrent permit vehicles at those nearby bridges.

2) Define the possible outcomes of that event:

The event outcome is defined as the combined weight of the concurrent permit vehicles.

3) Model a probability distribution of the possible outcomes:

The possible outcomes include a range of weights between 160,000 (any vehicle > 80,000 lbs. legally needs a permit) and the maximum concurrent weight observed at station 9913, which is 290,190 lbs. The purpose of part 3 is define the probabilities of specific outcomes (weights) from the occurrence of a single event (a single case of concurrent permit vehicles crossing WIM station 9913)

3-a. Create a histogram from all available observed event outcomes

There were a total of 568 concurrent permit vehicle events at WIM station 9913 over the three year period of data provided for that station. The weight from each of these events is used to create a normalized histogram (total area equals 1.0) of weight vs. probability. The normalized histogram that is produced from the observations of concurrent permit vehicles at WIM station 9913 is shown in Figure 5-8 (from thesis).

3-b. Fit an appropriate probability distribution to the histogram

The shape of this histogram is well suited for modeling with an exponential distribution. The details of this modeling procedure are provided on pages 65-67 in Chapter 5, and pages 20-23 in Chapter 3 of the thesis. The end result is the following model, which is plotted on top of the histogram in Figure 5-8:

$$f(W) = \frac{1}{130{,}190}\left(\lambda e^{-\lambda\left(\frac{W-160{,}000}{290{,}190-160{,}000}\right)}\right), \text{ where } \lambda = 6.638 \qquad \text{(Ch-5, Eq. 6)}$$

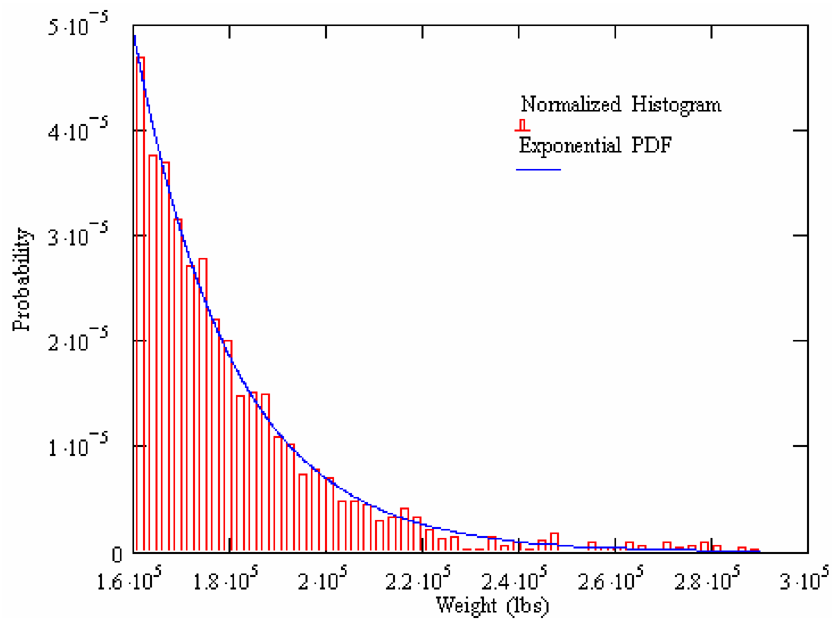

Figure 5-8 from thesis. Exponential PDF model and normalized histogram of the total weight from all observations of concurrent permit vehicles at WIM station 9913.

4) Define a time frame of interest:

One month.

5) Define how many times the event will occur in that chosen time frame:

The WIM data for station 9913 observed 568 events over three years, providing an average of 16 events per month.

6) Determine the probability that a particular outcome of that event will occur at least once in the chosen time frame (use binomial distribution):

In this case we wish to determine the probability that the combined weight exceeds a particular outcome of 220,000 lbs. within a time frame of one month. The probability of exceeding 220,000 lbs. in any given single event is determined by integration of the probability density function modeled in procedure step 3-b between 220,000 and the upper limit of the distribution (290,190 lbs.). The result of this integration is 4.6 %, or p = 0.046.

Recall the binomial distribution provided earlier:

$$P(y) = b(y; n, p) = \frac{n!}{y!(n-y)!} p^{y} (1-p)^{n-y} \tag{1}$$

We now have the following information:

p: the probability of exceeding 220,000 lbs in a single event (p = 0.046)
n: The number of events to be considered (n = 16 events per month)
y: The precise number of times out of n trials that we want to calculate the probability of the outcome occurring.

The probability of observing at least 1 occurrence of concurrent vehicles that exceed 220,000 lbs. in a one-month period is 1 minus the probability of observing 0 cases that exceed 220,000 lbs.

$$P(y>0) = 1 - b(0;16,0.046) = 1 - \frac{16!}{0!(16-0)!} 0.046^{0} (1-0.046)^{16-0} = 52.93\ \% \tag{5}$$

This provides a single entry into the table of values in the final product.

Extension of the Procedure for Predicting Concurrent Permit Vehicle Weight

Changing time frames:
Of course, the probability of observing at least one combined concurrent weight exceeding 220,000 lbs. within a full year is much higher than it would be within a month. To compute this probability, n = 16 is simply replaced with the rounded integer from 568/3 (568 observations in 3 years), giving n = 189. The probability of a single event of concurrent vehicles exceeding 220,000 lbs. remains p = 0.046, and equation (5) becomes:

$$\begin{aligned} P(y>0) &= 1 - b(0;189,0.046) \\ &= 1 - \frac{189!}{0!(189-0)!} 0.046^{0} (1-0.046)^{189-0} \\ &= 99.99\% \end{aligned} \tag{6}$$

Thus, there is a 99.99% chance of seeing at least one occurrence of concurrent permit vehicles exceeding 220,000 lbs within a one-year period at WIM station 9913. A summary of the year and number of observations of concurrent permit vehicles for each site is provided in Table 5-4 (excerpt from Table 5-4 in thesis). This can be used to determine the proper n value for any time frame. For example, n for a six-month period at site 9932 ≅ 6 [(61+87)/24].

Table 5-4. Occurrence of concurrent permit vehicles (excerpt from table 5-4 in thesis)

Site	Year	Total Trucks	2 Vehicles > 80,000 lbs		3 Vehicles > 80,000 lbs	
			Sum	Percent	Sum	Percent
9913	2001	442627	112	0.03%		
	2002	326560	147	0.05%		
	2003	266681	309	0.12%	1	0.0004%
9926	2002	532940	1395	0.26%	5	0.0009%
	2003	581476	743	0.13%	6	0.0010%
9932	2001	383310	61	0.02%		
	2002	368393	87	0.02%		
9936	1998	413997	44	0.01%		
	1999	583801	50	0.01%		
	2000	783286	95	0.01%	1	0.0001%
	2001	536465	229	0.04%		
	2002	1031798	789	0.08%		
	2003	433397	334	0.08%	2	0.0005%

Changing weight threshold

Going back to a one-month time frame, we move the threshold from 220,000 lbs. to 250,000 lbs. The probability that a single event of concurrent permit vehicles exceeding 250,000 lbs is 0.9% (p = 0.009) from integration of Ch-5 Eq-6 from 250,000 to 290,190. The one-month time frame again gives n = 16. Equation (5) becomes

$$\begin{aligned} P(y>0) &= 1-b(0;16,0.009) \\ &= 1-\frac{16!}{0!(16-0)!}0.009^{0}(1-0.009)^{16-0} \\ &= 13.47\% \end{aligned} \tag{7}$$

Thus, there is a 13.47% chance of seeing at least one occurrence of concurrent vehicles exceeding 250,000 lbs within a given month at WIM station 9913.

The Final Product: Weight Exceedence Probabilities for the Four WIM Stations

Chapter 5 of the student thesis presents Figs. 5-8 through 5-11 as the models for the probability of the combined weight of concurrent permit vehicle at stations 9913, 9926, 9932, 9936, respectively. A generalized version of Ch-5, Eq-6 is provided in Equation 8 below, and together with Table 1 describes the models for these four analyzed WIM stations.

$$P(W)=\frac{1}{ub-lb}\left(\lambda e^{-\lambda\left(\frac{W-lb}{ub-lb}\right)}\right) \tag{8}$$

Where:

$P(W)$ is the probability of a given combined weight of concurrent permit vehicles W
ub & lb are the observed upper and lower bounds in combined weight
λ is the shape parameter determined from observed data (method described in Chapter 3)

Table 1. Parameters used for the probability models at the four WIM stations

WIM Station	*lb* (lower bound)	*ub* (upper bound)	λ (shape parameter)
9913	160,000	290,190	6.638
9926	160,000	319,880	8.933
9932	160,000	250,930	5.850
9936	160,000	276,940	8.281

The solution procedure was applied to the four WIM stations using thresholds starting at 180,000 lbs and increasing in 10,000 lb increments to 250,000 lbs. Table 2 presents the results of a series of calculations for a one-month time frame. For each of the four WIM stations analyzed (9913, 9926, 9932, 9936), probabilities are presented for exceeding a series of threshold weights. All results in Table 2 present the probability of observing *at least one* occurrence of concurrent vehicles, within a one-moth time frame, whose total weight exceeds the indicated threshold at the given WIM station. Table 2 also provides the years of data available for each station, and the average number of concurrent permit vehicle events per month for each station. Figure 1 presents the same information found in Table 2 in a graph.

Comment on the Final Product: Table 2 and Figure 1 are likely un-conservative

The probability of the occurrence of concurrent permit vehicle weights exceeding the thresholds are likely greater than those presented in Table 2 and Figure 1. However, without additional datasets, there is no rational way to gauge this quantitatively. There are two considerations that make the final product un-conservative.

1) Chapter 3, pg. 16 of the thesis discusses the discovery that the WIM stations filter out vehicles that exceed 160,000 lbs. While vehicles this heavy are rare, such vehicles are known to travel major routes in Florida (see Chapter 4 regarding the permit vehicle dataset). Such vehicles were removed from the WIM data are thus not included in the distributions of the probability of combined weights provided in thesis Figures 5-8 through 5-11 and Table 1 above. If such data were included, the *p* values used in Equation (1), and hence the final exceedence probabilities in Table 2 below could be slightly higher than those calculated and presented. The influence of the absence of WIM data on vehicles that exceed 160,000 lbs may be negligible if:

    a. Such vehicles do not travel concurrent with other permit vehicles
    b. The occurrence of concurrent vehicles where one or more vehicles exceed 160,000 lbs is so rare as to have no statistical influence on Figures 5-8 through 5-11 and Table 1 above.

    A reasonable conclusion is that the absence of such data has only a minor influence, and is well within the bounds of uncertainty already associated with this study.

2) Truck volumes continue to increase (based upon FDOT statistics). This is generally supported by the values in Table 5-4. Thus, there will likely continue to be an increase in the volume of permit vehicle traffic in the future. This will raise the expected monthly occurrence rate (*n*), increasing the final value of threshold exceedence probability calculated with Equation (1) and presented in Table 2 and Figure 1 below. Given that the WIM stations in Florida continue to operate, the influence of increased truck traffic can

be evaluated on a yearly basis by re-running the analyses presented in this study on a yearly (or less frequent) basis.

Table 2. Probability of observing at least one instance of concurrent permit vehicles per month that exceeds a given left column weight threshold.

	WIM station [years of observation available] (average # of observed concurrent permit vehicles per month)			
Concurrent weight threshold	9913 [‘01 ‘02 ‘03] (16)	9926 [‘02 ‘03] (89)	9932 [‘01 ‘02] (6)	9936 [‘98 ‘99 ‘00 ‘01 ‘02 ‘03] (21)
	Probability of at least one occurrence of concurrent permit vehicle weight per month that exceeds the weight in the left column			
> 180,000	99.9%	100%	85%	99.7%
> 190,000	98%	100%	60%	93%
> 200,000	89%	100%	37%	72%
> 210,000	72%	99%	20%	46%
> 220,000	53%	96%	10%	26%
> 230,000	35%	84%	5%	14%
> 240,000	23%	63%	2%	6%
> 250,000	13%	42%	< 1%	2%

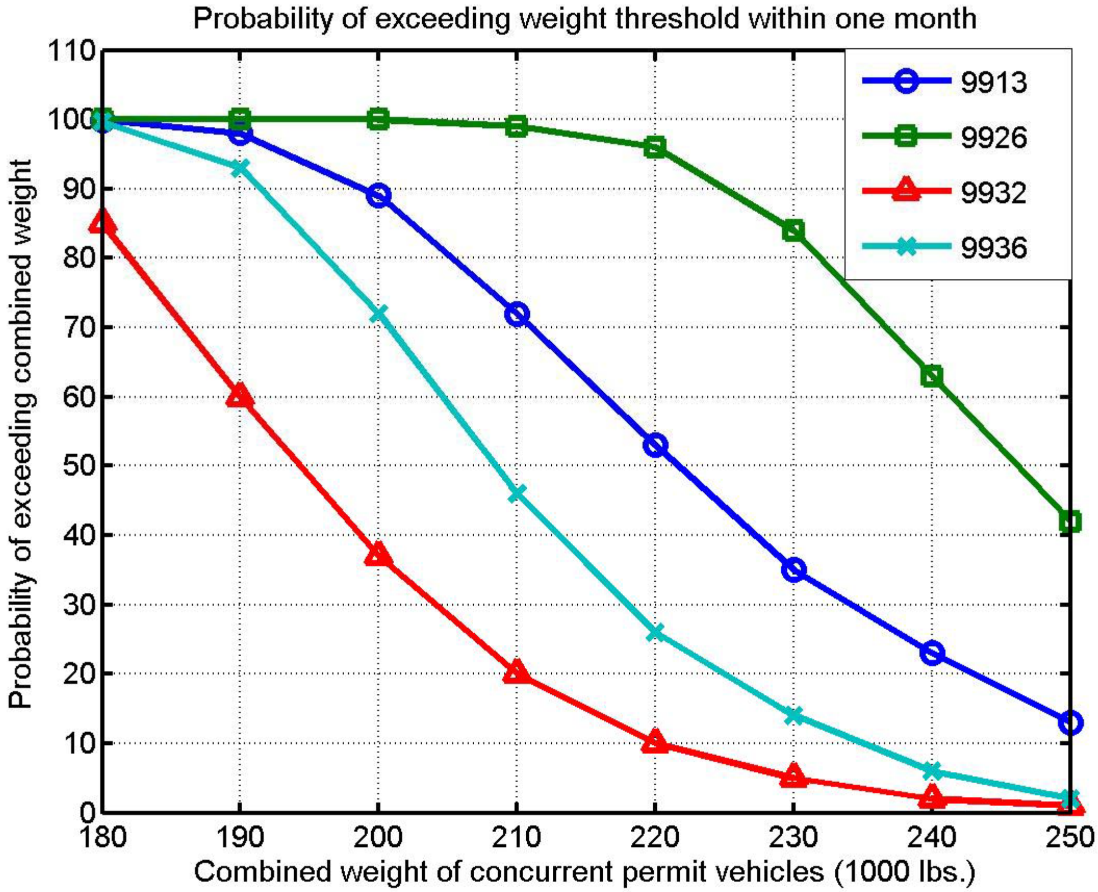

Figure 1. Graphical form of Table 2. Probability of at least one occurrence of concurrent permit vehicles that exceed the given x-axis weight threshold within a one-month time frame.

PROBABILISTIC ASSESSMENT OF BRIDGE LOADING CONCURRENT WITH PERMIT VEHICLES

By

MATTHEW CRIM

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ENGINEERING

UNIVERSITY OF FLORIDA

2005

This document is dedicated to my parents who have supported me throughout my undergraduate and graduate careers.

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of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Engineering

PROBABLISTIC ASSESSMENT OF BRIDGE LOADING CONCURRENT WITH PERMIT VEHICLES

By

Matthew Crim

May 2005

Chair: Scott Washburn
Cochair: Kurtis Gurley
Major Department: Civil and Coastal Engineering

Multi-presence factors in the AASHTO bridge code are designed to account for the occurrence of multiple lanes experiencing maximum standard AASHTO loads. Permit (overweight) vehicles represent a source of loading that exceeds standard vehicle weights. The presence of a single permit vehicle in addition to the loads from standard weight vehicles is arguably accounted for implicitly in the multi-presence factors. However, there is a concern that such multi-presence factors do not account adequately for the occurrence of more than one permit vehicle on a given bridge simultaneously.

The objective of this project was to develop a probability-based model to determine whether the occurrence rate of multiple permit vehicles on a given bridge is significant. Further, the model delineates the relative probability of the combined weight of concurrent permit vehicles. The model is site-specific, dependent upon the frequency of truck travel along a given route.

This project used information from the 37 Weigh-In-Motion sensors around the state of Florida. Weigh-In-Motion (WIM) sensors are commonly used to obtain truck weight data on major roadways throughout the state, employing passive weighing techniques so the operator is unaware that the truck is being monitored. An evaluation of the Florida Department of Transportation's (FDOT) WIM stations was done. Numerous irregularities in the data were found during the evaluation process. A major issue that was encountered was the fact that the WIM sensors did not record any truck weights greater than 160,000 lbs. An additional source of data was obtained from the FDOT and used to analyze the permit vehicles records over 160,000 lbs. These vehicles were evaluated using a regional analysis.

Using multiple years of data from the WIM sensors, a model was created to predict the presence of multiple permit vehicles concurrently on a bridge. The model was run on four of the most heavily traveled among the 37 WIM stations. The four particular WIM stations were chosen because they contained a high volume of trucks passing over the sensor, numerous trucks over 85,000 lbs, several bridges within a 15 mile radius, and together the sites represent different regions of the state.

Results indicate a significant number of observations of concurrent permit vehicles at each of the four analyzed stations. The resultant probability models of combined weight of concurrent vehicles represent an extreme loading condition with a considerable chance of occurrence.

CHAPTER 1
INTRODUCTION

Problem Statement

Multi-presence factors in the AASHTO bridge code are designed to account for the occurrence of multiple lanes experiencing maximum standard AASHTO loads. Permit (overweight) vehicles represent a source of loading that exceeds standard vehicle weights. The presence of a single permit vehicle in addition to the loads from standard weight vehicles is arguably accounted for implicitly in the multi-presence factors. However, such an assumption needs to be verified based on the specifications for permit vehicle weights and traffic patterns within the state of Florida. In addition, the presence of multiple permit vehicles in configurations that result in loads in critical locations may conceivably exceed the capacity of the bridge.

This study examined the loads (additional trucks or otherwise) that should be considered concurrent with the different permit loads for the purpose of calculating appropriate operating ratings. Existing Weigh-In-Motion and other records were analyzed to develop a probabilistic model of the relative likelihood of various concurrent vehicle combinations to describe realistic worst case loading configurations. The outcome will be used by Florida Department of Transportation (FDOT) engineers evaluating the existing bridge rating system.

This chapter presents a brief background and necessary definitions, followed by the specific objectives of the research.

Background

Truck travel has steadily increased in the recent years, and the amount of overweight trucks on the roadways has also increased. Trucks that exceed 80,000 lbs are considered overweight, and need special permission from the FDOT to operate on state roadways. Additionally, trucks that exceed length and height limits are rarely allowed to operate without a permit. Typically, these loads are short haul vehicles such as solid waste trucks and concrete mixers. Although these vehicles are above the legal limits, they are allowed to operate on the roadway due to “grandfather” provisions in state statutes, and are referred to as exclusion vehicles [1].

With the large amount of trucks on the roadway, both over and under the permit threshold limit of 80,000 lbs, monitoring the truck traffic flow is crucial to preserving Florida’s roadways and bridges. Weigh-In-Motion (WIM) sensors are commonly used to obtain truck weight data on major roadways throughout the state, employing passive weighing techniques so the operator is unaware that the truck is being monitored. This study analyzed the WIM data collected in the state of Florida in order to develop a statistical model of extreme loads on bridges due to overweight vehicles. More specifically, WIM data will be used to determine the likelihood of the occurrence of multiple heavy (permitted) vehicles on a given bridge simultaneously. The outcome of this study will provide information to FDOT engineers evaluating the state of Florida’s bridge rating system.

Bridge Rating System

Load rating is a component of the bridge inspection process. It consists of determining the safe load carrying capacity of bridges on an individual basis. The load rating process estimates the live load capacity of a structure based on its current condition through analysis or a load test. It determines if specific overweight vehicles can safely cross the structure, and whether a structure needs to be weight restricted.

In addition, every bridge has an inventory rating and an operating rating. These factors are used when evaluating the load rating of the bridge. The inventory rating represents the load level which can safely be placed on an existing structure for an indefinite period of time. The operating rating represents the absolute maximum permissible load level to which the structure may be subjected [2].

Florida's WIM Polling System

Florida has implemented a system of software programs that, every night, automatically poll each of the (approximately 37) WIM monitoring stations throughout Florida and process the collected data. While the computer is polling the field counters for their data, it is also processing the data from stations previously captured. All the binary files are converted to ASCII. Count and classification records are generated from WIM files. If these data pass some elementary filters, they are summarized by station, date, and direction and written to the database tables. Once the database is populated, the data are edited for quality [3]. Count and classification records are generated from WIM files.

Definition of a Permit Vehicle

According to the Florida Department of Transportation's Trucking Manual, a permit vehicle is any vehicle that needs special permission to operate on the roadway [4]. An overweight/oversized permit is required to move a vehicle or combination of vehicles of a size or weight that exceeds the maximum size or weight established by law over state highways. Except for certain vehicles exempt by law, any vehicle that exceeds the following size or weight limitations is not allowed to move without a permit:

1. The maximum width of the vehicle or vehicle combination and load exceeds 102 in. or exceeds 96 in. on less than 12 ft wide travel lane.

2. The maximum height of the vehicle or vehicle combination and load exceeds 13 ft 6 in.

3. The maximum length of a single-unit vehicle exceeds 40 ft. The trailer of the combination unit exceeds 48 ft. A 53 ft trailer with a kingpin distance which exceeds 41 ft, measured from the center of the rear axle, or group of axles, to the center of the kingpin of the fifth-wheel connection. The front overhang of the vehicle extends more than 3 ft beyond the front wheels or front bumper if so equipped.

4. The gross weight of the vehicle or vehicle combination and load exceeds 80,000 lbs.

Permit issuance

The intent of the law under which the FDOT issues vehicle movement permits is to protect motorists from traffic hazards caused by the movement of overweight and oversized vehicles or loads on state highways [4]. This ensures the comfort and convenience of other motorists on the highways and guards against undue delays in normal flow traffic. The permit process is also intended to minimize damage to pavement, highway facilities and structures, thus protecting the investment in the state highway system. Additionally, the permit process assist persons, companies or organizations with special transportation needs involving size and weight. Furthermore, permits are fee based, which will recover the DOT's administrative costs, as well as any wear caused to the state highway system by the permitted loads.

Permit types

Overweight vehicles require either a trip-based or blanket permit. A trip-based permit is used to cover a vehicle's move from the origin to the destination for one particular trip, allowing that trip to occur within five days of permit issuance. However, if the truck or trailer is oversized in any way, the return trip (empty) may be included on the permit. Trip based permits are generally issued for vehicles over 160,000 lbs, and often include route restrictions in which the permit is only valid if traveling over specific roads. Trip permits are more restrictive than blanket permits.

Blanket permits are issued to vehicles for a twelve month period of time. The vehicle can make as many trips as needed, as long as it is within the twelve month period. Blanket permits are generally issued for vehicles under 200,000 lbs.

Objectives and Tasks

The first objective was a literature review. The literature review traced the development of the current AASHTO provisions for bridge loading, and identified existing studies on extreme traffic loads, permit vehicle routes, and statistical characterizations of traffic flow over bridges. The FDOT Weigh-In-Motion and other data records related to both permit and other vehicles were examined for relevant information.

The second objective was the identification and classification of specific bridges within close proximity to WIM stations. The subjects of study for vehicle loading were bridges, but the available information on vehicle weight and frequency of occurrence exists at the WIM stations. Identifying bridges close to WIM stations will justify the extrapolation of WIM-based probability models to the nearby bridges.

The third objective was the development of a probabilistic model of concurrent vehicles. The collected information on the frequency, routes, and weights was used to develop a probabilistic model describing the likelihood of concurrent vehicles on bridges with permit vehicle traffic. This portion of the model (concurrent use) will not directly address critical locations for loading.

CHAPTER 2
LITERATURE REVIEW

The current AASHTO provisions for bridge loading account for the occurrence of multiple lanes experiencing the maximum standard AASHTO loads. Permit vehicles represent a source of loading that exceeds standard vehicle weights. The presence of multiple permit vehicles on a single bridge is not directly accounted for. A large number of papers were reviewed to identify any other studies that pertained to the work done in this study. The following text will summarize the articles that were found.

Studies Pertaining to Bridge Loading

A study by Chou et al. [5] discussed a method to evaluate overweight permit applications received in the state of Tennessee. A detailed structural analysis was required for all vehicles with a gross weight over 150,000 lbs. Due to the volume of overweight permit applications received, this policy resulted in a large demand in man-hours to perform the structural analysis. Chou et al. developed an empirical method to efficiently extract any suspicious overweight vehicles requesting a permit. The method utilized the route type, the combined effect of truck gross weight, axle loads, and axle spacing to assess the truck's effect on Tennessee highway bridges. An allowable weight curve was empirically developed to determine whether a permit request should be granted, rejected, or granted with restrictions. This reduced the detailed structural analyses required by about 50%. The results of the study also reduced the cost of the analyses and structural risk.

All states issue special permits for truck loads exceeding the weight limit of the highway jurisdiction. This causes structural stress levels higher than those induced by normal truck traffic. A study by Fu and Hag-Elsafi [6] discussed a method to develop live load models including over-load trucks, associated reliability models for assessing structural safety of highway bridges, and proposed permit load factors for over-load checking in the load and resistance factor format. The average bridge safety assured by the current AASHTO codes was used as the safety target in determining the load and resistance factors in the proposed procedure. The procedure proposed by Fu et al. will be useful to U.S. highway agencies as it can be used by engineers responsible for checking overloads for permit issuance. This method may be included in specifications for bridge evaluation subject to overweight trucks.

A study by Cohen et al. [7] presented a new method for predicting truck weight spectra resulting from a change in truck weight limits. This method was needed to estimate impacts of the change on highway bridges such as accelerated fatigue accumulation. This model was based on freight transportation behavior, and it was flexible for both across-the-board and local changes without restriction on the truck types to be impacted. Using data from Arkansas and Idaho, it was shown that the proposed method can capture effects of truck weight limit change on truck weight histograms and on resulting steel bridge fatigue.

A study by Ghosn [8] developed a new truck weight formula that regulates the weight of heavy trucks and axle groups. The formula was developed based on rational safety criteria. The procedure used to obtain the proposed formula utilized a reliability analysis such that the projected truckload effect will produce a uniform reliability index for existing bridges designed according to current AASHTO criteria.

A sensitivity analysis that was performed in the second of a two paper sequence by Ghosn and Moses [9] showed how the expected number of bridge deficiencies could be reduced if different truck weight regulations were adopted, or if different bridge safety criteria were used in the derivation of the truck weight formula. An analysis of twelve typical bridge configurations confirmed the results obtained from the generic analysis of the bridges taken from the National Bridge Inventory (NBI) files. The analysis indicated few bridges would need rehabilitation if operating stress criteria were used for bridge evaluation. However, several of these bridges would be considered deficient if working stress design stresses were used as the rating criteria.

A study by Brillinger [10] studied at risk analysis in a format non-specific to vehicles and/or bridges. Brillinger looked at low probability-high consequence events, events that lead to damage, loss, injury, death, and environmental impairment. Based on his findings Brillinger believes that the demand for risk analysis is growing steadily, in part because the costs of replacing destroyed structures are growing and in part because of the steady increase in the population living in hazardous areas. The article had two examples, the first one was seismic risk analysis and the second was forest fire probabilities. The method of risk analysis could be applied to predicting when multiple overweight trucks would appear on a given bridge, a low probability-high consequence event. Another study by Brillinger et al. [11] expanded on the forest fire study done in the previous paper.

A study by Fu et al. [12] researched the effects that various existing and projected truck configurations have as live loadings upon bridges which exist on the National Bridge Inventory (NBI). The study found that the live load truck capacity of existing bridges on the NBI was highly dependent upon the selection of the AASHTO Specification alternate, the analysis methodology, and assumptions used in applying the specification.

A study by Croce and Salvatore [13] presented a general theoretical stochastic traffic model that can be used in the assessment of existing bridges, as well as the design and analysis of bridges with less traditional schemes or subjected to particular traffic conditions. The model is intended for applications, not only to background studies for calibration of traffic load models in new bridge codes, but also in all those cases where precise evaluation of traffic effects are required.

A study by Galambos [14] presented a comparison of the AASHTO design live loadings for bridges with various other loading situations. Situations include normal permit overloads and abnormal permit loads among other loadings. Galambos concluded that the bridge load rating process needs to be improved. Also, a standard load rating vehicle test and method should be employed.

A study done by Kolozsi et al. [15] discussed a computer program that was used to determine routes for permit vehicles in Hungary. Weigh-In-Motion measuring units were usually applied along highly trafficked roads and close to major bridges to monitor weight. A noticeable difference between static mass and the loads of the moving vehicle were found. The moving vehicle mass was also found to be higher than the considered factors of the dynamic design specifications.

A study by Fryba [16] looked at the fatigue life of railway bridges. Fryba used the Palmgren-Miner theory of linear cumulative damage as a basis. Fryba looked at the effect of different parameters on the estimation of the bridge fatigue life. It was found that the rise in speeds of the traffic loads has resulted in shortened bridge life. It was also found that the increase in the number of stress cycles per year, the standard deviation of stress, and an increase in the mean value of the traffic loads diminish the life of the bridge.

The majority of articles that were found focus on the effects of overweight trucks once they are on the bridges. None of the articles were found on the travel patterns of overweight trucks, and the occurrence of concurrent vehicles on the same bridge. Nevertheless, each article listed has information that is relevant to this study.

FDOT Literature

Three documents supplied by the Florida Department of Transportation were used to get a better understanding of the project. The first document was the *Bridge Load Rating, Permitting and Posting Manual* [2], which provided information on the load rating process the FDOT used. The second document was the *Automated Editing of Traffic Data in Florida* [3]; it provided insight into the Weigh-In-Motion polling process used and the editing process that the FDOT used to filter out erroneous data. The third document was the *Trucking Manual* [4], it was used to get information on the types of permits the state of Florida issued along with when, why, and how permits were granted.

CHAPTER 3
PRELIMINARY ANALYSIS OF WEIGH-IN-MOTION DATA: SINGLE VEHICLE MODELING

The state of Florida has 37 Weigh-In-Motion (WIM) sites dispersed across the state. The truck data that these sites collect was downloaded to the FDOT central office in Tallahassee. This chapter focuses on the contents of the WIM data records, examples of preliminary analysis of these data, probabilistic modeling of the occurrence of a single vehicle weight, and a discussion on problems identified within the data files.

Retrieval of Data from FDOT

Retrieval of the weigh-in-motion data for the project came from the statistics office under Richard Reel's supervision. The data were copied onto a hard drive and brought back to the University of Florida. There were approximately 25,300 files of data that were collected and stored on the hard drive from January 1998 to August 2003. Each file consists of the individual samples of WIM data collected during one 24-hour period at one WIM station. Thus one WIM station could produces 365 files per year. A given file may range from a few dozen to a few thousand individual samples of vehicle information. Some WIM sites have data from all five years; others only have data from part of that time frame. This is due to a specific site not being operational for a period of time. Another reason for an incomplete five year time period was time constraints in the collection process at the FDOT.

The data retrieved from the FDOT were in ASCII format. An overview of the 37 WIM sites such as site location, county, and number of lanes can be found in Table 3-1.

An example of the contents of any given data file can be seen in Table 3-2. A key explaining each column in Table 3-2 can be found in Table 3-3. As can be seen in Tables 3-2 and 3-3, the WIM files contain details of the trucks being sampled, including date, time, and lane of travel (implies direction), vehicle class, travel speed, gross weight, and weight of each axle.

Table 3-1. Overview of the 37 WIM stations

Site	Site Location	County	Number of Lanes	Lane Orientation *	Original Sensor	Existing Sensor	Date Changed	Dates Copied
9901	I-10, Monticello	Jefferson	4	OE-OW	DAW-200	DAW-190	6/1/2003	1/98-12/99; 1/01-8/03
9904	I-75, Micanopy I-75, Micanopy-SB	Alachua	6	ON-OS	DAW-200 DAW-200	DAW-190	4/15/2002	1/01 - 8/03
9905	SR-9/I-95, Jacksonville	Duval	6	OS-ON	DAW-190	DAW-190		1/01 - 8/03
9906	I-4, Deltona	Volusia	4	OE-OW	ADR-WIM	ADR-WIM		1/01 - 8/03
9907	US-231, Youngstown	Bay	4	ON-OS	DAW-100	DAW-100		1/01 - 8/03
9908	US-319, Trk Rt, TLH	Leon	4	OE-OW	DAW-200	DAW-200		1/98 - 8/03
9909	US-19, Chiefland	Levy	4	ON-OS	DAW-200	DAW-190	8/14/2001	1/01 - 8/03
9913	Trnpk, St.Lucie Co.	St. Lucie	4	OS-ON	DAW-100	DAW-100		1/01 - 8/03
9914	SR-9A/I-295, Duval Co.	Duval	4	ON-OS	ADR-WIM	ADR-WIM		1/01 - 8/03
9916	US-29, Pensacola	Escambia	4	ON-OS	DAW-190	DAW-190		1/01 - 8/03
9917	US-41, Punta Gorda	Charolette	4	OS-ON	DAW-200	DAW-190	5/2/2002	1/01 - 8/03
9918	US-27, Clewiston	Hendry	4	ON-OS	DAW-100	DAW-100		1/01 - 8/03
9919	I-95, Malabar	Brevard	4	ON-OS	DAW-100	DAW-190	6/23/2003	1/01 - 8/03
9920	I-75, Sumter Co.	Sumter	4	ON-OS	ADR-WIM	DAW-190	10/2/2003	1/02 - 8/03
9921	SR-5, Martin Co.	Martin	4	ON-OS	DAW-100	DAW-190	4/11/2003	1/98 - 8/03
9922	I-275, Tampa	Hillsborough	6	ON-OS	DAW-200	DAW-190	7/21/2003	1/02 - 8/03
9923	I-95, Jacksonville	Duval	4	ON-OS	DAW-200	DAW-200		1/02 - 8/03
9924	I-110, Pensacola	Escambia	4	OS-ON	DAW-200	DAW-200		1/02 - 8/03
9925	US-92, Deland	Volusia	4	OW-OE	DAW-200	DAW-200		1/02 - 8/03
9926	I-75, Tampa	Hillsborough	6	ON-OS	DAW-200	DAW-200		1/02 - 8/03
9927	SR-546, Lakeland	Polk	4	OE-OW	DAW-200	DAW-200		1/02 - 8/03
9928	I-10, Walton Co.	Walton	4	OW-OE	DAW-200	DAW-200		1/02 - 8/03
9929	US-1, Edgewater	Volusia	4	ON-OS	DAW-200	DAW-190	4/11/2003	1/02 - 8/03
9930	US-1, Miami US-1, Miami-SB	Miami-Dade	6	ON-OS	DAW-200 DAW-200	DAW-190	3/21/2003	1/02 - 8/03
9931	Trnpk, Sumter Co.	Sumter	4	ON-OS	DAW-100	DAW-100		1/01 - 8/03
9932	Trnpk, Osceola Co.	Osceola	4	ON-OS	DAW-100	DAW-100		1/01 - 8/03
9934	Homestead Ext, Dade	Miami-Dade	7 (4S,3N)	OS-ON	DAW-100	DAW-190	6/3/2002	1/01 - 8/03
9935	US-27, Palm Beach Co.	Palm Beach	4	OS-ON	DAW-100	DAW-190	4/11/2003	1/98 - 8/03
9936	I-10/SR-8, Lake City	Columbia	4	OW-OE	DAW-100	DAW-190	1/30/2003	1/98 - 8/03
9937	SR-87, Milton	Santa Rosa	4	ON-OS	DAW-100	DAW-190	5/23/2002	1/98 - 8/03
9938	SR-83/US-331, Freeport	Walton	2	ON-OS	DAW-100	DAW-100		1/98 - 8/03
9939	SR-2, Graceville	Holmes	2	OE-OW	DAW-100	DAW-100		1/98 - 8/03
9940	SR-267, Quincy	Gadsden	4	OS-ON	DAW-100	DAW-100		1/98 - 8/03
9942	SR-85, Laurel Hill	Okaloosa	2	ON-OS	DAW-100	DAW-100		1/98 - 8/03
9943	SR-10/US-90, Cypress	Jackson	2	OE-OW	DAW-100	DAW-100		1/98 - 8/03
9944	SR-69, Selman	Calhoun	2	OS-ON	DAW-100	DAW-100		1/98 - 8/03
9946	SR-363, St. Marks	Wakulla	2	OS-ON	DAW-100	DAW-100		1/98 - 8/03

*OW, OE, OS, and ON represent the outside westbound, eastbound, southbound, and northbound lanes. E.g. OE-OW means lane 1 refers to the outside eastbound lane and lane 4 refers to the outside westbound lane.

Table 3-2. Contents of a selected WIM file (50 columns of data)

1	2	3	4	5	6	7	8	9	10	11	12	13
TAG	County	Station	Lane	Date	Time	Vehicle #	Class	Violation	Speed	Length	Gross Weight	L Axle 1
VTR	59	9946	2	12/27/1999	32716	29	9	0	45	6144	28880	4980
VTR	59	9946	2	12/27/1999	33519	31	9	14	38	6144	80340	4170
VTR	59	9946	2	12/27/1999	34414	34	9	0	57	4922	24340	4040
VTR	59	9946	2	12/27/1999	34419	35	9	0	58	4960	27380	4020
VTR	59	9946	1	12/27/1999	35433	38	9	0	51	7998	46740	6060
VTR	59	9946	2	12/27/1999	35741	40	8	0	65	4812	22220	3610
VTR	59	9946	2	12/27/1999	35751	41	8	0	57	4385	23860	3930
VTR	59	9946	2	12/27/1999	42447	46	8	0	48	4529	32920	5180
VTR	59	9946	1	12/27/1999	44215	50	9	1	67	6563	39360	6320
VTR	59	9946	2	12/27/1999	45534	51	9	0	63	4964	40580	6010
VTR	59	9946	1	12/27/1999	45732	52	9	0	63	6538	32840	5130
VTR	59	9946	2	12/27/1999	45931	54	9	1	53	6255	45260	6540
VTR	59	9946	2	12/27/1999	50813	56	8	0	70	4796	34700	5590
VTR	59	9946	2	12/27/1999	51657	57	8	0	67	4783	30240	4960
VTR	59	9946	2	12/27/1999	52122	60	9	15	59	6267	108740	7680

14	15	16	17	18	19	20	21	22	23	24	25	26
R Axle 1	Total Axle 1	L Axle 2	R Axle 2	Total Axle 2	L Axle 3	R Axle 3	Total Axle 3	L Axle 4	R Axle 4	Total Axle 4	L Axle 5	R Axle 5
4980	9960	2930	2930	5860	3070	3070	6140	1590	1590	3180	1870	1870
4170	8340	8370	8370	16740	8340	8340	16680	8730	8730	17460	10560	10560
4040	8080	3100	3100	6200	1980	1980	3960	1700	1700	3400	1350	1350
4020	8040	3180	3180	6360	2620	2620	5240	1220	1220	2440	2650	2650
6060	12120	4100	4100	8200	3840	3840	7680	4880	4880	9760	4490	4490
3610	7220	3680	3680	7360	1580	1580	3160	2240	2240	4480	0	0
3930	7860	4110	4110	8220	1580	1580	3160	2310	2310	4620	0	0
5180	10360	5480	5480	10960	3870	3870	7740	1930	1930	3860	0	0
6320	12640	3590	3590	7180	3760	3760	7520	3070	3070	6140	2940	2940
6010	12020	4180	4180	8360	4140	4140	8280	2640	2640	5280	3320	3320
5130	10260	2820	2820	5640	2870	2870	5740	3780	3780	7560	1820	1820
6540	13080	4660	4660	9320	4520	4520	9040	3310	3310	6620	3600	3600
5590	11180	5640	5640	11280	3130	3130	6260	2990	2990	5980	0	0
4960	9920	5540	5540	11080	2120	2120	4240	2500	2500	5000	0	0
7680	15360	11230	11230	22460	11080	11080	22160	12190	12190	24380	12190	12190

27	28	29	30	31	32	33	34	35	36	37	38
Total Axle 5	L Axle 6	R Axle 6	Total Axle 6	L Axle 7	R Axle 7	Total Axle 7	L Axle 8	R Axle 8	Total Axle 8	L Axle 9	R Axle 9
3740	0	0	0	0	0	0	0	0	0	0	0
21120	0	0	0	0	0	0	0	0	0	0	0
2700	0	0	0	0	0	0	0	0	0	0	0
5300	0	0	0	0	0	0	0	0	0	0	0
8980	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	0	0	0	0	0	0	0	0	0	0	0
5880	0	0	0	0	0	0	0	0	0	0	0
6640	0	0	0	0	0	0	0	0	0	0	0
3640	0	0	0	0	0	0	0	0	0	0	0
7200	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
24380	0	0	0	0	0	0	0	0	0	0	0

39	40	41	42	43	44	45	46	47	48	49	50
Total Axle 9	NS	NA	WHLB	ASP1	ASP2	ASP3	ASP4	ASP5	ASP6	ASP7	ASP8
0	4	5	5174	1381	421	2998	374	0	0	0	0
0	4	5	5096	1319	439	2939	399	0	0	0	0
0	4	5	3993	1311	447	1818	417	0	0	0	0
0	4	5	3975	1335	425	1821	394	0	0	0	0
0	4	5	6260	1773	510	3547	430	0	0	0	0
0	3	4	3824	1434	1981	409	0	0	0	0	0
0	3	4	3367	1311	1639	417	0	0	0	0	0
0	3	4	3530	1210	1942	378	0	0	0	0	0
0	4	5	5510	1395	488	3174	453	0	0	0	0
0	4	5	4032	1344	426	1869	393	0	0	0	0
0	4	5	5409	1475	459	3049	426	0	0	0	0
0	4	5	5278	1389	444	3029	416	0	0	0	0
0	3	4	3897	1493	2040	364	0	0	0	0	0
0	3	4	3871	1465	1988	418	0	0	0	0	0
0	4	5	5134	1361	433	2938	402	0	0	0	0

Table 3-3. A key to the column fields for Table 3-2

Column #	Field Name	Range	Units	Description	Example	Translation
1	TAG	N/A	N/A	Identifies what type of file it is.	VTR	Vehicle Truck Record
2	County	1 - 94	N/A	The county number where the site is located	59	station is in Wakulla county
3	Station	9901 - 9946	N/A	Station number (99xx) where 99 indicates a WIM station and xx is the site number	9946	WIM detector #46
4	Lane	1 - 7	N/A	Lane the truck was traveling in	2	vehicle was traveling in the northbound
5	Date	1/1/98 - 8/11/03	N/A	Date surveyed	12/27/1999	date of sample
6	Time	0 - 235959	hr, min, sec	Hours, minutes, seconds after 12:00 am vehicle crossed sensor (32716= 3:27:16 am)	32716	time vehicle went over sensor which is 3 hours 27 minutes and 16 seconds after
7	Vehicle #	1 - n	N/A	n^{th} vehicle to cross WIM station since 00:00:00	29	the 29th vehicle to pass over the sensor
8	Class	4 - 13	N/A	Classification of the vehicle according to scheme "F" of the D.O.T. classification system	9	3 axle tractor w/ 2 axle trailer or 2 axle tractor w/ 3 axle trailer
9	Violation	0 - 50	N/A	Type of violation	0	no violation
10	Speed	Variable*	MPH	Speed of vehicle	45	45 mph
11	Length	Variable*	FT	Length of Vehicle from bumper to bumper (format 99.99 decimal implied)	6144	61.44 ft
12	Gross Weight	Variable*	LB	Gross weight of the vehicle	28880	28,880 lb
13	L Axle 1	Variable*	LB	Left axle 1 weight	4980	4,980 lb
14	R Axle 1	Variable*	LB	Right axle 1 weight	4980	4,980 lb
15	Total Axle 1	Variable*	LB	Total axle 1 weight	9960	9,960 lb
16	L Axle 2	Variable*	LB	Left axle 2 weight	2930	2,930 lb
17	R Axle 2	Variable*	LB	Right axle 2 weight	2930	2,930 lb
18	Total Axle 2	Variable*	LB	Total axle 2 weight	5860	5,860 lb
19	L Axle 3	Variable*	LB	Left axle 3 weight	3070	3,070 lb
20	R Axle 3	Variable*	LB	Right axle 3 weight	3070	3,070 lb
21	Total Axle 3	Variable*	LB	Total axle 3 weight	6140	6,140 lb
22	L Axle 4	Variable*	LB	Left axle 4 weight	1590	1,590 lb
23	R Axle 4	Variable*	LB	Right axle 4 weight	1590	1,590 lb
24	Total Axle 4	Variable*	LB	Total axle 4 weight	3180	3,180 lb
25	L Axle 5	Variable*	LB	Left axle 5 weight	1870	1,870 lb
26	R Axle 5	Variable*	LB	Right axle 5 weight	1870	1,870 lb
27	Total Axle 5	Variable*	LB	Total axle 5 weight	3740	3,740 lb
28	L Axle 6	Variable*	LB	Left axle 6 weight	0	only a five axle truck, therefore no data
29	R Axle 6	Variable*	LB	Right axle 6 weight	0	only a five axle truck, therefore no data
30	Total Axle 6	Variable*	LB	Total axle 6 weight	0	only a five axle truck, therefore no data
31	L Axle 7	Variable*	LB	Left axle 7 weight	0	only a five axle truck, therefore no data
32	R Axle 7	Variable*	LB	Right axle 7 weight	0	only a five axle truck, therefore no data
33	Total Axle 7	Variable*	LB	Total axle 7 weight	0	only a five axle truck, therefore no data
34	L Axle 8	Variable*	LB	Left axle 8 weight	0	only a five axle truck, therefore no data
35	R Axle 8	Variable*	LB	Right axle 8 weight	0	only a five axle truck, therefore no data
36	Total Axle 8	Variable*	LB	Total axle 8 weight	0	only a five axle truck, therefore no data
37	L Axle 9	Variable*	LB	Left axle 9 weight	0	only a five axle truck, therefore no data
38	R Axle 9	Variable*	LB	Right axle 9 weight	0	only a five axle truck, therefore no data
39	Total Axle 9	Variable*	LB	Total axle 9 weight	0	only a five axle truck, therefore no data
40	NS	1 - 8	N/A	Number of axle spaces	4	4 axle spaces
41	NA	1 - 9	N/A	Number of axles	5	5 axles
42	WHLB	Variable*	FT	Wheel base, distance from first to last axle (format 99.99 decimal implied)	5174	51.74 ft
43	ASP1	Variable*	FT	Axle Space 1-2 (format 99.99 decimal implied)	1381	13.81 ft
44	ASP2	Variable*	FT	Axle Space 2-3 (format 99.99 decimal implied)	421	4.21 ft
45	ASP3	Variable*	FT	Axle Space 3-4 (format 99.99 decimal implied)	2998	29.98 ft
46	ASP4	Variable*	FT	Axle Space 4-5 (format 99.99 decimal implied)	374	3.74 ft
47	ASP5	Variable*	FT	Axle Space 5-6 (format 99.99 decimal implied)	0	only four axle spaces, therefore no data
48	ASP6	Variable*	FT	Axle Space 6-7 (format 99.99 decimal implied)	0	only four axle spaces, therefore no data
49	ASP7	Variable*	FT	Axle Space 7-8 (format 99.99 decimal implied)	0	only four axle spaces, therefore no data
50	ASP8	Variable*	FT	Axle Space 8-9 (format 99.99 decimal implied)	0	only four axle spaces, therefore no data

*The values can be found in the Automated Editing of Traffic Data in Florida on pages 12-13.

Conversion of Data

The 25,300 files needed to be arranged properly for the requirements of the project. A directory structure was created to organize the data. Each file contained one day's worth of data consisting of hundreds of truck entries. A folder was created for each of the 37 sites. Within each site's folder, the data were further subdivided into the specific year that it pertained to.

Preliminary Analysis of WIM Data

After the data were organized into the proper folder system, a preliminary statistical analysis was initiated. This section presents some of the original schemes applied to characterize the WIM data in a probabilistic framework. A global perspective was first used, in which the data from all WIM stations were combined to provide a view of the overall relative likelihood of heavy vehicle travel in Florida. Extreme value analysis was then applied to data from specific WIM sites over various time frames. The results of the analyses presented in this chapter represent a starting point for feedback to the FDOT project manager. Subsequent meetings narrowed the scope of the analysis to best fit the intended use of the project results, and are the subject of Chapter 5.

Initial Analysis of Data from All WIM Stations Combined

There were several steps taken that perfected what information needed to be pulled out of each file. A Visual Basic program was written to extract the minimum and maximum vehicle classification, the minimum and maximum weight, and the total number of vehicles for each day of data. The classification of the vehicles comes from the classification scheme “F” from the FDOT, which can be found in Appendix A. From the preliminary analysis of the data, it was found that the files consisted of only vehicles that were classified as trucks (i.e., cars and other non-FDOT-defined-trucks were filtered out).

The next step was to organize the weight of the vehicles into more precise groups. Since a permit vehicle is 80,000 lbs or greater, the program only considered trucks greater that 85,000 lbs. 85,000 lbs was chosen to account for weight measurement error, thus ensuring that the vehicle needs a permit to operate. On top of the information that was pulled out of each file by the first version of the Visual Basic program, the total number of vehicles greater than 85,000 lbs, 90,000 lbs, 105,000 lbs, 120,000 lbs, 135,000 lbs, and 150,000 lbs were also recorded.

The final step was to identify the vehicle classes that were carrying the heaviest loads. It is more significant if the weight of an extreme load is distributed over, for example, four axles rather than seven. In addition to the information extracted from each file in the second version of the program, the final version of the Visual Basic program identified the classification of any vehicle that was 150,000 lbs or greater.

Table 3-4 presents the summary statistics from the combined WIM records of all stations and all years. Of all vehicles that were weighed at the WIM stations, 6.12% exceed 85,000 lbs. 85,000 lbs was the overweight threshold to determine the percent of overweight vehicles within six ranges shown in Table 3-4. These are calculated as a percentage among only those vehicles that exceed 85,000 lbs. The highest recorded vehicle weight in any file was 160,000 lbs. The same information can be seen graphically in Figure 3-1. Detailed lists of the data broken down by years and site numbers can be found in Appendix B. The tables found in Appendix B give a better perspective of the data that were extracted from each site and each year.

This preliminary analysis of all WIM data confirmed the initial presumption that the WIM data ignores or otherwise filters any vehicle with a gross weight over 160,000 lbs. It was unclear at the start of the project whether this presumption was correct, and whether it implied the need for additional data sets beyond the WIM site data. The 160,000 lbs maximum confirmed by this preliminary analysis of all WIM data led to the acquisition of the permit data set that is the subject of Chapter 4.

Table 3-4. Summary of WIM data (all weight in 1000 lbs)

Total Recorded Vehicles	Total Vehicles >85	Percent Vehicles >85	Percentage of Weight within Weight Range Out of Vehicles Over 85,000 lbs *only*					
			85 - 90	90 - 105	105 - 120	120 - 135	135 - 150	150 - 160
29,897,981	1,829,854	6.12%	60.49%	33.33%	5.03%	0.77%	0.31%	0.06%

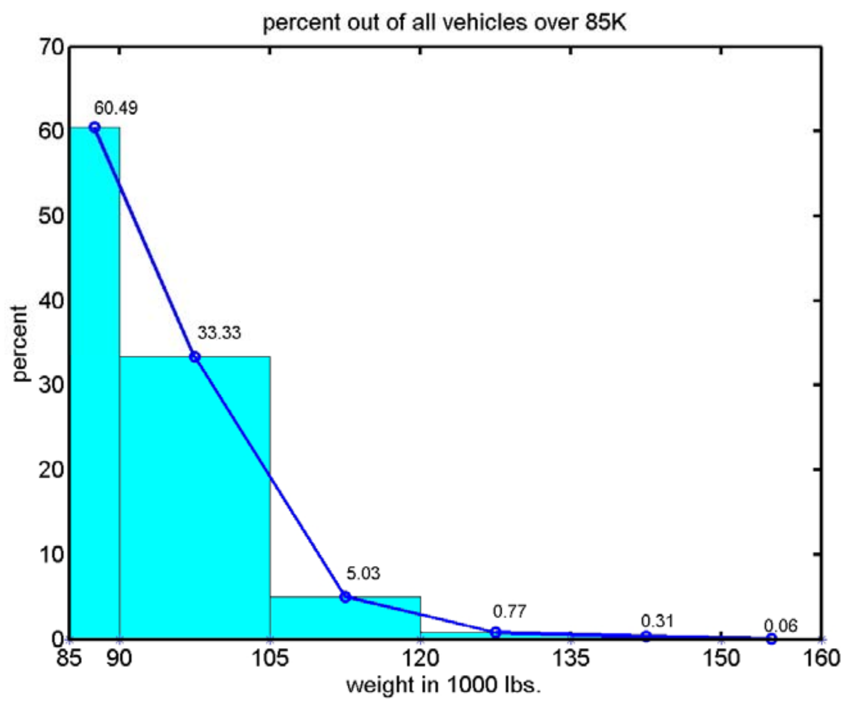


Figure 3-1. Weight category percentages out of all vehicles over 85,000 lbs

Histograms could now be generated for different years at different sites. The problem with generating histograms with the data pulled from the WIM files was that it was very limited. The number of bins and the bin widths were both fixed for the weight ranges shown in Table 3-4. The histograms that were generated also only apply to vehicle weights greater than 85,000 lbs, not the whole data set. A broader analysis of the data was conducted to generate histograms that were more flexible in what they could present. This involved the development of a companion Visual Basic program for more generalized processing of the WIM files. The next several sections discuss the analysis of data at specific WIM sites using an exponential probability model.

Generating Extreme Value Histograms from WIM Data

A Visual Basic program was created to examine all the WIM data files for a specified time period at a particular site. The program extracted the gross truck weight for every truck from every truck data file. The program then created a separate text file for each day, the contents of each consisted of only the gross weight for each truck record in the file. The program also created a table of contents file that contained a list of the names of all files that were processed. These files were then input into Mathcad [17] for analysis. An array of the gross weight data could then be read from a desired file.

For example, the 99320101_11.txt file represents the file for January 11, 2001 at site 9932. Numerous days at a given site (or multiple sites) could be loaded, creating one large continuous array with all of the data for the files specified. A histogram could be created by inputting the data source and the number of bins.

An example histogram is provided in Figure 3-2 from the full year of data at a single WIM station. The WIM station is #9932 which is located on the Florida Turnpike in Osceola County. The x-axis represents the vehicle weight; the y-axis represents the number of trucks within each bin at that weight. The general shape of the resulting histogram is bi-modal with a peak near 20,000 lbs and another near 45,000 lbs. The lower peak is a distribution of unloaded trucks, while the higher peak is the distribution of loaded vehicles.

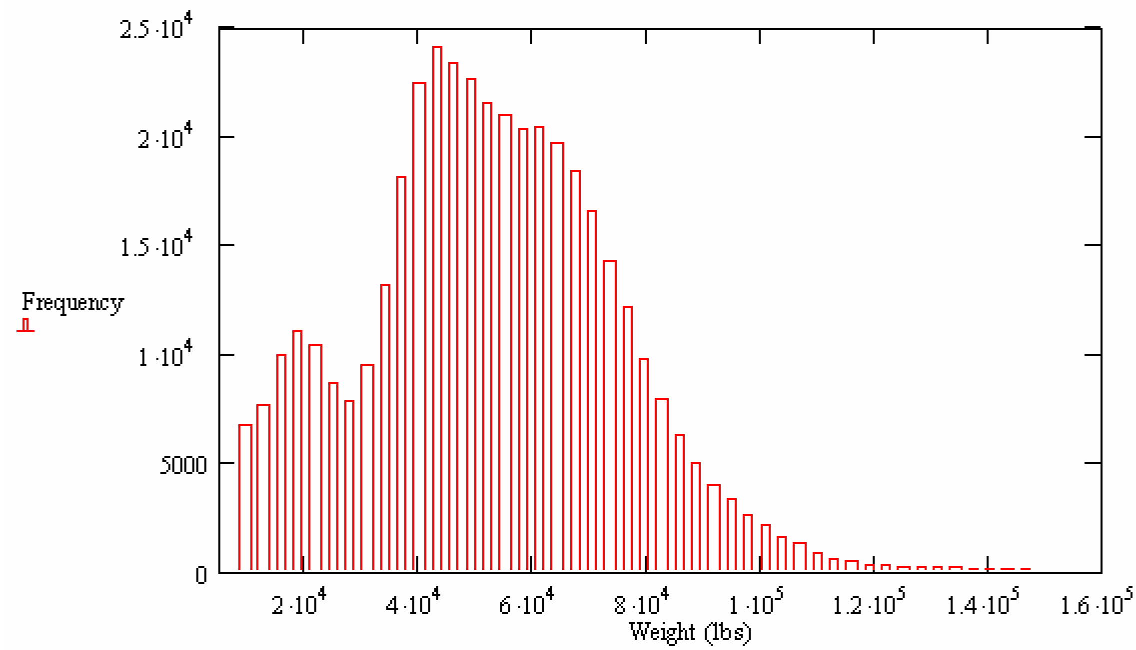


Figure 3-2. WIM station 9932, the full year of data from 2001.

The focus of the project was to model the occurrence of heavy vehicles. Therefore the dataset was filtered to only look at the heavier vehicles; the vehicles that were to the right of the second peak of the histogram. The histogram in this range appears to fit an exponential distribution, defined later in this chapter, as the monotonic decrease in probability from left to right. The portion of data that this study focuses on was the data over 80,000 lbs. For the histogram in this example, a cut off of 70,000 lbs was chosen. Only the samples over this level were kept for further extreme value analysis. Figure 3-3 shows the histogram produced from the full year of data from 2001 for the vehicles over 70,000 lbs.

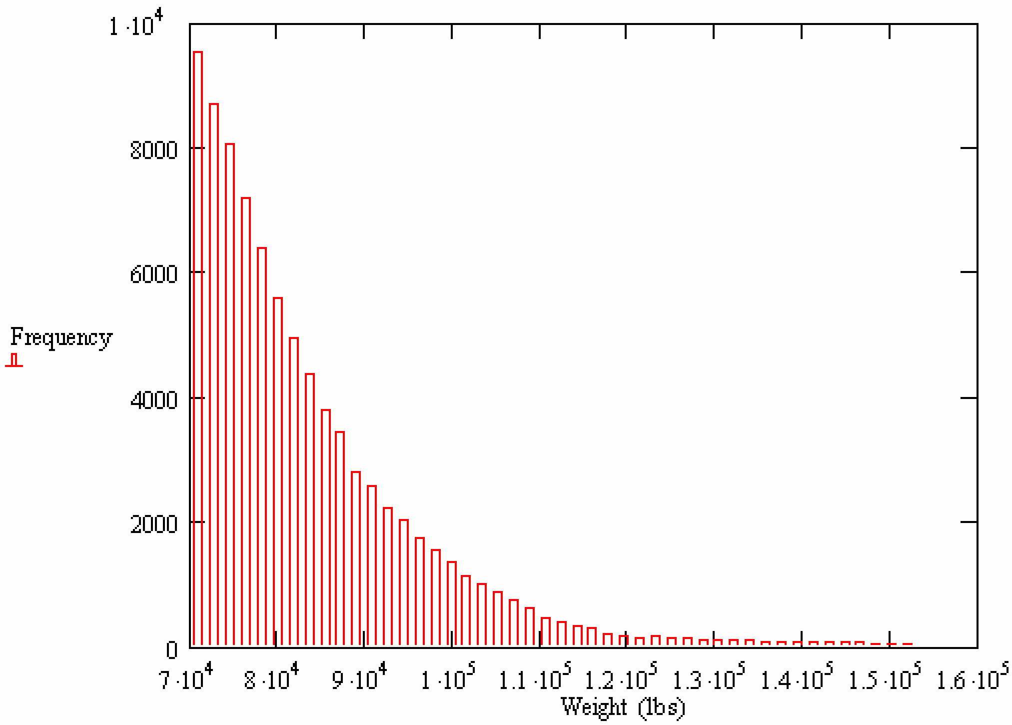


Figure 3-3. WIM station 9932 (vehicles greater than 70,000 lbs)

Meaning of the extreme value histogram

To use the histogram to determine probabilities, the data presented in Figure 3-3 needs to first be normalized so the area under the histogram equals one. The normalized histogram would then represent the probability, out of any vehicle between 70,000 and 160,000 lbs, of a given range of weights passing the given WIM sensor over the time frame chosen for analysis. An explanation of this process is discussed in the next section.

Modeling the extreme value histogram

It was desired to create an analytical parametric function that represented the information provided in the normalized extreme value histograms of the data of interest. A convenient functional form would be flexible enough to represent a variety of WIM data, from different WIM stations over various time frames. Thus a parametric probability density function (PDF) was sought that fits the WIM data well. The focus was again restricted to the extreme values of heavier vehicles.

Fortunately, the monotonic nature of the histogram above 70,000 lbs lends itself well to a simple PDF known as the exponential PDF. The exponential PDF is

$$f(x) = \lambda \times e^{-\lambda \times x} \tag{1}$$

where x is the weight, and λ is the parameter that is optimized such that the error between the exponential PDF and the normalized histogram is minimized. The procedure to identify λ involves finding the peak in the 'maximum likelihood function'.

Suppose that X is a random variable (such as weight) with the probability density function of $f(x, \Theta)$, where Θ is a generic single unknown parameter (such as λ). Let $x_1, x_2, \ldots, x_n$ be the observed values in a random sample of size n (the weights from the WIM data). Then the likelihood function of the sample is

$$L(\Theta) = f(x_1, \Theta) \times f(x_2, \Theta) \times \ldots \times f(x_n, \Theta) \tag{2}$$

which is the product of the model probability associated with each observed value.

The value of the likelihood function is a function of the unknown parameter Θ and the data. The maximum likelihood estimator of Θ is the value of Θ that maximizes the likelihood of the function $L(\Theta)$. That is, determine the value of Θ that makes the product of the probabilities of the observations the highest.

In the specific case of the exponential PDF, the likelihood function is

$$L(\lambda) = (\lambda \times e^{-\lambda \times x_1}) \times (\lambda \times e^{-\lambda \times x_2}) \times \ldots \times (\lambda \times e^{-\lambda \times x_n}) \tag{3}$$

The value of likelihood function $L(\lambda)$ was plotted over a range of values of λ, and the value of λ that corresponds to the peak value is the best descriptor of the data. Identifying the peak in the likelihood function was easily done in Mathcad using a built in optimization function.

It was more convenient to take logarithms and work with the log-likelihood function. Since the logarithm function is monotonic, the log-likelihood takes its maximum at the same point as the likelihood function presented in Equation (2). The likelihood function in this form is now a summation of the natural log of the probability of each sample (weight) rather than the product. The Mathcad function used to identify the maximum likelihood value is more reliable in this form:

$$l(\Theta) = \log L(\Theta) = \sum_{i=1}^{n} \log f\left(x_i ; \Theta\right) \tag{4}$$

Figure 3-4 illustrates the resulting log maximum likelihood function (Equation 4) plotted vs. λ for the data used to create Figure 3-3. Before calculating λ, the data were first linearly mapped from the 70,000 to 160,000 range into a range of 0 to 1. This was done since the functional form of the exponential distribution has a lower bound of zero. The value of λ that provides the maximum value in this case was 6.621, calculated using a Mathcad optimization routine. This λ value was used to create the model and substituted back into the exponential PDF (Equation 1), in this case $f(x) = 6.621e^{-6.621 \times x}$. This analytical function (exponential PDF) now represents the data over the range 0 to 1. In order to represent the data over the interval of 70,000 to 160,000 lbs, the analytical function needed to be adjusted to invert the data mapping. Since the interval had increased from 1 to 90,000, the exponential PDF needed to be divided by 90,000. In addition, the value of x would become $\left(\dfrac{W - 70{,}000}{160{,}000 - 70{,}000}\right)$. The new exponential PDF equation in terms of the data in its original values W is

$$f(W) = \frac{1}{90{,}000}\left(\lambda \times e^{-\lambda \times \left(\frac{W - 70{,}000}{160{,}000 - 70{,}000}\right)}\right) \tag{5}$$

The exponential PDF in Equation (5) was graphed on top of the normalized histogram to demonstrate how closely the two curves match in Figure 3-5. Figure 3-5 represents the full year of data from 2001 for all the trucks weighing more than 70,000 lbs. The blue line represents the exponential PDF model identified using maximum likelihood. This model was superimposed on the normalized histogram of the actual WIM data. Figure 3-5 denotes the normalized version of Figure 3-3.

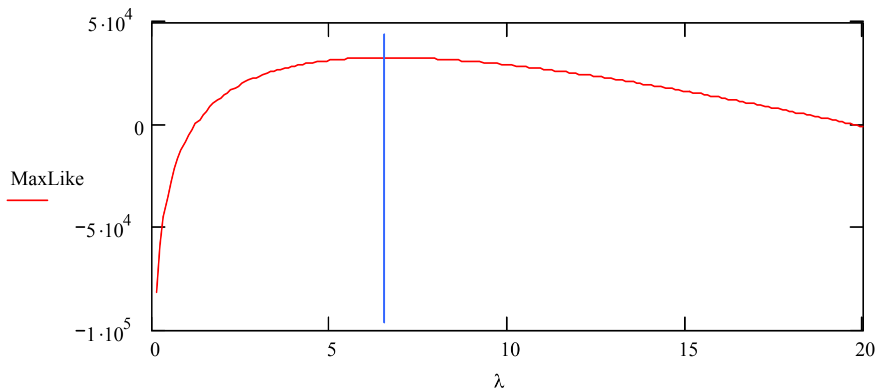


Figure 3-4. Example of a maximum likelihood function for WIM data as a function of λ

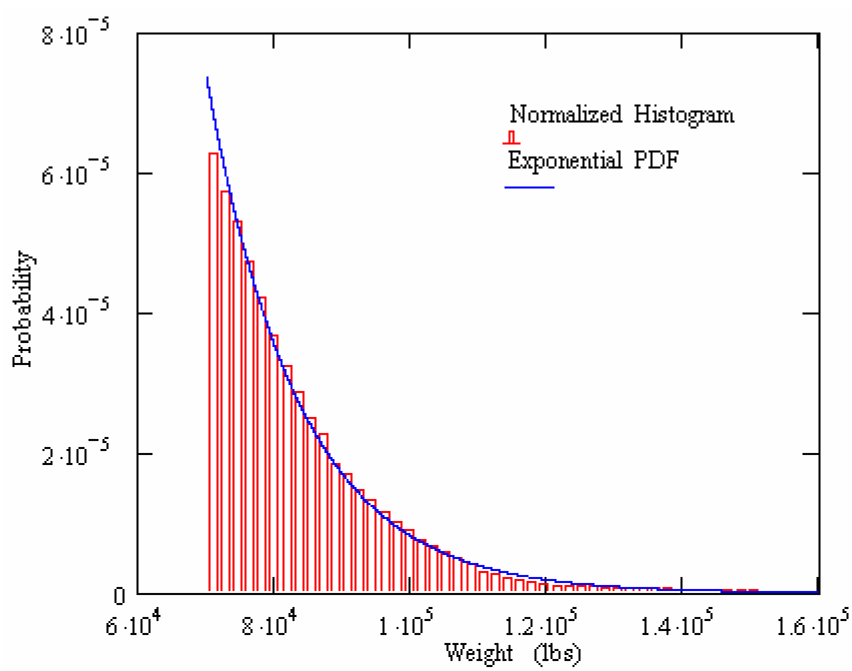


Figure 3-5. Exponential PDF model and normalized histogram (WIM station 9932)

Application of the extreme value model

An exponential PDF model of extreme vehicle weights was developed for many of the WIM stations over varying periods of time. This produced a view of the relative likelihood of heavy vehicles in various parts of Florida. Since the locations of the WIM stations were available, these distributions can be tied to bridges of interest. For example, the distribution fit to data from a WIM station along I-95 may vary considerably from a different station along I-10. The difference may show a much higher probability that heavier vehicles will approach a particular bridge on the east coast compared to a bridge in the panhandle. These studies may also show a change in the weight distributions at the same station during different seasons.

Two additional examples are presented. The first looks again at WIM station 9932, but only uses the data for the first three months of the year rather than the complete year. Figure 3-6 presents the full histogram of data from the first three months of 2001 from WIM station 9932. Figure 3-7 presents the resultant exponential PDF fit using maximum likelihood on the normalized extreme value histogram. From the full year to the first three months the λ parameter changed from 6.621 to 8.069.

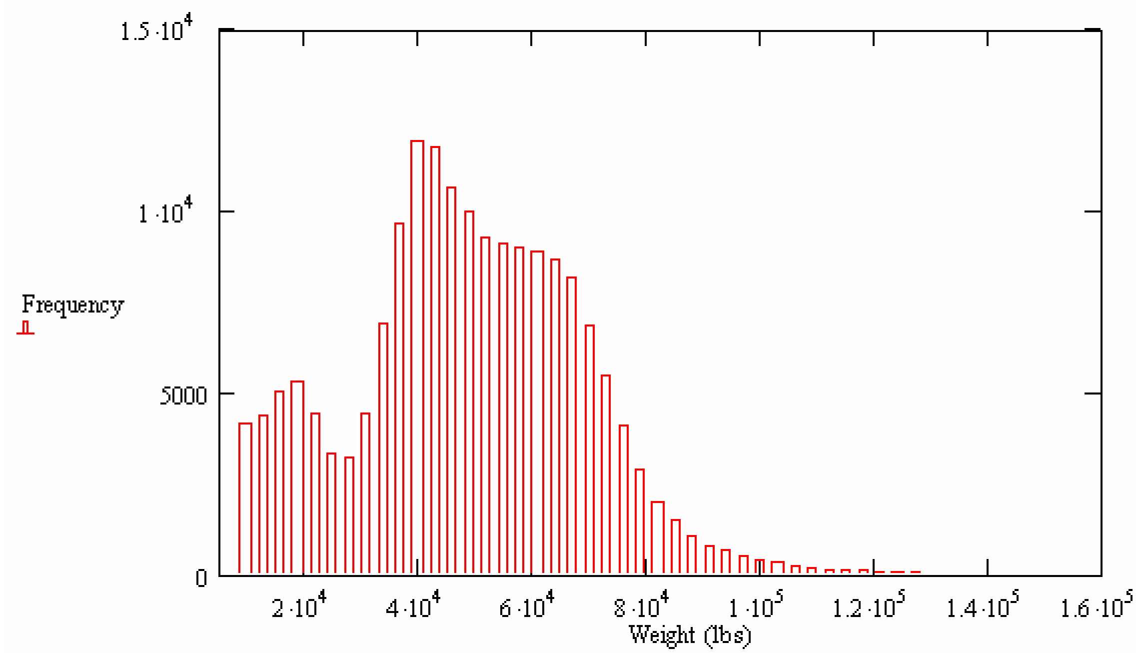


Figure 3-6. First three months of data for 2001 from WIM station 9932

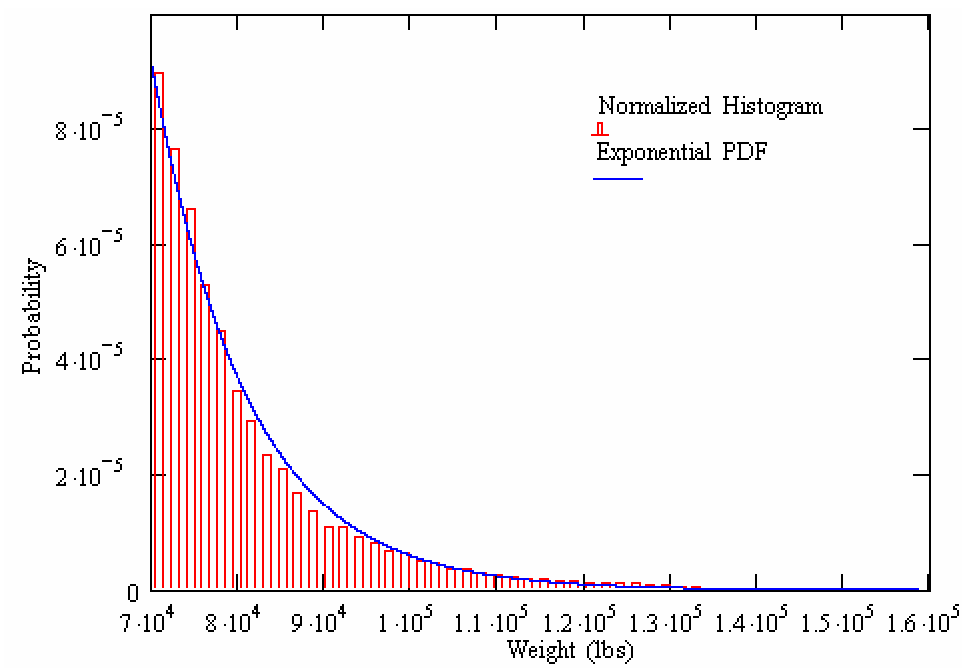


Figure 3-7. Exponential PDF model and normalized histogram (first three months from WIM station 9932)

The second example uses the entire year of 1998 from WIM station 9901, located on I-10 near Monticello in Jefferson County. Figure 3-8 presents the full histogram of data from WIM station 9901. Figure 3-9 presents the resultant exponential PDF fit using maximum likelihood on the normalized extreme value histogram. The cutoff point for the data from WIM station 9901 was 75,000 lbs instead of 70,000 lbs which was used for the previous two examples. The point where the exponential curve starts to develop differs from station to station; therefore the cutoff point was adjusted. From the full year (2001) at station 9932 to the full year (1998) at station 9901 the λ parameter changed from 6.621 to 20.323.

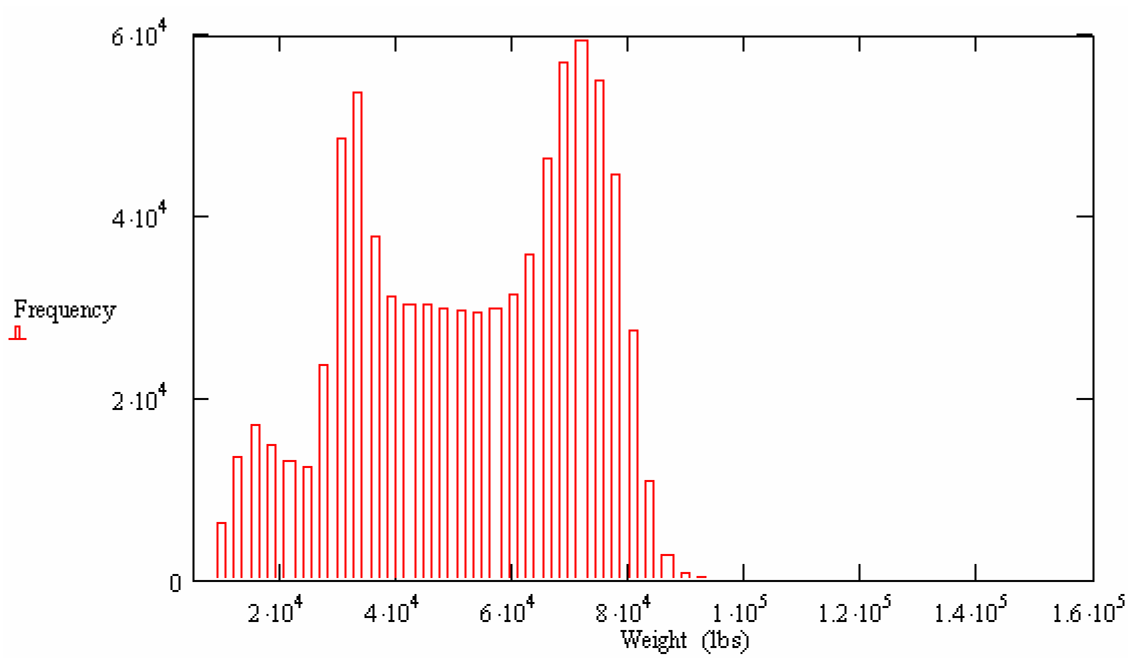


Figure 3-8. WIM station 9901, the full year of data from 1998

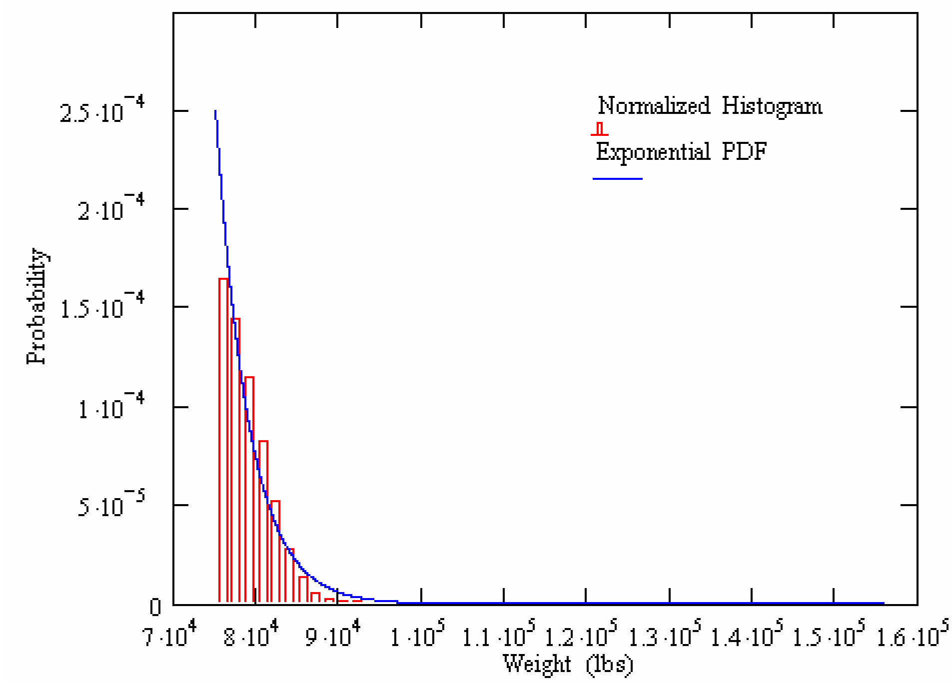


Figure 3-9. Exponential PDF model and normalized histogram (WIM station 9901)

A higher λ value indicates that the right tail of the distribution (the heaviest vehicle weights) were less probable when compared to low values of λ. That is, the higher the λ, the less likely heavier vehicles will be observed. Coupling such relative probability information with the frequency of observations of all trucks at a given WIM station provides a quantification of heavy vehicles traveling along that WIM route.

Extensions of the extreme value model

Thus far the extreme value modeling of heavy vehicles did not include information regarding the likelihood of multiple heavy vehicles on a bridge. The histograms that were produced (e.g., Figures 3-2 and 3-3) do not use the time between individual WIM records as an input. However, the methodology presented above can be adjusted to take advantage of the time stamp of each record, which was provided in the WIM records.

The modeling discussed above may be extended to include additional independent variables, such as time between WIM records. This extension will be useful for identifying the likelihood of multiple heavy vehicles approaching bridges. For example, similar modeling techniques can be used to identify probabilities for the total weight to pass a WIM station over a chosen time frame, say five minutes. Another distribution can be developed to describe the average headway between adjacent weighted vehicles. Total weights could potentially exceed 160,000 lbs if several heavy vehicles are traveling close together. Short of placing WIM sensors immediately before a bridge of interest, this modeling method is valid for helping determine the probability of simultaneous heavy vehicle loads on a bridge.

The consideration of headway information in probability modeling was a subject that was pursued more rigorously in Chapter 5, when the analysis was shifted to target the likelihood of multiple heavy vehicles occurring within a specified length of road. This includes multiple vehicles traveling together, and vehicles traveling opposite directions which cross the same WIM sensor within a short time frame.

The next section discusses in detail irregularities identified within the WIM data provided by the FDOT during the course of the preliminary analyses discussed thus far. The forms, sources and significance of these irregularities were investigated to determine whether they were likely to have a significant impact on subsequent data analysis.

Difficulties with the WIM Datasets

In the development of the Visual Basic programs and the preliminary analysis of the WIM data, numerous irregularities and difficulties were encountered. The next section will discuss some of the difficulties that have been observed with the contents of the WIM records. The next chapter moves from the WIM datasets to the permit vehicle records that contain information for vehicles over 160,000 lbs.

There were six complications that were encountered when analyzing the WIM datasets. The first two complications were resolved, while the last four remain unresolved. The next six subsections discuss these issues.

Inconsistent Formatting in WIM Data Files

The majority of the WIM data were set up so that each line of data represented all of the statistics for a single truck. Each new line represented a new truck that passed the sensor. Data at a few of the WIM stations were not broken up line by line for each truck that passed over the sensor; instead they were one continuous line of data. The site numbers and years of data that had the problem are listed in Table 3-5.

A solution was reached using a Visual Basic program. A rectangular box character, similar to the character shown in parentheses (□), separated adjacent entries on the same line. The Visual Basic program produced an identical file in the correct format. Each time a box was encountered, a new line of text was created below the previous line. This process eliminated the continuous text string and organized the file in a line by line basis.

Table 3-5. WIM stations with an inconsistent file format

Site Number	Years
9901	1998, 1999
9908	1998, 1999, 2000
9921	1998, 1999, 2000
9935	1998, 1999, 2000
9936	1998, 1999, 2000

Blank Data Files

Any single data file contained the data collected during a 24-hour period at a particular WIM station. Some data files contained no data for a given day. Ordinarily, if there were no data for a given day, there was no file for that day. The assumption was made that there must have been some complication in sending the data from the site back to the DOT. These files were omitted from the data files used for analysis. The site numbers and years of data that contained blank files are listed in Table 3-6. The table does not indicate that an entire year of data was missing, only that one or more days in that year were blank.

Table 3-6. WIM stations and years that contain blank files

Site Number	Year(s)	Site Number	Year(s)
9901	2001	9935	1999, 2000, 2003
9906	2001	9936	2001
9907	2002	9937	1998
9909	2001	9938	2000
9914	2001	9939	1998, 1999, 2000, 2003
9917	2001	9940	2003
9919	2001, 2002	9942	2000, 2001, 2002, 2003
9921	2000	9943	1999, 2003
9925	2002, 2003	9944	1998, 1999, 2001, 2003
9929	2003	9946	2000, 2003
9931	2001		

Same Vehicle Entry Recorded More than Once

Some data files contained many more entries than other files around the same time period (each file should be a single day). It was found that the large files were combining multiple records of days into one large file. This was not a big problem if any vehicle was simply recorded once, but stored in the wrong file (a different day). There was a time and date stamp associated with each record. However, in some cases one or more of the days that were contained within the large file would also have its own VTR (vehicle truck record) file. This means that some days of data were represented twice in a dataset. There were two different situations, the first was when a day in the large file was identical to its VTR file, and the second situation was when it was not identical.

An example of files with the first problem was found in records 99320209.041_VTR and 99320209.051_VTR. The first file represents the day September 4, 2002 and is 508 KB; the second file represents September 5, 2002 and is 991 KB. The September 5th file contains data from both days. When splitting the

September 5th file into two files, a 508 KB file and a 483 KB file were created which represent September 4th and 5th respectively. The two September 4th files were identical, therefore recording all the data from September 4th twice.

An example of files with the second problem was found in the files 99130202.111_VTR and 9932130202.121_VTR. The first file represents the day February 11, 2002 and is 166 KB; the second file represents the day February 12, 2002 and is 816 KB. The February 12th file contains data from both days. When separating the February 12th file into two files a 390 KB file and a 426 KB file were created which represent the complete files for both days. The reason the February 11th file increased from 166 KB to 390 KB was that the 166 KB file only had the first 11 hours of the day, whereas the 390 KB file contained all 24 hours. This meant that a portion of February 11th was recorded twice.

End of Month Carryover into the Subsequent Month

This problem was an extension of the previous problem. The issue was still multiple days of data being combined into one data file. In some cases the day or days at the end of a given month were combined with the beginning days in the subsequent month. When multiple data files were combined into one they were arranged in ascending order, adding the next day to the end of the previous day. The particular problem in this case was that when the data switched from one month to the next, the data from the prior month did not have the proper month number in its date stamp, but rather has the month subsequent to it.

An example of a file that has this problem was found in the file 99469812.021. This file should only contain the data from December 2, 1998. Instead it contained the data from November 30th, December 1st, and December 2nd. The day of data from

November 30th had been improperly date stamped as December 30th, thus the file appears to contain December 30th, December 1st, and December 2nd. At this WIM station there was no November 30th file, but there was a separate December 30th file. The actual December 30th file and the part of the December 2nd file that contained data improperly stamped as December 30th have nothing in common (no repeats of specific vehicle weights or times). Thus, the conclusion was that November 30th was a part of the December 2nd record with an improper date stamp.

Multiple Days of Data in a File with No Reset of the Vehicle Count

This problem was similar to the previous two problems. It deals with multiple days of data being combined into one file. The end of any given day should result in a resetting of the time to midnight (00:00:00) and vehicle number to 1, thus providing a count of vehicles per day. The issue was that when the combined file switched from one day to the next, the survey hour, minute, second, and vehicle number did not reset for the new day. A file with this problem was 99350110.021_VTR. This file was supposed to contain October 2, 2001 data. The records within jumped dates from September 21st to October 21st to October 1st before a 24-hour period was completed and the time and vehicle number were reset. However, when it went from October 1st to October 2nd, it did not encounter this problem. Table 3-7 presents an example from portions of WIM station 9935 on October 2, 2001. This site contained more than one day of data without resetting the time stamp or vehicle number. The light grey highlight represents when the time stamp and vehicle number do not reset. The dark grey highlight represents the correct reset of the time stamp and vehicle number.

Table 3-7. WIM file 99350110.021_VTR

File Type	County Number	Station Number	Date	Hour	Minute	Second	Vehicle Number
VTR	93	9935	9/21/2001	1	55	40	146
VTR	93	9935	9/21/2001	1	55	46	147
VTR	93	9935	9/21/2001	1	56	8	149
VTR	93	9935	10/21/2001	1	56	15	150
VTR	93	9935	10/21/2001	1	57	42	151
VTR	93	9935	10/21/2001	1	59	9	152
:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:
VTR	93	9935	10/21/2001	14	24	59	4241
VTR	93	9935	10/21/2001	14	25	6	4242
VTR	93	9935	10/1/2001	14	29	56	4252
VTR	93	9935	10/1/2001	14	33	26	4281
VTR	93	9935	10/1/2001	14	33	50	4283
:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:
VTR	93	9935	10/1/2001	23	58	19	3274
VTR	93	9935	10/1/2001	23	58	25	3275
VTR	93	9935	10/1/2001	23	58	34	3276
VTR	93	9935	10/2/2001	0	1	55	4
VTR	93	9935	10/2/2001	0	8	20	9
VTR	93	9935	10/2/2001	0	8	27	10

Naming of Combined Files by the Last Day

The last problem identified in the WIM files again deals with multiple days of data being combined into one file. Whenever multiple days of data were combined into one file, the file was named for the last day of recorded data in the combined file. Looking at the file 99350110.021_VTR again, the file was supposed to represent October 2, 2001. This means that the last day in the file should be October 2, 2001. Instead the file continues to record days up to October 13th.

Resolving Problems with WIM Files

The underlying issue in the four unresolved problems was that they all were combining multiple days of data into a single file. Each identified problem was slightly different, but inevitably came down to multiple days of data being recorded as a single day. To figure out how widespread of a problem this was, an evaluation of the data needed to be done to see how many files combined data. A Visual Basic program was created to open each file and look for a change in the date. If the program came across a file with more than one date it would record the file name, the dates that it had combined in the file and the starting and ending hours for each of the dates. The starting and ending hours were recorded to check to see if an entire day of data was recorded. A text file was created for each year at each of the 37 WIM stations summarizing all the files that were combining days of data. The text output from 2001 for site 9921 is shown in Table 3-8.

Table 3-8. List of the files with multiple days of data for the site 9921, year 2001

File Number	File Name	File Date	Start Time			End Time		
			Hr.	Min.	Sec.	Hr.	Min.	Sec.
165	99210106.151_VTR	6/14/2001	2	45	22	22	46	11
165	99210106.151_VTR	6/15/2001	0	40	3	23	45	16
176	99210106.271_VTR	6/26/2001	14	45	6	21	18	17
176	99210106.271_VTR	6/27/2001	0	18	43	19	18	35
212	99210108.021_VTR	8/1/2001	2	47	31	22	29	46
212	99210108.021_VTR	8/2/2001	0	32	32	22	22	24
219	99210108.161_VTR	8/15/2001	13	57	0	20	10	36
219	99210108.161_VTR	8/16/2001	3	18	3	18	52	0
285	99210110.211_VTR	10/20/2001	1	46	55	23	46	17
285	99210110.211_VTR	10/21/2001	1	48	46	22	52	42
294	99210110.301_VTR	10/29/2001	0	29	13	22	18	54
294	99210110.301_VTR	10/30/2001	3	13	50	18	40	1

Once the evaluation of the dataset was complete, it was found that out of 25,300 files, 1,284 files recorded multiple days of data into one day. This is roughly 5% of the data files. Given the complexities involved in untangling files that suffered from one or more of the above identified problems, there was not enough confidence that any one solution (algorithm) could be created to solve these issues within a reasonable time frame. Further, there was the possibility that there were additional problems with these files that had not been identified. Thus, fixing the identified problems would not guarantee that the data now offered a clean representation of the actual vehicle travel at those WIM stations and days. It was important to make an effort to remove data that may contaminate the results of the statistical analyses. For this project, the files with multiple days of data were omitted from the analysis. A summary of all the files with multiple days of data can be found in Appendix C.

CHAPTER 4
PERMIT VEHICLE ANALYSIS:
REGIONAL VEHICLE MODELING

The vehicle truck records that were obtained from the Florida Department of Transportation's WIM sensors did not include records for trucks that weighed in excess of 160,000 lbs or had more than nine axles. Another source of data was required to account for vehicles that fit this description. As discussed in Chapter 1, the FDOT issued permits to vehicles that exceed standard size and/or 80,000 lbs. Each permit was recorded, and therefore served as a potential source of information for vehicles over 160,000 lbs. The permitting office supplied a hard copy of the permits issued to trucking companies in Florida from January 2002 to April 2004. Processing and analysis of these permit records is addressed in this chapter.

Formatting and Processing

The data supplied in the permit records consisted of: permit vehicle weight, vehicle width, permit number, the date the permit was issued, company name, permit type, permit class ID, vehicle route, and route restrictions. The categories with the most significance to the project were the vehicle weight, permit date, permit type, and route/restrictions.

The hard copy of the permit listing obtained from FDOT was scanned into electronic format using optical character recognition software. An example of one of the scanned sheets is shown in Figure 4-1. The hundreds of pages of scanned data were carefully reviewed to find errors created during the scanning process. After the identifiable errors in the data had been fixed, a categorization of where the trucks were traveling throughout the state was needed.

OVERWEIGHT PERMITS ISSUED 160K - 200K 10:33 Monday, April 19, 2004 21
FROM 01/01/2003 TO 12/31/2003

------- TYPEPERM=T PRMT_CLS_ID=S -------
(continued)

Obs	WEIGHT	WIDTH	PERMIT NUMBER	PERMDATE	PERMIT NAME	ROUTE
980	160000	14	12337	21AUG03	DAILY EXPRESS, INC.	US-27, SR-80, US-441, US-98, SR-809, SR-
981	160000	14	12430	22AUG03	COMBINED TRANSPORT, INC.	I-10, I295, I-95, I-595
982	160000	14	12596	22AUG03	LEE MAR BUILDING & CONSTRUCTION CORP	I-75, SR-78
983	160000	14	12682	23AUG03	ADMIRAL MERCHANTS MOTOR FREIGHT	US231 SR20 SR267 US98 USALT27 I75 SR44 U
984	160000	14	12721	25AUG03	DAILY EXPRESS, INC.	US-27, SR-80, US-441, US-98, SR-809, SR-
985	160000	14	13003	25AUG03	SOUTHWEST UTILITY SYSTEMS	US-41
986	160000	12	13048	25AUG03	RINGPOWER CORP	SR-263, I-10, I-75, SR-64, US-27, US-98
987	160000	16	13089	26AUG03	COUNTS CONST.	US-441, SR-326
988	160000	16	13147	26AUG03	INTERNATIONAL TRUCKING & RIGGING CO INC	SR-826, US-27
989	160000	14	13161	26AUG03	LEE MAR BUILDING & CONSTRUCTION CORP.	SR884, I75
990	160000	14	13371	26AUG03	HUBBARD CONSTRUCTION COMPANY	SR-436, SR-434
991	160000	12	13500	26AUG03	UNITED ROAD SERVICE	I-10
992	160000	12	13566	27AUG03	RINGPOWER CORP.	I-95, US-1
993	160000	14	13621	27AUG03	AMERICAN ENG. & DEY. CORP.	US-441, SR-848, I-95, SR-858, US-1, SR-8
994	160000	12	13899	27AUG03	HYDRO ROCK COMPANY, INC.	I-75
995	160000	14	13935	27AUG03	SOUTHWEST UTILITY SYSTEMS	I75
996	160000	14	13939	27AUG03	HUBBARD CONSTRUCTION COMPANY	SR482, SR436. SR426, & RETURN
997	160000	14	14041	28AUG03	LEE MAR BUILDING & CONSTRUCTION CORP	SR-78, I-75
998	160000	14	14198	28AUG03	RINGPOWER CORP	US 90, SR 115, SR 202, US 1
999	160000	12	14463	29AUG03	VESCO SPECIALIZED CARRIERS	US-319, SR-61, I-10, SR-263
1000	160000	14	14469	29AUG03	MCTYRE TRUCKING CO INC	US-17, I-4, SR-423
1001	160000	14	14470	29AUG03	MCTYRE TRUCKING CO INC	SR-423, I-4, US-17
1002	160000	14	14620	02SEP03	ADMIRAL MERCHANTS MOTOR FREIGHT	US231 SR20 SR267 US98 USALT27 I75 SR44 U
1003	160000	12	14743	02SEP03	LEWARE CONSTRUCTION COMPANY	US-27, FTP, I-4, US-441
1004	160000	14	14916	03SEP03	KAUFF'S OF MIAMI	SR 704, SR 809, I-95, SR 60
1005	160000	12	15097	03SEP03	RINGPOWER CORP	US-17, SR-100, SR-21, I-295, SR-13, SR-1
1006	160000	14	15194	03SEP03	RINGPOWER CORP	SR-16, I-95, US-1
1007	160000	12	15195	03SEP03	MCTYRE TRUCKING CO INC	SR-44, I-75, I-275 S, SR-60
1008	160000	12	15277	04SEP03	RING POWER CORP	SR-263, I-10, US-129, US-41
1009	160000	12	15278	04SEP03	RING POWER CORP	US-41, US-129, I-75, SR-326, US-301
1010	160000	14	15282	04SEP03	AMERICAN ENG & DEV CORP	US-441
1011	160000	14	15320	04SEP03	RINGPOWER CORP.	SR-206, I-95, US-1
1012	160000	14	15442	04SEP03	KEARNEY DEVELOPMENT CO INC	SR-60, US-301
1013	160000	14	15449	04SEP03	JOHNSON BROTHERS CORP	US 192 W, US 27, I-4 W, US 98 S, SR 60 W
1014	160000	14	15467	04SEP03	AMERICAN ENG & DEV CORP	US-1, SR-858, I-95, SR-848
1015	160000	14	15593	05SEP03	HUBBARD CONSTRUCTION COMPANY	SR-426. SR-436, I-4, SR-423, SR-438
1016	160000	14	15595	05SEP03	HUBBARD CONSTRUCTION COMPANY	US-1, I95, I-295
1017	160000	14	15604	05SEP03	HUBBARD CONSTRUCTION COMPANY	I-4, SR-435
1018	160000	12	15608	05SEP03	C D S SITEWORK & TRUCKING, INC.	US-192, I-4, US-27
1019	160000	14	15865	05SEP03	KEARNEY DEVELOPMENT	US-301, I-4, I-275, SR-60, US-19A, SR-58
1020	160000	14	15998	05SEP03	C D S SITEWORK & TRUCKING, INC.	US-192, US-27, SR-60
1021	160000	14	16322	08SEP03	SOUTHWEST UTILITY SYSTEMS	I-75
1022	160000	12	16324	08SEP03	KEARNEY DEVELOPMENT CO, INC	SR-686, I-275, I-4, I-75, SR-60
1023	160000	12	16341	08SEP03	RING POWER CORPORATION	SR-482, US-441, I-4, I-95, US-1
1024	160000	14	16379	08SEP03	JOHNSON BROTHERS CORP.	US-192, US-27, I-4, US-98, SR-60
1025	160000	12	16504	09SEP03	PATCO CONTRACTORS INC	US-41, SR-50, I-75, SR-44, US-27/441, SR
1026	160000	16	16639	09SEP03	COUNTS CONST.	SR-200
1027	160000	14	16764	10SEP03	AMERICAN ENG. & DEV CORP.	US-441, SR-820
1028	160000	14	16817	10SEP03	HUBBARD CONSTRUCTION COMPANY	US-441, I-4, SR-434, SR-419
1029	160000	14	17075	10SEP03	ADMIRAL MERCHANTS MOTOR FREIGHT	US231, SR20, SR267, US98, US27. SR75, SR
1030	160000	12	17157	11SEP03	MCTYRE TRUCKING CO INC	I-10, I-75, FTP, US-27

Figure 4-1. FDOT permit listing sheet scanned using optical recognition software

Several of the companies on the list that had a large number of vehicles permitted were contacted for further information regarding vehicle weight, permit date, and route.

Many company representatives were hesitant to talk to someone inquiring about the movements of their permit vehicles, but several were forthcoming and cooperative.

It was found through these phone interviews that the weight on the FDOT permit was typically within 5% of the actual truck weight. The permit date and permit type provided a window of time for the permit use. A blanket (B) permit is valid for one year, thus a single blanket permit may be used over the same route by the same vehicle multiple times. Blanket permits are used for vehicles that do not exceed 200,000 lbs. A trip (T) permit is valid for a single use to or from a destination. The trip permit allows the truck a five day travel window for its single use. Finally, the provided routes consist only of major roads. These major roads had restrictions listing specific locations off limits. Each company's representative claimed strict adherence to the permissions granted in the permit. The penalty of violation can severely damage the company's ability to conduct business.

Zones for Permit Vehicle Travel

A goal of this project was to develop likelihood functions that describe the probability of excessive weight occurring along Florida bridges due to heavy vehicle traffic. Precise data records of vehicle weight, location and time of travel were most useful for developing these functions. In the case of the permit records for vehicles over 160,000 lbs, the specific origin, destination, and route were not provided in the permit records. For example, a route may be listed simply as I-95, or SR-823, or some combination of roads. From the perspective of this project, a single permitted vehicle may travel numerous times over a year (blanket type), or a single time (trip type) anywhere along the listed route(s).

The lack of specificity in vehicle location, time and frequency of travel necessitates a procedure to identify the most likely regions of travel within Florida for a given permit. The roads in the state needed to be divided into regions to better determine what part(s) of Florida a given permit allowed travel.

The determination of regions was conducted using ArcMap, a Geographic Information System (GIS) based software tool that is part of a larger software package called ArcGIS [18]. ArcMap can overlay user selected layers of data called shape files onto a map. Using the Florida Geographic Data Library (FGDL) [19], an image of all the counties in the state of Florida was loaded. Once the shape file was loaded, the state was divided into regions to better determine what part(s) of Florida the permitted vehicles were traveling in. Five regions were chosen, each region having at least one major metropolitan area, and a major interstate. Once the regions were determined, they could be used to designate which roads should be assigned to which region. Figure 4-2 shows the regional breakdown of Florida developed for this study.

The list of roads came from two different sources. The first list of roads came from the major roads shape file in the FGDL. The second list came from the FDOT website [20], from which a U.S. highways shape file and state highways shape file were downloaded. The two lists were loaded into ArcMap, and the roads were broken down into the five regions.

A Visual Basic program was written to compare the roads that each truck used (as provided in the scanned, processed permit records) to the roads in each region defined in Figure 4-2. An analysis of where the trucks were traveling within Florida (by region) was then determined. Many of the permit records had routes that spanned more than one region. For example, permits that included I-95 as a route were in at least regions 2, 4, and 5. A random sample of five permit records were pulled from the database to show what the records look like after the zone classification was done. These permit records are provided in Table 4-1.

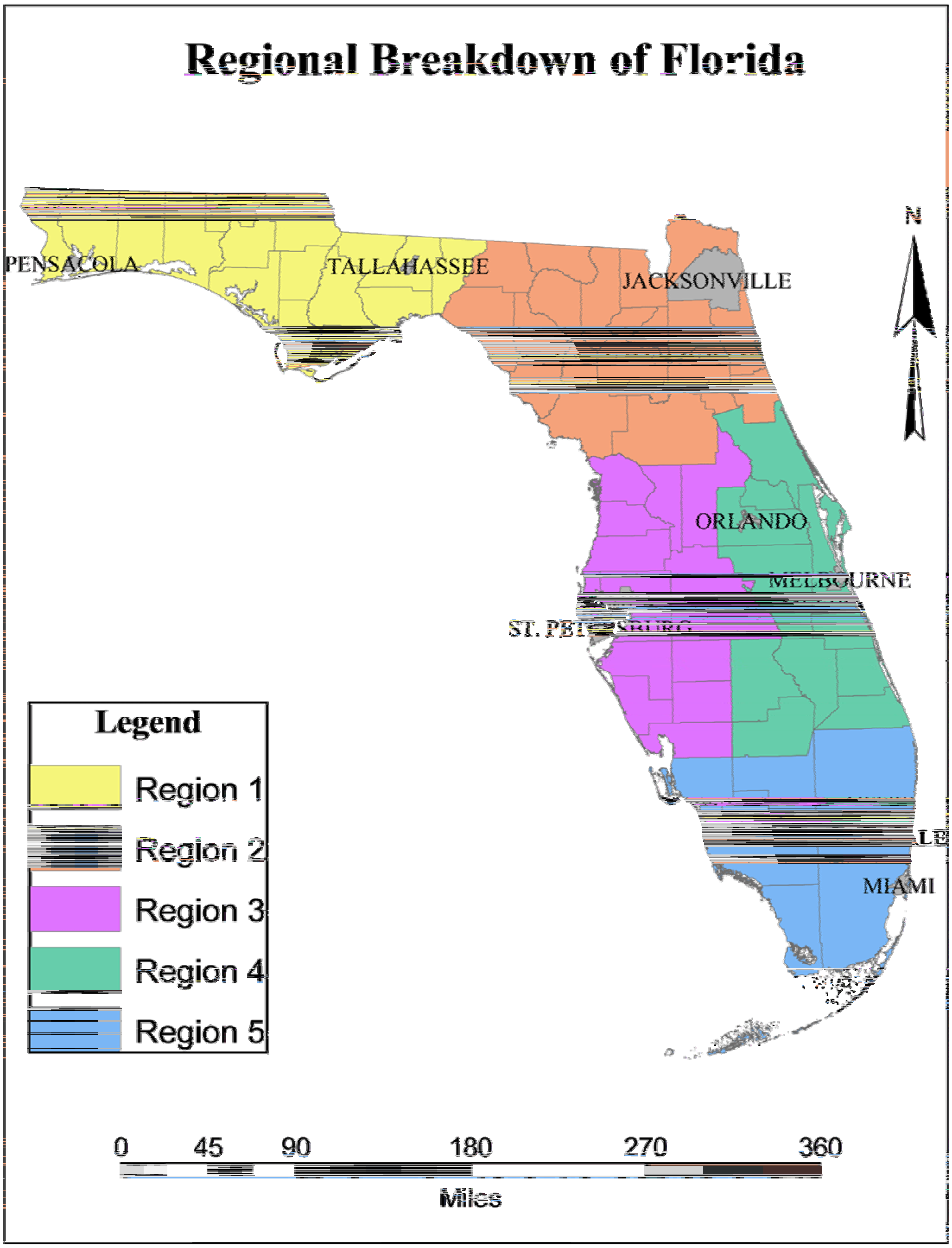


Figure 4-2. Regional partitioning of Florida for classification of travel for permitted vehicles greater than 160,000 lbs

Table 4-1. Examples of processed permit vehicle records

WEIGHT	PERMIT NUMBER	PERMIT DATE	COMPANY	ROUTE	PERMIT TYPE	REGION
160000	53437	5-Feb-02	COMPANY A	US-27, I-4, US-17, US-92	T	1 2 3 4 5
160000	87912	19-Jun-02	COMPANY B	I-95	T	2 4 5
160000	67493	26-Mar-02	COMPANY C	SR-823	T	5
180500	53555	5-Feb-02	COMPANY D	I-75, I-10, US-221, US-90	T	1 2 3 5
197000	60278	28-Feb-02	COMPANY E	SR-37, SR-60, I-4	T	3 4

Difficulties with the Permit Vehicle Datasets

Overall, the issues and complications with the data within the permit vehicle listings were minimal. However, the detail within the permit vehicle datasets was fairly limited, and therefore the detail of what could be extracted was limited. The most significant example was a lack of specific time and location of travel for any given vehicle.

Unknown Routes

Some of the routes that were scanned into the database did not appear in the list of roads in either the FGDL shape file or the FDOT website. To ensure that no roads were left out, a third source, the Florida Traffic Information (FTI) 2002 CD [21] was used. Even after including this third source, there remained roads listed in the permit records that were still not accounted for. Every road that did not appear in any of the three sources was compared to the resulting hard copy entry to ensure there was no error in the route entry due to the scanning process. One possible error source was a data input error in the hard copy of permit records supplied to the project by the FDOT.

A list of the roads that did not show up in any of the three different sources were sorted by year and shown in Table 4-2. Inspection was done to see whether an incorrect prefix explained the error. For example, since SR-27 could not be found, US-27 was checked. However, if US-27 had not existed or fit into the travel pattern of the vehicle given its other listed routes, the number rather than the prefix may have been incorrectly entered.

It was not anticipated that the presence of these unaccounted for routes would substantially alter the results of the analysis of the permit vehicle datasets. Routes that could not be accounted for would simply be ignored when assigning the region(s) to that permit record. This represented a small fraction of the total records available.

Table 4-2. Routes not accounted for in the permit records

2002		2003		2004	
SR-27	SR-648	SR-28	SR-484	SR-1	SR-532
SR-36	SR-672	SR-32	SR-532	SR-33A	SR-540A
SR-58	SR-675	SR-58	SR-588	SR-42	SR-587
SR-98	SR-689	SR-67	SR-672	SR-99	SR-640
SR-99	SR-702	SR-86	SR-782	SR-110	SR-672
SR-131	SR-788	SR-135	SR-828	SR-210	SR-709
SR-169	SR-812	SR-182	SR-846	SR-283	SR-778
SR-197	SR-828	SR-204	SR-864	SR-288	SR-854
SR-198	SR-846	SR-236	SR-896	SR-395	SR-866
SR-210	SR-896	SR-269	US-42	SR-455	US-21
SR-221	SR-957	SR-306	US-50	SR-466	US-24
SR-236	US-33	SR-460	US-94	SR-470	US-47
SR-280	US-39	SR-462	US-482	SR-475A	US-701
SR-284	US-39	SR-466	US-92-BUS	SR-512	
SR-286	US-44	SR-466A	I-575		
SR-319	US-111	SR-470	I-594		
SR-325	US-175				
SR-328	US-275				
SR-379	US-279				
SR-395	I-45				
SR-448	I-85				
SR-485	I-294				
SR-532	I-785				
SR-587	I-810				

Routes through Non-Contiguous Regions

When the permit vehicle records were assigned to regions, it was assumed that when a vehicle travels through multiple regions, the regions would be adjacent to each other. When examining the permit records it was found that in some circumstances a vehicle would travel through two regions that were not contiguous. An example of this was a truck permitted to use SR-80 and SR-104. SR-80 runs through Lee, Hendry, and Palm Beach counties in south Florida (region 5). SR-104 is located outside Jacksonville in Duval County (region 2). The permit records were double checked to guarantee there was not an error in the scanning process. Possible explanations for this could be that one or more routes were left off the FDOT permit records, or that one of the routes listed in the description are incorrect.

Determination of Multiple Vehicles on a Bridge

The major point of interest for this project was modeling the probability of the occurrence of more than one heavy vehicle on a bridge at the same time. The permit data did not provide this data directly. The specific time or date of travel was not given, nor was the specific path from origin to destination provided. Without this information a concurrency evaluation could not be done for the vehicles over 160,000 lbs.

Blanket and Trip Permit Implications

Another significant consideration was contained within the legal travel conditions associated with each of the two permit types. In addition to the lack of specification of date and time of travel, blanket permits may be re-used over a one year period as often as needed. Thus, a single permit may represent hundreds of individual occurrences of a vehicle of that permitted weight traveling anywhere within its identified regions. Trip permits represent a single occurrence any time within a five-day period within its regions.

Accounting for the multiple trips per permit, for blanket-type permits, could be accomplished by simply weighting the number of individual blanket permits by a factor that represents an average number of trips per permit. However, such a factor was not easily determined, and would be better represented by a discrete random variable. The characterization of this random variable could be the topic of a subsequent study, but was beyond the scope of this study.

The probabilistic modeling presented in the next section did not account for this issue, and simply treats each permit entry as an individual occurrence of a weight within a region or regions. It was known that this approach would produce skewed results in the modeled probability density functions. Most likely this would manifest as an underestimation of the relative probability of weights closer to the low end of 160,000 lbs compared to the high end of 1,000,000 lbs. This was because the blanket permits were clustered between the 160,000 and 200,000 lb end of the weight range. Heavier vehicles were required to have trip permits (single occurrence only) rather than blanket (multi-trip potential).

Within the context of the exponential distribution that was applied in the next section, this skewing of the data caused by counting blanket permits as a single occurrence will produce λ values that are too low. Recall from Chapter 3 that a larger λ value indicates a higher relative probability at the lower range of possible values for weight (the random variable). Thus, if lower weight vehicles were multi-counted due to blanket permit travel, a lower λ value would be expected corresponding to a steeper distribution that attenuates more quickly as it approaches higher weights.

Probabilistic Modeling of the Permit Vehicle Data

Rather than providing a model at individual WIM stations, the format of the permit vehicle data required that models represent travel within the five regions in Figure 4-2. This would make it more difficult to extrapolate the models to individual bridges, but the route restriction data helped to narrow down the possibilities.

The weights from all the permit vehicle data were input into Mathcad for analysis. There were 8,968 permit vehicle records. Of the 8,968 records, nineteen were over 1,000,000 lbs. The highest weight that was found in the printouts was 8,300,000 lbs. They represent special cases where travel was closely monitored to guarantee precise route and speed restriction adherence. Any bridges en route for these cases were specifically analyzed for the presence of this vehicle, and no other vehicle was permitted on the bridge at the same time. Therefore, they do not represent a 'random occurrence' of a heavy vehicle, and were left out of the analysis.

A histogram was generated in the same manner as was used for the WIM data in Chapter 3. Figure 4-3 shows the histogram of all permit data (between the weights of 160,000 lbs and 1,000,000 lbs). The *x*-axis represents the vehicle weight and the *y*-axis represents the number of trucks within each weight category. The histogram is not nearly as smooth as the histograms generated for the WIM data. The reasons for this were that there was not as much data for vehicles over 160,000 lbs and the fact that the data were bunched into weight groups and do not represent the exact weight of the vehicle. This was more evident as the weight got higher. Figure 4-4 shows the resultant exponential PDF fit using maximum likelihood on the normalized histogram.

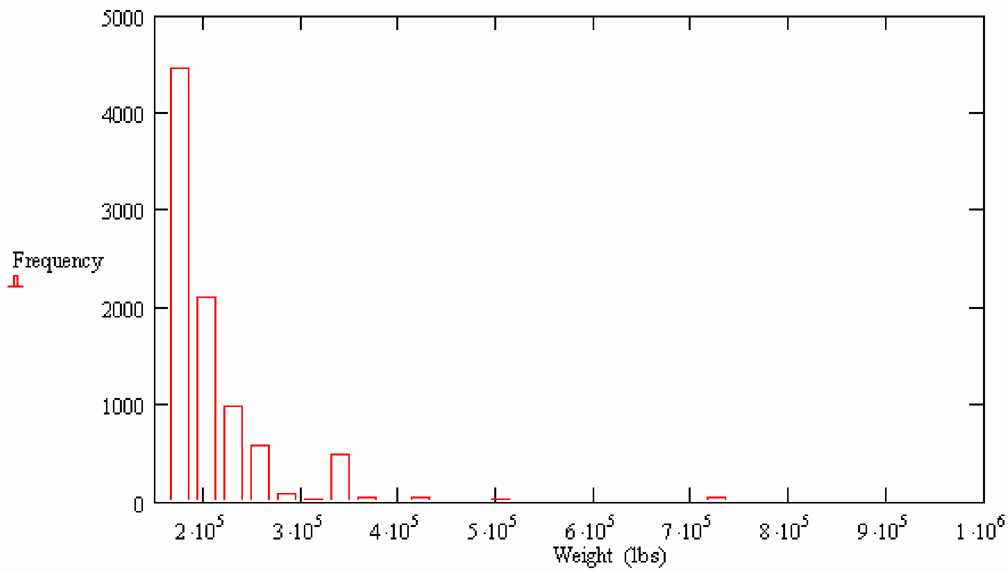


Figure 4-3. Histogram of all permit vehicle data excluding weight over 1,000,000 lbs

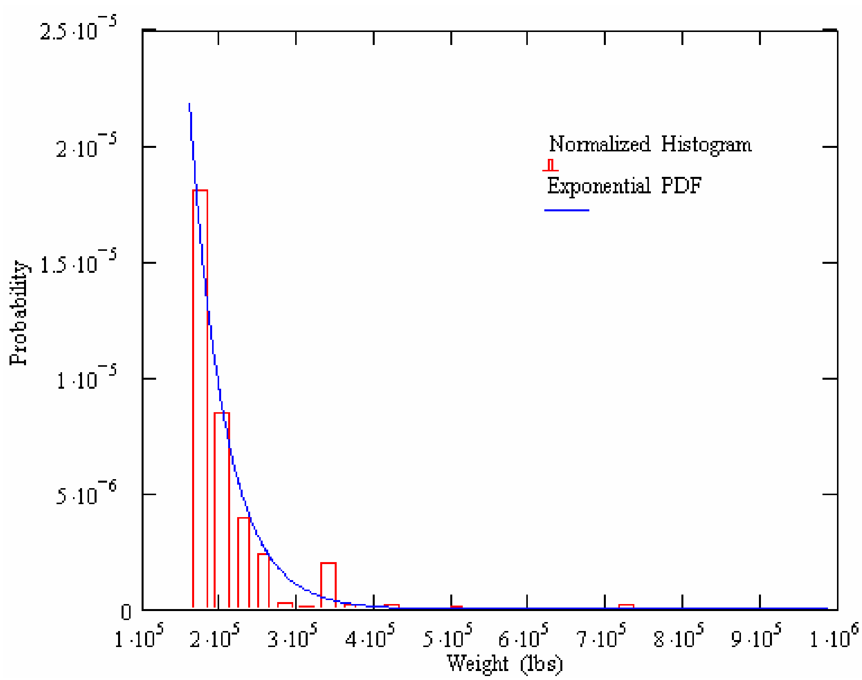


Figure 4-4. The exponential PDF model on the normalized extreme value histogram

Regional Probabilistic Modeling of the Permit Vehicle Data

When these records were divided into the regions of travel (Figure 4-2) the number of records became limited. Region 5 had the most permit vehicle records for one region with 236. The other four regions all had less than 80 vehicles that only passed through their region. With such a small number of vehicles it was hard to generate a histogram that has any statistical significance. However, the benefit of having the five regions was the ability to look at truck travel throughout different parts of the state that encompass multiple regions.

Using the regional partitioning of the state, an exponential PDF was generated for different parts of Florida. The four areas were the east coast of Florida (regions 2, 4, and 5), the Florida panhandle (regions 1 and 2), central Florida (regions 3 and 4), and south Florida (region 5). Each area was analyzed for vehicles between the weights of 160,000 lbs and 1,000,000 lbs. Figure 4-5 shows the exponential PDF models using the maximum likelihood function for the permit vehicle data from different areas of Florida.

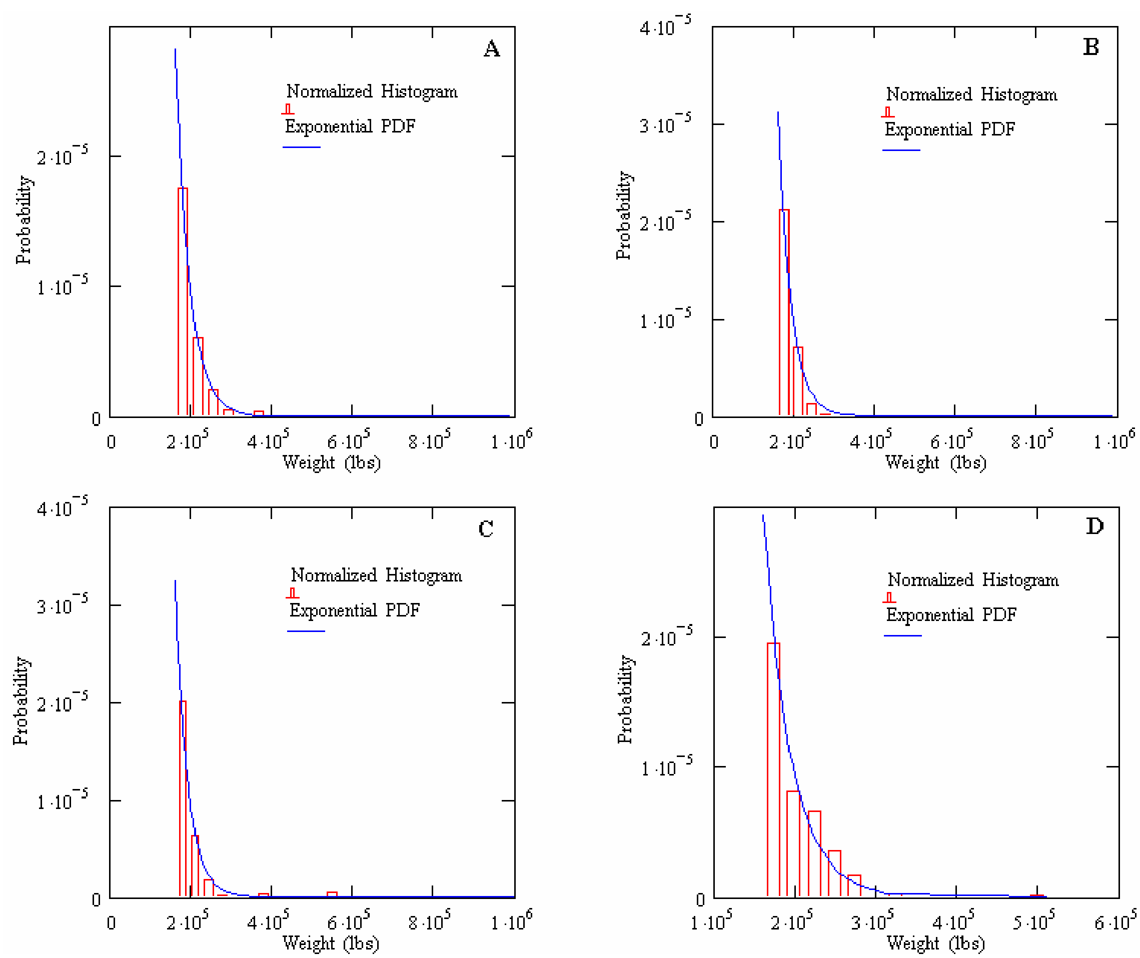


Figure 4-5. Exponential PDF models on the normalized extreme histogram. A) East coast of Florida. B) Florida's panhandle. C) Central Florida. D) South Florida

The λ parameter was different for each area. The east coast of Florida had a λ parameter of 23.278, the Florida panhandle had a λ parameter of 25.373, central Florida had a λ parameter of 27.255, and south Florida had a λ parameter of 10.27. If the numbers of occurrences of blanket permit weights were multi-counted as suggested in the previous section, these λ values would increase. Thus, the distributions in Figure 4-5 would become steeper, with a higher relative probability of the lower range of weights.

Conclusions

This information was presented to the FDOT project manager. After discussion of the limits of the permit data precision, it was concluded that only the WIM data would be used for subsequent analysis. Even with the ability to separate the permit data into regions, the inability of the permit data to give specific times and locations of truck travel did not allow for an exact analysis of multiple vehicles on a bridge. The gap of information between the WIM data and the permit data prevented analysis of both at this time. Further modeling and analysis of the permit vehicle data is left as a subject for a possible future project.

CHAPTER 5
ANALYSIS OF WEIGH-IN-MOTION HEADWAY DATA: CONCURRENT VEHICLE MODELING

The previous chapter presented the datasets provided by the FDOT. Some preliminary statistical analyses and problems were identified within the datasets. This chapter discusses the methods developed to evaluate concurrent vehicles on a bridge at the same time. This final course of analysis was determined after consultation with the FDOT project manager.

The fundamental approach was to model the measured headway between vehicles in order to evaluate the probability of concurrent vehicles appearing at a given WIM station. Several WIM stations had more than one bridge within close proximity. Thus, the evaluation of multiple heavy vehicles at a WIM station could be extrapolated to the nearby bridges. An examination of all the WIM sites was conducted to find a small sample of sites that had the combination of a high percentage of trucks over 80,000 lbs, a high number of bridges close to the site, and a high volume of truck traffic. These WIM sites were then used for the remainder of the analyses.

Headway Analysis

Headway is defined by the *Highway Capacity Manual* as the time, in seconds, between two successive vehicles as they pass a point on the roadway, measured from the same common feature of both vehicles (for example, the front axle or the front bumper) [20]. A Visual Basic program was created to load each WIM file and obtain the headway between pairs of vehicles. The program created a new file (per station, per day) that contained the list of the headways for all the vehicles for each day of data. A master file with a list of all files produced was also created. A sample of the headways at each site was taken to get an initial view of the distribution. This sample excluded all files that had any of the problems identified in Chapter 3. Only the headway values that were between zero and thirty minutes were examined. This eliminated any other irregularities in the WIM files. These processed headway files were then loaded into Mathcad for analysis. After analyzing the headway data it was found that the distribution of the headway data followed an exponential curve. The histograms of headway data differed from site to site, but always followed an exponential curve. A summary of the critical statistics for the headway data from all WIM sites is presented in Table 5-1. The total number of vehicles sampled were the vehicles that were within the zero to thirty minute headway range. The information presented in Table 5-1 represents a one or two year sample of data from each WIM station depending on the number of years of data that were collected.

Examples of the headway histograms are shown in Figure 5-1. Two histograms are displayed in Figure 5-1 showing WIM stations 9908 and 9940. WIM station 9908 is located on US-319 in Tallahassee and WIM station 9940 is located on SR-287 in Quincy. The two WIM stations are located in Leon and Gadsden counties, respectively.

Table 5-1. Headway data statistics

Station	Number of Vehicles Sampled	Headway Statistics (in seconds)			
		Mean	Standard Deviation	Median	Mode
9901	1,466,370	27.83	35.19	*	*
9904	939,314	20.52	30.76	12	*
9905	874,402	17.43	27.85	9	*
9906	537,499	37.53	102.33	13	2
9907	106,634	90.03	150.17	42	2
9908	190,069	131.69	222.93	60	3
9909	54,652	247.57	311.56	132	2
9913	594,678	53.72	77.12	30	2
9914	1,393,713	14.46	23.22	*	*
9916	88,813	154.09	226.37	78	3
9917	37,587	252.80	312.24	141	3
9918	297,304	38.09	63.20	19	2
9919	902,377	16.05	21.57	9	*
9920	227,855	16.32	22.36	9	1
9921	77,563	247.86	305.53	139	0
9922	84,511	34.71	51.83	18	2
9924	127,763	103.25	181.26	44	2
9925	46,747	203.71	275.88	108	2
9926	1,114,120	20.02	34.36	10	*
9927	105,252	102.84	161.06	50	3
9928	511,397	24.89	31.79	15	1
9929	8,613	364.69	362.13	249	2
9930	31,330	310.81	342.85	193	3
9931	547,775	23.85	30.88	14	2
9932	751,230	48.26	63.43	29	*
9934	456,940	39.01	93.00	15	2
9935	672,615	38.85	64.16	18	*
9936	1,445,407	21.07	29.08	*	*
9937	94,690	204.42	280.75	106	3
9938	105,565	192.17	170.61	99	2
9939	35,968	425.45	418.16	285	3
9940	132,696	226.23	295.32	120	3
9942	66,204	366.83	379.85	238	2
9943	105,655	270.49	325.50	154	2
9944	47,783	349.01	365.55	225	3
9946	78,319	413.74	397.56	284	3

*The values could not be calculated by Mathcad because the dataset was too large.

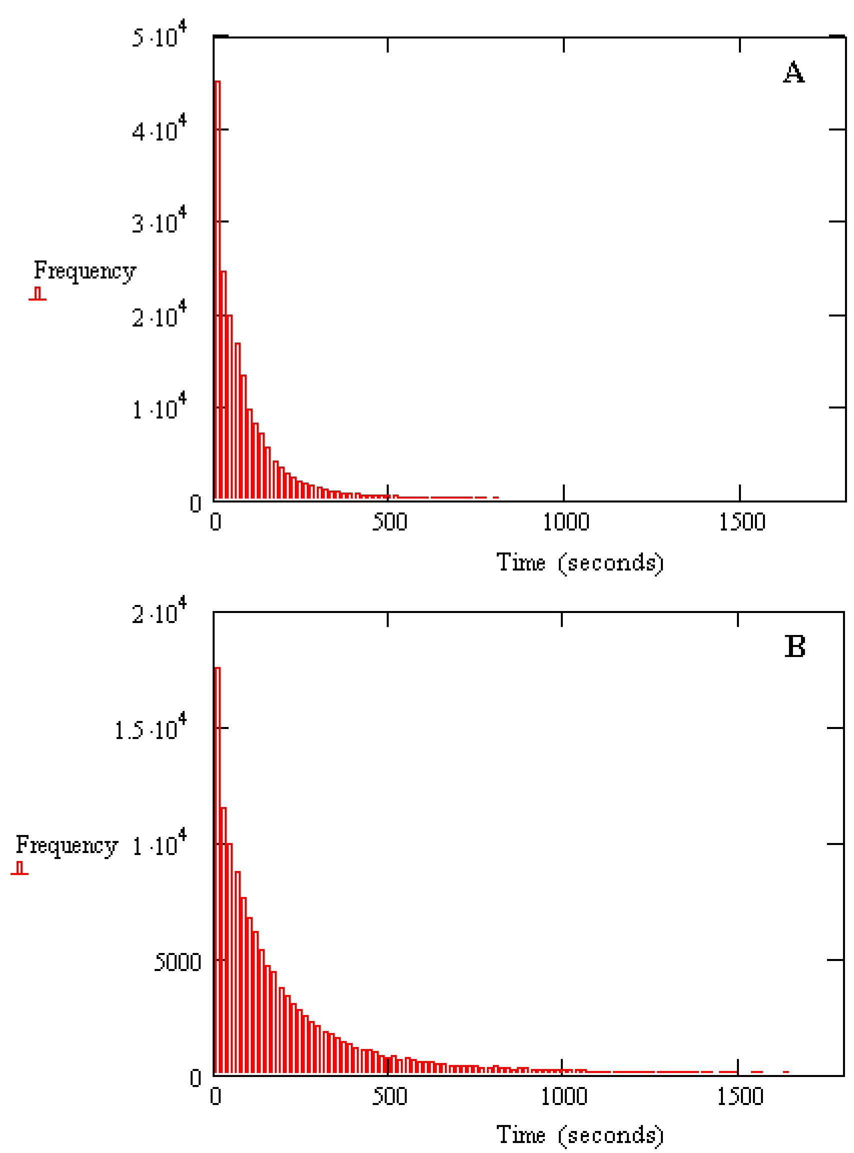


Figure 5-1. Headway frequency histograms. A) Represents site 9908. B) Represents site 9940

Identification of WIM Sites to Conduct Headway Analysis

The ultimate goal of this project was to determine the probability of the existence of concurrent permit vehicles on a bridge. Since the headway data were coming from the WIM stations and not bridges, it was difficult to predict when exactly these vehicles would be on nearby bridges. A determination of which sites were in close proximity to bridges was conducted. The assumption was that the occurrence of concurrent permit vehicle at a given WIM site was as likely to have occurred at a nearby bridge. Thus, the concurrence study at a given WIM station was extrapolated to nearby bridges.

Two shape files were downloaded from the FDOT website [18] to provide input to the GIS platform used in this study. The first one contained the location of the WIM sensors along Florida's roadways. The second contained bridge locations in the state of Florida. Using ArcMap, the layers were loaded along with the major roads and the county boundaries shape files from the Florida Geographic Data Library (FGDL) [17]. A 15-mile radius was created around each of the WIM sites. Bridges within this 15-mile radius were pulled from the original shape file and assigned to the WIM station they pertained to. Four new shape files were created, each containing only the bridges that related to their respective WIM stations. Once the bridges were assigned to each WIM station, only the bridges that were located along the WIM route were extracted. For example, bridges that were on other major roads within the 15-mile radius were eliminated.

Only a sample of the WIM sites had this analysis conducted for them. From previous analyses (found in Appendix B), only the sites with a high number of passing trucks and a high percentage of trucks over 85,000 lbs were considered. The WIM shape file did not contain the locations of WIM station 9914 or 9916. Since the WIM stations were not in the WIM shape file, they were also omitted from the analysis. Table 5-2 shows the results from the ArcMap analysis of the bridges within the 15-mile radius of the WIM sites. The grey entries were the sites that were not evaluated in ArcMap; the four highlighted entries were the sites for which the detailed headway analysis was conducted. The four sites highlighted in Table 5-2 were chosen because they contained a high volume of trucks passing over the sensor, numerous trucks over 85,000 lbs, and several bridges within the 15-mile radius. Additionally, this selection of sites provided some variance in regional location. Figure 5-2 shows the locations of the four selected WIM sites, as well as the regional partitioning of the state.

Table 5-2. Results from the ArcMap analysis of bridges

Site	Bridges	Region	Trucks	Years of Data	% of Trucks >85,000
9901	16	1	3,590,583	4	0.36
9904	30	2	943,096	2	4.44
9905		2	1,064,202	2	2.08
9906	26	4	540,931	2	4.71
9907	17	1	468,160	3	3.22
9908	8	1	869,124	6	1.08
9909	4	2	208,210	3	6.76
9913	29	4	1,121,712	3	4.31
9914		2	1,525,164	2	4.08
9916		1	391,967	3	5.04
9917		3	83,960	2	1.17
9918	3	5	1,533,122	3	10.07
9919		4	1,692,297	3	0.96
9920		3	227,899	1	3.89
9921	10	5	361,043	6	0.35
9922		3	84,545	1	1.80
9923		2	0	0	0
9924	15	1	194,583	1	0.74
9925	7	4	120,248	2	3.93
9926	78	3	1,153,455	2	4.32
9927		3	370,861	2	0.28
9928	9	1	846,732	2	1.97
9929		4	15,195	2	0.17
9930		5	118,513	2	0.74
9931	19	3	1,390,339	3	4.72
9932	17	4	901,222	3	6.11
9934		5	698,562	3	4.82
9935	4	5	2,872,418	6	6.01
9936	16	2	4,352,192	6	3.22
9937	3	1	357,374	5	3.65
9938	9	1	274,550	3	4.33
9939	9	1	136,363	6	3.14
9940	7	1	453,541	6	2.02
9942		1	187,081	6	4.26
9943	4	1	323,456	6	9.60
9944	2	1	149,946	6	9.09
9946	0	1	245,335	6	7.40

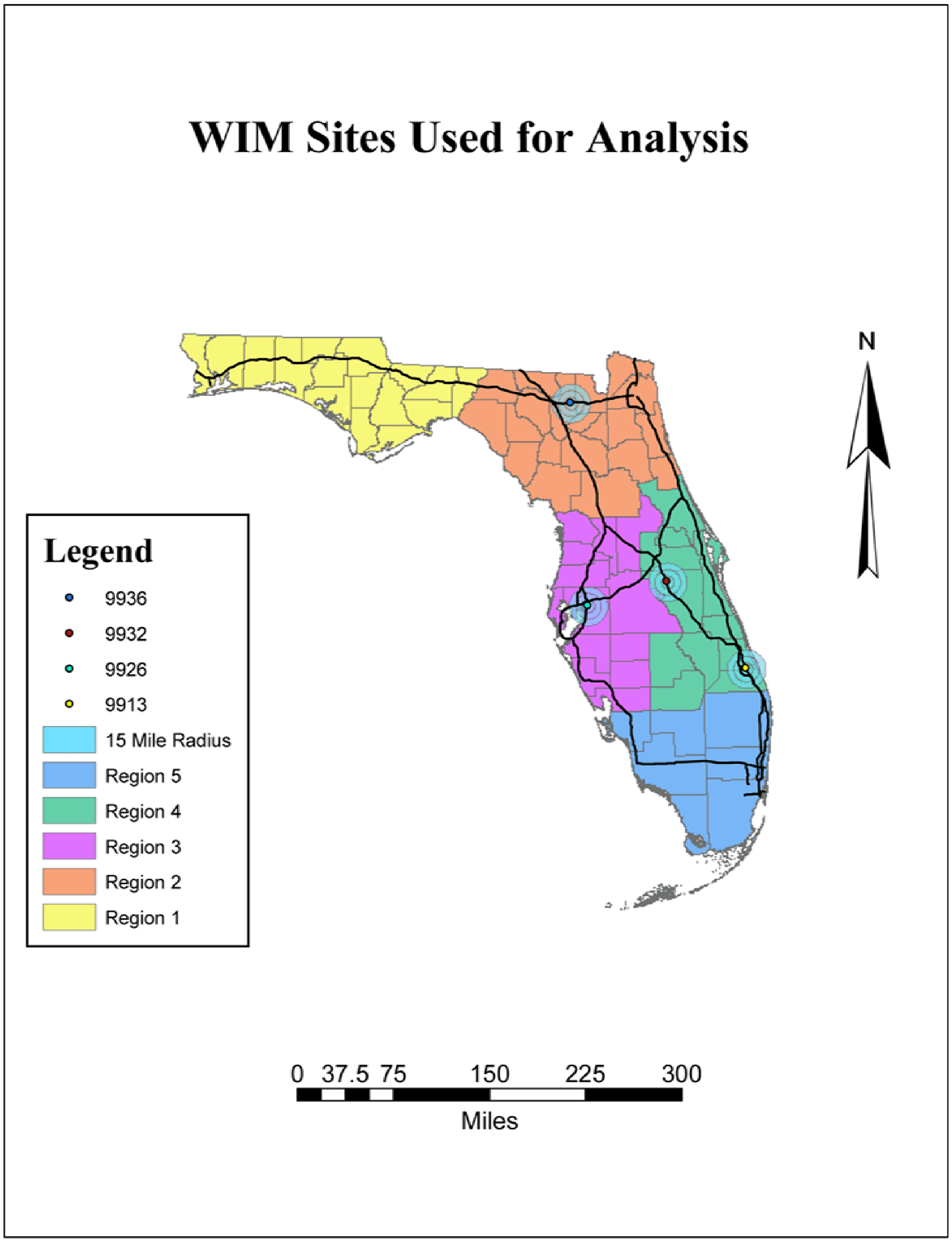


Figure 5-2. Locations of the four WIM sites selected for headway analysis

Analysis of the Four Chosen WIM Sites

The four chosen WIM stations were 9913, 9926, 9932, and 9936 (indicated in Figure 5-2). These WIM stations were looked at closely in ArcMap to include only the bridges along the route and to exclude any overpasses or exit ramps. After looking at the bridges a second time, the number of bridges was reduced to 11 bridges at WIM station 9913, 56 bridges at WIM station 9926, 15 bridges at WIM station 9932, and 10 bridges at WIM station 9936. Figure 5-3 shows a close up view of each of the four WIM stations, the 15-mile radius, the WIM sensor, the route the WIM sensors are located on, the major roads in the area, and the bridges along the WIM route.

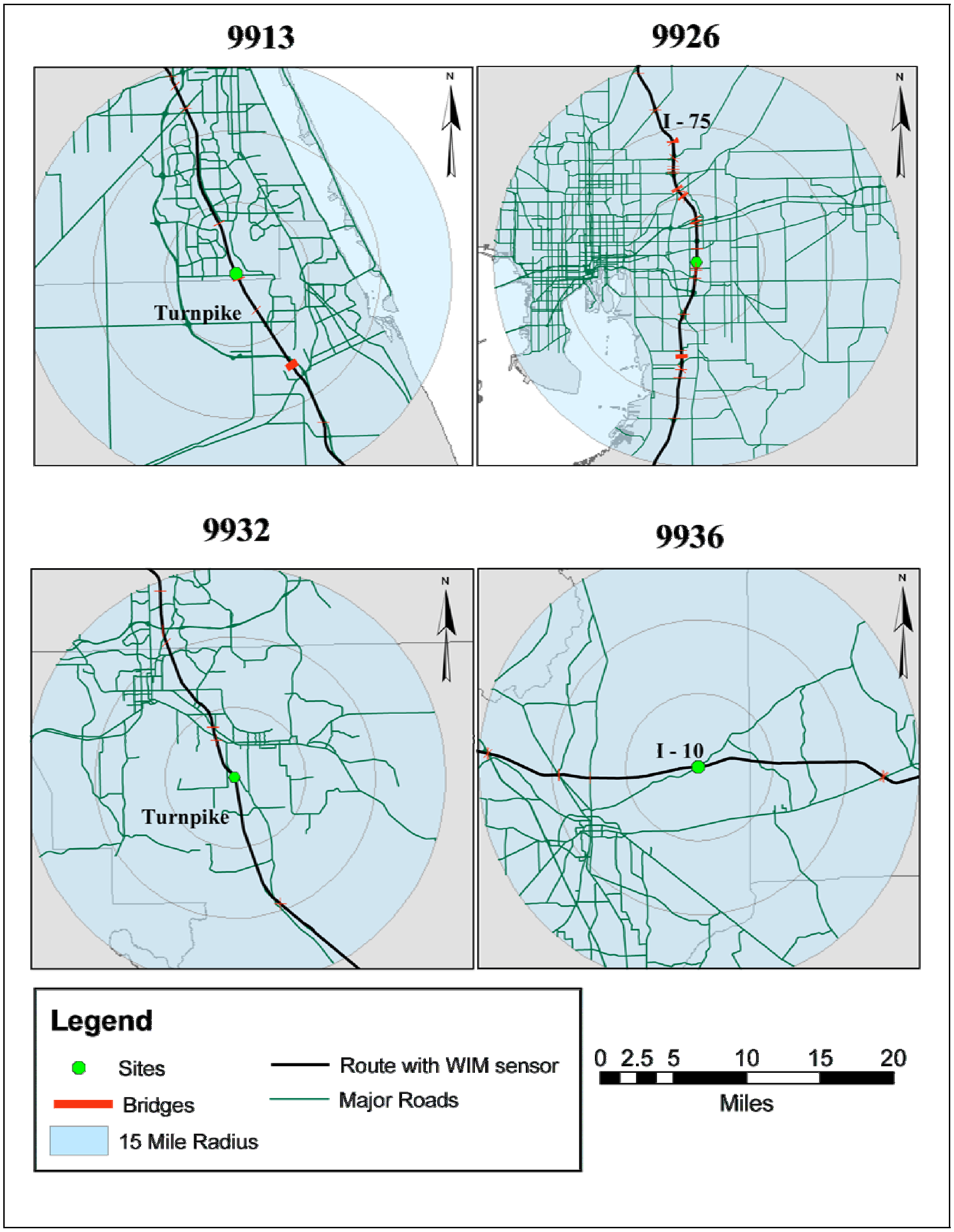


Figure 5-3. Detailed view of the four WIM sites selected for headway analysis

Bridge Length Determination

Once the sites with multiple bridges were selected and documented, the length of the bridges around each of the four sites was determined. Each of the bridges contained in the bridges shape file had attributes associated with them. One of those attributes was length. The length was pulled from the attributes table for each of the bridges. From these, the average bridge length was calculated for all the bridges within the 15-mile radius and used for each individual site's headway analysis.

Speed Determination

To ascertain an average speed that the trucks were traveling over the WIM sensor, a Visual Basic program was created to pull out the minimum, maximum, and average vehicle speeds for each WIM file. Once the average speed for vehicles in each WIM file was determined, yearly and overall speed averages were calculated. Table 5-3 shows the average vehicle speeds and the average bridge lengths for the four sites. Total trucks refers to all trucks registered by the WIM station, not just those over 85,000 lbs.

Table 5-3. Average speeds and bridge lengths

Site	Year	Total Trucks	Avg. Speed	Site Avg. Speed (mph)	Avg. Bridge Length (ft)
9913	2001	442627	67.38	**67.14**	**314.08**
	2002	326560	66.61		
	2003	266681	67.39		
9926	2002	532940	63.25	**63.23**	**317.84**
	2003	581476	63.21		
9932	2001	383310	66.31	**67.17**	**186.53**
	2002	368393	68.08		
	2003	6942	66.66		
9936	1998	413997	67.20	**68.09**	**229.58**
	1999	583801	67.79		
	2000	783286	67.73		
	2001	536465	67.65		
	2002	1031798	68.50		
	2003	433397	69.52		

Headway Determination at the Four WIM Sites

Another Visual Basic program was written to give a more detailed evaluation of the headway of vehicles passing the four selected WIM sites. The program extracted any vehicles that were within a user-specified headway time interval for each of the four sites. Using the average speed and average bridge length for each site (see Table 5-3), a specific headway time interval was calculated for each site that would capture when multiple vehicles would be around each WIM station. This represents their potential concurrent occurrence on a bridge within the 15-mile radius area. The appropriate headway interval calculated for the four WIM stations were as follows

- WIM Station 9913: 3 seconds
- WIM Station 9926: 3 seconds
- WIM Station 9932: 2 seconds
- WIM Station 9936: 2 seconds

These headway intervals were rounded to the nearest second because the precision of the timestamp from the WIM files was integer seconds. The headway interval represents a period of time that captures any number of vehicles that cross the WIM station, not just the time between two consecutive vehicles.

The headways mentioned in the previous paragraph were calculated for vehicles that were traveling in the same direction. However, for vehicles traveling in opposing directions, the headway time was divided in half. Since the vehicles were traveling in opposite directions, their speeds were additive. A vehicle traveling 60 mph one way and another traveling 60 mph the other way equaled a total of 120 mph. This was twice the speed for the same distance (i.e. bridge length), therefore, it equaled half the time.

The Visual Basic program grouped vehicles into different headway groups based on the aforementioned headway input for the different sites. The time stamp, lane of travel, and vehicle classification were also recorded. The lane of travel was useful in the determination of what direction the vehicles were traveling when they appeared on the bridge, that is, whether the vehicles were traveling in the same direction or opposing directions. The program created a text file for each individual day of data. A summary file was also produced listing the total number of vehicles, the groups of two vehicles on the bridge, the groups of three vehicles on the bridge, the groups of four vehicles on the bridge, the groups of five vehicles on the bridge, the number of groups containing at least two vehicles 80,000 lbs or greater, and whether the 80,000 lb vehicles were traveling in the same direction or opposing directions.

In addition to the output described in the previous paragraph, the Visual Basic program created another file for each individual day of data containing the summation of the weights of vehicles in each headway group for that day. Along with the weight summation, the program also created a table of contents file that contained a list of all the filenames that had the summation of headway weight extracted from them. These files were then input into Mathcad for analysis.

In total, the Visual Basic program created four new files. For each individual day of data the program created two files, one containing the headway groups, and one containing the summation of weight from each headway group. For example, when the file 99130202.011_VTR was processed, the files 99130202.011_VTR.txt and 99130202.011_VTRWT.txt were created. For each year of data that were processed, a stat.txt and a toc.txt file were created. The stat.txt file contains the summary information from all the *_VTR.txt files and the toc.txt file was the file that was read into Mathcad containing all the names of the *_VTRWT.txt files.

Results

The occurrence of concurrent vehicles each 80,000 lbs or greater was a rare event when compared to the amount of trucks traveling Florida's roads. Site 9926 had the highest percentage of concurrent 80,000+ lb vehicles on a bridge for a single year with 0.26%. This was relative to the total trucks passing over the WIM station. Even though the rate was relatively small, the frequency of this event occurring was not negligible. For example, in 2002 at site 9936 there were 789 instances where at least two 80,000 lb vehicles were within two seconds of each other at the location of the WIM sensor. That translates to an average of just over two times every day for the entire year. In the case of site 9926, the phenomenon of two 80,000 lb vehicles occurred four times a day for the year of 2002.

Table 5-4 shows the results from the headway analysis. The table shows the total trucks passing the WIM site, the groups of two, three, four, and five vehicles on a bridge (i.e., within the calculated headway for that WIM site as defined earlier), and the percent of the total vehicles in each of those groups relative to the total number of trucks passing the given WIM station that year. The last four columns show the frequency of two concurrent vehicles over 80,000 lbs, the percent of those vehicles out of the total truck population passing the WIM station, the frequency of three concurrent vehicles over 80,000 lbs, and the percent of those vehicles out of the total truck population passing the WIM station, respectively.

Table 5-4. Summary of headway results

Site	Year	Total Trucks	Groups of 2		Groups of 3		Groups of 4		Groups of 5		2 Vehicles > 80,000 lbs		3 Vehicles > 80,000 lbs	
			Sum	Percent	Sum	Percent	Sum	Percent	Sum	Percent	Sum	Percent	Sum	Percent
9913	2001	442627	25335	5.72%	758	0.17%	15	0.003%			112	0.03%		
	2002	326560	17562	5.38%	475	0.15%	3	0.001%			147	0.05%		
	2003	266681	14429	5.41%	327	0.12%	3	0.001%			309	0.12%	1	0.0004%
9926	2002	532940	63200	11.86%	3753	0.70%	137	0.026%	6	0.001%	1395	0.26%	5	0.0009%
	2003	581476	85833	14.76%	6311	1.09%	305	0.052%	10	0.002%	743	0.13%	6	0.0010%
9932	2001	383310	6931	1.81%	56	0.01%					61	0.02%		
	2002	368393	7527	2.04%	62	0.02%					87	0.02%		
	2003	6942	133	1.92%										
9936	1998	413997	19283	4.66%	244	0.06%					44	0.01%		
	1999	583801	30197	5.17%	438	0.08%					50	0.01%		
	2000	783286	41364	5.28%	614	0.08%					95	0.01%	1	0.0001%
	2001	536465	29065	5.42%	471	0.09%					229	0.04%		
	2002	1031798	53546	5.19%	934	0.09%	1	0.0001%			789	0.08%		
	2003	433397	13826	3.19%	224	0.05%	3	0.001%			334	0.08%	2	0.0005%

Of the vehicles over 80,000 lbs that arrived within the given headway interval for each of the four WIM stations, the majority (at least 70%) of these vehicles were traveling in the same direction. Table 5-5 shows the results for the case of only two concurrent vehicles near the WIM station. The fifteen instances when there were three permit vehicles occurring near the WIM station, twelve times (80%) two of the three vehicles were traveling in the same direction. Three times (20%) all three vehicles were traveling in the same direction.

Table 5-5. Summary of the travel direction of 80,000+ lb vehicles

Site	2 Vehicles > 80,000 lbs	Traveling in the Same Direction		Traveling in Opposing Directions	
		Vehicles	Percent	Vehicles	Percent
9913	568	486	85.56%	82	14.44%
9926	2138	1516	70.91%	622	29.09%
9932	148	125	84.46%	23	15.54%
9936	1541	1382	89.68%	159	10.32%

Table 5-6 presents a comparison of the number of vehicles appearing concurrently at the WIM station that were 80,000 lbs or greater traveling in the same direction to the total number of vehicles 80,000 lbs or greater passing the WIM station. Table 5-5 and 5-6 together show that, although concurrent permit vehicles travel the same direction 70% of the time, this concurrence occurs as only a small percentage of total permit vehicle traffic. This suggests that permit vehicles traveling in convoys close enough to allow concurrent bridge loading was the exception rather than the trend or rule.

Table 5-6. Summary of same direction concurrent permit vehicles compared to all 80,000+ lb vehicles

Site	Total Permit Vehicles	Permit Vehicles within Headway Interval Traveling in the Same Direction	
		Frequency	Percentage
9913	45,990	487	1.06%
9926	46,754	1518	3.25%
9932	45,083	125	0.28%
9936	127,818	1382	1.08%

Generating Concurrent Vehicle Histograms from Headway WIM Data

Using Mathcad to analyze the total concurrent weight information that was provided by the Visual Basic program, an idea of the weight distribution over the given headway interval for each WIM station could be determined. In the same manner that the data were input to generate histograms in Chapter 3, an array of the total weight data over the headway interval was read from a desired file. All the data from each year were input into Mathcad for each WIM station. The next four figures show the resultant histogram of the summation of the total weight passing the WIM station within the assigned headway interval from the Mathcad analysis of the four WIM stations. Figure 5-4 shows the histogram for WIM station 9913, Figure 5-5 shows the histogram for WIM station 9926, Figure 5-6 shows the histogram for WIM station 9932, and Figure 5-7 shows the histogram for WIM station 9936.

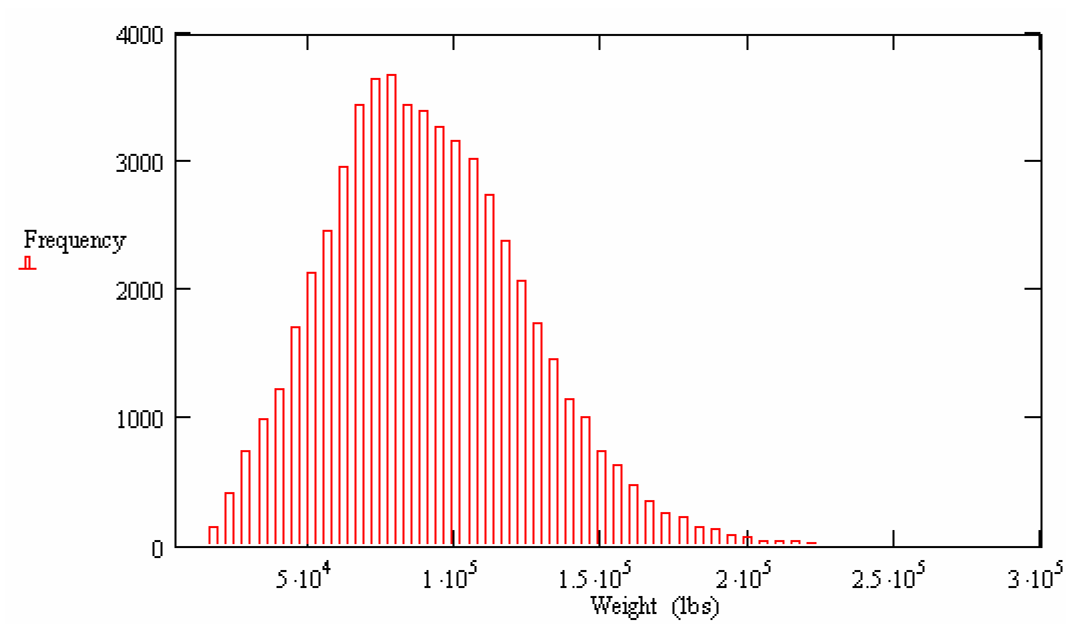


Figure 5-4. Histogram of total weight passing WIM station 9913 in a 3-second interval

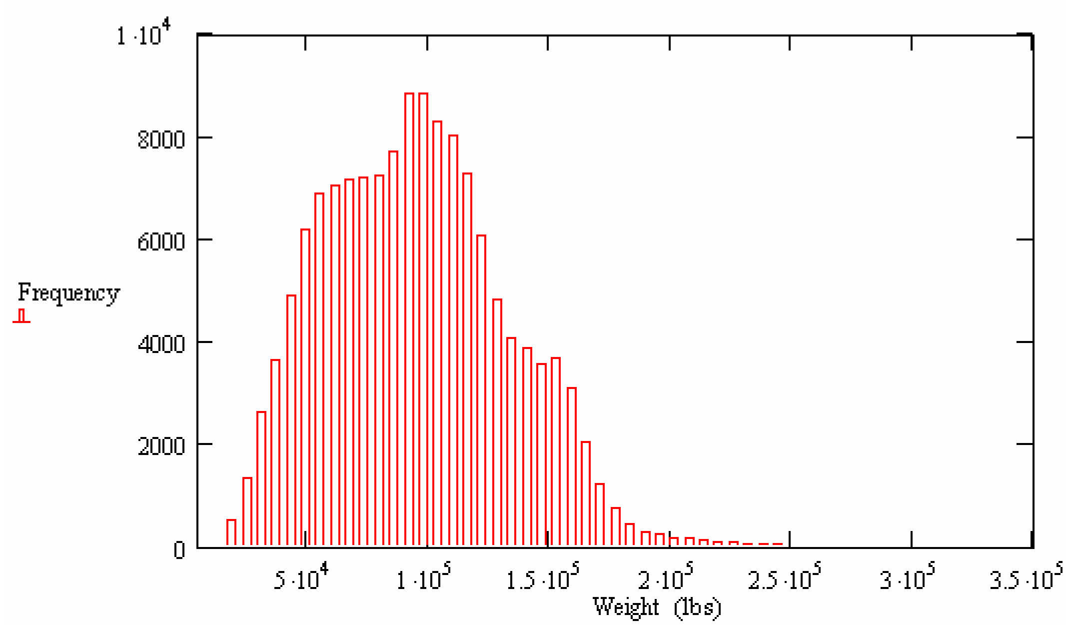


Figure 5-5. Histogram of total weight passing WIM station 9926 in a 3-second interval

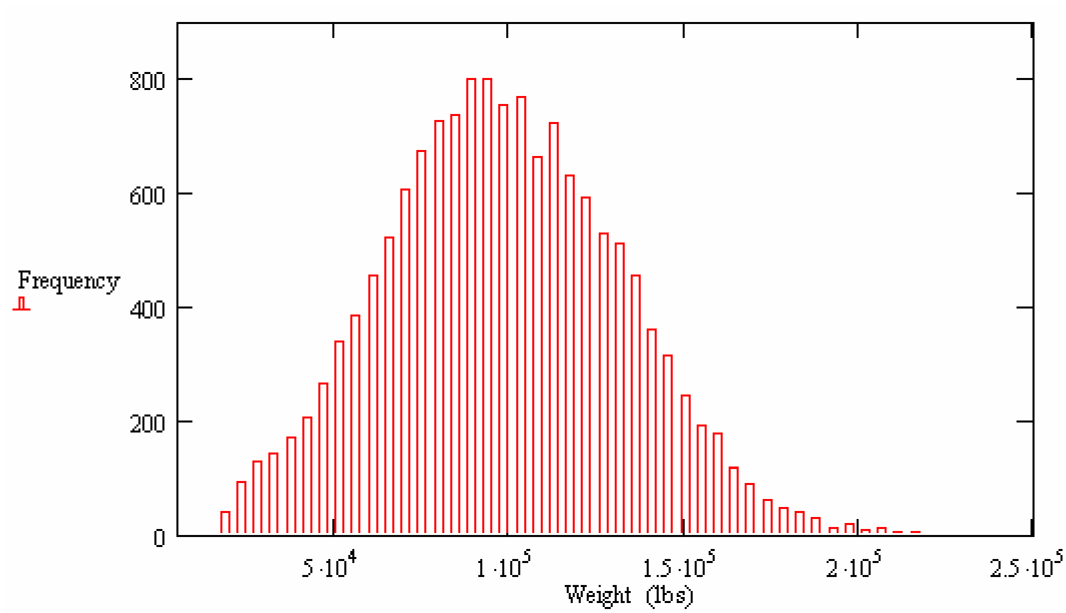


Figure 5-6. Histogram of total weight passing WIM station 9932 in a 2-second interval

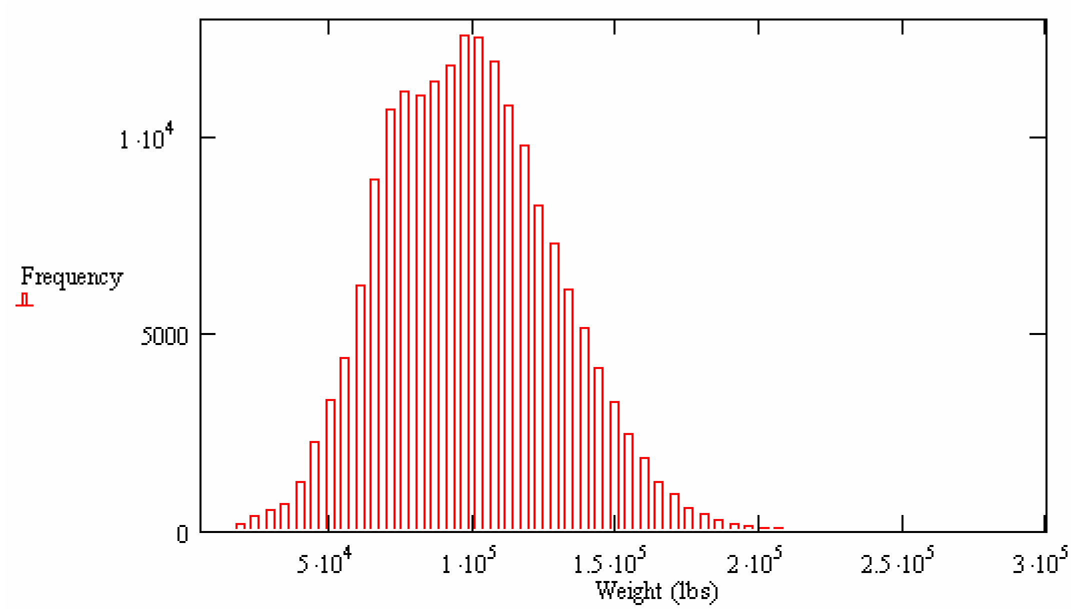


Figure 5-7. Histogram of total weight passing WIM station 9936 in a 2-second interval

Modeling the Extreme Value Histogram – Concurrent Permit Vehicles

The minimum total weight that two concurrent permit vehicles should weigh is 160,000 lbs (assuming they are loaded—i.e., not empty on a return trip). Thus the modeling of an extreme value histogram evaluated weights above this threshold. All weights above this threshold were not necessarily combinations of permit vehicles; but combinations of any trucks that were captured within the headway interval. The lower limit of 160,000 lbs represents the minimum combined weight of two permit vehicles. This study assumes that the weight of four 40,000 lb vehicles was as significant as two 80,000 lb vehicles. The upper limit used differed from site to site. The maximum weight of a group of vehicles within the assigned headway at WIM station 9913 was 290,190 lbs, at WIM station 9926 it was 319,880, at WIM station 9932 it was 250,930, and at WIM station 9936 it was 276,940.

It was desired to create an analytical parametric function that represented the information provided in the normalized extreme value histograms of the data of interest.

A convenient functional form would be flexible enough to represent WIM data from the four different WIM stations. Thus a parametric probability density function (PDF) was sought that fits the WIM data well. The focus was restricted to the extreme values of total vehicle weights heavier than 160,000 lbs.

The exponential PDF model was used to fit the extreme value histograms. The same process used to fit the extreme value histograms in Chapter 3 was used for this analysis, using a different range of *W*. Equations (1) through (4) (see Chapter 3) apply to the extreme value modeling conducted in this chapter. Substituting the exponential PDF equation ($f(x) = \lambda * e^{-\lambda * x}$) into the log maximum likelihood function, defined as $l(\Theta) = \log L(\Theta) = \sum_{i=1}^{n} \log f\left(x_i;\Theta\right)$, enables an optimization routine to be run in Mathcad to calculate the λ values.

Since this chapter had a different range of weight data, Equation (5), found in Chapter 3, would change. Before calculating λ, the data were linearly mapped from the 160,000 to 290,190 range (WIM station 9913) into a range of 0 to 1. The upper limit of the range changed for each of the four WIM stations depending on the maximum weight. This λ value was used to create the model and substituted back into the exponential PDF (Equation 1). In the case of WIM station 9913 it would be $f(x) = 6.638e^{-6.638 \times x}$. This analytical function (exponential PDF) now represents the data over the range 0 to 1. In order to represent the data over the interval of 160,000 to 290,190 lbs, the analytical function needed to be adjusted to invert the data mapping. Since the interval had increased from 1 to 130,190, the exponential PDF needed to be divided by 130,190. In addition, the value of x would become $\left(\dfrac{W-160{,}000}{290{,}190-160{,}000}\right)$. The new exponential PDF equation in terms of the data in its original values W is

$$f(W)=\frac{1}{130{,}190}\left(\lambda e^{-\lambda\left(\frac{W-160{,}000}{290{,}190-160{,}000}\right)}\right) \tag{6}$$

The λ parameter for WIM station 9913 that provided the maximum value was 6.638. The exponential PDF for WIM station 9913 now takes the form of $f(x)=6.638e^{-6.638*x}$. The λ parameters for the other three WIM stations were 8.933, 5.850, and 8.281 for WIM stations 9926, 9932, and 9936, respectively.

Figures 5-8, 5-9, 5-10, and 5-11 show the exponential PDF model and the normalized histogram of the summation of the total weight equaling at least 160,000 lbs passing the WIM station in the headway interval from the Mathcad analysis of WIM stations 9913, 9926, 9932, and 9936, respectively.

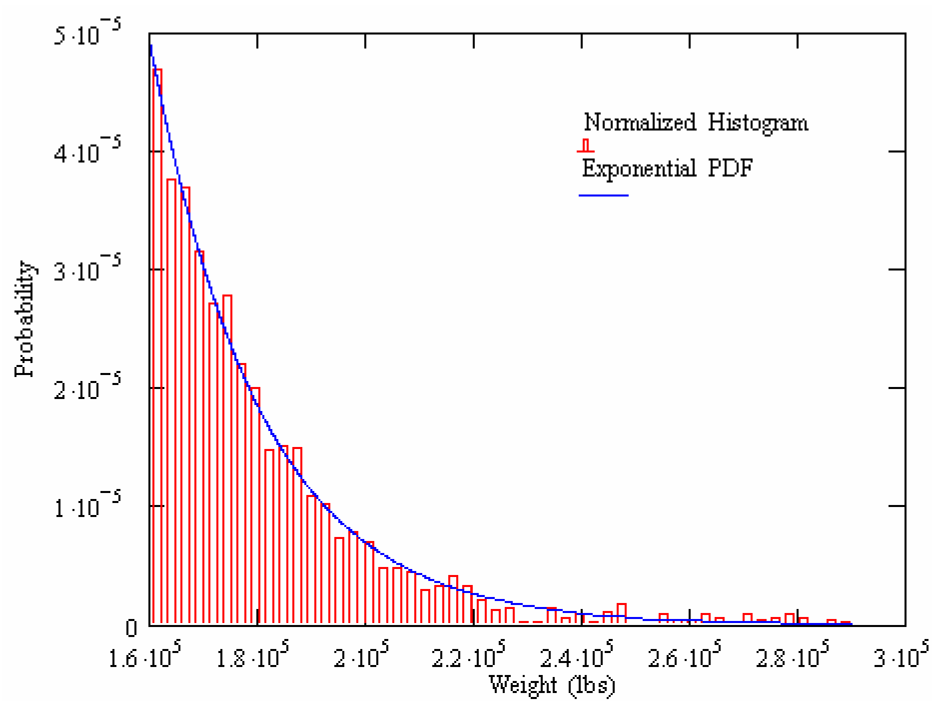


Figure 5-8. Exponential PDF model and normalized histogram (WIM station 9913)

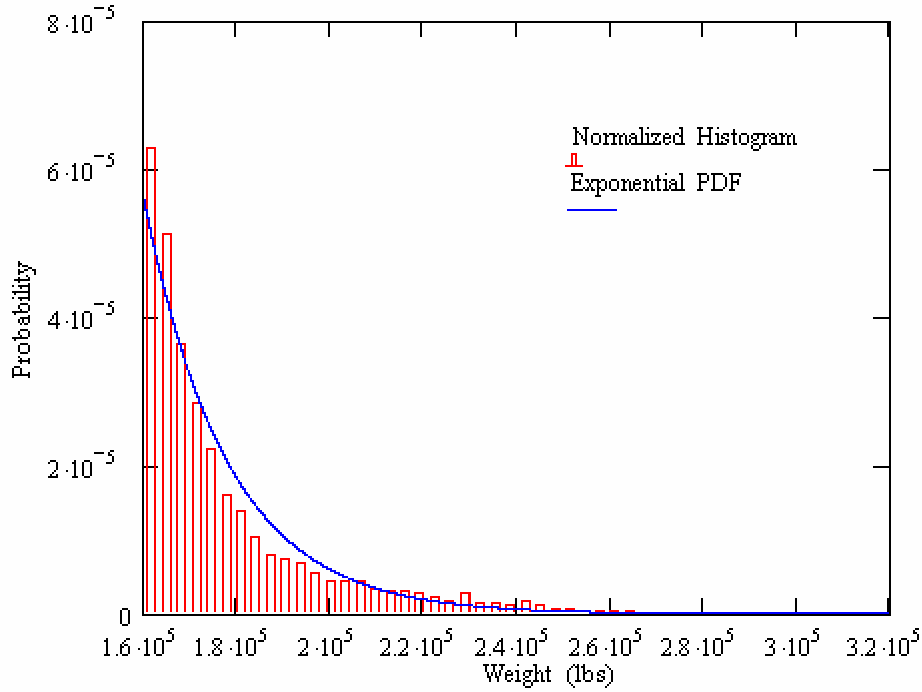


Figure 5-9. Exponential PDF model and normalized histogram (WIM station 9926)

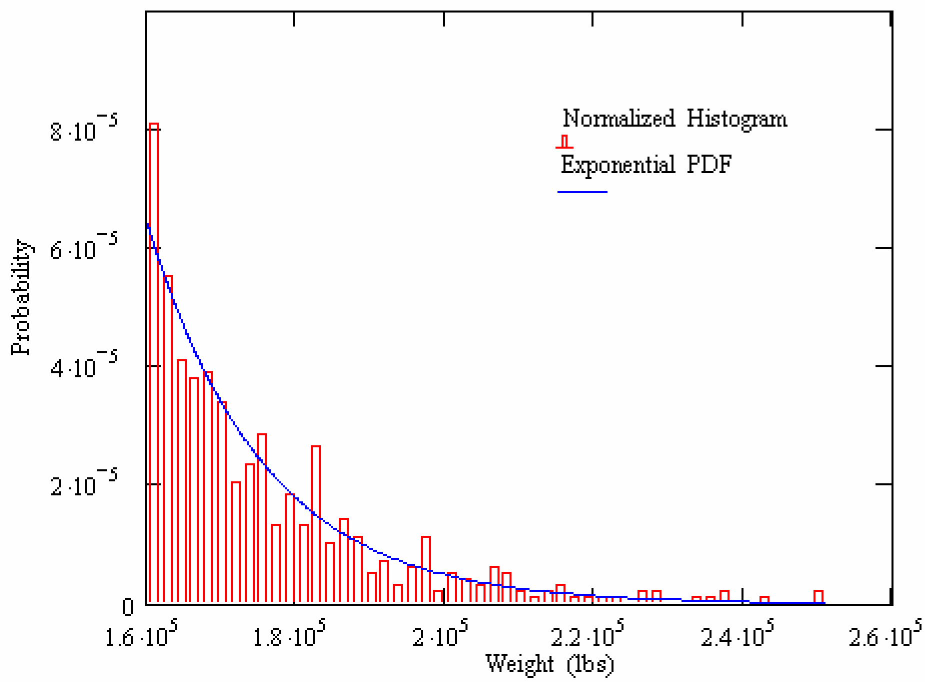


Figure 5-10. Exponential PDF model and normalized histogram (WIM station 9932)

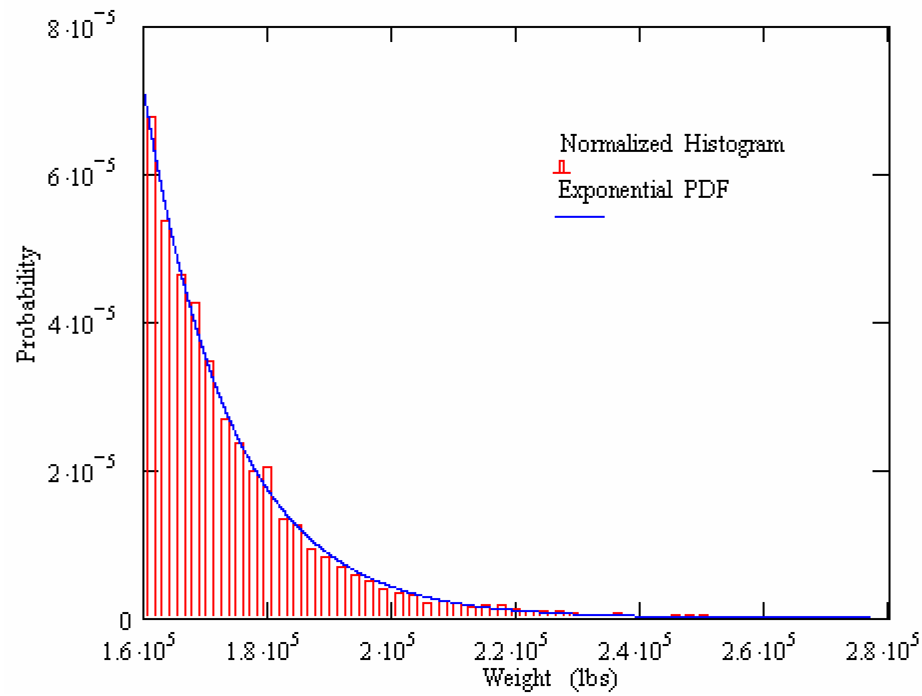


Figure 5-11. Exponential PDF model and normalized histogram (WIM station 9936)

Interpretation of the Extreme Value Histogram

Figures 5-8 through 5-11 represent conditional probabilities. They provide probabilities of the total combined weight of vehicles *given that* the total combined weight of the vehicles at the WIM sensor was at least 160,000 lbs, which was equivalent to two permit vehicles. The conditional probability is represented as $P\langle w|\, p\rangle$, where w is any weight combination of vehicles and p is the event that a combination of vehicles is 160,000 lbs or greater. If the conditional probability is multiplied by the probability that a weight of at least 160,000 lbs shows up at the WIM sensor, the probability of that particular load combination can be found. This is represented as

$$P\langle w\rangle = P\langle w|\, p\rangle \times P\langle p\rangle \tag{7}$$

Referring to Table 5-4, two permit vehicles of at least 80,000 lbs (giving a total weight of at least 160,000 lbs) occur at any of the evaluated WIM stations at least once in the time span analyzed. This means that the probability of at least one weight combination of at least 160,000 lbs per WIM station in a given year was reasonably estimated at 100%. This simplifies Equation (7) above to

$$P\langle w | p\rangle = P\langle w\rangle \tag{8}$$

Thus Figures 5-8 through 5-11 can be viewed directly as the probability of the likelihood of total concurrent weight *W* within several years (number of years varies among stations, see Table 5-4).

The histograms generated at the four WIM stations could not be used directly to represent the probability of total weight of concurrent permit vehicles at other locations around the state. The lambda values were customized to the individual WIM stations using specific information of vehicle travel speed at the WIM station and average bridge length in the area. The WIM station was then used as a hypothetical bridge that would experience concurrent vehicle occurrence and reasonably be extrapolated to other bridges in the vicinity of and along the same route as the WIM station.

This same method of analysis could be conducted at any of the other 33 WIM stations. An analysis of the surrounding bridges within a specified radius from the WIM station and an analysis of the speed of the vehicles passing the WIM station would first be conducted to accurately represent the conditions at each of the WIM stations. Once that information was evaluated, an extreme value histogram and an exponential PDF fit could be determined at any other WIM station around the state.

Applications of Extreme Value Concurrent Weight Models

'Concurrent' is defined as the occurrence of more than one vehicle within an interval that is within the average length of nearby bridges on same route. Here are three examples of how the extreme value concurrent weight models (Figures 5-8 through 5-11) can be used.

Given that multiple vehicles occurred concurrently at WIM station 9913, what is the probability that the total weight is between 200,000 and 250,000 lbs? The solution would be to integrate the normalized histogram or fitted exponential PDF model between 200,000 and 250,000 lbs. The area is the probability in decimal form.

Given that multiple vehicles occurred concurrently at WIM station 9926, what is the probability that the total weight will exceed 280,000 lbs? The solution would be to integrate the normalized histogram or fitted exponential PDF model from 280,000 lbs to the upper limit (319,880 lbs).

Given that multiple vehicles occurred concurrently at WIM station 9936, what is the probability that the total weight is at most 230,000 lbs? The solution would be to integrate the normalized histogram or fitted exponential PDF model from the lower limit of 160,000 lbs to 230,000 lbs.

These data are bounded between a lower limit of 160,000 lbs and an upper limit that ranges from 250,930 to 319,880 lbs depending on what site was being analyzed. The PDF model will not provide probabilities of concurrent vehicles over the upper limit or under 160,000 lbs. That is, direct extrapolation of the PDF model beyond its defined range is not valid. However, more data provided over a larger range of weights could be used to develop a similar model that covers the range of interest.

CHAPTER 6
SUMMARY AND RECOMMENDATIONS

This thesis documents a study on overweight vehicle travel, specifically the characterization of concurrent permit vehicles on bridges at four different WIM stations located in the state of Florida. The following sections summarize contributions to and conclusions about, the research found in this document and present recommendations for future research.

Summary

Chapter 3 discussed the preliminary analysis of the WIM data. An initial extreme value model was created along with the identification of numerous irregularities in the data. Out of the 25,300 files, approximately 5% of the data files were not used due to these irregularities. The analysis of the data found that no WIM data file contained a weight greater than 160,000 lbs. This was due to a filter that was set to discard any data above that threshold. This filter was beyond the control of the investigators, and filtered data was deemed irretrievable.

A second source of data was needed to evaluate the vehicles over 160,000 lbs. Chapter 4 discussed the use and limitations of the permit data. The permit data were scanned into electronic format and placed into one of five partitioned regions of Florida. The permit data were then examined on a regional basis. It was concluded that only the WIM data would be used for subsequent analysis. Even with the ability to categorize the travel patterns of heavy vehicles from the permit data into regions, the inability of the permit data to give specific times and locations of truck travel does not allow for quantitative analysis of multiple vehicles on a bridge.

Chapter 5 discussed the development of a probabilistic model of concurrent vehicle weights at a WIM station using measured headway intervals determined by average speed and average length of bridges local to the given WIM station. The results represent the likelihood of various levels of combined total weight from concurrent permit vehicles at the WIM station. A more specific (accurate) probability model would require the installation of WIM sensors on or next to bridges of interest.

In the evaluation of the headway data, this study observed an appreciable likelihood of permit vehicles (vehicles over 80,000 lbs) appearing concurrently on each of the four analyzed WIM stations (Table 5-4). Thus, the resultant probability models of combined weight of concurrent vehicles directly represent the likelihood of an extreme loading condition.

Permit vehicles were traveling in the same direction in 70% of the observed concurrent cases. Although same direction concurrent permit vehicles account for a total of about 1% of the total number of observed permit vehicles among the four WIM stations, this still represents hundreds of concurrent vehicle loading events per year per analyzed WIM station. Thus, this was more than a negligible occurrence.

The exponential PDFs generated from the four WIM stations (Figures 5-8 through 5-11) can be used to predict the probability of occurrence of the combined weight of concurrent vehicles around the given WIM station. An assumption was made that this analysis data can be extrapolated to the nearby bridges on the same route as, and within 15 miles of, the WIM station. That is, it was reasonable to expect that the observed occurrences of concurrent permit vehicles could have as likely occurred at a nearby bridge, and thus Figures 5-8 through 5-11 can be applied directly to the bridges.

The histograms generated at the four WIM stations cannot be used to give the probability of occurrence of concurrent permit vehicles at other locations around the state. They can only be used to predict concurrent permit vehicle weights at or around the four WIM stations. Each of the four WIM stations used specific information of vehicle travel speed at the WIM station and average bridge length in the area. However, this same method of analysis could be conducted at any of the other 33 WIM stations. An analysis of the surrounding bridges within a specified radius from the WIM station and an analysis of the speed of the vehicles passing the WIM station would first be needed to accurately represent the conditions at each of the WIM stations. Once that information is evaluated, an extreme value histogram and an exponential PDF fit could be determined at any other WIM station around the state.

It needs to be reemphasized that the probability models of concurrent permit vehicle weight did not include weights from individual vehicles that exceed 160,000 lbs. Although such vehicles were generally rare, it was reasonable to assume that the probability models developed without these data were skewed in a non-conservative way toward a higher probability of lower concurrent weights. Additional data collection would be needed at WIM stations that retain 160,000+ lb vehicles to ascertain the impact of this unaccounted for data.

Recommendations

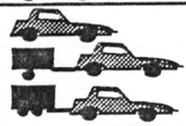
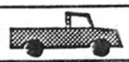
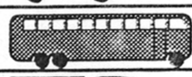
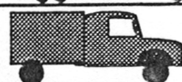
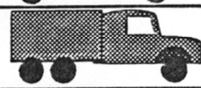
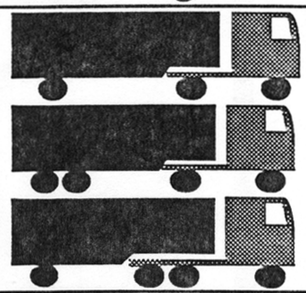
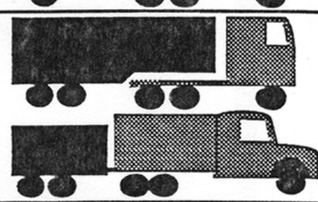
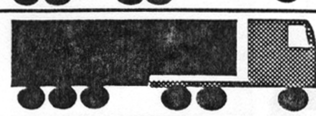
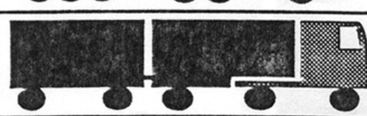
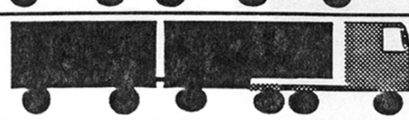
There is a need for the WIM data that is being processed to incorporate the weights of all vehicles that pass the sites. The inability for the WIM sensors to record weight over 160,000 lbs severely limits the ability to perform a realistic analysis of the most extreme weights. In addition, the difficulties with the WIM data files, like combining multiple days of data into one file, need to be addressed and corrected. An overhaul of the WIM sensors and collection process is recommended to better reflect the increasingly likely occurrence of heavier vehicles.

The project did not focus on individual vehicles with specific axle configurations. The next step would be to look at individual vehicles with specific axle configurations that the FDOT has a special interest in. Weight by itself is only one factor, the axle configuration at any given weight can be another significant factor. A study that predicts the probability of these special interest vehicles and the occurrence of concurrent combinations of special interest vehicles on bridges is recommended.

The project evaluated the permit vehicle records (vehicles over 160,000 lbs), but did not do an in-depth analysis of the data. One major obstacle was the inability to know how many trips a vehicle with a blanket permit makes within a year. Determining a system to weight blanket permits (how many trips per blanket) is recommended and would be the first step in the process to further analyze the permit vehicle records collected through 2004. However, future collection of such vehicles at the WIM stations directly would be most beneficial.

APPENDIX A
FDOT CLASSIFICATION SCHEME “F”

CLASSIFICATION SCHEME "F"

CLASS. GROUP		DESCRIPTION	NO. OF AXLES
1		MOTORCYCLES	2
2		ALL CARS CARS W/ 1-AXLE TRLR CARS W/2-AXLE TRLR	2 3 4
3		PICK-UPS & VANS 1 & 2 AXLE TRLRS	2, 3, & 4
4		BUSES	2 & 3
5		2-AXLE, SINGLE UNIT	2
6		3-AXLE, SINGLE UNIT	3
7		4-AXLE, SINGLE UNIT	4
8		2-AXLE TRACTOR, 1-AXLE TRLR(2S1) 2-AXLE TRACTOR, 2-AXLE TRLR(2S2) 3-AXLE TRACTOR, 1-AXLE TRLR(3S1)	3 4 4
9		3-AXLE TRACTOR, 2-AXLE TRLR(3S2) 3-AXLE TRUCK, W/2-AXLE TRLR	5 5
10		TRACTOR W/ SINGLE TRLR	6 & 7
11		5-AXLE MULTI-TRLR	5
12		6-AXLE MULTI-TRLR	6
13	ANY 7 OR MORE AXLE		7 or more

System Usage Data 1/9/90

APPENDIX B
WIM DATA SUMMARY

The content of this appendix summarizes the preliminary analysis of the WIM data obtained from the FDOT. The data summarized here contains data from every file acquired from the FDOT including files that contain multiple days of data. The subsequent pages present the name and location of every site and are broken down in a yearly basis. Within each year are the number of days of data, the total vehicles, the number of vehicles 85,000 lbs or greater, the number of vehicles 90,000 lbs or greater, the number of vehicles 105,000 lbs or greater, the number of vehicles 120,000 lbs or greater, the number of vehicles 135,000 lbs or greater, and the number of vehicles 150,000 lbs or greater.

9901: I-10, Monticello

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	309	824570	4472	1134	258	100	34	10
1999	295	783805	1612	635	191	81	34	7
2002	268	1256199	3287	1652	653	228	79	13
2003	179	726009	3490	1241	428	175	60	21

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	309	824570	0.542	0.138	0.031	0.012	0.004	0.0012
1999	295	783805	0.206	0.081	0.024	0.010	0.004	0.0009
2002	268	1256199	0.262	0.132	0.052	0.018	0.006	0.0010
2003	179	726009	0.481	0.171	0.059	0.024	0.008	0.0029

9908: US-319, Tallahassee

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	345	182175	2582	508	49	6	2	0
1999	217	128603	1606	273	32	6	4	0
2000	185	109917	617	204	45	7	0	0
2001	348	190605	716	368	74	9	3	0
2002	319	169719	632	293	51	6	0	0
2003	184	88105	3244	1192	45	4	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	345	182175	1.417	0.279	0.027	0.003	0.001	
1999	217	128603	1.249	0.212	0.025	0.005	0.003	
2000	185	109917	0.561	0.186	0.041	0.006		
2001	348	190605	0.376	0.193	0.039	0.005	0.002	
2002	319	169719	0.372	0.173	0.030	0.004		
2003	184	88105	3.682	1.353	0.051	0.005	0.001	

9904: I-75, Micanopy

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	72	234387	14426	10041	1834	10	4	0
2003	163	708709	27461	8196	338	79	26	5

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	72	234387	6.155	4.284	0.782	0.004	0.002	
2003	163	708709	3.875	1.156	0.048	0.011	0.004	0.0007

9905: SR-9/I-95, Jacksonville

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	145	914464	17635	7846	546	68	17	5
2003	43	149738	4483	2042	82	16	3	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	145	914464	1.928	0.858	0.060	0.007	0.002	0.0005
2003	43	149738	2.994	1.364	0.055	0.011	0.002	

9906: I-4, Deltona

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	245	545530	24263	13018	1317	42	3	0
2002	53	25401	2652	1840	324	4	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	245	545530	4.448	2.386	0.241	0.008	0.001	
2002	53	25401	10.441	7.244	1.276	0.016		

9907: US-231, Youngstown

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	200	163858	3706	2406	363	3	1	0
2002	200	194693	6369	4131	673	7	0	0
2003	125	109609	4977	3164	583	3	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	200	163858	2.262	1.468	0.222	0.002	0.001	
2002	200	194693	3.271	2.122	0.346	0.004		
2003	125	109609	4.541	2.887	0.532	0.003	0.001	

9909: US-19, Chiefland

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	61	20204	467	252	13	0	0	0
2002	246	131818	13354	8365	1107	5	2	1
2003	211	56188	261	72	3	1	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	61	20204	2.311	1.247	0.064			
2002	246	131818	10.131	6.346	0.840	0.004	0.002	0.0008
2003	211	56188	0.465	0.128	0.005	0.002		

9913: Turnpike, St.Lucie Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	270	481322	11923	8697	4859	2521	964	103
2002	214	364043	12827	9552	4789	2529	1040	115
2003	163	276347	23595	15745	4670	2173	1152	329

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	270	481322	2.477	1.807	1.010	0.524	0.200	0.0214
2002	214	364043	3.523	2.624	1.316	0.695	0.286	0.0316
2003	163	276347	8.538	5.698	1.690	0.786	0.417	0.1191

9914: SR-9A/I-295, Duval Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	265	1419714	57701	30506	2785	60	2	0
2002	21	105450	4555	2424	201	1	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	265	1419714	4.064	2.149	0.196	0.004	0.0001	
2002	21	105450	4.320	2.299	0.191	0.001		

9916: US-29, Pensacola

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	241	176376	7673	4858	802	5	0	0
2002	254	125943	6086	3795	597	3	0	0
2003	185	89648	5984	4452	1252	5	2	1

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	241	176376	4.350	2.754	0.455	0.003		
2002	254	125943	4.832	3.013	0.474	0.002		
2003	185	89648	6.675	4.966	1.397	0.006	0.002	0.0011

9917: US-41, Punta Gorda

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	234	44385	876	456	29	3	0	0
2003	167	39575	108	39	6	5	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	234	44385	1.974	1.027	0.065	0.007		
2003	167	39575	0.273	0.099	0.015	0.013	0.003	

9918: US-27, Clewiston

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	310	657107	68711	44619	6717	55	6	1
2002	277	573517	64732	44787	7689	26	4	0
2003	138	302498	20938	14084	2760	28	7	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	310	657107	10.457	6.790	1.022	0.008	0.001	0.0002
2002	277	573517	11.287	7.809	1.341	0.005	0.001	
2003	138	302498	6.922	4.656	0.912	0.009	0.002	

9919: I-95, Malabar

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	172	932345	8136	3985	554	98	26	3
2002	153	754340	6917	3099	304	59	11	2
2003	2	5612	1197	861	163	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	172	932345	0.873	0.427	0.059	0.011	0.003	0.0003
2002	153	754340	0.917	0.411	0.040	0.008	0.001	0.0003
2003	2	5612	21.329	15.342	2.904			

9920: I-75, Sumter Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2003	44	227899	8869	695	99	45	16	8

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2003	44	227899	3.892	0.305	0.043	0.020	0.007	0.0035

9921: SR-5, Martin Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	341	75433	229	131	13	0	0	0
1999	329	73589	157	84	11	0	0	0
2000	353	87598	169	84	4	0	0	0
2001	356	59830	449	300	53	0	0	0
2002	298	41157	210	149	23	0	0	0
2003	136	23436	45	26	1	1	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	341	75433	0.304	0.174	0.017			
1999	329	73589	0.213	0.114	0.015			
2000	353	87598	0.193	0.096	0.005			
2001	356	59830	0.750	0.501	0.089			
2002	298	41157	0.510	0.362	0.056			
2003	136	23436	0.192	0.111	0.004	0.004		

9922: I-275, Tampa

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2003	34	84545	1521	392	25	8	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2003	34	84545	1.799	0.464	0.030	0.009	0.001	

9923: I-95, Jacksonville

No data was available from this site.

9924: I-110, Pensacola

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	202	194583	1447	312	15	3	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	202	194583	0.744	0.160	0.008	0.002		

9925: US-92, Deland

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	248	67844	2499	635	19	2	0	0
2003	169	52404	2231	615	20	1	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	248	67844	3.683	0.936	0.028	0.003		
2003	169	52404	4.257	1.174	0.038	0.002	0.002	

9926: I-75, Tampa

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	158	571238	38034	18087	410	84	20	7
2003	126	582217	11823	2493	321	86	27	6

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	158	571238	6.658	3.166	0.072	0.015	0.004	0.0012
2003	126	582217	2.031	0.428	0.055	0.015	0.005	0.0010

9927: SR-546, Lakeland

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	320	262155	755	179	33	15	3	0
2003	138	108706	295	63	14	5	1	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	320	262155	0.288	0.068	0.013	0.006	0.001	
2003	138	108706	0.271	0.058	0.013	0.005	0.001	

9928: I-10, Walton Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	154	590918	3946	863	235	82	29	8
2003	75	255814	12713	2217	144	55	18	4

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	154	590918	0.668	0.146	0.040	0.014	0.005	0.0014
2003	75	255814	4.970	0.867	0.056	0.021	0.007	0.0016

9929: US-1, Edgewater

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	93	11805	20	4	0	0	0	0
2003	66	3390	6	6	2	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	93	11805	0.169	0.034				
2003	66	3390	0.177	0.177	0.059			

9930: US-1, Miami

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2002	425	81082	722	427	39	2	2	1
2003	208	37431	150	81	12	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2002	425	81082	0.890	0.527	0.048	0.002	0.002	0.0012
2003	208	37431	0.401	0.216	0.032			

9931: Turnpike, Sumter Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	180	725162	33099	13734	842	57	13	0
2002	25	101323	1808	650	96	27	2	0
2003	156	563854	30742	13494	612	138	40	6

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	180	725162	4.564	1.894	0.116	0.008	0.002	
2002	25	101323	1.784	0.642	0.095	0.027	0.002	
2003	156	563854	5.452	2.393	0.109	0.024	0.007	0.0011

9932: Turnpike, Osceola Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	208	409997	28542	19491	5744	1956	833	186
2002	232	484283	26145	17329	4680	1657	723	219
2003	4	6942	369	257	73	24	10	3

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	208	409997	6.962	4.754	1.401	0.477	0.203	0.0454
2002	232	484283	5.399	3.578	0.966	0.342	0.149	0.0452
2003	4	6942	5.315	3.702	1.052	0.346	0.144	0.0432

9934: Homestead Ext, Dade Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
2001	16	30289	230	102	12	1	0	0
2002	79	238014	7591	4690	765	92	40	17
2003	201	430259	25881	16925	2978	192	106	31

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
2001	16	30289	0.759	0.337	0.040	0.003		
2002	79	238014	3.189	1.970	0.321	0.039	0.017	0.0071
2003	201	430259	6.015	3.934	0.692	0.045	0.025	0.0072

9935: US-27, Palm Beach Co.

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	145	364949	22170	14014	2481	39	12	0
1999	144	350648	55989	40870	8674	24	6	2
2000	231	588584	21551	11158	751	34	15	1
2001	253	840365	9662	4077	341	65	10	4
2002	150	504232	38625	20387	1101	73	21	3
2003	94	223640	24650	14785	988	32	11	3

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	145	364949	6.075	3.840	0.680	0.011	0.003	
1999	144	350648	15.967	11.656	2.474	0.007	0.002	0.0006
2000	231	588584	3.661	1.896	0.128	0.006	0.003	0.0002
2001	253	840365	1.150	0.485	0.041	0.008	0.001	0.0005
2002	150	504232	7.660	4.043	0.218	0.014	0.004	0.0006
2003	94	223640	11.022	6.611	0.442	0.014	0.005	0.0013

9936: I-10/SR-8, Lake City

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	129	424264	4102	1440	213	65	20	1
1999	155	659277	4871	1976	293	88	20	3
2000	217	972530	11280	5345	511	111	29	3
2001	157	806091	27243	15053	1563	142	40	8
2002	252	1051368	64182	36897	3787	245	88	21
2003	144	438662	28509	13936	1066	138	49	15

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	129	424264	0.967	0.339	0.050	0.015	0.005	0.0002
1999	155	659277	0.739	0.300	0.044	0.013	0.003	0.0005
2000	217	972530	1.160	0.550	0.053	0.011	0.003	0.0003
2001	157	806091	3.380	1.867	0.194	0.018	0.005	0.0010
2002	252	1051368	6.105	3.509	0.360	0.023	0.008	0.0020
2003	144	438662	6.499	3.177	0.243	0.031	0.011	0.0034

9937: SR-87, Milton

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	190	63037	2926	1497	35	2	0	0
1999	250	82509	3957	1845	64	6	2	0
2000	224	119253	4657	2230	42	1	0	0
2002	123	49569	758	218	9	3	0	0
2003	142	43006	734	193	11	2	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	190	63037	4.642	2.375	0.056	0.003		
1999	250	82509	4.796	2.236	0.078	0.007	0.002	
2000	224	119253	3.905	1.870	0.035	0.001		
2002	123	49569	1.529	0.440	0.018	0.006		
2003	142	43006	1.707	0.449	0.026	0.005		

9938: SR-83/US-331, Freeport

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	350	113611	5753	2571	82	3	3	2
1999	303	126454	4733	2028	83	1	1	0
2000	79	34485	1390	765	61	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	350	113611	5.064	2.263	0.072	0.003	0.003	0.002
1999	303	126454	3.743	1.604	0.066	0.001	0.001	
2000	79	34485	4.031	2.218	0.177			

9939: SR-2, Graceville

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	191	9778	151	67	6	1	0	0
1999	255	24757	598	243	10	0	0	0
2000	325	27295	621	315	21	0	0	0
2001	288	25089	1030	508	36	1	0	0
2002	330	32941	1361	650	44	0	0	0
2003	155	16503	514	195	11	1	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	191	9778	1.544	0.685	0.061	0.010		
1999	255	24757	2.415	0.982	0.040			
2000	325	27295	2.275	1.154	0.077			
2001	288	25089	4.105	2.025	0.143	0.004		
2002	330	32941	4.132	1.973	0.134			
2003	155	16503	3.115	1.182	0.067	0.006		

9940: SR-267, Quincy

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	192	73852	2896	1538	54	0	0	0
1999	286	101696	3087	1505	40	0	0	0
2000	94	38085	1075	485	25	2	1	0
2001	357	100330	1287	424	22	0	0	0
2002	331	98275	568	177	18	2	0	0
2003	159	41303	252	74	9	5	4	1

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	192	73852	3.921	2.083	0.073			
1999	286	101696	3.036	1.480	0.039			
2000	94	38085	2.823	1.273	0.066	0.005	0.003	
2001	357	100330	1.283	0.423	0.022			
2002	331	98275	0.578	0.180	0.018	0.002		
2003	159	41303	0.610	0.179	0.022	0.012	0.010	0.002

9942: SR-85, Laurel Hill

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	133	20524	770	310	16	0	0	0
1999	176	39656	1772	801	36	0	0	0
2000	218	32375	909	356	23	0	0	0
2001	271	40798	2122	656	15	0	0	0
2002	236	32758	1487	529	18	1	1	0
2003	164	20970	902	410	32	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	133	20524	3.752	1.510	0.078			
1999	176	39656	4.468	2.020	0.091			
2000	218	32375	2.808	1.100	0.071			
2001	271	40798	5.201	1.608	0.037			
2002	236	32758	4.539	1.615	0.055	0.003	0.003	
2003	164	20970	4.301	1.955	0.153			

9943: SR-10/US-90, Cypress

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	108	23132	1676	1066	102	0	0	0
1999	167	47649	4395	2511	151	1	0	0
2000	318	72664	5709	3336	255	0	0	0
2001	364	74764	5861	3522	212	1	0	0
2002	315	67930	7481	4719	735	3	0	0
2003	161	37317	5936	2242	47	6	3	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	108	23132	7.245	4.608	0.441			
1999	167	47649	9.224	5.270	0.317	0.002		
2000	318	72664	7.857	4.591	0.351			
2001	364	74764	7.839	4.711	0.284	0.001		
2002	315	67930	11.013	6.947	1.082	0.004		
2003	161	37317	15.907	6.008	0.126	0.016	0.008	

9944: SR-69, Selman

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	48	5826	610	350	21	0	0	0
1999	209	22367	2347	1301	77	1	1	0
2000	266	23217	1278	674	29	0	0	0
2001	277	38592	3843	2216	180	0	0	0
2002	331	46343	5160	3392	591	0	0	0
2003	162	13601	388	108	11	2	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	48	5826	10.470	6.008	0.360			
1999	209	22367	10.493	5.817	0.344	0.004	0.004	
2000	266	23217	5.505	2.903	0.125			
2001	277	38592	9.958	5.742	0.466			
2002	331	46343	11.134	7.319	1.275			
2003	162	13601	2.853	0.794	0.081	0.015		

9946: SR-363, St. Marks

YEAR	# OF DAYS	VEHICLES	WT > 85,000	WT > 90,000	WT > 105,000	WT > 120,000	WT > 135,000	WT > 150,000
1998	123	20703	2076	771	76	0	0	0
1999	348	64538	4523	1674	381	2	1	0
2000	353	53761	3694	1420	344	0	0	0
2001	362	47797	3142	1500	486	1	0	0
2002	329	38201	2975	2018	656	0	0	0
2003	161	20335	1733	1279	555	0	0	0

YEAR	# OF DAYS	VEHICLES	% > 85,000	% > 90,000	% > 105,000	% > 120,000	% > 135,000	% > 150,000
1998	123	20703	10.028	3.724	0.367			
1999	348	64538	7.008	2.594	0.590	0.003	0.002	
2000	353	53761	6.871	2.641	0.640			
2001	362	47797	6.574	3.138	1.017	0.002		
2002	329	38201	7.788	5.283	1.717			
2003	161	20335	8.522	6.290	2.729			

APPENDIX C
SUMMARY OF FILES CONTAINING MULTIPLE DAYS OF DATA

The content of this appendix summarizes the number of corrupted files in the WIM dataset. Each line in the subsequent table contains the number of corrupted files for a particular year at a particular site, the total number of files for the particular year, and the percent of corrupted vehicles contained within the year. The last page of this appendix contains the total number of corrupted data files, the total number of data files, and the percent of corrupted files in the whole dataset.

Site	Year	Files Containing Multiple Days of Data	Total Number of Files (Days of Data)	Percent of Corrupted Files
9901	1998	14	309	4.53%
9901	1999	19	295	6.44%
9901	2002	37	280	13.21%
9901	2003	1	188	0.53%
9904	2002	2	78	2.56%
9904	2003	0	163	0%
9905	2002	22	158	13.92%
9905	2003	0	47	0.00%
9906	2001	5	245	2.04%
9906	2002	0	53	0%
9907	2001	12	203	5.91%
9907	2002	18	229	7.86%
9907	2003	6	125	4.80%
9908	1998	11	345	3.19%
9908	1999	8	217	3.69%
9908	2000	2	203	0.99%
9908	2001	13	351	3.70%
9908	2002	20	324	6.17%
9908	2003	6	184	3.26%
9909	2001	3	61	4.92%
9909	2002	27	262	10.31%
9909	2003	0	211	0%
9913	2001	11	281	3.91%
9913	2002	10	227	4.41%
9913	2003	3	163	1.84%
9914	2001	4	265	1.51%
9914	2002	0	21	0%
9916	2001	12	241	4.98%
9916	2002	23	254	9.06%
9916	2003	0	185	0%
9917	2002	21	234	8.97%
9917	2003	1	167	0.60%

Site	Year	Files Containing Multiple Days of Data	Total Number of Files (Days of Data)	Percent of Corrupted Files
9918	2001	9	310	2.90%
9918	2002	38	277	13.72%
9918	2003	3	138	2.17%
9919	2001	5	172	2.91%
9919	2002	11	153	7.19%
9919	2003	0	2	0%
9920	2003	0	44	0%
9921	1998	24	341	7.04%
9921	1999	31	329	9.42%
9921	2000	11	352	3.13%
9921	2001	6	356	1.69%
9921	2002	25	298	8.39%
9921	2003	3	136	2.21%
9922	2003	0	34	0%
9924	2002	32	202	15.84%
9925	2002	21	248	8.47%
9925	2003	13	169	7.69%
9926	2002	5	158	3.16%
9926	2003	2	126	1.59%
9927	2002	13	320	4.06%
9927	2003	4	138	2.90%
9928	2002	6	154	3.90%
9928	2003	0	75	0%
9929	2002	8	93	8.60%
9929	2003	6	66	9.09%
9930	2002	27	426	6.34%
9930	2003	4	208	1.92%
9931	2001	15	180	8.33%
9931	2002	0	25	0%
9931	2003	3	156	1.92%
9932	2001	10	218	4.59%
9932	2002	17	232	7.33%
9932	2003	0	4	0%
9934	2001	0	16	0%
9934	2002	21	79	26.58%
9934	2003	1	201	0.50%
9935	1998	23	145	15.86%
9935	1999	30	144	20.83%
9935	2000	12	231	5.19%
9935	2001	42	253	16.60%
9935	2002	23	150	15.33%
9935	2003	2	94	2.13%

Site	Year	Files Containing Multiple Days of Data	Total Number of Files (Days of Data)	Percent of Corrupted Files
9936	1998	2	129	1.55%
9936	1999	9	155	5.81%
9936	2000	23	217	10.60%
9936	2001	26	157	16.56%
9936	2002	5	252	1.98%
9936	2003	1	144	0.69%
9937	1998	8	190	4.21%
9937	1999	36	250	14.40%
9937	2000	24	224	10.71%
9937	2002	10	123	8.13%
9937	2003	0	142	0%
9938	1998	5	350	1.43%
9938	1999	42	303	13.86%
9938	2000	7	79	8.86%
9939	1998	11	191	5.76%
9939	1999	11	255	4.31%
9939	2000	6	325	1.85%
9939	2001	5	288	1.74%
9939	2002	7	330	2.12%
9939	2003	1	155	0.65%
9940	1998	4	192	2.08%
9940	1999	13	286	4.55%
9940	2000	10	94	10.64%
9940	2001	12	357	3.36%
9940	2002	4	331	1.21%
9940	2003	5	159	3.14%
9942	1998	1	133	0.75%
9942	1999	31	176	17.61%
9942	2000	12	218	5.50%
9942	2001	3	271	1.11%
9942	2002	5	236	2.12%
9942	2003	5	164	3.05%
9943	1998	10	108	9.26%
9943	1999	34	167	20.36%
9943	2000	7	318	2.20%
9943	2001	2	364	0.55%
9943	2002	7	315	2.22%
9943	2003	2	161	1.24%

Site	Year	Files Containing Multiple Days of Data	Total Number of Files (Days of Data)	Percent of Corrupted Files
9944	1998	0	48	0%
9944	1999	6	209	2.87%
9944	2000	15	266	5.64%
9944	2001	3	277	1.08%
9944	2002	7	331	2.11%
9944	2003	1	162	0.62%
9946	1998	2	123	1.63%
9946	1999	10	348	2.87%
9946	2000	11	353	3.12%
9946	2001	3	362	0.83%
9946	2002	2	329	0.61%
9946	2003	1	161	0.62%
TOTAL		**817**	**14022**	**5.83%**

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BIOGRAPHICAL SKETCH

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