A METHODOLOGY FOR OVERSIZED VEHICLE TRIP SCHEDULING

Final Report

by

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16. Abstract

Because of the technological growth and economic development, there are more and more oversized commercial trucks traveling on the highway systems. In order to increase driving safety, federal and Virginia laws restrict oversized vehicles traveling on interstate and federal-aid highway without a special permit.

Currently, the permit procedure for oversized vehicles involves the approval of a proposed route, with no restriction on departure time or arrival time, except that the trip must occur in daylight hours. The purpose of this thesis is to develop a scheduling methodology to be used by the State Permit Office. That methodology is intended to enable the Permit Office to add advisory trip scheduling information to the permit approval and thereby enhance oversized vehicle traveling safety.

The methodology seeks to establish for an approved route the best time of travel that has the optimum combination of the lowest accident rate and minimum accident consequence. To implement the methodology requires that crash and traffic volume data be available for the study routes. A case study that demonstrates the applicability of the methodology was completed for the Hampton Roads Area.

The results of this study show that traffic flow, accident rate, and accident-caused congestion are affected remarkably by time of day. These findings are also consistent with past research. It justifies the feasibility of developing a scheduling strategy that incorporates traffic parameters and time of travel to reduce oversized vehicle accident rate and accident consequence. The sample scheduling solutions generated by the proposed methodology confirm the applicability of the proposed methodology.

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Currently, the permit procedure for oversized vehicles involves the approval of a proposed route, with no restriction on departure time or arrival time, except that the trip must occur in daylight hours. The purpose of this thesis is to develop a scheduling methodology to be used by the State Permit Office. That methodology is intended to enable the Permit Office to add advisory trip scheduling information to the permit approval and thereby enhance oversized vehicle traveling safety.

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Chapter 1: Introduction

In order to increase driving safety, federal and Virginia laws restrict oversized vehicles traveling on interstate and federal-aid highway without a special permit. According to highway laws of Virginia, 1998 [1], "*it should be unlawful to operate a vehicle or combination of vehicles on any public highway or section thereof when the size exceeds the maximum posted without a permit*".

Oversized vehicles are the ones whose dimensions exceed size limitations specified by the *Virginia Hauling Permit Manual.*[2] The detailed size limitations are given in Appendix A. If the dimensions of the vehicle combination or nondivisible load, or both, exceed the limitations, a hauling permit is required. These regulations ensure that the vehicle configuration is transported safely, with minimal disruption to the traveling public and to protect the highways and structures of the state.

1.1 Problem Statement

Because of oversized vehicles' handling characteristics, like large sizes, long brake distance, and blind spots, they are dangerous on the road. In addition, if an accident involving an oversized vehicle occurs, severe congestion and delay might be caused.

Currently, the permit procedure for oversized vehicles mainly involves the approval of a proposed route. All the proposed routes will be evaluated by permit engineers, who exam certain geometry restrictions or other restrictions due to maintenance or construction. If the proposed route is incompatible with the characteristics of the vehicle and load, the application is rejected.

On Virginia highway systems, there are no restrictions on departure time or arrival time, except that the trip must occur in daylight hours. *Virginia Hauling Permit Manual* specifies that normal time of travel for permitted loads is 30 minutes after sunrise to 30 minutes before sunset, Monday through Saturday. This specification allows for a wide range of starting times for oversized vehicles to travel.

To date there has been little analysis on how time of travel impacts oversized vehicle traveling risks and there is no established scheduling methodology to facilitate the Permit Office to assess what is optimum time of travel for an approved route. Avoiding peak hour periods is not a feasible solution because studies [3,4,5,6,7] have shown that peak traffic volume does not necessarily lead to high crash rates. Besides, different highway segments might have different peak hour time widows. It is not appropriate to apply a default peak hour time widow to all highway segments without examining their traffic pattern first.

There are two basic problems associated with making scheduling decisions:

1. If the trip is short, which portion of an off-peak hour period would be the best time of travel?

2. If the trip is long and peak hours can not be avoided, what are the peak hours for each segment and which segment is an appropriate one for traveling during the peak hours?

To answer the above questions, a scientific and systematic scheduling methodology is more appropriate than permit engineers' experience only.

1.2 Purpose of Study

This thesis is to investigate the feasibility of improving oversized vehicle traveling safety by offering drivers advisory information about optimum time of travel. The hypothesis is that a good scheduling strategy can significantly reduce oversized vehicle accident rate and accident consequence, especially when there are no escort vehicles traveling beside it.

1.3 Tasks of Study

To achieve the above objective, the three major tasks of this study are:

1. To review related studies;
2. To develop a methodology for scheduling; and
3. To test the applicability of the methodology by a case study.

Chapter 2 Background and Literature Review

A review of past research on the characteristics of hauling permits and oversized vehicles was carried out using the sources of the University of Virginia Library, the Virginia Transportation Research Council Library, and the Transportation Research Information Service (TRIS).

2.1 Virginia Permit Process Review

The power to regulate motor vehicle traffic on Virginia's highways rests with the General Assembly. The Assembly delegates to the Commonwealth Transportation Board the responsibility to issue special permits for commercial oversized vehicles. Under this grant of authority, the Board has promulgated the *Virginia Hauling Permit Manual*, which establishes size limitations for special trip permits on all commercial vehicles. The Virginia Department of Transportation (VDOT) Permit Office is the entity responsible for handling permit requests.

According to the *Virginia Hauling Permit Manual*, oversized vehicles are vehicles whose dimensions exceed one of the size limitations which are given in appendix A. When the dimensions of the vehicle exceed one of these size limitations, a hauling permit is required. The size limitations for oversized vehicle identification are complicated.

There are three types of hauling permits available from the Permit Office:

1. Blanket Permits

2. Single Trip Permits

3. Superload Permits

The blanket permit allows the shipper to continually transport loads across specifically designated state-maintained roadways for a 1- or 2-year period. The single trip permit is valid for 13 days and for one trip only. Superload hauling permits authorize the movement of vehicle configurations that exceed the limits for Single Trip hauling permits. Superload hauling permits vary in the period for which they are valid depending upon the dimension or weight of the vehicle configuration and are valid for one trip only.

Superload refers to those loads with dimensions that exceed any or all of the 14-foot height, 14-foot width, 100-foot length, or 90,000-pound limitations contained in the *Manual.* Widths in excess of 14 feet are subject to section 5.0170(4) of the *Manual*, which states that "permits will not be issued for movements in excess of fourteen feet width except in the case of emergencies, movements certified as essential to national defense, or for short distances where other means of transportation are not available."

After an application is submitted, the Permit Office will analyze the routes the shipper proposes for the oversized load movement. Important factors in the approval process include a determination of whether the proposed route can safely accommodate the oversized load and possible congestion problems. [5] The Permit Office's overriding concern, once an application is deemed to fit section 5.0170(4), is ensuring the safest possible move with the least amount of inconvenience to others on the roadway.

2.1.1 Timing Constraints

According to the *Virginia Hauling Permit Manual, 1996*, permitted vehicle configurations are allowed to travel from 30 minutes after sunrise to 30 minutes before sunset, Monday through Saturday, except on the following state observed holidays: New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day.

2.1.2 Speed Limits

Unless otherwise specified within the permit, the maximum speed limit for all permitted vehicles is 10 miles per hour less than the posted speed limit.

2.2 Improvement on Permit Issuance Process

In the literature review for this project, most of the recent studies that were related with improving the efficiency of the special hauling permitting processes, were focused on implementing a procedure for the automated route evaluation for overweight/oversize vehicles. The schedule-support procedure was seldom discussed in the past research.

In 1995, a study [8] pointed out that most states' procedure for attending permit requests is largely handled by a manual system. A recent email communication with the Permit Office, Virginia Department of Transportation also shows that currently in Virginia, the permit issuance process is handled manually. Now, most states face greater number of overweight truck permits[8]. Several research projects have been carried out in the past to improve the efficiency of the special hauling permitting process. Some state Departments of Transportation are using computer-aided permitting and routing systems to automate what has traditionally been a manual process: issuing permits for oversize and overweight trucks and tracking their movement. The software's foundation of these systems is a digital base map that includes data on a state's highway infrastructure and ongoing road, bridge, and construction activities.

Work done by Lina Nozick, Mark Turnquist, George List (1995) presented a design for an electronic permit issuance system for oversized and/or overweight vehicles. The system has been designed for use by the New York State Department of Transportation (NYSDOT). The electronic system is designed to replace a largely manual system of data checking, route verification and permit issuance. By linking personal computers at transmission companies (third parties that prepare and submit permit applications for truckers) directly to computers at NYSDOT and equipping these computers with automated route verification capability using a geographical information system (GIS), improved service can be offered at a reduced cost to the state.

A project [9] carried out for the Texas Department of Transportation (TxDOT) also featured by the use of a network routing procedure within a geographic information system (GIS) operating in a PC environment. Bridge load formulas were used to evaluate the adequacy of bridge structures for incoming overloads. The project describes a procedure that automatically identifies all bridges on a specified route and evaluates the adequacy of the bridge structures as well as vertical and horizontal clearance requirements for a given vehicle.

Recognizing that the evaluation of a permit request may require the input of multiple offices (such as the permit office, bridge office, etc.), the Tennessee Department of Transportation, with the assistance of Cambridge Systematics, Inc, implemented permit routing software to computerize the permit issuance process[10]. This new system applies groupware concepts to the flow, storage and processing of permit request data. The system also includes the ability to screen permit requests based upon axle weights/spacings and bridge evaluation features based upon statistical sampling methods.

Most of the past research projects were focused on automating the routing evaluation, which usually would take the sizes and weight of trucks, the bridge height and clearance into consideration. In the literature review, no published studies were found especially dealing with oversized vehicle trip scheduling.

Chapter 3: Risk-Minimum Methodology

The objective of this project is to develop a practical methodology which can help permit engineers offer advisory trip scheduling information to oversized vehicle drivers.

3.1 Risk Analysis Approach

Important factors in the approval process include a determination of whether the proposed route can safely accommodate the oversized load and possible congestion problems.[11] A good scheduling strategy should also be capable to address the above concerns about safety and accident consequence. The idea behind the proposed scheduling methodology is intended to (a) enhance the safety by minimizing the accident probability, and (b) minimize the consequences of accidents. The methodology guideline is based on the selection of minimum-risk scheduling solution, on which risk is determined for the studied route segments by the equation :

$$Risk = (Accidentprobability) \times (Accidentconsequences) \qquad (1)$$

3.1.1 Accident Probability

Conventionally accident probability is measured by accident rate. Accident rate on roadway sections is defined as the number of accidents per million vehicle miles traveled. It is related to three parameters: the number of accidents during the study period, traffic volume entering the study location, and length of the study highway section. The accident rate on roadway segments can be calculated by the following equation[12]:

$$AccidentRate = \frac{AccidNum \times 100{,}000{,}000}{L \times AADT \times 365 \times n} \quad (2)$$

Where

$AccidNum$ = n years' number of all-vehicle accidents

$AADT$ = average annual daily traffic

L = length (in miles) for the study site

n = number of years

3.1.1.1 Oversized Vehicle Accident Rate

Similarly oversized vehicle accident rate can be computed by Equation (3) as following:

$$AR_{ov} = \frac{AccidNum_{ov} \times 100{,}000{,}000}{L \times AADT \times 365 \times n} \quad (3)$$

Where

AR_{ov} = oversized vehicle accident rate

$AccidNum_{ov}$ = n years' number of oversized vehicle accidents

$AADT$ = average annual daily traffic volume

n = number of years

But it is very difficult to obtain number of oversized vehicle accidents and oversized vehicle percentage in the traffic stream for all the highway sections that allow for oversized vehicle traveling.

In addition, even if these data are obtainable, these accident data must be used cautiously. In the Highway Traffic Records Information System (HTRIS) database, the amount of oversized vehicle accidents is small. (It is probably caused by the low number of miles traveled by oversized vehicles. The total number of permits issued in Virginia for the calendar year of 2000 was 89,598. Because the amount of accidents is directly proportional to vehicle miles traveled, when the amount of vehicle miles traveled was extremely low, the probability of exposure to accident is small)

Because available oversized vehicle accident sample sizes for a particular route segment are small, these accident data must be used cautiously. For example, consider three 1-mile highway segments. In a five year period, one of these segments experiences no oversized vehicle accidents, another experiences one oversized vehicle accident, and the third experiences two oversized vehicle accidents. To treat the first segment as having no risk of accident would certainly be incorrect, but this is the conclusion one would reach using the oversized vehicle accident rate in Equation 3.

In the field, it is suggested to substitute oversized vehicle accident rates to adjusted all-vehicle accident rates.

Similar substitution can be found in 1994 FHWA publication *Guidelines for Applying Criteria to Designate Routes for Transportation Hazardous Material*[13]. In the *Guidelines*, the same risk assessment model was used for identifying preferred routes for hazardous materials transportation. Highway transportation of hazardous materials is conducted by truck while all-vehicle accident rates are based primarily on passenger car accidents. But in the *Guidelines*, all-vehicle accident rate is substituted for truck accident rate. The main reason is the estimation of truck accident rates requires truck accident and corresponding traffic data, but highly qualified data was not widely available.

3.1.1.2 Adjusted All-Vehicle Accident Rate

In this proposed methodology it is assumed that oversized vehicle accident rate be substituted by adjusted all-vehicle accident rate. Adjusted all-vehicle accident rates are more directly applicable to the probability of accidents involving oversized vehicles than all-vehicle accident rates. The computation of an adjusted all-vehicle accident rate will not take single passenger car, van, and light truck accidents into account.

In this study, accidents were classified into three categories:

1. Single passenger vehicle accidents (according to the definition of passenger vehicle accident given in *Large Truck Crash Profile: The 1997 National Picture*[14], this category includes single passenger car, van, and light truck accidents)
2. Multi-vehicle accidents (two or more vehicles involved)
3. Single Large/Oversized Vehicle accidents

Adjusted all-vehicle accident rate, AR_{adj}, is used to measure the probability for accidents that oversized vehicles experience. AR_{adj}, can be computed by the following equations:

$$AR_{adj} = \frac{AccidNum_{adj} \times 100{,}000{,}000}{L \times AADT \times 365 \times n} \tag{4}$$

$$AP_{ov} = AR_{adj} \tag{5}$$

Where

AP_{ov} = oversized vehicle accident probability (the amount of probability for accidents that oversized vehicle experience)

AR_{adj} = adjusted all-vehicle accident rate (the number of Category 2 and 3 accidents per million vehicle miles traveled)

$AccidNum_{ad}$ = n years' number of accidents in Category 2 and 3

$AADT$ = average annual daily traffic volume

L = length (in miles) for the study site.

n = number of years

The substitution is based on an assumption that single vehicle accidents (disabled vehicles, collision with fixed objectives, and et.) will not contribute to the amount of probability for accidents that oversized vehicles experience, but Category 2 and 3 accidents would.

Although oversized vehicles are defined in terms of sizes and large trucks are defined in terms of weight (gross vehicle weight rating greater than 10, 000 pounds), large trucks and oversized vehicles have the similar handling problems because of their sheer size, long braking distances, and blind spots.

Therefore, in this project, it is assumed that the accident probability oversized vehicles and large trucks experience is roughly the same. So all of the large vehicle accidents (Category 3) are taken into account in the estimation of the oversized vehicle accident probability.

Furthermore, a study[15] done by the National Highway Traffic Safety Administration indicated that if a two-vehicle fatal crash involving a large truck occurs, most likely it is the passenger vehicle driver who is responsible for the cause of accident, for instance due to driver inattention or wrong maneuvers.

Large Truck Traffic Safety Facts 1995 states that:

> *"Only 1.3 percent of the drivers of large trucks involved in fatal crashes in 1995 were intoxicated, compared with 19.2 percent for passenger cars, 22.4 percent for light trucks, and 29.1 percent for motorcycles."*
>
> *"In almost three-fourths (72 percent) of the two-vehicle fatal crashes involving a large truck and another type of vehicle, police reported one or more factors for the other driver and none for the truck driver. In 17 percent, one or more factors were reported for the truck driver and none for the other driver. In 9 percent, factors were reported for both drivers, and in 2 percent no factors were reported for either driver."*

The frequent occurrence of these passenger vehicle drivers' driving errors will increase the amount of oversized vehicle accident probability. So category 2 accidents were also used for AP_{ov} estimation.

3.1.2 Accident Consequence

Traffic flow usually will be disrupted and delayed at an accident site because the traffic capacity and the vehicle speed are lower at the accident site than at other portions of the roadway. An accident that has an oversized vehicle involved may block the traffic completely. Although oversized vehicles generally have good safety records, the severe consequence of oversized vehicle accidents is reminder of the harm that can be done and underscores the need to become more aware of these risks and attempt to reduce them. Permit engineers, who are engaged in ensuring the highway operating efficiency, have to take this potential accident-cause consequence into consideration when making scheduling decisions.

In the proposed methodology, accident consequence is defined as traffic congestion and delay caused by accidents. More specifically, it is defined as the length of time it takes for traffic to resume the normal operations after the occurrence of oversized vehicle accidents.

In the *Highway Capacity Manual 2000* [16], phases of an accident were divided into four parts (Figure 1). The first phase represents the time interval between the occurrence of the incident and its verification. The response phase is the time interval between incident verification and arrival of police or towing vehicles to clear the incident. The third phase is the clearance or treatment time, which is the time interval between arrival of police and emergency vehicles, towing trucks, and clearance of the incident. Accident treatment or clearance may include total freeway closure, towing vehicles involved in the incident to right/left shoulders, and eventually, leaving the incident scene. Finally the fourth phase is the recovery time or the time required for traffic conditions to return back to normal operation. Accident duration is the length of first three phases.

During the first three phases of an oversized vehicle accident, some lanes probably will be closed for accident treatment. If traffic demand exceeds the reduced capacity, a queue will develop and level of service (LOS) will deteriorate to F. After the blockage is removed, vehicle queues begin to dissipate, but full capacity can not be regained until all queues are dissipated. Before full capacity is regained, LOS E would best describe Traffic condition at phase 4 (Figure 1).

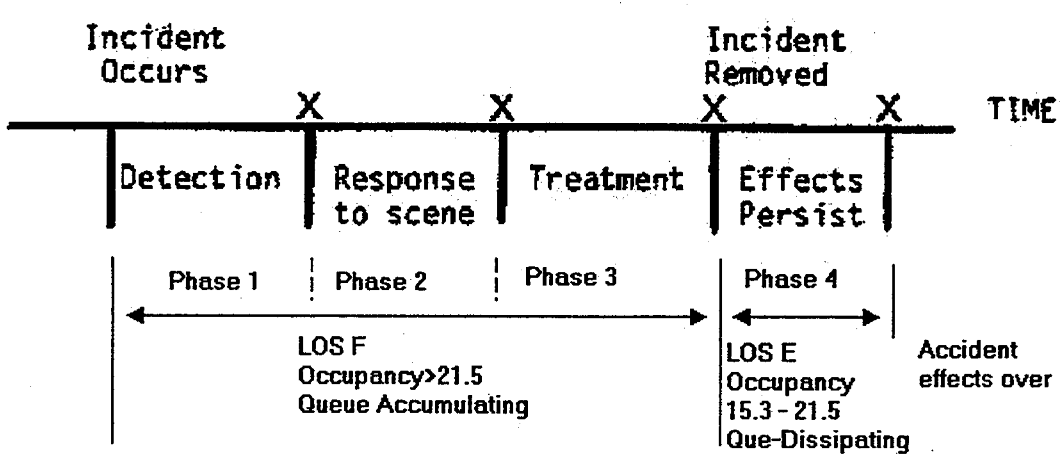

Figure 1. Four phases of an accident

3.1.2.1 Methods for Accident Delay Estimation

The methods for accident delay estimation were be classified by Al-Deek et al.[17] (1995) into three types:

1. Methods based on queuing analysis [for example, Morals (1986) and the TRB Highway Capacity Manual (1994 and 2000)]
2. Method based on shock wave analysis [for example, Wirashinghe (1978), and Chow (1974)]
3. Method based on freeway traffic simulation [for example, FRESIM (1994)]

The theoretical shock wave models assume constant densities throughout each traffic flow region, which affects the accuracy of the models. The Morales and HCM methods are widely used by practitioners and researchers to estimate incident delay [17]. To ensure the proposed methodology is practical in the field, a method similar to the HCM was adopted to estimate accident delay.

Although the method for delay estimation used in this thesis is similar to the HCM method, there is a significant difference between them.

Highway Capacity Manual 2000 uses the same queue discharge rate during the blockage and after the blockage removed. But it should be different in the field. When an oversized vehicle accident occurs, statistically there would be two lanes closed. From the accident phase 1 to phase 3, if demand exceeds capacity, a queue of vehicles will develop upstream of the accident location. If the gap between demand and reduced capacity increases, the rate by which the queue builds increases and the LOS will deteriorate to E or F. After the blockage is removed, the standing queue begins to dissipate and the level of service gets better. After the queue is over, the effect of accident will be over and finally full capacity will recover.

The methodology proposed by this project will use different q-discharge rates to represent these two different traffic phases. S_1 is used to represent q-dischage rate during blockage and S_2 for q-dischage rate after blockage is removed.

3.1.2.2 Reduced Capacity and Q-discharge Rate

Queue-discharge rate is the average traffic flow rate at an accident location during congestion. It is actually the rate of the queued vehicles being discharged from the accident zone. Reduced capacity (accident zone capacity) is an important parameter to describe the impact of the accident on traffic, but it is not necessarily needed in delay estimation, because accident zone capacity is not the exact number of vehicles passing through the accident location during congestion. As defined in the *Highway Capacity Manual 2000*, capacity is "maximum hourly rate". Although traffic flow rate could be occasionally higher than the accident zone capacity during congestion, the average flow rate should remain below the accident zone capacity.

Since accident zone capacity does not accurately represent the number of vehicles passing through the accident zone, it will not be used for delay estimation. Instead queue-discharge rate will be used for the estimation of traffic delay at the accident zone.

3.1.2.3 Accident Delay Quantification

Figure 2 is a simplified diagram that helps illustrate what happens to the traffic flow when an oversized vehicle accident occurs. Suppose that an oversized vehicle accident occurs on a four-lane freeway segment during the daylight hours. From the moment the accident occurs to the time it is cleared from the road, the blockage lasts 60 minutes. The slope of D1 represents the demand rate during the first hour and the slope of D2 represents the second hour demand. The queue-discharge rate from phase 1 to 3 is represented by the slope of S_1. Once the accident is cleared from the freeway, the queue-discharge rate is represented by the slope of S_2, which approaches to the freeway capacity. The triangle area is total vehicle delay. The first three phases are accident duration. The length from phase 1 to 4 is the time back to normal flow (TNF).

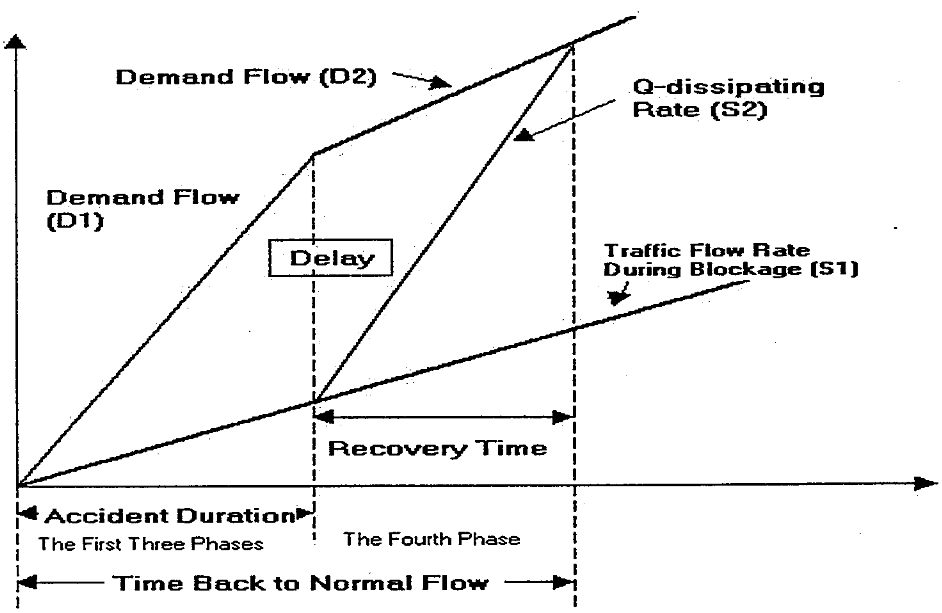

Figure 2. A simplified diagram to quantify delay

For the above diagram, the following equations for computing delay can be derived:

$$TNF = T_d + T_r \qquad (6)$$

Where:

TNF = time back to the normal flow

T_d = accident duration (read from the police accident reports, in minute)

T_r = recovery time (in minute)

An expression for the recovery time can be written as follows:

$$\text{Recovery Time} \quad T_r = \frac{\frac{T_d}{60}(D_1 - S_1) + D_2}{S_2} \qquad (7)$$

Where:

D_1 = the demand rate during the accident blockage

D_2 = the demand rate after the blockage is removed

S_1 = the average traffic flow rate during the accident blockage

S_2 = the queue dissipating rate after the blockage is removed

At the same time, the total vehicle delay can be calculated by the following equation:

$$\text{Total vehicle delay} = \tfrac{1}{2}\, T_d/60\, (D_1 - S_1)\, (T_d + D_2/S_2) \qquad (8)$$

3.1.3 Time-Dependent Traveling Risk Calculation

The traveling risk for oversized vehicles to pass through the section *s* at time *y* can be calculated by the following equation:

$$Risk_{sx} = (AccidentRate_{sx}) \times (AccidentConsequences_{sx}) \qquad (9)$$

Where:

$Risk_{sx}$ = traveling risk of passing section *s* at time *x*

$Accident\ Rate_{sx}$ = accident rate at section *s* at time *x*

$AccidentConsequence_{sx}$ = delay caused by the accident that occurred at section *s* at time *x*

$s \in$ (a, b, c,,, z); $x \in$ (6, 7, 8,,, 18)

3.1.4 Scheduling Method

After the values of $Risk_{sx}$ on the approved route are obtained, the minimum-risk scheduling solution can be identified by the following equations:

$$Risk_x = R_a^x + R_b^{x+n} + ... + R_s^{x+j} \qquad (10)$$

Where:

$Risk_x$ = total traveling risk of passing section *a*, section *b* ..... consecutively and finally passing section *s*

R_a^x = traveling risk of passing section *a* at time *x*

x = the time passing through section *a*, (in hour), $x \in$ [6,18] and $x+j \leq 18$;

x and $x+j$ should be within the time window restraint for oversized vehicle traveling

n = the distance between section a and section s, (in hour), $n \in [0, 12]$

R_b^{x+n}= traveling risk of passing section b at time $x+n$

Highway sections are denoted by s, s $\in$ (a, b, c,,, z)

The best scheduling solution $Risk_X$ should make sure that oversized vehicle traveling risk through out all of the study sections will be minimized. The best time X to pass section a could be identified by the following equation:

$$Risk_X = MIN(Risk_6, Risk_7, Risk_8,,, Risk_{18-j}) \quad (11)$$

Then the best time to pass Section s will be $X+j$

This scheduling method can be conducted based a worksheet as following:

Time	Risk @ A	Time	Risk @ B	.....	.....	Time	Risk @ S	Risk(X)
6	R_{a6}	6+n	$R_{b(6+n)}$	.....	.....	6+j	$R_{s(6+j)}$	***R(6)***
7	R_{a7}	7+n	$R_{b(7+n)}$	.....	.....	7+j	$R_{s(7+j)}$	***R(7)***
8	R_{a8}	8+n	$R_{b(8+n)}$	.....	.....	8+j	$R_{s(8+j)}$	***R(8)***
9	R_{a9}	9+n	$R_{b(9+n)}$	.....	.....	9+j	$R_{s(9+j)}$	***R(9)***
10	R_{a10}	10+n	$R_{b(10+n)}$	.....	.....	10+j	$R_{s(10+j)}$	***R(10)***
11	R_{a11}	11+n	$R_{b(11+n)}$	.....	.....	11+j	$R_{s(11+j)}$	***R(11)***
12	R_{a12}	12+n	$R_{b(12+n)}$	.....	.....	12+j	$R_{s(12+j)}$	***R(12)***
13	R_{a13}	13+n	$R_{b(13+n)}$	.....	.....	13+j	$R_{s(13+j)}$	***R(13)***
14	R_{a14}	14+n	$R_{b(14+n)}$	.....	.....	14+j	$R_{s(14+j)}$	***R(14)***
15	R_{a15}	15+n	$R_{b(15+n)}$	.....	.....	15+j	$R_{s(15+j)}$	***R(15)***
16	R_{a16}	16+n	$R_{b(16+n)}$	.....	.....	16+j	$R_{s(16+j)}$	***R(16)***
17	R_{a17}	17+n	$R_{b(17+n)}$	.....	.....	17+j	$R_{s(17+j)}$	***R(17)***
18	R_{a18}	18+n	$R_{b(18+n)}$	.....	.....	18+j	$R_{s(18+j)}$	***R(18)***

Table 1. Scheduling methodology based on worksheet.

Risk @ s = the traveling risk of passing through Section s.

Time 6 = Time interval between 5:30am and 6:30 am.

Suppose that it takes oversized vehicle n hours to travel from section a to b, and j hours from section a to s. Risk-minimum scheduling solution will be to pass section a at time X, then pass section b at time $X + n$, and finally pass section s at time $X + j$.

3.1.5 Section Selection Strategy

Along an approved route, if more sections with data involve in the risk computation, higher scheduling accuracy can be achieved. But there is a tradeoff between accuracy and workload. The permit office has three strategies in section selection:

1. All sections with data along the approved route
2. Only accident-prone sections (above a certain threshold of accident rate)
3. Only the most dangerous section (highest accident rates)

Due to a typically large number of candidate highway sections, strategy 1 will not be an efficient solution, which requires permit engineers to exam all the highway sections one by one. Strategies 2 and 3 seem to be more practical.

3.2 Scheduling Procedures and Steps

Summarily, the methodology consists of the following 3 procedures, which will be illustrated by a case study in the following chapters.

Procedure 1

Procedure 1 shows the steps to identify along an approved route the accident-prone segments that might be selected for further analysis. Procedure 1 is illustrated in Chapters 4 and 5.

Step1. Divide the approved route into smaller roadway sections to ensure traffic data collected can better describe the traffic pattern around these sections.

Step 2. Collect AADT from either reference books[18,19,20] or other data resources for each small section. Identify the total number of accidents during a given time period.

Step 3. Compute the accident rate for each section with Equation 2. Rank degree of hazardousness by accident rate and identify accident-prone sections.

Step 4. Use an appropriate section selection strategy to identify final study sections.

Procedure 2

Procedure 2 shows the steps to set up time-dependent traveling risk ($Risk_{sx}$) database for all the selected sections (final study sites) along the approved route. It will be illustrated in Chapter 6 and Chapter 7.

Step 1. Collect and compile traffic flow data (traffic flow by time of day) for the selected sections. Estimate hourly volume percentage by time of day. Convert AADT into hourly volume.

Step 2. Collect and compile detailed accident information, such as time and date of occurrence, distance from the interchange, number of lanes blocked, number of vehicles involved, type of vehicles involved. Exclude accidents in Category 1 from further analysis. Determine adjusted all-vehicle accident rate by time of day with Equation 4.

Step 3. Collect the traffic flow data (traffic flow, occupancy, and speed) corresponding to the time of accident occurrence for each final study site. Estimate queue-discharge rate by time of occurrence.

Step 4. Model the relationship between the traffic consequence and time of occurrence for each final study site

Step 5. Use Equation 9 to determine time-dependent traveling risk ($Risk_{sx}$). Establish $Risk_{sx}$ database for all the final study sites along the approved route

Procedure 3

Procedure 3 shows how to identify the risk-minimum scheduling solution for the approved route. It will be illustrated in Chapter 8.

Use proposed scheduling method (Equation 10 and Equation 11) and the $Risk_{sx}$ database to identify the minimum-risk scheduling solution.

Chapter 4: Case Study Description

In this section a case study that demonstrates the applicability of the proposed scheduling methodology is described briefly. Suppose a 10-foot wide oversized vehicle is approved to travel within the Hampton Roads area along the Interstate 64 west and then truning right onto the Virginia primary highway 264 east. The trip begins from the intersection of 64W and Indian River Road and ends at the intersections of 264 E and North Birdneck Road.

The two highway sections on 64 west and 264 east were respectively divided into 2 and 8 smaller sections. Each of them is about one mile long. Traffic and accident data were collected for each small section so that the traffic data can accurately describe the traffic conditions around these sections.

The sections on the Interstate 64 west are listed in Table 2 and sections on the Virginia primary highway 264 are listed in Table 3. Each of these sections is located between interchanges, one on either side, and is sufficiently far from the interchanges so as to be considered a basic freeway segment. The site name gives the interstate on which the site is located and the major roads on either side of the location. The length of the site is the distance between the ramps (major roads) on either side.

Section	Interstate 64 W Small Sections	From Node	To Node	Mileage
1	From Indian River to JB Norfolk Va Beach	483250	483251	1.36
2	From JB Norfolk Va Beach to Rt 264 E	483249	483250	0.83

Table 2: Sections on Interstate 64 West

Section	Primary Highway 264E Initial Small Sections	From Node	To Node	Mileage
3	From Newtown Rd to Witchduck Rd	541021	541025	1.15
4	From Witchduck Rd to Independence Rd	541026	541028	1.00
5	From Idependence Rd to Truck INSP. STA	541033	718379	1.25
6	From Truck INSP.STA to Rosement Rd	718380	541035	0.53
7	From Rosement Rd to Lynnhaven Parkway	541040	541041	1.42
8	From Lynnhaven Parkway to Great Neck Rd	541046	541048	1.06
9	From Great Neck Rd to Colonial Rd	541048	541049	1.22
10	From Colonial Rd to North Birdneck	541052	541055	1.19

Table 3: Sections on Virginia primary highway 264 West

Figure 3 shows the highway sections (blue lines) selected for case study.

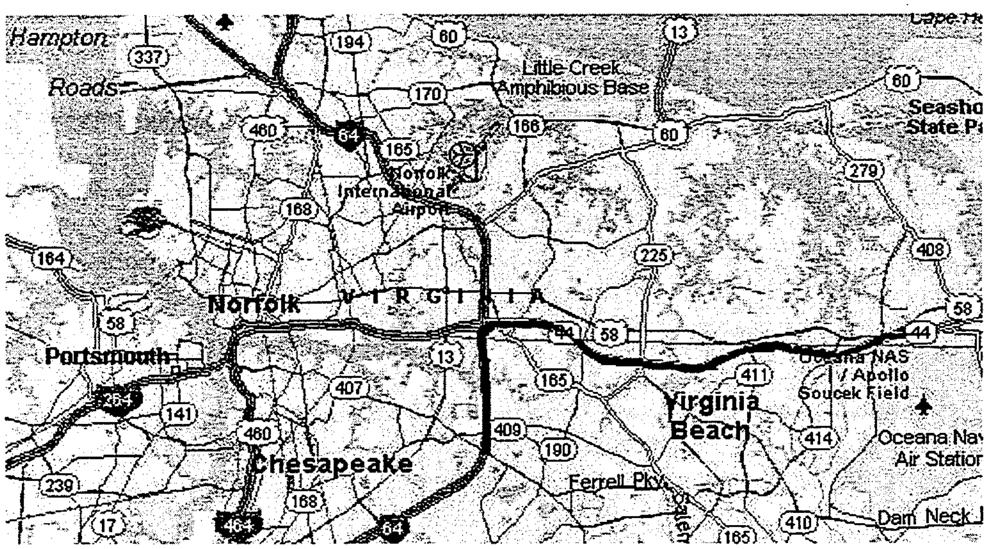

Figure 3. The route selected for case study

Chapter 5: Data Collection

In this section, traffic data (traffic flow by time of day) was collected from the Smart Travel lab at the University of Virginia. Accident data (number of total accidents for the samll sections) was extracted from the HTRIS database.

5.1 Traffic Data from the Smart Travel Lab

The Smart Travel Lab at the University of Virginia is connected to the Hampton Roads Smart Traffic Center in the Hampton Roads area. The lab receives traffic volume, speed, and occupancy data from the 203 detector stations on 31-km (19 mi.) of freeway and associated interchanges in the I-264/I-64 corridor in the Hampton Roads System. The lab receives the traffic flow data every 2 minutes from the detector stations and this data is archived in an *Oracle* database. The Lab has historic data for all the detector stations from June of 1998.[21]

The traffic data for this project were retrieved from the Master Database using *Data Xtractor v2.0*, a tool developed by the Smart Travel Lab. This tool allows for retrieving data from the database for a given period of time for any of the 203 stations in the Hampton Roads System.

The Excel database generated by the *Data Xtractor v2.0* (a data-extracting tool available in the Smart Travel Lab) has the following fields:

- Station ID
- Data and time of the traffic data

- The collection length which indicates the time period for which the traffic data was collected
- Number of vehicles that were spotted during the collection length
- Occupancy of the vehicles (in percentage) spotted during the collection length and
- Time mean speed (in mph) of the vehicles spotted during the collection length
- Number of Lanes with data

Appendix B shows a sample Excel file that includes the above-mentioned fields for the traffic records. The estimation of average hourly traffic flow percentage does not need occupancy and speed data. But these two parameters are needed at Step 3 of Procedure 2, which will be illustrated in Chapter 7.

The station ID gives the ID of the detector station located on the site. By identifying the station numbers at the chosen sites, the traffic flow data were thus obtained directly from the Smart Travel Lab in a spreadsheet format. Number of lanes with data is the number of lanes that have detectors functioning to collect traffic data. For example, Station 4 reports data only for two lanes but there are four lanes in the field. A simplified solution to this problem is that the total traffic volume for the site was computed by converting the lab data for four lanes by multiplying by a factor of two. The station IDs for the corresponding highway sections are given in Table 4 and Table 5.

Section	Interstate 64 W Small Sections	From Node	To Node	Mileage	Station ID
1	From Indian River to JB Norfolk Va Beach	483250	483251	1.36	21, 23
2	From JB Norfolk Va Beach to Rt 264 E	483249	483250	0.83	4

Table 4: Station numbers for the corresponding sections on 64W

Section	Primary Highway 264E Initial Small Sections	From Node	To Node	Mileage	Station ID
3	From Newtown Rd to Witchduck Rd	541021	541025	1.15	154, 155
4	From Witchduck Rd to Independence Rd	541026	541028	1.00	165, 167
5	From Idependence Rd to Truck INSP. STA	541033	718379	1.25	180, 182
6	From Truck INSP.STA to Rosement Rd	718380	541035	0.53	185
7	From Rosement Rd to Lynnhaven Parkway	541040	541041	1.42	193, 195
8	From Lynnhaven Parkway to Great Neck Rd	541046	541048	1.06	N/A
9	From Great Neck Rd to Colonial Rd	541048	541049	1.22	N/A
10	From Colonial Rd to North Birdneck	541052	541055	1.19	N/A

Table 5: Station numbers for the corresponding sections on 264E

5.2 Accident Data from the HTRIS Database

Since all the oversized vehicles have to travel during daylight hours, the accidents collected shall all fall within the following time window:

- From 6:00am to 6:00pm

The HTRIS database provides the time of occurrence of the accident to the nearest hour. For example, any crash that occurred between 7:30 AM and 8:30 AM in the morning will be assigned a time of 8.

Because weekday traffic pattern might be different from weekend traffic pattern, in the case study, only weekday data (both crash and traffic data) was used to illustrate the scheduling procedure. The same data collection and processing procedure applies to weekend data. The complete accident records in the past five years were used. So accident data collected are within another two time windows:

- From Monday to Friday
- From 01/01/1996 to 12/31/2000

Each freeway section has a starting node and an end node. After the starting and end nodes are identified, the HTRIS will come up with the length of the section and the number of accidents within a given period of time.

A sample spreadsheet showing the accident records with the fields of interest is included in Appendix C.

5.3 Average Annual Daily Traffic

Average Annual Daily Traffic (AADT) for the Virginia highway sections can be obtained from either the HTRIS database or reference books[18,19,20]. After AADT, total number of accidents, and lengths of study sections are identified, the accident rates (all-vehicle) for each study section can be computed by Equation (2). The results are put in Table 6 and Table 7.

Section	Interstate 64W Initial Small Sections	Miles	AccidNum	AADT	Accid Rate
1	From Indian River to JB Norfolk Va Beach	1.36	72	74200	39
2	**From JB Norfolk Va Beach to Rt 264 E**	**0.83**	**203**	**73500**	**182**

Table 6: All-vehicle accident rates for the sections on 64W

Section	Primary Highway 264E Initial Small Sections	Miles	AccidNum	AADT	Accid Rate
3	From Newtown Rd to Witchduck Rd	1.15	163	93250	83
4	**From Witchduck Rd to Independence Rd**	**1**	**153**	**79900**	**105**
5	From Idependence Rd to Truck INSP. STA	1.25	64	78500	36
6	From Truck INSP.STA to Rosement Rd	0.53	35	78500	46
7	From Rosement Rd to Lynnhaven Parkway	1.42	102	51250	77
8	From Lynnhaven Parkway to Great Neck Rd	1.06	30	36000	43
9	From Great Neck Rd to Colonial Rd	1.22	21	36000	26
10	From Colonial Rd to North Birdneck	1.19	25	36000	32

Table 7: All-vehicle accident rates for the sections on 264E

5.4 Section Selection Strategy

After the starting node and the end node of a study highway section are identified in the HTRIS database, all IDs of the accidents that occurred within this section will be displayed. Each accident ID was then used to obtain other detailed information about the accident such as:

- time and date of occurrence
- distance from the interchange

- number of lanes blocked
- number of vehicles involved
- type of vehicle involved

The information above cannot be obtained without checking all the accidents one by one in the HTRIS database, and this process has to be done manually. To reduce the workload, Section Selection Strategy Three was adopted: not all these sites, but only the most dangerous sites (highest accident rates) were selected for analysis. They are Section 2 on the Interstate 64 west and Section 4 on the Virginia primary highway 264 east (Table 8).

SITE	Route	Station ID	Final Study Site Description	Lanes	Miles	AADT	Total Accids	Accd Rate
SITE I	64 W	4	From JB Norfolk Va Beach to Rt 264 E	4	0.83	73500	203	182
SITE II	264E	165, 167	From Witchduck Rd to Independence Rd	4	1.00	79900	153	105

Table 8: Final Study Sites

Chapter 6: Accident Rate Calculation and Analysis

This section will complete Step 1 and 2 of Procedure 2, which will model relationships among time of day, accident rate, and traffic volume for the two final study sites on 64 west and 264 east.

In Chapter 3, it was suggested to use adjusted all-vehicle accident rate, AR_{adj}, to measure oversized vehicle accident probability, AP_{ov}. Oversized vehicle accident probability by time of day, AP_{ov}^{x}, can be computed by the following equations:

$$AP_{ov}^{x} = AR_{adj}^{x} = \frac{AccidNum_{ad}^{x} \times 100{,}000{,}000}{L \times AAHT_{x} \times 365 \times n} \qquad (12)$$

$$AAHT_{x} = AADT \times \partial_{x} \qquad (13)$$

Where

AP_{ov}^{x} = oversized vehicle accident probability at time x

AR_{adj}^{x} = adjusted all-vehicle accident rate at time x

$AccidNum_{adj}^{x}$= n years' number of categories 2 and 3 accidents occurred at time x

$AAHT_{x}$ = average annual hourly traffic at time x

$AADT$ = average annual daily traffic

∂_{x} = hourly traffic percentage at time x

x = time of day, $\in$ [6, 18]

Before the computation of AP_{ov}^{x} , ∂_{x} and $AccidNum_{adj}^{x}$ should be identified first. Next step is to estimate average hourly traffic percentage, ∂_{x}.

6.1 Weekday Traffic Volume by Time of Day

Traffic data were extracted from the Smart Travel Lab to estimate Annual Average Hourly Traffic (AAHT), (Table 9 and 10). ∂_x is the average hourly traffic percentage in the year of 2000 at time x (only weekday traffic data were used).

Time Period	Mar	Jun	Sept	Dec	Average ∂x
4:30 - 5:30	0.022	0.025	0.030	0.026	**0.026**
5:30 - 6:30	0.084	0.076	0.074	0.075	**0.077**
6:30 - 7:30	0.114	0.096	0.099	0.106	**0.104**
7:30 - 8:30	0.100	0.081	0.094	0.094	**0.092**
8:30 - 9:30	0.052	0.057	0.055	0.048	**0.053**
9:30 - 10:30	0.040	0.042	0.039	0.041	**0.040**
10:30 - 11:30	0.044	0.047	0.045	0.046	**0.045**
11:30 - 12:30	0.048	0.050	0.047	0.047	**0.048**
12:30 - 13:30	0.048	0.049	0.047	0.045	**0.047**
13:30 - 14:30	0.052	0.051	0.049	0.052	**0.051**
14:30 - 15:30	0.060	0.058	0.058	0.060	**0.059**
15:30 - 16:30	0.074	0.069	0.069	0.080	**0.073**
16:30 - 17:30	0.078	0.081	0.087	0.087	**0.083**
17:30 - 18:30	0.061	0.060	0.063	0.060	**0.061**
18:30 - 19:30	0.042	0.038	0.039	0.035	**0.039**

Table 9. Estimation of hourly traffic percentage by time of day at Site I

Time Period	Mar	Jun	Sep	Dec	Average ∂x
4:30 - 5:30	0.011	0.007	0.008	0.012	**0.009**
5:30 - 6:30	0.032	0.029	0.030	0.046	**0.034**
6:30 - 7:30	0.050	0.046	0.049	0.052	**0.049**
7:30 - 8:30	0.057	0.061	0.057	0.058	**0.058**
8:30 - 9:30	0.043	0.046	0.048	0.046	**0.046**
9:30 - 10:30	0.047	0.047	0.046	0.046	**0.046**
10:30 - 11:30	0.050	0.055	0.056	0.052	**0.053**
11:30 - 12:30	0.054	0.055	0.054	0.055	**0.054**
12:30 - 13:30	0.061	0.055	0.054	0.054	**0.056**
13:30 - 14:30	0.061	0.059	0.060	0.058	**0.059**
14:30 - 15:30	0.071	0.071	0.074	0.076	**0.073**
15:30 - 16:30	0.087	0.102	0.090	0.095	**0.094**
16:30 - 17:30	0.096	0.119	0.094	0.094	**0.101**
17:30 - 18:30	0.069	0.068	0.069	0.065	**0.068**
18:30 - 19:30	0.051	0.046	0.050	0.047	**0.049**

Table 10. Estimation of hourly traffic percentage by time of day at Site II

The values of ∂_x are presented graphically by Figure 4 and Figure 5. Figure 4 shows there are two well-shaped peak hour periods at site I.

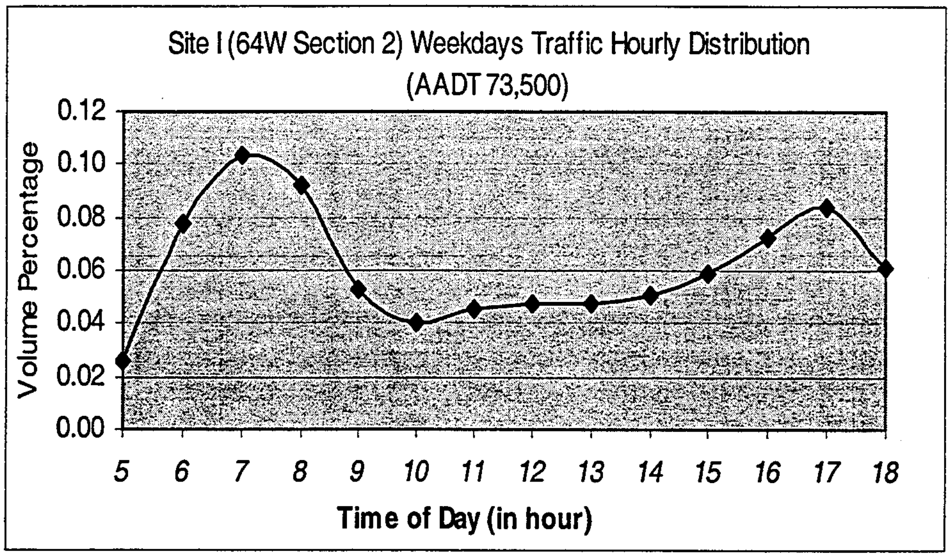

Figure 4. Weekday hourly traffic percentage by time of day at Site I

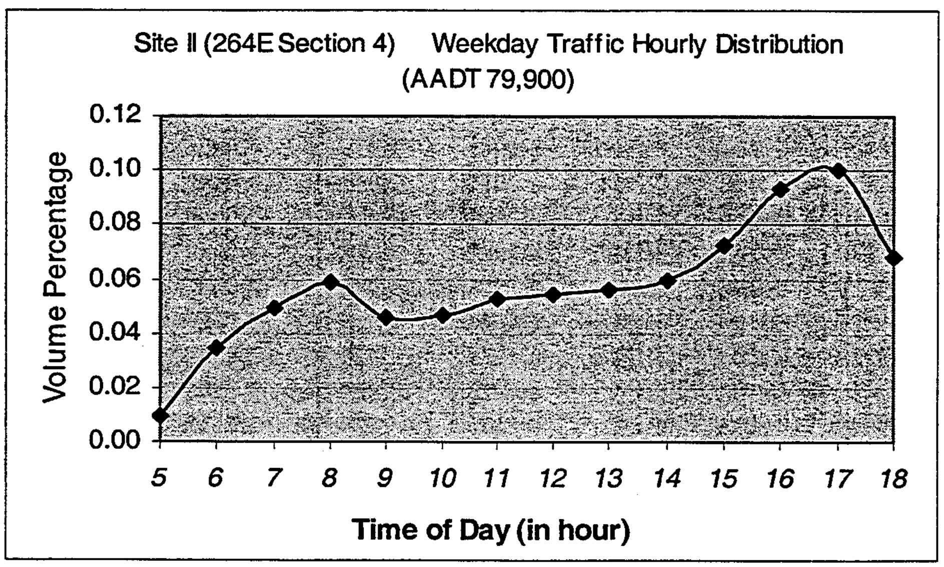

Figure 5. Weekday hourly traffic percentage by time of day at Site II

6.2 Accident Rate Calculation

As discussed in Chapter 3, accidents in Category 1 should be excluded from the computation of AP_{ov}^{x}. Besides, AADT and other detailed traffic information on ramps were not available, neither from the Smart Travel Lab, nor from the reference books. So these accidents that occurred on ramps will not be considered in the case study. In the HTRIS database, all the accidents that occurred at a distance of less than 0.04 miles away from the interchange are defined as intersection accidents. These accidents will be excluded from the case study. The criteria for accidents included are given below:

- They are sufficiently far away from ramps and interchanges (at least 0.04 miles away from ramps and interchanges)
- They are not single passenger car, van, and light truck accidents

The acceptable accident data after data screening is given in Table 11.

Data Screening	Site I	Site II
Total Accidents	203	153
After 1st data screening (accident categories 2 and 3)	191	137
After 2nd data screening (accidents on freeway section)	**152**	**81**

Table 11: acceptable accidents at the final study sites.

Detailed accident information like time of occurrence, number of vehicles involved, vehicle types, and number of lanes blocked will be collected manually only for the accidents that were accepted after two data screening processes. In Figures 6 and 7, the number of accepted accidents was distributed by time of day, for Site I and Site II respectively.

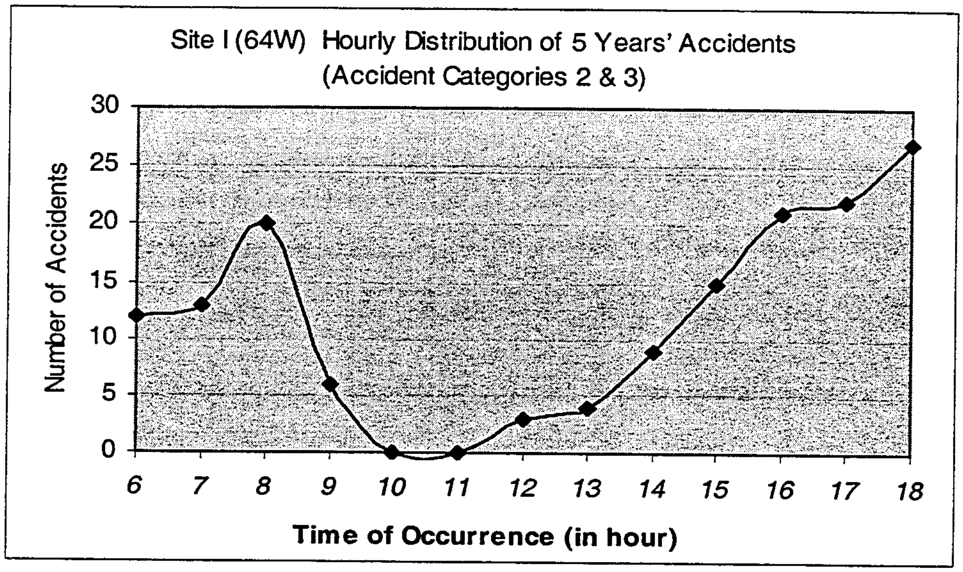

Figure 6: Hourly distribution of acceptable accidents by time of day, site I

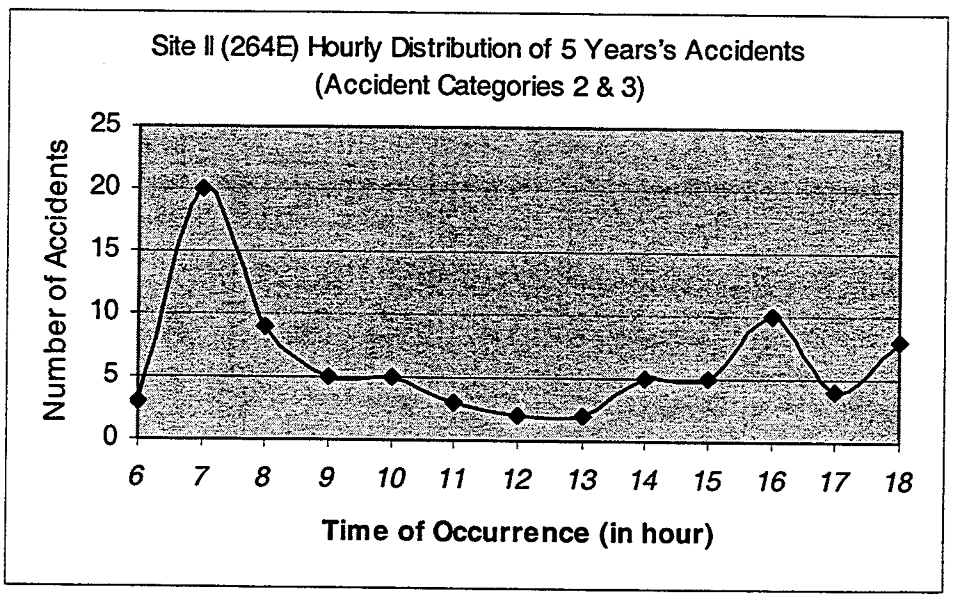

Figure 7: Hourly distribution of acceptable accidents by time of day, site II

After ∂_x and $AccidNum_{ad}{}^x$ are identified, $AP_{ov}{}^x$ can be computed by Equation 12. Figure 8 and Figure 9 show the results.

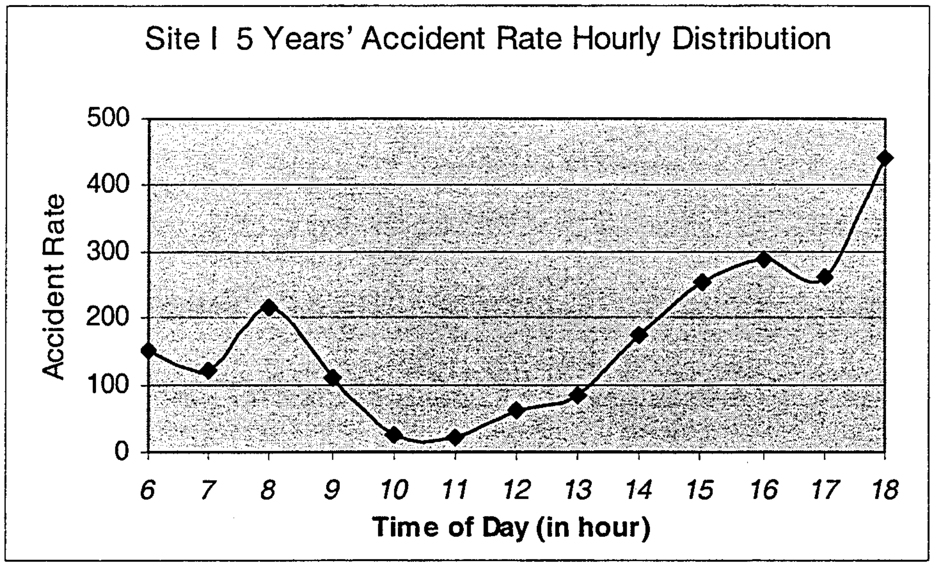

Figure 8. The oversized vehicle accident probability by time of day, Site I

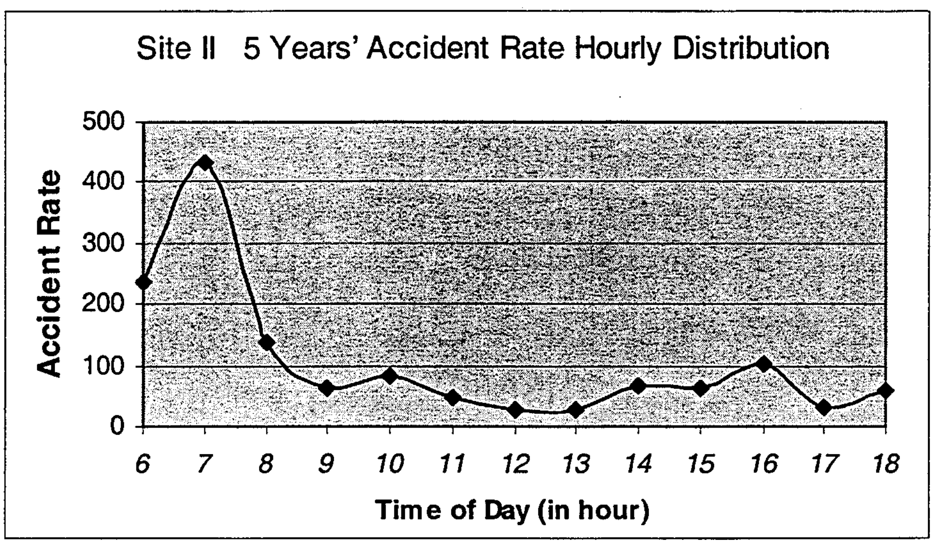

Figure 9. The oversized vehicle accident probability by time of day, Site II

At site II, even through the traffic volume during the afternoon peak hours is higher than traffic for other time periods (Figure 5), the accident rate during this time period is surprisingly low (Figure 9). An explanation is that under high traffic volumes, vehicles travel at lower speeds, which in turn decrease the speed variance which affects accident rate.

Figure 10 and Figure 11 represent the relationships between accident rate and traffic volume for the study sites. Figure 10 shows that high traffic volume does not lead to high accident rate. Basically there is a U-shaped relationship between accident rate and traffic volume. The highest accident rates occurred during hours in which low volume was observed.

At Site II, Figure 11 shows that when traffic volume goes up, the accident rate seems not affected.

Time	Hourly Volume %	AADT	**HVol**	Mile	AccidNum	**AccidRate**
6	0.077	73500	**5680**	0.75	12	**154**
7	0.104	73500	**7622**	0.75	13	**125**
8	0.092	73500	**6795**	0.75	20	**215**
9	0.053	73500	**3884**	0.75	6	**113**
10	0.040	73500	**2964**	0.75	1	**25**
11	0.045	73500	**3332**	0.75	1	**22**
12	0.048	73500	**3532**	0.75	3	**62**
13	0.047	73500	**3466**	0.75	4	**84**
14	0.051	73500	**3739**	0.75	9	**176**
15	0.059	73500	**4335**	0.75	15	**253**
16	0.073	73500	**5353**	0.75	21	**287**
17	0.083	73500	**6128**	0.75	22	**262**
18	0.061	73500	**4479**	0.75	27	**440**

Table 12. Accident Rate Hourly Distribution by Time of Day at Site I

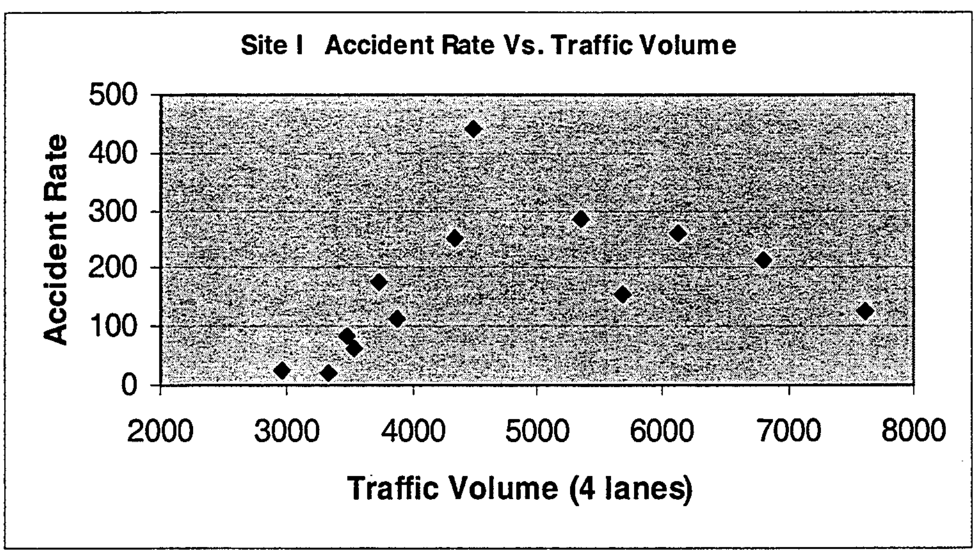

Figure 10. Accident Rate Vs. Traffic Volume at Site I

Time	Hourly Volume %	AADT	**HVol**	Mile	AccidNum	**AccidRate**
6	0.034	79883	2744	0.92	3	237
7	0.049	79883	3941	0.92	20	434
8	0.058	79883	4660	0.92	9	136
9	0.046	79883	3657	0.92	5	64
10	0.046	79883	3699	0.92	5	81
11	0.053	79883	4236	0.92	3	48
12	0.054	79883	4347	0.92	2	28
13	0.056	79883	4466	0.92	2	27
14	0.059	79883	4748	0.92	5	67
15	0.073	79883	5820	0.92	5	63
16	0.094	79883	7477	0.92	10	102
17	0.101	79883	8031	0.92	4	32
18	0.068	79883	5424	0.92	8	59

Table 13. Accident Rate Hourly Distribution by Time of Day at Site II

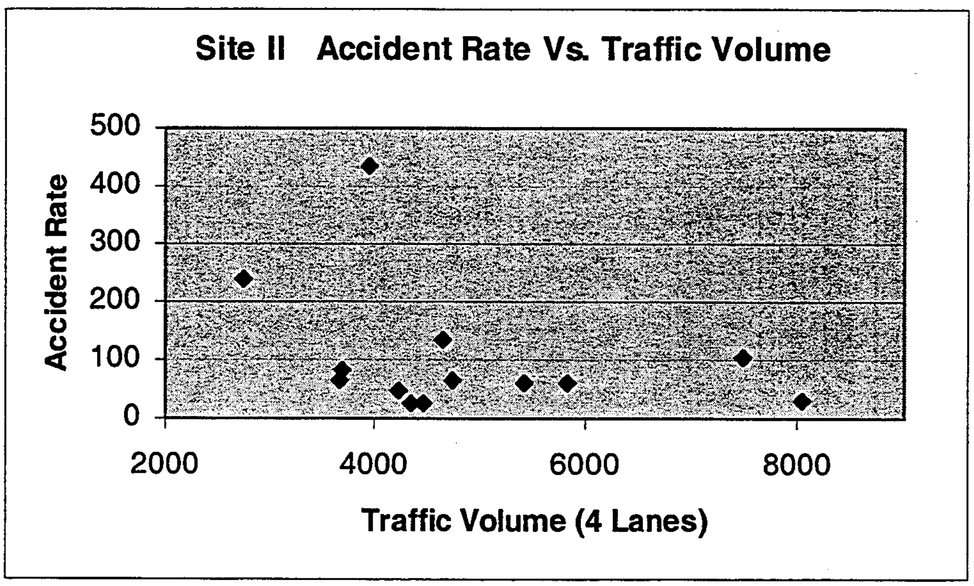

Figure 11. Accident Rate Vs. Traffic Volume at Site II

Chapter 7: Accident Consequence Calculation and Analysis

This chapter is going to model the relationships between accident consequence and time of occurrence for each final study site. It will take Step3 and 4 of Procedure 2 to get these results. It will also take Step 5 of Procedure 2 to set up $Risk_{sx}$ database.

7.1 Accident-caused Congestion Quantification

In Chapter 3, the magnitude of accident-caused congestion is measured by time back to the normal traffic flow (TNF). TNF is the length of time it takes for traffic to resume the normal operations after the occurrence of oversized vehicle accidents. It can be computed by the following equations:

$$TNF = T_d + T_r \qquad (6)$$

$$T_r = [T_d/60(D_1 - S_1) + D_2]/S_2 \qquad (7)$$

Where:

TNF = time back to the normal traffic flow

T_d = accident duration (obtained from the police reports for traffic accidents, in minute)

T_r = recovery time (in minutes)

D_1 = the demand rate during the accident blockage

D_2 = the demand rate after the blockage is removed

S_1 = the traffic flow rate during the accident blockage

S_2 = the queue dissipating rate after the blockage is removed

Oversized vehicle accident durations can be obtained either from the HTRIS database or from police accident reports. The police reports can be obtained from the VDOT main office in Richmond. In the case study, two estimations were made based on the study of the collections of accident duration of large and oversized vehicles in the past five years (from 01/01/1996 to 12/31/2000). They are:

1. Average oversized vehicle accident duration (T_d), estimated to be 1 hour
2. Average number of lanes blocked, estimated to be 2

The demand flow is generally fixed by external circumstances, such as the location of study segments, number of lanes, and time of day. The hourly distributions of weekday traffic volume for Site I and Site II were determined in the Chapter 6 (See Figure 6 and Figure 7). Next step is to estimate S_1 and S_2.

7.2 Queue-discharge Rate Estimation

This sub-section is to estimate S_1 and S_2. Figure 12 illustrates a procedure to estimate S_1 and S_2.

After accident time and location are identified, the traffic flow, speed, and occupancy right before and after the accident can be obtained from the Smart Travel Lab. The traffic flow, speed and occupancy before and after a historical accident that occurred in the year of 2000 on Virginia Primary Highway 264 East was displayed in Figure 12.

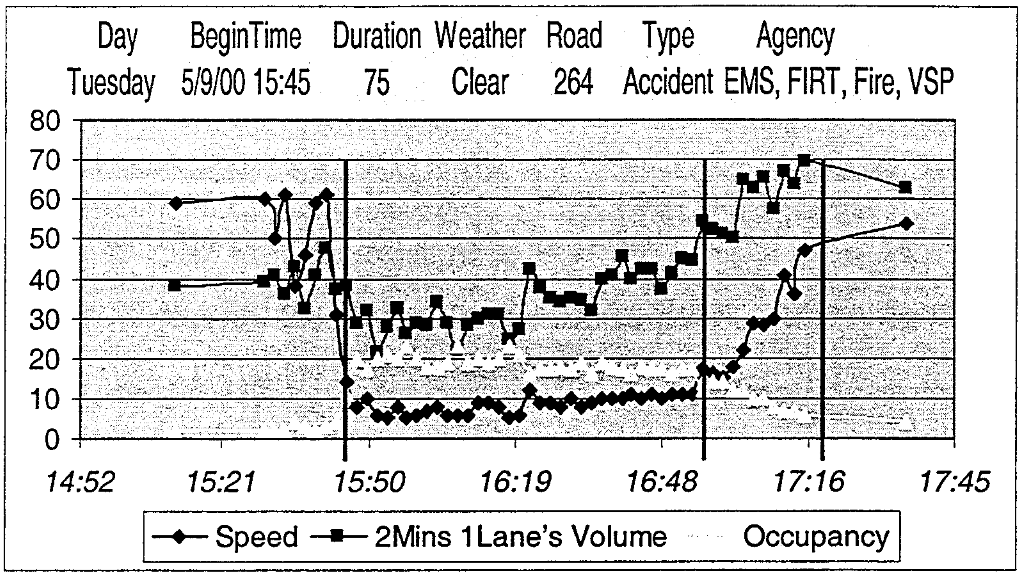

Figure 12. Traffic flow, speed, and occupancy curves for Q-discharge rate identification

Since S_1 is defined as the average traffic flow within accident duration, it would be the equivalent hourly flow converted by the average traffic volume during accident-cause blockage. Figure 12 shows that during the accident-caused congestion, the vehicle speed in the accident zone is considerably lower and traffic flow rate changes irregularly. During accident-caused blockage, occupancy increases dramatically up to 20 (the corresponding Level of Service is F). The police report shows that the blockage lasted 75 minutes before the final clearance of accident. According to the changes of occupancy, the accident duration is estimated to be between 15:44 and 17:00. So S_1 would be the equivalent hourly flow converted by the traffic volume between 15:45 and 17:00.

The recovery time is the time required for traffic conditions to return to normal operation after blockage is removed. S_2 can be estimated by the equivalent hourly flow converted from the average traffic volume during the recovery time. When the occupancy decreases to 8 (LOS C), the traffic returns to normal condition and the recovery time is over. So S_2 would be the equivalent hourly flow converted from the average traffic volume between 17:00 and 17:20.

Following the procedure illustrated by Figure 12, five years' large and oversized vehicle accidents were collected from the HTRIS database for the final study sections. The traffic flow data (flow, occupancy, and speed) within the time period between one hour before and three hours after the time of occurrence was collected from the smart travel lab to conduct S_1 and S_2 estimation. Based on the historical traffic data collected before and after accidents, S_1 and S_2 can be estimated by the average traffic flow during blockage and after blockage. The results for Site I and Site II are given in Table 14.

Mean Q-discharge Rate	Site I	Site II	Lanes Open
S1	2549	2124	2
S2	7037	7762	4

Table 14. Q-discharge rates during and after blockage for Site I and Site II

After traffic demand (D_x) and the queue discharge rate (S_1 *and* S_2) are identified, TNF at the accident zone can be calculated by Equation (6). The results are given in Table 15 and Table 16, and graphically presented by Figure 13 and Figure 14.

Time	Initial D1	Mean S1	Que	Cumulative D2	Mean S2	TNF (Minutes)
6	5680	2549	3131	10753	7037	>120
7	7622	2549	5072	11868	7037	>120
8	6795	2549	4246	8130	7037	>120
9	3884	2549	1335	4299	7037	97
10	2964	2549	415	3747	7037	92
11	3332	2549	783	4315	7037	97
12	3532	2549	983	4449	7037	98
13	3466	2549	917	4656	7037	100
14	3739	2549	1190	5525	7037	107
15	4335	2549	1786	7139	7037	>120
16	5353	2549	2804	8932	7037	>120
17	6128	2549	3579	8058	7037	>120
18	4479	2549	1930	1930	7037	76

Table 15. Magnitude of Accident Delay by Time of Occurrence at Site I

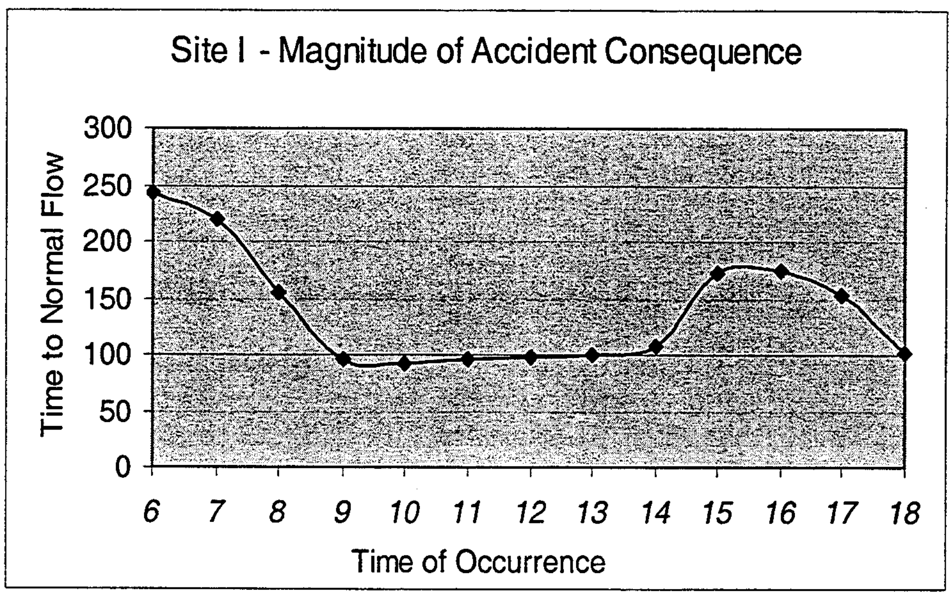

Figure 13. Magnitude of Accident Delay Distribution by Time of Occurrence at Site I

Time	Initial D1	Mean S1	Que	Cumulative D2	Mean S2	TNF (Minutes)
6	2744	2124	621	4562	7762	95
7	3941	2124	1817	6477	7762	110
8	4660	2124	2536	6194	7762	108
9	3657	2124	1534	5233	7762	100
10	3699	2124	1576	5812	7762	105
11	4236	2124	2113	6460	7762	110
12	4347	2124	2224	6690	7762	112
13	4466	2124	2343	7091	7762	115
14	4748	2124	2625	8444	7762	>120
15	5820	2124	3696	11174	7762	>120
16	7477	2124	5354	13385	7762	>120
17	8031	2124	5907	11331	7762	>120
18	5424	2124	3301	3301	7762	86

Table 16. Magnitude of Accident Delay by Time of Occurrence at Site II

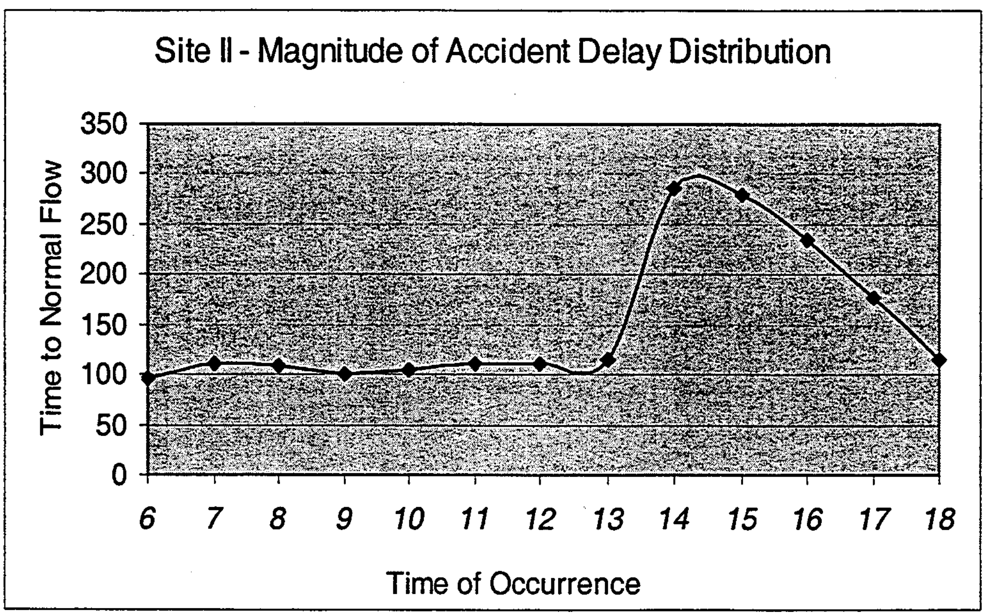

Figure 14. Magnitude of Accident Delay Distribution by Time of Occurrence at Site II

7.3 Traveling Risk of Passing the Study Sections

This sub-section takes Step 5 of Procedure 2 to identify the oversized vehicle traveling risks by time of day for the two selected sites.

After accident rates were obtained in Chapter 6 and time back to normal flow (TNF) was identified in the previous sub-section, the traveling risk of passing though each selected site by time of day can be determined by Equation (9), which was given in Chapter 3.

$$Risk_{sx} = (AccidentRate_{sx}) \times (AccidentConsequences_{sx}) \qquad (9)$$

The time-dependent risks of passing through the selected sites, together with the TNF, accident rate, and traffic demand, are given in Table 17 and Table 18, respectively for Site I and Site II. In order to display the values of these two parameters within the range from 0 to 600, traffic demand is divided by 4 and risk is divided by 100.

RISKsx at Sit I (64W Section 2)				
Time	Demand(plph/4)	Crash Rate	TNF	Risk/100
6	355	154	243	375
7	476	125	220	274
8	425	215	155	333
9	243	113	97	109
10	185	25	92	23
11	208	22	97	21
12	221	62	98	61
13	217	84	100	84
14	234	176	107	188
15	271	253	173	437
16	335	287	174	499
17	383	262	153	401
18	280	440	101	445

Table 17. Traffic Demand, Crash Rate, Consequence, and Risk Curves for Site I

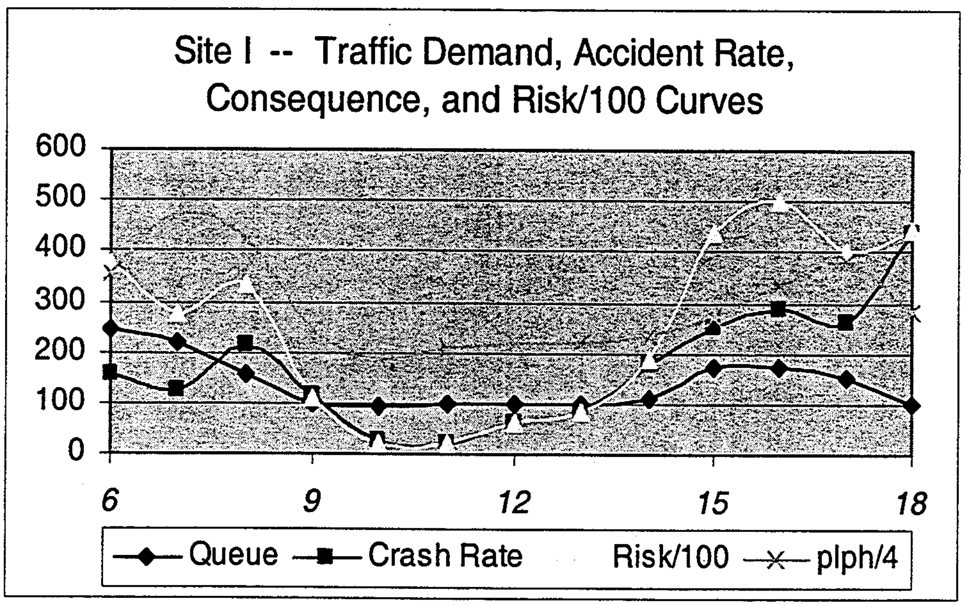

Figure 15. Traffic Demand, Crash Rate, Consequence, and Risk Curves for Site I

RISKsx at Sit II (264E Section 4)				
Time	Demand(plph/4)	Crash Rate	TNF	Risk/100
6	172	237	95	225
7	246	434	110	478
8	291	136	108	147
9	229	64	100	64
10	231	81	105	85
11	265	48	110	53
12	272	28	112	31
13	279	27	115	32
14	297	67	287	191
15	364	63	280	176
16	467	102	235	240
17	502	32	178	57
18	339	59	116	69

Table 18. Traffic Demand, Crash Rate, Consequence, and Risk Curves for Site II

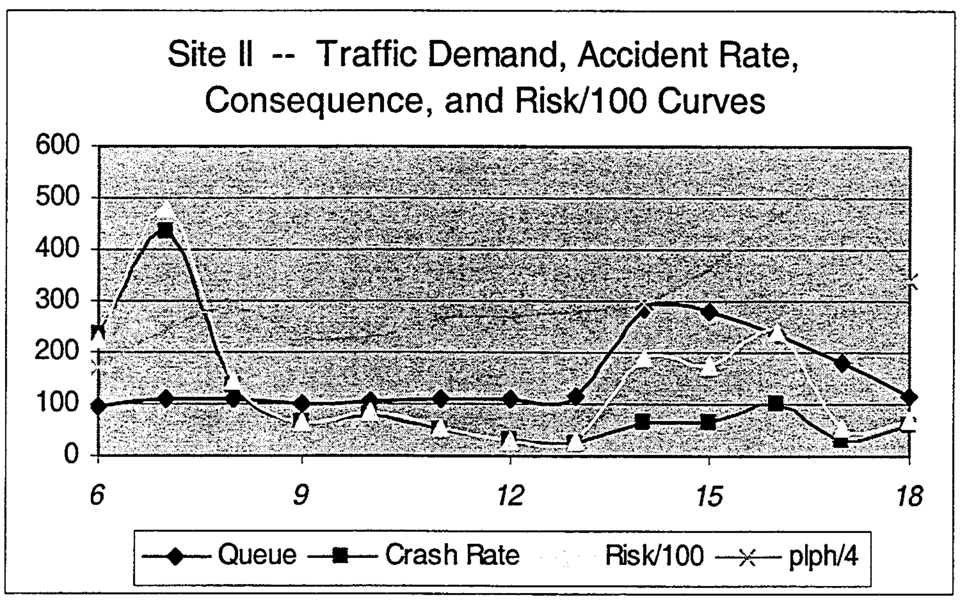

Figure 16. Traffic Demand, Crash Rate, Consequence, and Risk Curves for Site II

Chapter 8: Scheduling Methodology and Solutions

This section employs Procedure 3, which will use the proposed scheduling method in Chapter 3 and the $Risk_{sx}$ database established in Chapter 7 to identify the minimum-risk scheduling solution.

The scheduling method is based on worksheet foundation. Because in the case study there are only two final study sties, the scheduling method can be described by the following equations:

$$Risk_x = R_1^x + R_2^{x+j} \qquad (13)$$

Where:

$Risk_x$ = total traveling risk of passing Site I at time x, and then passing Site II at time $x+j$

R_1^x = traveling risk of passing Site I at time x, $x = 6, 7, 8,,,18\text{-}j$

x = the time of passing through Site I, (in hour)

j = the distance between Site I and Site II, (in hour)

R_2^{x+j}= traveling risk of passing Site II at time $x+j$

The best scheduling solution should make sure that traveling risk through Site I and Site II would be minimized. It can be identified by Equation (11) given in Chapter 3:

$$Risk_x = MIN(Risk_6, Risk_7, Risk_8,,, Risk_{18-j}) \qquad (11)$$

8.1 Scheduling Solution Analysis

In the case study, Site I and Site II are located very closely to one another. The travel time between them is less than 30 minutes. The minimum risk traveling schedule can be identified by worksheet I. The best time to pass Site I and Site II is any time between 10:30 and 11:30. In this way the total traveling risk will be minimized.

Site I		Site II		
Time	Risk/100	Time	Risk/100	Sum of Risk
6	375	6	225	600
7	274	7	478	752
8	333	8	147	480
9	109	9	64	173
10	23	10	85	108
11	**21**	**11**	**53**	**74**
12	61	12	31	92
13	84	13	32	116
14	188	14	191	380
15	437	15	176	613
16	499	16	240	739
17	401	17	57	458
18	445	18	69	514

Table 19. The minimum risk traveling schedule identification, Worksheet I

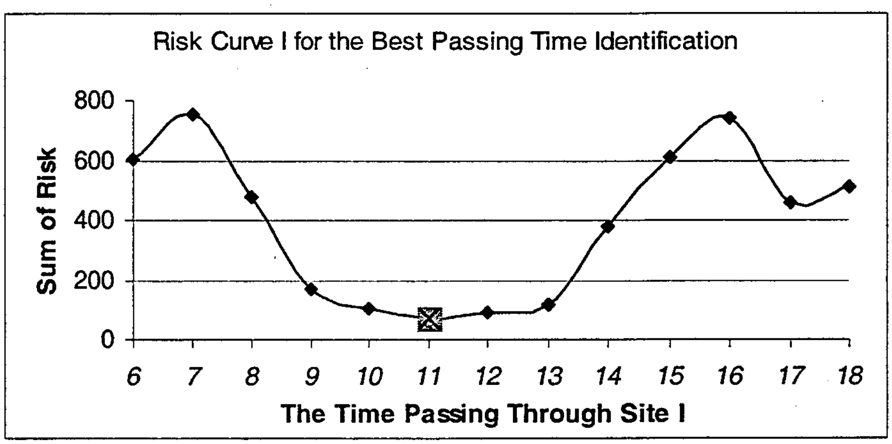

Figure 17. Risk Curve I for the minimum risk traveling schedule identification

In order to better illustrate the scheduling method, we go on to examine what would be the risk-minimum scheduling strategy if the travel time between Site I and Site II were longer.

If the travel time between Site I and Site II is more than 30 minutes but less than 90 minutes, it is simplified as one-hour distance between them. The risk-minimum scheduling solution can be identified by worksheet II. The total traveling risk will be minimized if the oversized vehicle passes Site I between 10:30 and 11:30, and then passes Site II between 11:30 and 12:30.

Site I		Site II		
Time	Risk/100	Time	Risk/100	Sum of Risk
6	375	7	478	853
7	274	8	147	421
8	333	9	64	397
9	109	10	85	195
10	23	11	53	76
11	**21**	**12**	**31**	**53**
12	61	13	32	92
13	84	14	191	276
14	188	15	176	364
15	437	16	240	678
16	499	17	57	555
17	401	18	69	470

Table 20. The minimum risk traveling schedule identification, Worksheet II

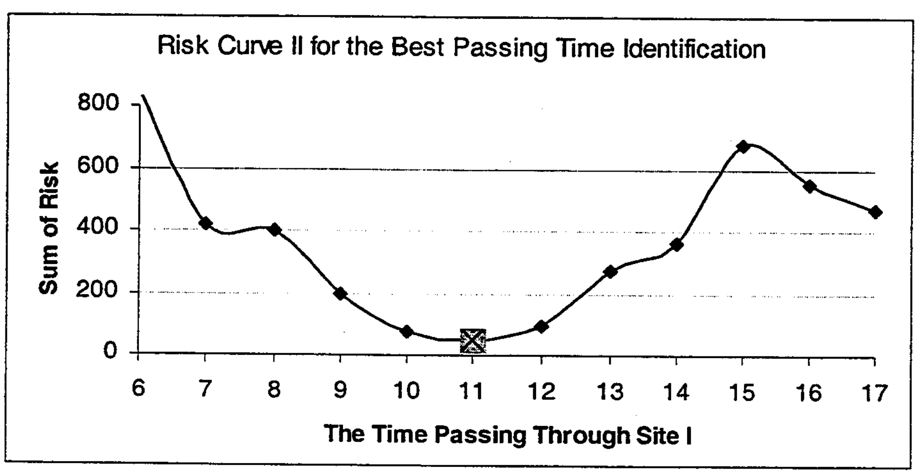

Figure 18. Risk Curve II for the minimum risk traveling schedule identification

If the travel time between Site I and Site II is more than 90 minutes but less than 150 minutes, it is simplified as a two-hour distance between them. The risk-minimum traveling schedule can be identified by worksheet III. Although the traveling risk at time 10 is a little higher than that of time 11, compared with the traveling risk at other times of day, this small difference is not significant and can be ignored. The best time to pass Site I will be between 9:30 and 11:30, then the best time to pass Site II will be anytime between 11:30 and 13:30.

Site I		Site II		
Time	Risk/100	Time	Risk/100	Sum of Risk
6	375	8	147	522
7	274	9	64	338
8	333	10	85	419
9	109	11	53	163
10	**23**	**12**	**31**	**54**
11	**21**	**13**	**32**	**53**
12	61	14	191	252
13	84	15	176	260
14	188	16	240	429
15	437	17	57	494
16	499	18	69	568

Table 21. The minimum-risk traveling schedule identification, Worksheet III

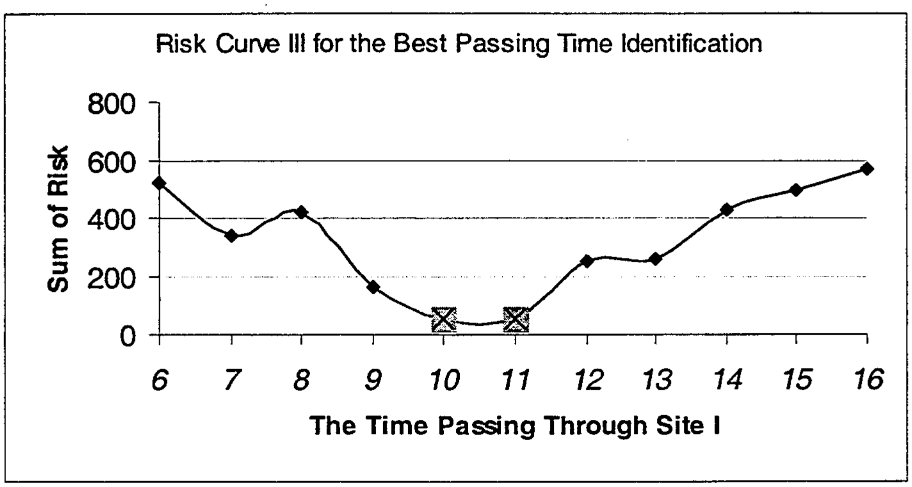

Figure 19. Risk Curve III for the minimum risk traveling schedule identification

When the travel time between Site I and Site II is more than 150 minutes but less than 210 minutes, the traveling risk will be minimized if the oversized vehicle passes Site I between 9:30 and 10:30, and then pass the Site II anytime between 12:30 and 13:30.

Site I		Site II		
Time	Risk/100	Time	Risk/100	Sum of Risk
6	375	9	64	439
7	274	10	85	360
8	333	11	53	386
9	109	12	31	141
10	**23**	**13**	**32**	**54**
11	21	14	191	213
12	61	15	176	236
13	84	16	240	325
14	188	17	57	245
15	437	18	69	506

Table 22. The minimum risk traveling schedule identification, Worksheet IV

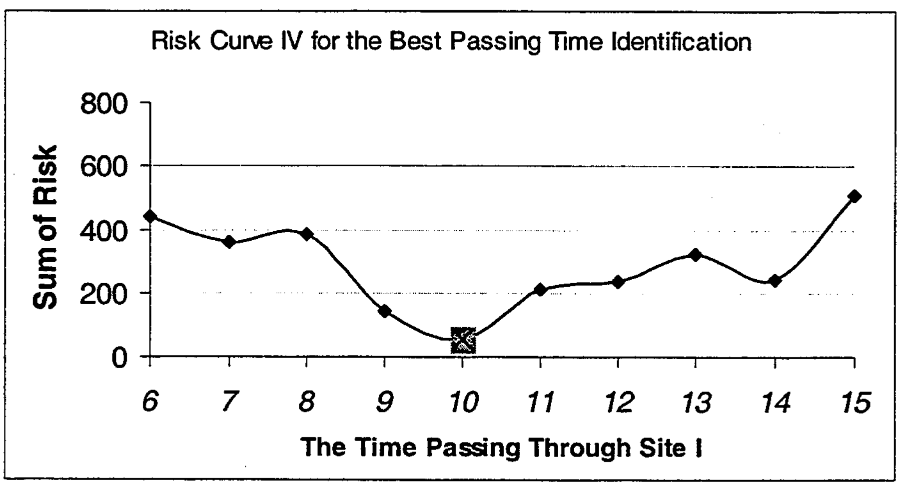

Figure 20. Risk Curve IV for the minimum risk traveling schedule identification

If the travel time is more than 210 minutes and less than 270 minutes, it is simplified as a four-hour distance between them. The best scheduling solutions can be:

- Pass Site I between 8:30 and 9:30 and then pass Site II anytime between 14:30 and 13:30, or
- Pass Site I between 12:30 and 13:30 and then pass Site II anytime between 16:30 and 17:30

It is noted that in this example oversized vehicle has to travel within one of the peak hour periods to make total traveling risk minimum.

Site I		Site II		
Time	Risk/100	Time	Risk/100	Sum of Risk
6	375	10	85	461
7	274	11	53	327
8	333	12	31	365
9	**109**	**13**	**32**	**141**
10	23	14	191	214
11	21	15	176	197
12	61	16	240	301
13	**84**	**17**	**57**	**141**
14	188	18	69	257

Table 23. The minimum risk traveling schedule identification, Worksheet V

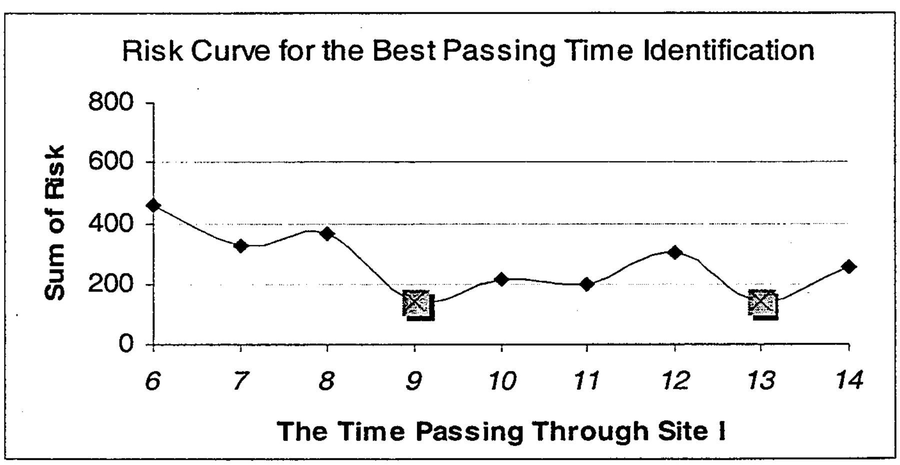

Figure 21. Risk Curve V for the minimum risk traveling schedule identification

Summarily, these scheduling solutions show that when travel distance is short, the shape of the risk curve will be similar to that of traffic volume and the best time to pass the study sections will probably be found during off-peak hour periods. But when travel time is long, such as more than 4 hours in Virginia, the shape of cumulative risk curves is "distorted" and not similar to that of traffic volume curves. The best passing time might be hard to predict and probably is not located within off-peak hour periods.

Chapter 9: Conclusions and Recommendations

The conclusions and recommendations are given in this section.

9.1 Conclusions

These study results show that to avoid peak-hour periods is not always a good strategy for scheduling. Figures 4 and 5 show that different highway segments might have different traffic patterns and different time windows for peak hours. It is not appropriate to apply a standard peak-hour time window to all highway sections without a traffic pattern study for each highway segment. Besides, both of the final study sites show that high traffic volume does not lead to high accident rate. At Site I, there was a U-shaped relationship between accident rate and traffic volume (Figure 10). At Site II, it was found that when traffic volume went up, the accident rate seemed not to be affected (Figure 11). So avoiding peak hours does not necessarily guarantee drivers avoid the highest accident probability in the whole trips.

This project presented a methodology that is intended to enhance oversized vehicle driving safety by minimizing both accident probability and accident consequence. Figures 15 and 16 show that accident rate, accident consequence, and risk do vary remarkably by time of day. It means that a good travelling schedule is capable to reduce accident rates and accident consequence.

The case study shows that the proposed methodology is easily implemented in the field. The implementation of scheduling method is based on the $Risk_{sx}$ database. If $Risk_{sx}$ is available for each segments on the approved route, Risk-minimum scheduling strategy can be easily identified by either the Permit Office or the trucking companies themselves.

9.2 Recommendations

The proposed scheduling methodology requires both accident and traffic data. AADTs on interstate, arterial and primary routes are available from the reference books[18,19,20]. Accident data can be extracted from the HTRIS database. But traffic data (traffic volume by time of day) is available only for limited Virginia highway segments.

There are two options to deal with this problem. One is to set up more detector stations in Virginia highway systems. The use of hourly traffic percentage based on study routes is generally preferable, because these values will be most suited to local conditions. But it is costly and cannot be implemented immediately. Another option is to establish a default hourly traffic percentage for all the highway segments that share the same geometric characteristics, like roadway type and area type (urban or rural). Since AADTs for each highway segments are available from the reference books, hourly traffic can be computed by multiplying AADT with the corresponding default hourly traffic percentage for a specific roadway type. This eliminates the need to set up detector stations all around Virginia. The second option seems more feasible and is recommended by this project.

In the proposed scheduling methodology, only accident-caused delay was taken into consideration. The delay caused by oversized vehicles traveling on the road was not considered in the risk analysis model. The incorporation of this delay into the scheduling method will generate a more practical result. It could be an area for further search.

References

[1] Highway laws of Virginia, 1998.

[2] Virginia Hauling Permit Manual, 1996.

[3] Pfundt K. 1969. *Three difficulties in the comparison of accident rates.* Accident Analysis and Prevention. Vol. 1. pg. 253-259.

[4] Garber, N.J. and Ravi Gadiraju. 1988. *Factors Affecting Speed Variance and Its Influence on Accidents.* AAA Foundation for Traffic Safety. Falls Church, VA. July 1988.

[5] Nicholas J. Garber and Angela Ehrhart. 2000. *The effect of Speed, Flow, and Geometric Characteristics on Crash Frequency on Different Types of Highways.* VTRC Report No. 00-R15. Charlottesville, Virginia Transportation Research Council.

[6] Hall, J. W. and O. J. Pendelton. 1990. *Rural Accident Rate Variations with Traffic Volume.* Report No. TRR 1281. Pg. 62-70. Transportation Research Board. National Research Council. Washington, D.C.

[7] Gwynn, David W. 1967. *Relationship of Accident Rates and Accident Involvements with Hourly Volumes.* Traffic Quarterly. Vol. XXI. No. 3. pg. 407-418.

[8] Lina K. Nozick, Mark A. Turnquist, George F. List. *Electronic Issuance of Special Hauling Permits.* Proceeding of the 1995 Annual Meeting of ITS AMERICA, 1995

[9] Roberto Osegueda; Alberto Garcia-Diaz; Suleiman Ashur; Octavio Melchor, *GIS-based network routing procedures for overweight and oversized vehicles*, Journal of Transportation Engineering, Vol. 125, i4 P324 (8), 1999.

[10] Leatherwood, TD, *The Application of Groupware Software Systems to Permit Vehicle Routing,* Eighth Transportation Research Board Conference on Bridge Management, 1999

[11] Robert Borhart, Cindy Jackson, and Andrew Hager, *Review of Virginia's Program To Regulate and Control Highway Transpot of Overwidth Vehicles.* Virginia Transportation Research Council, 1994.

[12] Nicholas J. Garber, Lester A. Hoel, Traffic and Highway Engineering, second edition. PWS publishing, 1996.

[13] *Guidelines for Applying Criteria to Designate Routes for Transportation Hazardous Material.* Research and Special Programs Administration, U.S. Department of Transportation, 1994.

[14] *Large Truck Crash Profile: The 1997 National Picture,* National Highway Traffic Safety Administration, U.S. Department of Transportation.

[15] *Large Trucks Traffic Safety Facts 1995*, National Highway Traffic Safety Administration, U.S. Department of Transportation,

[16] Highway Capacity Manual 2000

[17] Al-Deek, H.M., Garib, A., and Radwan, A. E. *New Method for Estimating Freeway Incident Congestion*. Transportation Research Record, 1494, 1995.

[18] *1997 Average Daily Traffic Volumes with Vehicle Classification data on Interstate, Arterial and Primary Routes*. Commonwealth of Virginia, Department of Transportation

[19] *1999 Average Daily Traffic Volumes with Vehicle Classification data on Interstate, Arterial and Primary Routes*. Commonwealth of Virginia, Department of Transportation

[20] *2000 Average Daily Traffic Volumes with Vehicle Classification data on Interstate, Arterial and Primary Routes*. Commonwealth of Virginia, Department of Transportation

[21] Nicholas Garber and Sankar Subramanyan, *The Feasibility of Developing Congestion Mitigation Measures That Incorporate Crash Risk. A Case Study: Hampton Roads Rear*. 2000

[22] Jian, Y. Traffic Capacity, *Speed and Queue-Discharge Rate of Indiana's Four-Lane Freeway Work Zones*. Transportation Research Record 1657, TRB, National Research Council, Washington, D.C., 1999.

[23] Ni-Bin Chang, H. Y. Lu, and Y. L. Wei, *GIS technology for vehicle routing and scheduling in solid waste collection systems*, Jounal of Environmental Engineering, Vol. 123, No. 9, 1997

[24] Garber, NJ; Patel, S; Kalaputapu, R, *The Effect of Trailer Width and Length on Large-Truck Accident, Final Report,* Virginia Transportation Research Council, 1992.

[25] Garber J. Garber; Sarath C. Joshua, *Traffic and Geometric Characteristics Affecting the Involvement of Large Trucks in Accidents, Volume 1.* Virginia Transportation Research Council, 1990

[26] Nicholas J. Garber, Kirsten A. Black, *Advanced technologies for improving large-truck safety on two-lane secondary roads*, Virginia Transportation Research Council, 1995.

[27] A. Garib, A. Radwan, and H. Al-Deek, *Estimating Magnitude and Duration of Incident Delays*. Journal of Transportation Engineering, 1998.

[28] Lester A. Hoel, et al. *Truck Weight Limits – Issues and Options,* special report 225, Transportation Research Board. 1990

[29] *Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials.* Report DOT/RSPA/OHMT-89-02. Research and Special Programs Administration, U.S. Department of Transportation, 1989.

[30] Douglas W.H., John G.V., and Eugene R.R. *Truck Accident Rate for Hazardous Material Routing.* Transportation Research Record, 1264, 1990.

[31] List, GF; Nozick, LK;Turnquist, MA, 1994. *Improved Customer Service and Automated Route Verification for the Issuance of Special Hauling Permits by the New York State Department of Transportation.* University Transportation Research Center, Region II.

[32] Arnim H. Merburg, et al. *Collecting Usage Data for Analyzing a Heavy-vehicle, Divisible-load Premit System.* Transportation Research Record 1613.

[33] Overweight Vehicle – Permits and Penalties, *An Inventory of State Practices for Fiscal Year 1989*, report 11. Federal Highway Administration, 1991.

[34] *Providing Access for Large Trucks*, Special Report 223. Transportation Research Board, 1989.

[35] Bruce Janson, Wael Awad, Juan Robles, Jake Kononov, and Brian Pinkerton. *Truck Accidents at Freeway Ramps: Data Analysis and High-Risk Site Identification*. Colorado Department of Transportation, 1995.

[36] NCHRP synthesis 241, Truck Operating Characteristics. 1997

Appendix A: Statutory Size Limits for Virginia Highways

If the dimensions of the vehicle combination or nondivisible load, or both, exceed the limitations, a hauling permit is required.

	Interstate systems and designated hIghways
Width	8 feet 6 inches
Height	13 feet 6 inches
Length	Trailer -- 48 feet Semitrailer -- 53 feet including load Twin trailer -- 28 1/2 feet Tractor truck semitrailer combinations -- No overall length restriction Automobile and watercraft transporters -- 65 feet plus 3-foot overhang to front and 4-foot overhang to rear Stinger-steered automobile and watercraft transporters -- 75 feet plus 3-foot overhang to front and 4-foot overhang to rear

Statutory Size Limits for Virginia Interstate Systems and Designated Highways

	Primary and secondary systems
Width	8 feet excluding mirrors.
Height	13 feet 6 inches
Length	Trailer -- 40 feet Semitrailer -- 48 feet including load Twin trailer -- 28 1/2 feet Tractor semitrailer combinations -- 65 feet including load Combination of a towing vehicle and any manufactured hoursing -- 60 feet including load and coupling

Statutory Size Limits for Virginia Primary and Secondary Highway Systems

Appendix B: Sample Traffic Data for Site II (264E) from Smart Travel Lab

DateX	StationID	Volume	Occu	Speed	CollLength	LanesWithData
9/7/00 6:00	165	20	0	58	118	3
9/7/00 6:02	165	27	0	48	119	3
9/7/00 6:04	165	21	0	51	120	3
9/7/00 6:06	165	33	0	58	120	3
9/7/00 6:08	165	52	1	46	120	3
9/7/00 6:10	165	42	1	57	121	3
9/7/00 6:12	165	44	1	58	120	3
9/7/00 6:14	165	63	2	55	119	3
9/7/00 6:16	165	61	2	52	120	3
9/7/00 6:18	165	55	1	58	119	3
9/7/00 6:20	165	53	1	58	121	3
9/7/00 6:22	165	51	1	56	119	3
9/7/00 6:24	165	77	2	55	122	3
9/7/00 6:26	165	59	2	60	120	3
9/7/00 6:28	165	54	1	60	120	3
9/7/00 6:30	165	73	2	58	120	3
9/7/00 6:32	165	71	2	60	123	3
9/7/00 6:34	165	71	2	56	118	3
9/7/00 6:36	165	80	2	55	121	3
9/7/00 6:38	165	84	2	61	120	3
9/7/00 6:40	165	81	2	61	119	3
9/7/00 6:42	165	74	2	57	120	3
9/7/00 6:44	165	94	3	59	119	3
9/7/00 6:46	165	87	2	45	119	3
9/7/00 6:48	165	101	3	60	122	3
9/7/00 6:50	165	95	2	62	118	3
9/7/00 6:52	165	96	2	53	120	3
9/7/00 6:54	165	89	2	51	121	3
9/7/00 6:56	165	88	3	61	120	3
9/7/00 6:58	165	97	3	58	120	3
9/7/00 7:00	165	81	2	60	123	3
9/7/00 7:02	165	86	2	56	119	3
9/7/00 7:04	165	84	2	62	118	3
9/7/00 7:06	165	77	2	61	122	3
9/7/00 7:08	165	83	2	61	118	3
9/7/00 7:10	165	100	3	42	119	3
9/7/00 7:12	165	90	2	55	121	3
9/7/00 7:14	165	72	2	61	122	3
9/7/00 7:16	165	82	2	61	117	3
9/7/00 7:18	165	99	3	60	120	3
9/7/00 7:20	165	100	3	60	120	3
9/7/00 7:22	165	91	2	48	122	3
9/7/00 7:24	165	100	3	59	120	3
9/7/00 7:26	165	102	3	58	119	3
9/7/00 7:28	165	107	3	59	119	3
9/7/00 7:30	165	107	3	59	119	3

The above data is for the site on I-264E represented by station 165. The following table explains the fields seen in the traffic data obtained from the Smart Travel Lab

Field	Remarks
DateX	Date and Time
StationID	Station Number
Volume	Number of vehicle detected
Occu	Occpancy (in %)
Speed	Time mean speed (in mph)
CollLength	Collection length (in seconds)
LanesWithData	Number of lanes reporting data

Appendix C: Crash Data from the HTRIS Database

All-Vehicle Accident Data for Site 1(64W) from1996 to2000
(The Time field gives the time of occurrence of the accident)

Crash ID	Date	Time
001172639	04/19/2000	6
982641572	09/18/1998	6
971971102	07/02/1997	6
980720800	03/09/1998	6
992720131	09/20/1999	6
993190287	10/25/1999	6
001011519	03/22/2000	6
001661203	06/06/2000	6
980911478	03/30/1998	6
992280758	08/10/1999	6
982661640	09/23/1998	6
960471497	02/09/1996	6
960960683	03/27/1996	6
970730837	02/26/1997	7
992580234	08/30/1999	7
982641576	09/17/1998	7
990951720	04/02/1999	7
990250370	01/04/1999	7
981870915	06/30/1998	7
992421290	08/25/1999	7
980720822	03/04/1998	7
990392148	01/26/1999	7
991740163	06/08/1999	7
992582651	09/08/1999	7
983002153	10/19/1998	7
973462077	12/11/1997	7
981750390	06/17/1998	7
001220753	04/27/2000	7
961030673	03/27/1996	7
961030681	04/03/1996	7

961921615	06/21/1996	7
962611773	09/03/1996	7
962611785	09/03/1996	7
962611766	08/30/1996	7
983161734	11/06/1998	8
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