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16. Abstract

The focus of this project is to use a standard methodology to evaluate the Super-Two concept for improving the geometrics of two-lane, two-way rural highways. This concept modifies existing lane usage by providing some form of alternative passing lanes on a reconfigured 44-foot cross section. The study includes the determination of signing and striping requirements. It also includes developing criteria for a test roadway and proposed geometric design requirements.

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Proposed Geometric Design For Two-Lane, Two-Way Highway Intermittent Passing Section (Texas Super Two).

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IMPLEMENTATION STATEMENT

The results of this project will yield the documentation necessary to readily produce construction project plans for use in pilot projects in the Childress District. If the design proves successful, TxDOT highway design criteria would then be augmented with a mid-range alternative to providing a full four-lane highway. This option will prove to be particularly attractive in those areas where traffic volumes are marginal and right-of-way costs are high. The Super Two design would provide a solution for the problem of safe passing without the necessary sight distances. Additionally, as the design was proliferated across the State, driver behavior would be altered to operate on the roadway as it was designed. The best means to convey the findings of this research is through the project summary report and the design drawings.

DISCLAIMER

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Without their help, professional guidance, and direction, the work would have been much more difficult and time consuming.

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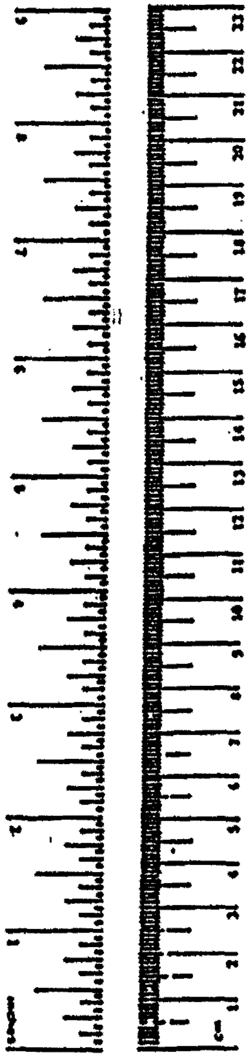
METRIC CONVERSION FACTORS

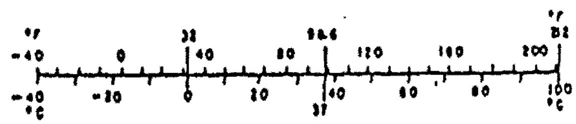
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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PROPOSED GEOMETRIC DESIGN OF TWO-WAY, TWO-LANE HIGHWAY INTERMITTANT PASSING SECTION (TEXAS SUPER TWO)

Introduction

Two-lane rural roads are of great importance in the American Highway System. There are more than 3 million miles (4.8 million kilometers) of two-lane rural highways in the United States, and they comprise about 97 % of the total rural system and 80 % of all U.S. roadways. It is estimated that 68 % of rural travel and 30 % of all travel occur on these rural two-lane roads. Funding is limited considering the extensiveness of the rural highway system and environmental concerns, and research for ways to improve the service of these roadways is essential. Because of the low ADT levels carried on these rural highways, low-cost improvement methods such as construction of Super sections are advantageous over the classical methods involving major modifications such as four-lane sections, extensive modification of road geometry.

The purpose of the study is to justify the implementation of intermittent passing lanes on rural two-way, two-lane highways where passing opportunities are limited. In this study, passing lane length and the distance between passing lanes are correlated to two major parameters: ADT and percentage of trucks. Passing opportunities are modeled to decrease with increasing oncoming traffic. In addition, as ADT increases, delay time savings increase. Also, the increase in the percentage of trucks creates more delay which results in a need for more passing lanes. A high percentage of trucks also causes operational problems in terms of reduced level of service, increasing passing attempts, aborted passes and driver frustration. An economic analysis is performed to reveal the benefit-cost ratios (B/C) for different situations. Reduction of queues and enhanced passing opportunities yield travel time savings and a predicted reduction in accidents. Taken together, these output parameters form the benefits accrued by implementing Super Two highway design.

Super Two geometry is essentially an attempt to provide improved highway capacity for those two lane rural highways whose ADT does not justify an upgrade to a full four lane cross section. This study used as its basis a typical two-lane highway cross-section of about 13.4 meters (44 feet) shown in Figure 1. Figure 2 depicts the Super Two cross-section that requires a widening of 60 centimeters (2 feet) to furnish a small shoulder on the passing side of the cross-section. Texas drivers are known to pull out onto the shoulder to let a faster moving vehicle pass on a rural road. Thus, the change to the Super Two cross-section essentially stripes the road the way Texas drivers actually drive it. The requirement for a shoulder is added to ensure that the economic analysis is conservative and comes from discussions with numerous TxDOT construction and maintenance engineers who feel that the shoulder is desirable as a protection for the pavement's edge.

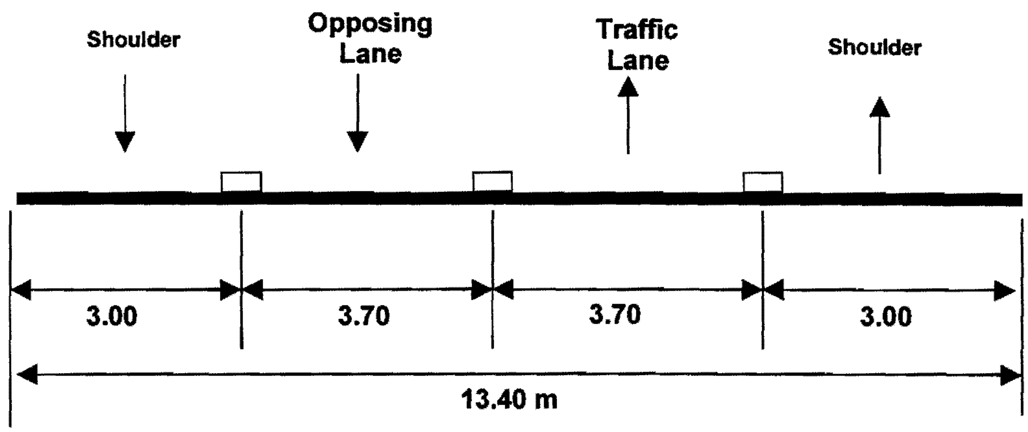


Figure 1. Existing Rural Two-Lane, Two-Way, Cross-sectional Geometric Section.

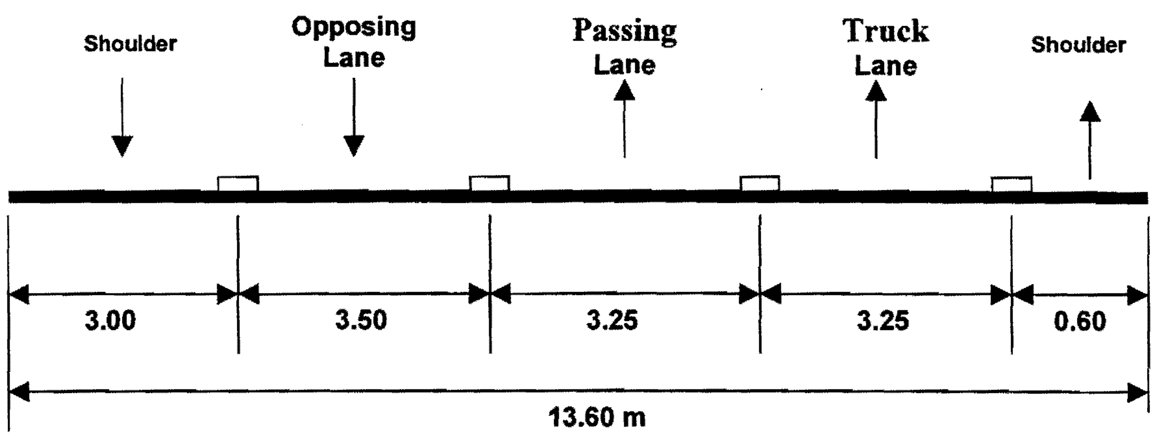


Figure 2. Proposed Super Two Cross-sectional Geometric Section.

Background

The recent statutory change in the speed limit has had a dramatic impact on rural two-lane, two-way traffic. In years past, heavy trucks tended to utilize the interstate highway system because at the 55 mile per hour (mph) (88 k/h) speed limit, it provided the least path of resistance. While actual distance driven were somewhat greater, trip times were roughly equal when compared to the use of rural highways owing to the delays encountered while driving through towns. The new speed limit changed that equation. By being able to travel at greater speeds, truck traffic can now realize a beneficial time saving by taking more direct routes to their ultimate destinations by using the rural highways. Thus, the percentage of truck traffic has increased. With this increase in large vehicles comes an increase in the number of passing movements required by passenger vehicles on rural highways. This condition is a direct function of the allowable speeds for the various types of vehicles. While passenger vehicles may travel at speeds up to 70 mph (112 k/h), trucks are restricted to 60 mph (96 k/h) and school buses are required to drive no faster than 50 mph (80 k/h). This relative speed deviation creates a condition where drivers in open terrain like that in West Texas are tempted to execute potentially unsafe passing movements for three reasons. First, because the terrain is relatively flat they believe that they have the necessary passing sight distance when in many cases they do not. Secondly, because the traffic is generally light, they are more confident that they can execute this movement safely. Third and most critically for this study's purpose, they know that they must execute a passing movement at some point in time if they do not want to follow a slow moving vehicle to the next town because there are no alternatives.

This condition is further exacerbated by a driving behavior peculiar to Texas. It is customary in rural areas to pull over onto the shoulder and permit a faster moving vehicle to pass without having to pull completely into the oncoming lane of traffic. In fact, this practice has been carried to the point where a vehicle in the oncoming lane who sees a passing movement being executed ahead of it will also pull onto the shoulder, thus temporarily making a three-lane road out of a two lane one. While this certainly speaks well for the courtesy of West Texas drivers, this habit creates unsafe conditions in and of itself, not to mention the structural damage incurred to the paved shoulders. In order to change this driving habit, two conditions must exist. First, the driver must know that an opportunity to pass a slower moving vehicle will occur in a reasonable amount of driving time, and secondly, the driver must also know that the safe passing opportunity will occur independently from the status of oncoming traffic.

The ideal solution to this problem is to widen these rural roads and provide a four-lane highway. However, between $1.0 and $2.0 million per mile of construction cost, this is not economically feasible (Heimbach, et. al, 1974). The logical alternative is to determine at what volumes the additions of periodic passing lanes are justified, and develop several possible design alternatives to provide this capacity. Most states provide passing lanes on two-lane roads where passing sight distances are impossible to attain on hills and around long radius horizontal curves. Nevertheless, only a few have experimented with providing these lanes on terrain with adequate sight distances. New Mexico is one nearby state that has experimented with this concept. US Highway 64/87 between Raton and Clayton utilizes a Super Two style design (Eyler, et. al, 1996) with widened sections that permit passing at five to eight mile (8 to 13 km) intervals. Thus, passenger vehicles know that a passing section will be available every two to five minutes. A traffic study was conducted on that highway in New Mexico and its extension into Texas where no Super Two exists to verify that this change in highway geometry indeed enhances level of service. Details are contained in Appendix E to this report.

Several foreign countries have also taken a similar interest in enhancing the safety of their highways without incurring the construction costs of building four-lane highways. Appendix A to this report contains the details of intermittent passing lane design geometry currently in use in Canada, Mexico, and Germany. The recent enactment of the North American Free Trade Agreement (NAFTA) makes the study of the Mexican and Canadian Super Two standard designs very important. At this point in the study, it appears that the Mexican section will be most easily adapted to use in Texas. Considering the relative proximity of Mexico and the relative percentage of Mexican traffic as opposed to Canadian traffic, modeling the Texas Super Two design after the Mexican approach makes a lot of sense. The German design springs from a severe restriction on the amount of available right-of-way in European countries. Therefore, it seeks to minimize the required cross-section. It only requires a total of 12 meters (40 feet) from shoulder to shoulder, but to achieve this, the Germans use only 0.25 meter shoulders (10 inch) and require a 0.5 meter (1.64 feet) separation between the opposing lanes traffic with a physical barrier if possible. This is not typical of the cross-section generally presented to U.S. drivers on rural roads. It will probably not only confuse them, but the virtual lack of shoulders would present a hazard in a stopped vehicle situation. The Canadian design uses two 1.2 meter (4 feet) shoulders while the Mexican design provides for a wider shoulder on the opposing lane side than on the passing lane side. This makes the most sense in that a vehicle breakdown on either side of the Super Two section will still leave sufficient room for one unobstructed lane in each direction.

A Mexican study of truck lanes was published in the *Transportation Research Record* (Mendoza & Mayoral, 1996) which indicated that benefits accrued from increased travel speeds as measured by the World Bank method outweighed the construction costs by as much as five times (Mendoza & Mayoral, 1996). Turkey has considered a similar scheme as an option to leverage scarce construction dollars while enhancing safety as that country builds its interstate highway system. Studies have also been done in Great Britain (McDonald, et al, 1994), China (Xing, 1989), and Australia (Oppy, 1992) regarding the provision of alternating passing lanes to both relieve congestion and enhance safety on two-lane roads with a high percentage of truck and bus traffic. The British study is particularly interesting in that one does not consider Britain as country with a lot of long rural roads. The motivation in that study was to minimize right-of-way acquisition cost in a country where available right-of-way is extremely rare and comparatively costly. Even this parallels the current environment in Texas, especially when one considers Super Two as a means to increase highway capacity within existing right-of-way limits.

This project had three major phases. First, a bench marking analysis of the literature, current TxDOT design criteria and cross sections, and assembly of appropriate standards for geometric design, signing/striping, and minimum traffic volumes was conducted. The output of this initial effort identified potential alternatives for providing this capacity that were evaluated in the next phase. It also estimated traffic volume justification criteria (maximum and minimum ADT's) which will permit this design to be a feasible alternative to four-lane highways. The second phase entailed a formal feasibility study to assess the costs and potential benefits of each of the various Super Two alternatives. Benefits and costs due to delay attributed to differential speed and headway were estimated using queuing theory (Khasnabis et. al, 1980). At the outset, a limited Monte Carlo simulation (Khasnabis et. al, 1980) was considered as a way to more accurately estimate delay savings benefits, but this was determined to be unnecessary as the ADT's involved did not justify themselves on a classically derived warrant basis. It was also found that Super Two could not be justified on delay savings alone. Accident savings had to be included and make up the majority share of the savings. Thus, a deterministic approach to calculating delay savings was determined to be adequate. The predicted values were then tested in a limited field traffic study on the case study highway to ensure that the deterministic model matched actual field observations. Details of the traffic study can be found in Appendix B. The final phase formalized the results of the first two phases by producing the necessary design documents to bring the concept to life on a test project. The documents include engineering drawings, signing, and striping plans are contained in Appendix C.

Application of Queuing Theory to Super Two Geometric Design

In order to model the traffic flow characteristics on a two-way, two-lane highway, queuing theory is applied. Queues are observed on that kind of highways when the opportunity to overtake a slow-moving vehicle is limited. The two basic components of queuing are arrival and service rate and their distributions. As traffic increases, the number of vehicles in a queue also gets larger because of increasing arrival rate and decreasing passing opportunities. Knowing these parameters, one can compute the average number of vehicles waiting to overtake the slow-moving vehicle. Light to medium traffic conditions on a rural roadway can be modeled using Poisson arrival distribution for the arrival rate. Assuming a negative exponential service rate distribution, expected number of vehicles in a queue (E(m)) and average waiting time (E(w)) for a vehicle in a queue can be calculated using equations 1 and 2 respectively.

$$E(m) = \frac{q^2}{Q(Q-q)} \tag{1}$$

$$E(w) = \frac{q}{Q(Q-q)} \tag{2}$$

Where q is arrival rate and Q is the service rate, both terms are expressed as the number of vehicles per unit time. As can be seen from equation 1, E(m), increases rapidly as the arrival rate increases or service rate decreases. Increasing ADT values on a roadway causes both the arrival rate to increase and service rate to decrease. In a situation where the arrival rate and service rates are close to each other, the queues tend to be infinite. This behavior of queuing theory makes the model applicable to simulate rural roadway traffic conditions. The average number of vehicles in a queue obtained from queuing theory is used for determination of the passing lane length. Average amount of time spent in a queue is utilized to calculate the time savings that passenger cars will benefit from the construction of passing lanes.

Arrival and Service Rate Computation

A major difficulty in the application of the theory on a traffic problem is the dynamic characteristics of the traffic flow. The computation of the service rate (Q) should incorporate the fact that the truck percentage will have an influence on the service rate. Therefore, the service rate, Q, is computed using equation 3 (Highway Capacity Manual, 1987) below. This equation gives the maximum service volumes (SV), on rural two-lane, two-way highways under uninterrupted flow conditions. Service volume is then converted into service rate (Q) using a directional factor to find the service rate in one direction (in the case study a directional factor of 0.6 is assumed). Q values are further substituted into the equations 1 and 2. Unlike the service rate calculation, arrival rate, (q) is directly obtained from ADT values. Therefore, the arrival rate is an adjusted ADT value in one direction of roadway for a peak hour traffic volume. It is further assumed that the trucks are evenly distributed along the highway and they are not involved in passing maneuvers. Hence, the number of trucks are subtracted from ADT values during the calculation of the arrival rate.

$$SV = 2000\ (v/c)\ W_L\ T_L \qquad (3)$$

Where: SV = Service volume (mixed vehicles per hour, total for both directions)

v/c = Volume to capacity ratio

W_L = Adjustment for lane width and lateral clearance at a given level of service

T_L = Truck factor at a given level of service

The truck factor (T_L) and adjustment for lane width and lateral clearance (W_L) are taken from the Highway Capacity Manual (1987). Volume to capacity ratio values are obtained from the Highway Capacity Manual (1987). A level of service of B is assumed to simulate the mid volume rural conditions that are considered in this study. The volume to capacity ratio (v/c) is a function of the probability of a passing sight distance of 1500 feet (460 meters). Volume to capacity ratios are interpolated according to changing probability of having a passing sight distance of 1500 feet (460 meters). Since the roadway is on level terrain, the probability of having a passing site distance is 100 %. However, this probability will change according to the available gap between two vehicles in oncoming traffic. This gap will be a function of ADT level and the probability of having a gap equal or greater than 1500 feet (460 meters) is calculated using equation 4 assuming a Poisson distribution in oncoming traffic. Given that the probability of passing sight distance is 100 %, the probability value obtained from equation 4 can be directly substituted into equation 3 to determine the service rate.

$$P(h \geq t) = e^{-\lambda t} \qquad (4)$$

Where: λ = average number of vehicles in the opposing direction per unit time

h = time gap between two consecutive opposing vehicles

t = time gap between two opposing vehicles which are 1500 feet apart.

The average number of vehicles in the opposing direction per unit time (λ) is a direct function of ADT values. Equation 4 implies that as the traffic volume on a roadway increases, probability of having a time gap that will enable a safe passing opportunity will decrease. This decrease in the probability will reduce the service to capacity ratio obtained from the Highway Capacity Manual. Lower service to capacity ratios will cause a drop in the service volume or service rate. This theory is then extended to develop a design algorithm which optimizes both passing lane length and the distance between passing sections with respect to ADT and truck percentage. The details of this method can be found in Texas Department of Transportation Research Report TX-98/7-3951-2R (Gransberg et. al, 1998) and are detailed in Appendix D. The method assumes that the optimum length of a passing lane is controlled by the time it takes the average queue to overtake the slow moving vehicle that has caused the queue to form. The optimum distance between passing sections is related to the time it takes for the queue to form behind the next slow moving vehicle. As a safety factor the design uses a length based on the average queue plus one car. As arrival rates are assumed to be modeled by the Poisson distribution, this provides an effective length that should permit safe passing for about 85% of the predicted distribution of queue sizes

Benefit-Cost Analysis

To justify the implementation of Super Two design on a public project, the benefits accrued by the design geometry must outweigh the cost of implementation. This is typically portrayed by dividing the equivalent annual benefit by the equivalent annual cost to compute the ratio of benefits to costs. If the resultant value is greater than unity, the project is economically feasible and warranted at the constraints imposed on the analysis by its underlying assumptions (Newnan, 1996). To complete such an analysis on Super Two highway design, the benefits are defined as the value of savings due to accident reduction and the value of time saved due to decreased delay. These benefits are computed as follows. Accident cost savings are obtained from the model provided by the equation 5 (Taylor and Jain, 1988). The constant 1.36 in equation 5 is used to convert 1988 dollars to 1998 dollars.

$$B_{acc} = (AC)(365)(ARF)(ADT)(10^{-8})(L_{pl100})(1.36) \qquad (5)$$

Where B_{acc} = Annual accident cost savings provided by a one mile passing lane ($/yr/mile); AC = average cost of accidents by severity (value is taken to be $26,780 in 1988 dollars); and ARF = average reduction in accidents by severity for different ADT values (value is taken to be 37.7)

Time savings of the cars is the amount of time that can be accrued from the application of the design methodology. The value shows the amount of time that is saved by a car avoiding any waiting time behind a truck for a chance to overtake. The average waiting time per car, E(w) that had already been calculated from the queuing theory, Equation 2 is assumed to form the basis of time saving calculations. The major assumption is the elimination of this waiting time with the application of passing lane sections. In other words, with the application of passing lanes the cars are modeled to have an almost uninterrupted design speed. Time savings per vehicle per 100 kilometers (62.5 miles), (B_{time}) is annualized by multiplying them by ADT values and number of days in a year, 365 as shown in Equation 6. Number of trucks is excluded from the total number of vehicles since they don't benefit from time savings. The different time cost of business and leisure trips are incorporated in the calculations (Taylor and Jain, 1988).

$$B_{time} = (1 - TP)(ADT)(S_{100})(365)(P_{bt}S_{bt} + P_{lt}S_{lt})AN_p \qquad (6)$$

Where: S_{100} = time saving benefits per 100 kilometers
S_{bt} = time value of business trips
P_{bt} = percentage of business trips
S_{lt} = time value of leisure trips
P_{lt} = the percentage of leisure trips
AN_p = average number of passengers passenger vehicle

Construction Costs

To calculate a corresponding construction cost per 100 kilometers (62.5 miles) of road, a conceptual design of the amount of roadway which must be upgraded to Super Two cross-sectional geometry must be determined. Additionally, it is assumed that the upgrade will consist of an average widening of 60 centimeters (2 feet). It should be noted that if the specific project in question is determined to not require a small shoulder on the passing lane side, then the cost of implementing Super Two geometry is merely the cost of new signage and striping. The conceptual design begins with determining the effective length of a Super Two passing lane. An effective length of passing lane is long enough for the drivers of the passenger cars to feel comfortable overtaking the slower moving truck. There should also be enough length provided for the trucks to merge into the passing lane. Tapered sections at the beginning and end of the passing lane would effectively provide this space. But the tapered sections would not be included in the length of the passing lane. The tapered sections should be equal to the distance traveled by the truck as it moves into and out of the passing lane safely clearing the passenger cars in the queue.

$$L_{epl} = (t_{acc} + t_{pl})V_{tr} \qquad (7)$$

Where: L_{epl} = Effective length of passing lane (meters)
t_{acc} = Time for a passenger car to accelerate (seconds)
t_{pl} = Time for platoon in queue to pass (seconds)

The distance from the point where a car overtakes the first truck to the point where it reaches the next truck is considered as the distance between two passing lanes, (D_{pl}) as shown in equation 8. Assuming an even distribution of the trucks and trucks will cause no delay for cars, this length also includes the passing lane section of the highway. Ideally the passing lanes are designed to be located at the points when cars reach the next slow moving truck. It is assumed that the queue with an average number of cars, E(m) would be formed by the time the platoon reaches the next passing lane.

$$D_{pl} = \frac{\frac{V_{tr}}{q_{tr}}}{\Delta V_{pc-tr}} V_{pc} \qquad (8)$$

Where: D_{pl} = distance between passing lanes (meters)
V_{tr} = truck speed; q_{tr} = truck arrival rate
V_{pc} = passenger car speed
ΔV_{pc-tr} = differential speed between truck and passenger car

The calculated values for the length and the separation of the passing lanes will be converted into a representation per a reference basis. For practical purposes presenting the values in a per distance basis is more meaningful. Therefore an interval of 100 kilometers (62.5 miles) is selected to form that basis. Equation 9 represents the number of passing lanes per 100 kilometers (PL_{100}). Since, the distance between passing lanes has already been calculated, the number per 100 kilometers is obtained by dividing 100 kilometers to distance between passing lanes. It should be kept in mind that this distance includes the passing lane length and the result will directly give the number of passing lanes per 100 kilometers. Total length of the passing lanes per 100 kilometers can also be calculated after the number of passing lanes per 100 kilometers (L_{pt100}) is shown in Equation 10.

$$PL_{100} = \frac{100}{D_{pl}} \tag{9}$$

$$L_{pl100} = PL_{100} L_{pl} \tag{10}$$

Construction cost per 100 kilometers of roadway section, C_{pl}, is found from Equation 11 by multiplying by two since the passing lanes in the opposing direction must be considered. The length of merge and diverge areas is not a function of length of passing lane.

$$C_{pl} = 2\left(\frac{UC_{pl} L_{epl100}}{1000} + UC_{cd} PL_{100}\right) \tag{11}$$

Where: UC_{pl} = Construction cost of 1 kilometer of passing lane
UC_{cd} = Construction cost of converge and diverge sections per each passing lane

The construction cost is a one-time cost that occurs at the beginning of the project. It should be incorporated in the economical analysis in annual basis so that comparison of the cost and benefit values can be done. Equation 12 annualizes the construction cost of the passing lanes using a life cycle of n years and an interest value i. Life cycle period of the project should be estimated according to the characteristics of the roadway.

$$AC_{pl} = C_{pl}(A \setminus P, i\%, n) \tag{12}$$

$(A \setminus P, i\%, n)$ = Capital recovery factor for an interest value of *i%* and for *n* years

Case Study-Parametric Calculations of Time Savings

A case study using actual data from Highway 87 between Dalhart and Texline in Dallam County, Texas is presented in the following sections to exemplify the proposed equations. The most critical ADT level of 3600 vehicles/day is chosen for the example. Each formula presented in the previous section will be calculated based on assumed parameters. Various calculations for different ADT and truck percentage levels are presented in this report. The design speeds for the passenger cars and slower moving trucks are decided to 70 mph and 60 mph, respectively. However, for the sake of metric unit calculations their speeds are taken as 112 k/h and 96 k/h, respectively. A representative truck percentage of 10% is chosen for this specific case study. The upgrade of the existing roadway to a 3-lane pavement with a passing lane is planned with a 60 centimeter pavement widening as shown in Figure 2. Since the structural capacity of the existing 3-meter (10 feet) shoulders is the same with regular lane sections, shoulders should be kept as they are. The 60 centimeter (2 feet) new construction is foreseen with the same structural capability of present pavement. The existing and proposed sections are comprised of a 0.6 meter (2 feet) flexible subbase, a 0.6 meter (2 feet) fly ash base, and a two course surface treatment

After the pavement is extended 60 centimeters (2 feet), a final seal coat application is designed to cover existing markings. This prepares for the striping of new pavement markings. Another construction activity would be the merge and diverge areas or the tapered areas of the passing lanes. The cost of these areas does not depend on the length of the passing lane. The approximate construction costs are as follows.

- A two-course surface treatment with AC-5, Grade 4 aggregate is needed on the new shoulder. Application rate of binder is 2 l/m^2, and distribution rate of aggregate is 137 m^2/m^3. It is calculated to be $1,020/0.6m width/1kilometers length.
- A one-course seal coat application with AC-5, Grade 4 aggregate is needed across the entire cross section. The application rate of binder is 2 l/m^2, and the distribution rate of aggregate is 137 m^2/m^3. It is calculated to be $12,309/13.80m width/1kilometers length.
- Fly ash stabilized base construction cost is calculated to be $9,000/0.6m width/1kilometers length.
- Flexible subbase construction cost is calculated to be $6,000/0.6m width/1kilometers length.
- Excavation cost is $1,391/0.6m width/1kilometers length.
- Embankment cost is $1,105/0.6meters/1kilometers length.
- Cost of diverge and converge areas is $1,222 / 0.6meters width/passing lane.
- Total cost excluding signing cost is $30,825.

The analysis shown in Figure 3 is performed at a constant truck percentage of 10% and with varying ADT levels. The B/C ratio increases with increasing ADT levels. The Super Two Highway can be justified from an ADT level of 2500. This justification is mainly caused by the accident cost saving benefits. The equation used in this calculation can be further elaborated or examined to conform to the actual accident cost saving analysis specifically conducted for a roadway section. It is evident that time saving benefits are not adequate to justify the construction of the Super Two Highway (approximately 15% of the savings are contributed by the time saving benefits). However, the construction cost pertaining to the upgrading of the highway is primarily widening cost. Many people with highway construction experience agree that widening is not a necessity. For the segments of the highway with passing lanes, striping will be adequate for safe traffic conditions. The cost of striping is much less than construction cost. If highway agencies can adopt this idea, the construction of passing lanes at given intervals will be a viable solution to the improvement of the two-way two-lane rural highways.

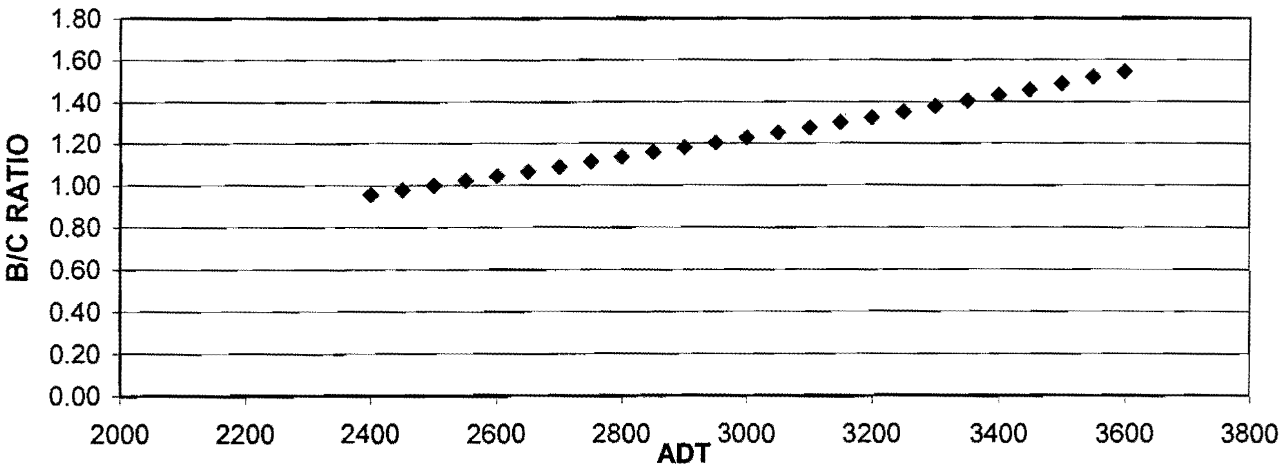


Figure 3. Super Two Benefit Cost (B/C) Ratio versus Average Daily Traffic (ADT).

It is evident that, time saving benefits are not adequate to justify the construction of the Super Two section (approximately 15% of the savings are contributed by the time saving benefits). However, the construction cost pertaining to the upgrading of the highway is primarily widening cost. Many people with highway construction experience agree on that widening is not a big necessity and they think that for the segments of the highway with passing lanes only striping will be adequate for safe traffic conditions. The cost of striping is much less than construction cost, if highway agencies can adopt this idea then construction of passing lanes at given intervals will always be a viable solution to the improvement of the two-way two-lane rural highways.

Another outcome of the constant ADT and changing truck percentage analysis is the B/C ratio is not sensitive to truck percentage. This is caused by the structure of the accident cost benefit equation. Figure 4 is plotted for a constant ADT of 3600 and varying truck percentage. An almost constant line is observed. This is because accident cost savings included in the numerator and construction costs included in the denominator are both functions of the passing lane length, and therefore cancel each other out. This leaves a constant B/C with respect to truck percentage.

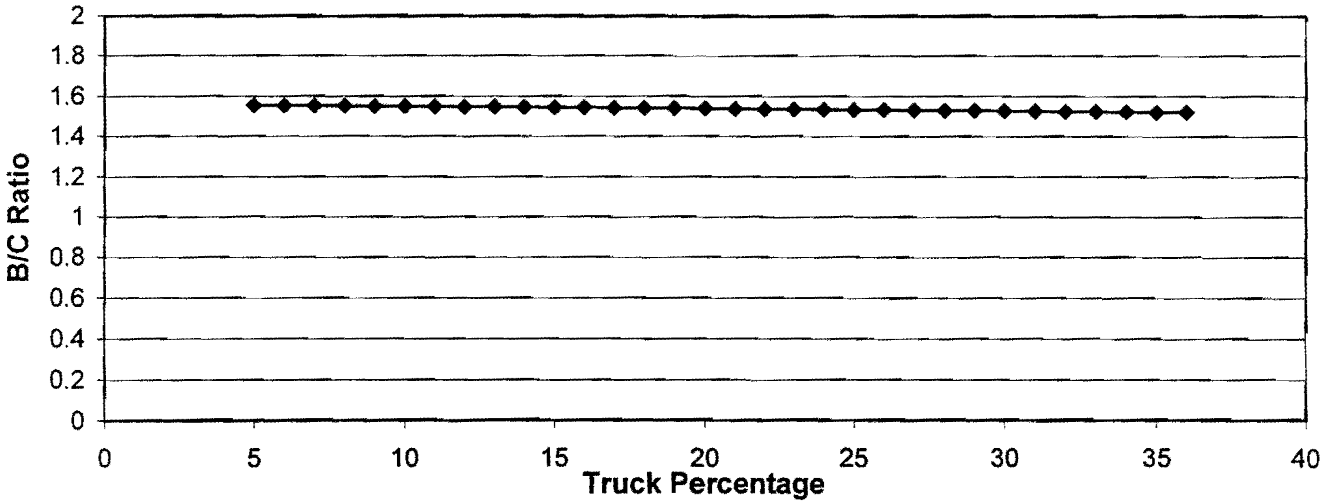


Figure 4. Super Two Benefit Cost (B/C) Ratio versus Truck Percentage

Designing the Super Two Section

The previous equations are drawn from a more detailed derivation contained in Appendix D. This analysis optimizes both the length of passing section and the number of passing sections per 100 kilometers (62.5 miles) of highway with respect to cost. For this analysis, a passing section is defined as provision of passing lanes for both directions of travel. It can be seen in Appendix A that there are four basic types of Super Two sections. In Type B, Separated Passing Sections, the engineer will need to be careful to ensure that there is a passing section developed for both directions. At this point, the design methodology is very simple and straightforward. Its steps are as follows.

1. Determine the ADT and percentage of trucks for the highway in question. This can be based either on existing traffic data adjusted for future growth or from another more appropriate method or policy.

2. With this input data, enter Tables 1 and 2, and determine the number of passing sections per 100 kilometers (62.5 miles) and the minimum length of each passing section.

3. Taking plan and profile information for the highway in question, determine those portions of the road where safe passing sight distance is not available due to horizontal curves, vertical curves, and other obstructions.

4. Allocate Super Two passing sections to roadway sections where passing site distance is unavailable.

5. Distribute any remaining passing sections evenly between the passing sections already allocated.

6. Taking the average passing section length from Table 1, adjust as necessary for those sections without adequate passing sight distance to provide safe passing throughout the length of the sight distance restriction.

Table 1: Minimum Passing Section Length Based on ADT and Percent Trucks

Truck % / ADT	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
2400	735	735	735	735	736	735	736	735	735	735	736	736	736	735	735	736	736	736	736	736	736	736	736	736	736	736	737	737	737	737	737	737
2450	739	739	739	739	739	739	739	739	739	739	739	739	740	740	740	740	740	740	740	740	740	740	740	741	741	741	741	741	741	741	741	742
2500	743	743	743	743	743	743	744	744	744	744	744	744	744	744	744	744	744	744	745	745	745	745	745	745	745	745	746	746	746	746	746	746
2550	748	748	748	748	748	748	748	748	748	749	749	749	749	749	749	749	749	749	749	750	750	750	750	750	750	750	750	751	751	751	751	751
2600	753	753	753	753	753	753	753	754	754	754	754	754	754	754	754	754	754	755	755	755	755	755	755	755	756	756	756	756	756	756	757	757
2650	758	758	759	759	759	759	759	759	759	759	759	760	760	760	760	760	760	760	760	761	761	761	761	761	761	761	762	762	762	762	762	763
2700	764	764	765	765	765	765	765	765	766	766	766	766	766	766	766	766	766	766	767	767	767	767	767	767	768	768	768	768	768	769	769	769
2750	771	771	771	771	771	771	771	772	772	772	772	772	772	772	773	773	773	773	773	773	773	774	774	774	774	774	775	775	775	775	776	776
2800	778	778	778	778	778	778	778	779	779	779	779	779	779	779	780	780	780	780	780	781	781	781	781	781	782	782	782	782	782	783	783	783
2850	785	785	785	786	786	786	786	786	786	786	787	787	787	787	787	788	788	788	788	788	789	789	789	789	789	790	790	790	791	791	791	791
2900	793	793	794	794	794	794	794	794	795	795	795	795	795	796	796	796	796	796	797	797	797	797	798	798	798	798	799	799	799	800	800	800
2950	802	802	803	803	803	803	803	803	804	804	804	804	804	805	805	805	805	806	806	806	806	807	807	807	807	808	808	808	809	809	809	810
3000	812	812	812	812	813	813	813	813	813	814	814	814	814	815	815	815	815	816	816	816	816	817	817	817	818	818	818	819	819	820	820	820
3050	823	823	823	823	823	824	824	824	824	824	825	826	826	826	826	826	826	827	827	827	828	828	828	829	829	829	830	830	831	831	831	832
3100	834	834	835	835	835	836	836	836	836	836	837	837	837	837	838	838	838	839	839	839	840	840	841	841	841	842	842	843	843	844	844	845
3150	847	847	847	848	848	848	848	849	849	849	850	850	850	851	851	851	852	852	852	853	853	854	854	855	855	855	856	856	857	858	858	859
3200	861	861	862	862	862	862	863	863	863	864	864	864	865	866	866	866	866	867	867	868	868	869	869	870	870	871	871	872	872	873	874	874
3250	877	877	877	878	878	878	879	879	879	880	880	880	881	881	882	882	883	883	884	884	885	885	886	886	887	887	888	889	889	890	891	892
3300	894	894	895	895	895	896	896	897	897	897	898	898	899	899	900	900	901	901	902	902	903	904	904	905	906	906	907	908	908	909	910	911
3350	913	914	914	915	915	915	916	916	917	917	918	918	919	919	920	921	921	922	922	923	924	924	925	926	927	927	928	929	930	931	932	933
3400	935	936	936	937	937	938	938	939	939	940	940	941	941	942	943	943	944	945	946	946	947	948	949	949	950	951	952	953	954	955	956	957
3450	960	960	961	961	962	963	963	964	964	965	966	966	967	968	968	969	970	971	972	972	973	974	975	976	977	978	979	980	981	983	984	985
3500	988	988	989	990	990	991	992	992	993	994	994	995	996	997	998	999	1000	1000	1001	1002	1003	1004	1005	1007	1008	1009	1010	1012	1013	1014	1016	1017
3550	1020	1020	1021	1022	1023	1023	1024	1025	1026	1027	1028	1029	1029	1030	1031	1032	1034	1035	1036	1037	1038	1039	1041	1042	1043	1045	1046	1048	1049	1051	1053	1054
3600	1057	1058	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1071	1072	1073	1074	1076	1077	1078	1080	1081	1083	1084	1086	1088	1090	1092	1094	1096	1098

Table 2: Number of Passing Sections per 100 Kilometers Based on ADT and Percent Trucks

Truck %	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
ADT																																
2400	2	2	2	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12
2450	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	11	12
2[illegible]	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12
2550	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12
2600	2	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	
2650	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	11	12	12	12	13
2700	2	2	3	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13
2750	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13
2800	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	12	13	13	14
2850	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13	14
2900	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	14	14
2950	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14
3000	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14
3050	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14	15
3100	2	2	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	15	15
3150	2	3	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	14	15	15
3200	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	15
3250	2	3	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	13	14	14	15	15	16
3300	2	3	3	4	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	15	15	15	16
3350	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	13	14	14	15	15	16	16
3400	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16
3450	2	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	16	16	17
3500	2	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16	17
3550	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17
3600	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	14	15	15	16	16	17	17

Case Study Design Example

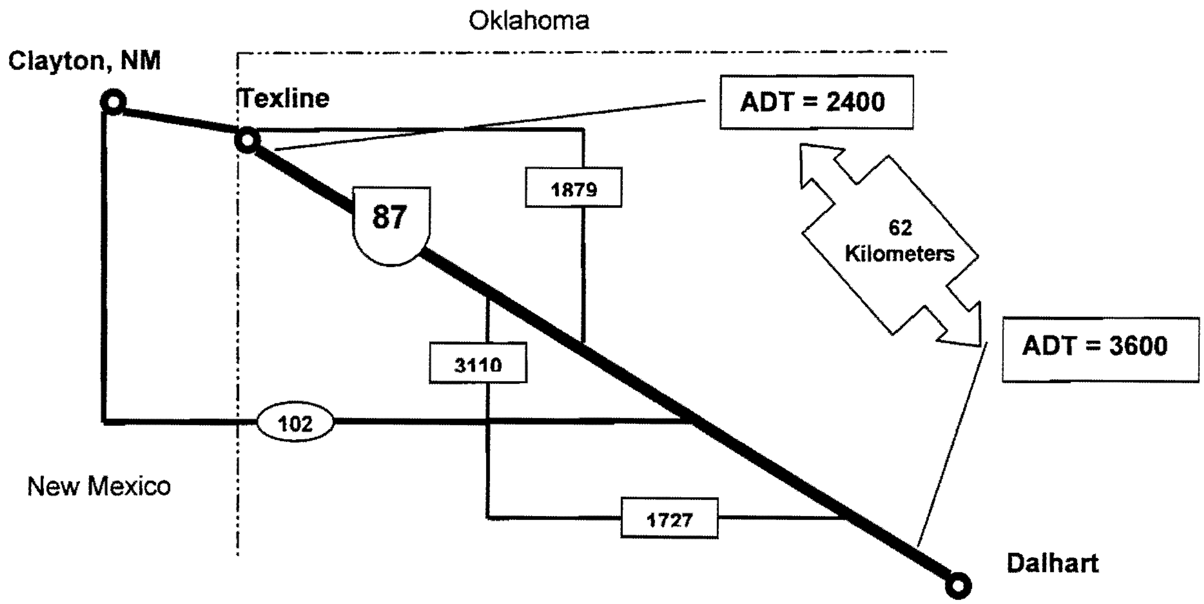


Figure 5: Case Study Map

Figure 5 shows the details of the case study area. This is also the area on which the traffic study was conducted to validate the deterministic queuing model on which the design methodology is based. The ADT volumes come from the current Amarillo District traffic map. As ADT ranges from 2400 to 3600, a Super Two design is warranted as minimum ADT is greater than or equal to 2400.

For purposes of illustration only, let us assume that design ADT will equal 3600 with 10 percent trucks. Using Table 1, we find that the average length of the passing section will be 1061 meters. From Table 2, we find that 5 passing section per 100 kilometers are warranted. The distance is 62 kilometers; therefore, the number of sections must be adjusted as follows.

$$\text{Actual number of sections} = \frac{62 \text{ km } (5 \text{ sec})}{100 \text{ km}} = 3.1 \Rightarrow 3 \text{ passing sections}$$

Thus, the engineer must distribute three Super Two sections along the road between Dalhart and Texline. As this highway runs between two population centers, the first passing section will be a Type A split with the westbound half exiting Dalhart and the eastbound half exiting Texline. This permits those passenger cars that catch the slow moving vehicles in town due to the slower speeds to take advantage of their faster acceleration to highway speed and avoid forming queues immediately outside of the two towns. That leaves two passing sections to be distributed between the two towns. The priority would be to place these at locations where passing sight distance is inadequate. To minimize construction costs, these remaining sections would be Type B, Separated Super Two sections. They would be roughly 20 kilometers apart. Figure 6 is an idealized depiction of the final design layout.

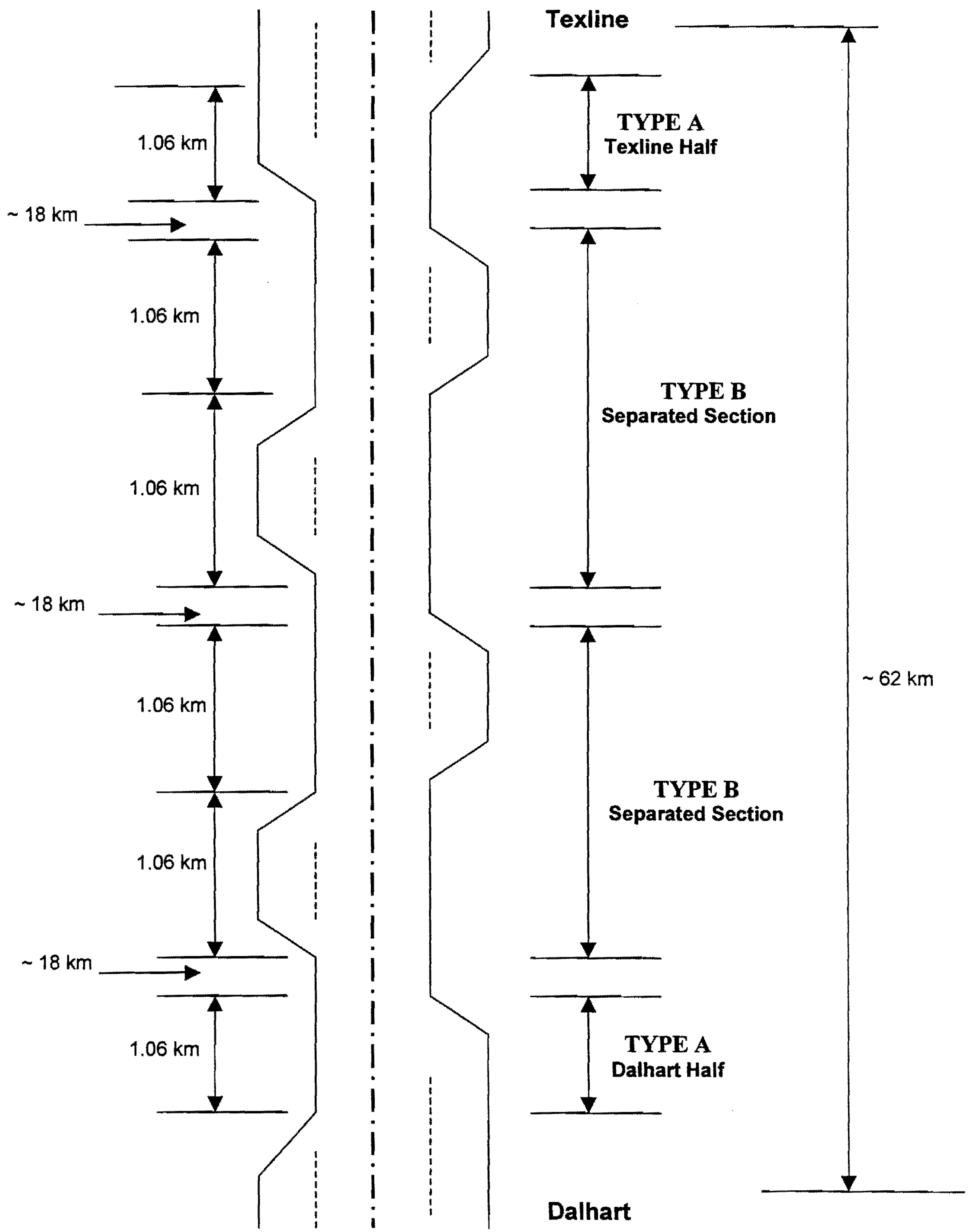


Figure 6. Super Two Design for US 87 from Dalhart to Texline.

Field Traffic Study of Case Study Area

A short traffic study was done on the case study area in July 1998 to compare the actual observed effect of Super Two geometry to the effect computed in the deterministic queuing model. The observed peak hour volume on July 17, 1998 was 532. The average number of vehicles for the same hour is counted as 3.00 according to Traffic Count Summary Sheet (Table E-1). The same parameter can be found from the design method as described earlier in the Case Study portion of the report. The peak hour corresponds to an ADT of 3547 by using a peak hour factor of 0.15. As a result, the average number of vehicles per queue calculated by the deterministic queuing model for the case study is 3.15 vehicles per queue. This result validates the model and the design approach of basing passing lane length and spacing on an average predicted queue plus one.

The traffic study also validated the hypothesis that implementing Super Two would greatly enhance level of service on low volume rural highways. From Table E-6, one observes that the average number of vehicles in queues going towards North at the data collection point in Texas is 3.54. Whereas, the same parameter becomes 2.40 after vehicles cross Clayton where the effect of Super Two passing lane sections occur. The reduction rate is 32 percent. In the other direction, the following numbers are observed. In New Mexico, the average number of vehicles in queue is 1.81 (Table E-8) for the vehicles leaving the passing lane where this number has direct effect of passing lane. The same parameter becomes 3.73 in Texas (Table E-6). Then, the corresponding reduction rate in the average number of vehicles in queues due to Super Two is 52 percent. Thus implementing Super Two can be concluded as having a strong positive impact on traffic flow.

Conclusions

A number of interesting conclusions can be made. This methodology can be used to justify the Super Two Highway at ADT levels less than 4200 vehicles per day. A Super Two section that requires a 60-centimeter widening is economically feasible at ADT levels greater than 2400 vehicles per day. If no widening is required (i.e. no shoulder on passing section side), then Super Two is economically justified at much lower ADT levels. Super Two B/C ratio is insensitive to truck percentage. Typical queues will contain less then four vehicles. Designing for the number of passing lanes per 100 kilometers of road provides high design flexibility without introducing significant error. If ADT levels exceed 4200 vehicles per day, the passing lane design should be based on simulations or other appropriate urban design methods.

It should be noted once again that 0 to 4200 vehicles per day is the ADT range where the feasibility study is applicable. After a certain level of ADT, waiting times of the passenger car in the queue become very large and then the values drop below zero. This drastic change in the values is caused by the characteristic of queuing theory. The theory is valid for the arrival rates (q) less than service rate (Q). However, the research model has increasing arrival rates with ADT, and service rate decreases as ADT values become larger because of the physical limitations of the highway. The point where two values intersect there is an infinite queue. This is obviously not an appropriate situation for the rural highways. The limiting ADT value for the application of the model is 4200. For the upper traffic levels other techniques like simulation programs may be used to model the real traffic conditions. This kind of method, however, is not in the scope of this research.

The combination of the traffic study in New Mexico and the results of the deterministic model, validate the design methodology detailed in this report. The economic justification comes not from delay savings, but from the savings accrued by a reduction in accidents. However, when the section is implemented, additional savings will be accrued due to enhanced level of service. These savings are not included in the model. Therefore, the model is a conservative approach to this issue.

Finally, it must be remembered that the model developed in this study assumes a required widening of the standard 13.4 meter (44 feet) cross-section to 13.6 meters (46 feet). The determination of the requirement for a shoulder on the passing lane side of the road is a judgement call that should reflect actual conditions for each individual project. There are numerous examples of slow moving vehicle passing lanes throughout the State of Texas where no shoulder is provided. If this can be done, Super Two is economically justified at much lower ADT's than those shown in economic analysis of the model. One could argue that if project conditions permit the use of no shoulder, Super Two could be implemented for the cost of a seal coat, new striping, and new signage. Therefore, the Department could accrue significant benefits due to increased level of service and decreased accidents at very little cost.

Recommendations

We have two recommendations as a result of the above discussions. First, the Department should implement Super Two as soon as possible. It provides a means to upgrade level of service on highways that cannot justify an upgrade to a four-lane cross-section. It also enhances safety for the traveling public at very little incremental cost. Secondly, the Department should survey its major rural highways and identify those that could be upgraded to Super Two without the requirement for a shoulder. These roads could be systematically converted to Super Two geometry in conjunction with the districts' annual seal coat contracts. The only additional expense would be a slight increase for striping and the cost of resigning the Super Two sections. This is an opportunity to immediately implement the results of this research.

APPENDIX A: LITERATURE REVIEW

Introduction

In recent years there has been an increasing interest in the operation of two-lane rural and suburban roadways. Increase of traffic volume and reduced funding levels are some of the primary reasons behind it. The recent statutory change of speed limit causes a significant impact on rural two-lane, two-way traffic. The new speed limits of 70 mph for passenger vehicles, 60 mph for trucks and 50 mph for school buses have changed the flow of traffic through these rural highways. Trucks are now using these rural highways for higher speed limit (which was 55 mph) and shorter travel distance. This increase in traffic volume and differential speed limit causes drivers to take potentially unsafe passing maneuvers. The flat terrain of West Texas is also working as a catalyst to that. Now there is a growing need to maximize capacity, mobility and safety of existing two-lane highways.

One way to solve the problem is to provide four lane highways. However, The cost of construction, $1.0 to 2.0 million per mile, is not economically feasible. That's why the "Super Two" concept comes into the frame with a median to provide passing facilities alternately. The access to this median will be controlled according to the flow of traffic.

The concept of Super Two is not totally new. There are many roadways that meet super two requirements such as two-lane freeways that have been built, either as a first stage or as a final product. These versions of the Super Two usually have been considered only as interim steps to full four-lane freeways. Some of the key features of the Super Two are full width lanes, full width shoulders, frequent passing lane locations and the extensive use of right turn lanes, left turn lanes, and continuous left turn lanes. Therefore the Super Two will provide facilities of a four-lane highway with low construction cost.

Definition

Super Two refers to a freeway or controlled access at-grade roadway with a single through lane per direction. The idea behind Super Two is to increase the capacity and safety of the existing two-lane two way highways.

The key elements of a Super Two Highway are listed below.

1) Full width lanes, paved shoulders and clear zones
2) A center passing lane
3) Limited access, with turn lanes for all permitted turns
4) Horizontal and vertical curves with high speeds
5) Passing lanes, speed differential, and truck lanes
6) Provisions for expansion to freeway or divided roadway
7) Proper interchange design for a two-lane freeway

For a new facility to be classed Super Two, most guidelines should be met. For upgrading an existing roadway, these defining features can serve as a menu of improvements for consideration.

Project Objective

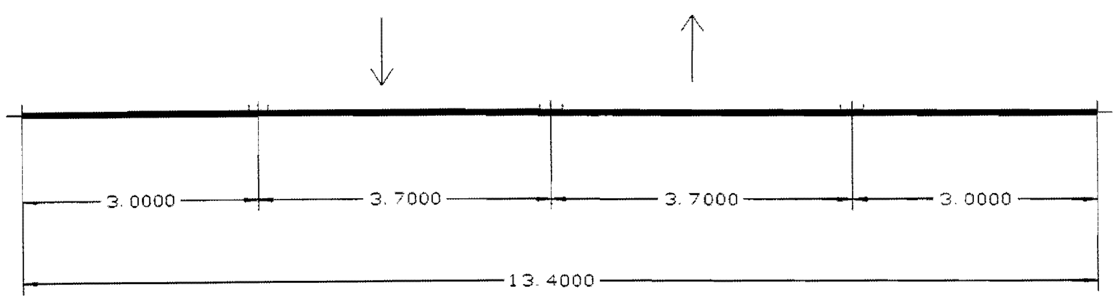
The objective of this project is to produce a standard methodology to design and to construct a Super Two highway. This means to modify the existing two-lane two-way highways to a Super Two highway. This goal will be achieved in three phases. In the first stage, reviews of literature, TxDOT design criteria, and cross sections and standards for signings and striping have been accomplished. The result of these reviews and studies is the design alternatives we set for further discussions. The next phase will be the cost-benefit analysis for the different design alternatives and ADT's for these roadways. In order to find the cost of delay, an analytical technique involving queuing theory will be implemented at this phase. The possible two or three design alternatives will be decided from the outcome of this analysis. The third and the final phase will be to summarize the results of the above two phases with necessary design documents and drawings to be implemented into a test project. This will be arranged with engineering drawings, cross sections, passing lane design details, signing, and striping. The documents will include proposed traffic volume criteria, cost estimation information and a formal constructibility review for each design alternative.

Design Philosophy

The philosophy of Super Two is to provide smooth traffic movement and overtaking maneuvers in the traditional two-lane two-way highways. If constructed as a two-lane freeway, the Super Two will provide the facilities of a four-lane at-grade roadway. In planning a regional road system, the Super Two would be a type of facility that would typically be used for minor arterials and volume principal arterials.

Design Features

Two-Lane Rural Highway



The basic two-lane highways have two middle lanes of 3.7 m in each direction (as shown in the above figure) and shoulders of 3.0 m each. That makes the total width of the highway 13.40 m, and cross slope is 2%. There is no passing lane in it, and shoulders are designed fully surfaced.

Design Speed

The Design Speed for Super Two should range from 80 to 110 km/h when an existing two-lane highway is upgraded to Super Two. In all new construction and reconstruction, the Design Speed of 100 to 110 km/h should be used throughout (Minnesota DOT). In all cases, when upgrading the existing roadway, the designer should apply the speed that is greater than or at least equal to the posted speed.

Average Daily Traffic

The ADT value of 2000 is considered to be the critical ADT between two and four lane highways. In a study published in the Transportation Research Record (TRR) 1303, "Warrants for Passing Lanes", shows that Passing Lanes on rural two-lane highways have favorable benefit/cost ratio at ADT's of 6500 and greater.

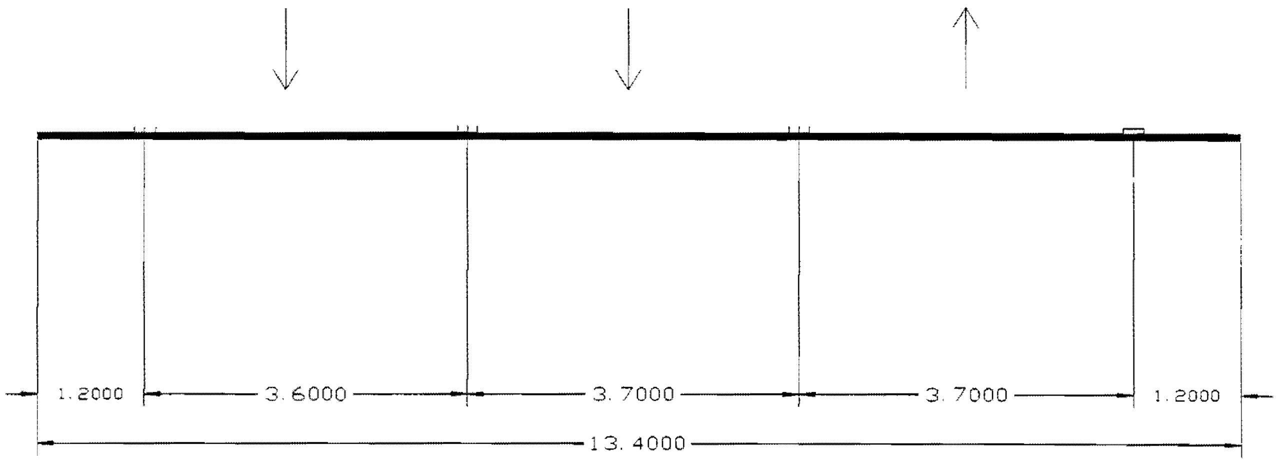
The length of a passing lane is dependent on the volume of vehicles per hour (vph) for the project. The optimal length of passing lanes to reduce platooning is 0.8 to 1.6 km (Minnesota DOT). A general guideline for the development of design length is as follows.

Vehicles per hour (vph) one way	Length of passing lane
400	1.2 to 1.6 km
700	1.6 to 2.0 km

The spacing design for a passing lane is dependent on traffic volume. For a vph of less than 700, this spacing may vary from 16 to 24 km. On the other hand this spacing may vary from 5 to 8 km or even more frequent for a vph of 700 or more.

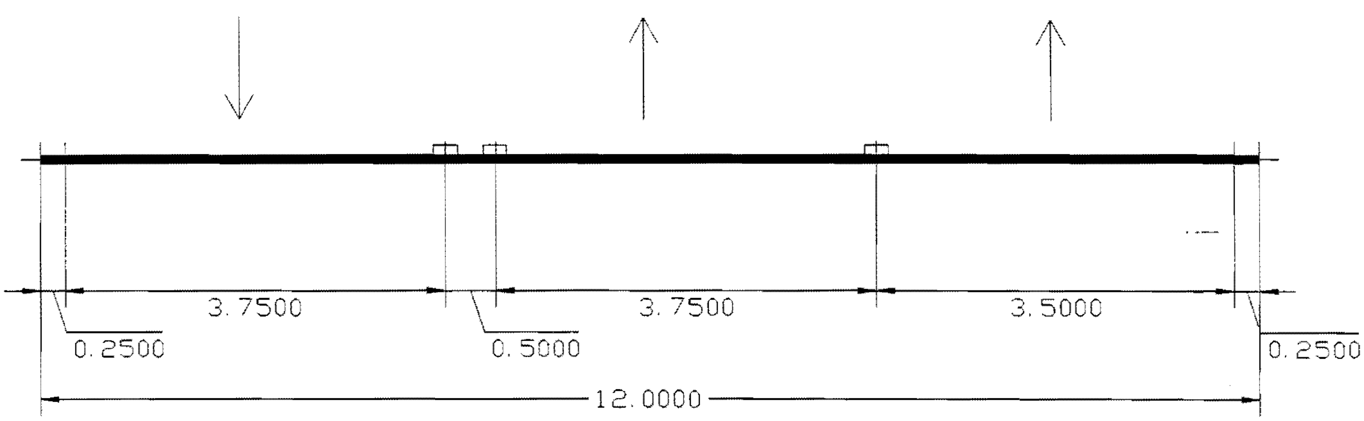
The three-lane section consists of an added lane in the middle to provide passing facilities in alternate directions. This change of direction of the middle lane may be uniform or traffic actuated, depending on situation. The center lane added to the two-lane section is of the same width or a bit different than that. The shoulders of a three-lane section may be narrower than that in the two-lane section, as being practiced in Germany, Canada, Mexico, Turkey, and some other countries of the world. Brief description of the German, Canadian and the Mexican cross sections are as follows.

Three Lane Highway Cross Section in Canada



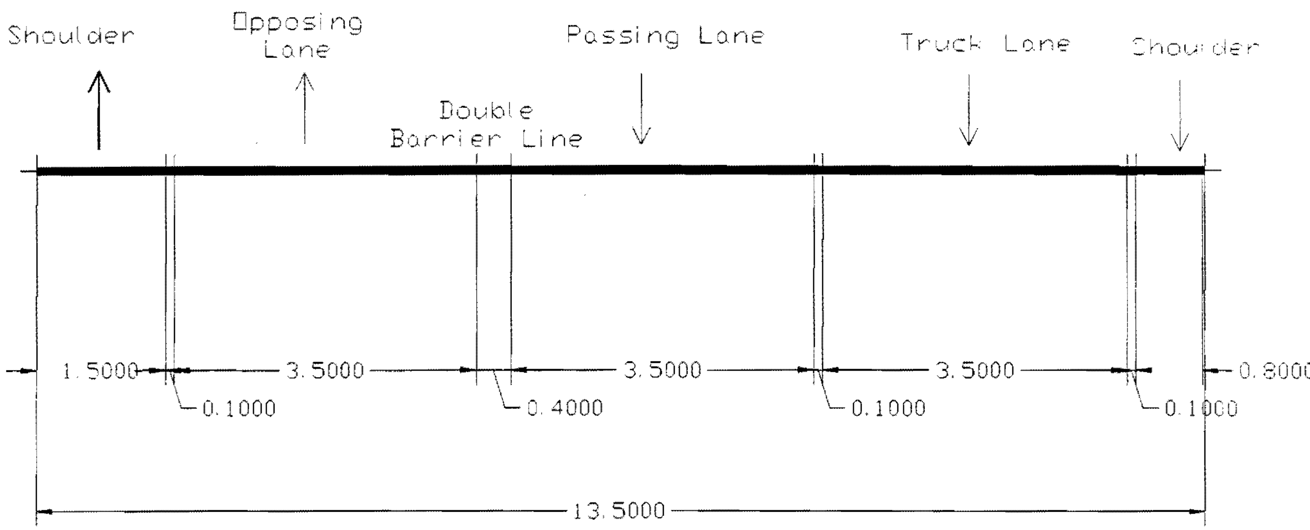
The design consists of two 3.7 m lanes and a 3.6 m lane with shoulders of 1.2 m each. The direction of passing will have a 3.7 m and a 3.6 m lane as shown in the above figure. The total width of the highway remains 13.40 m.

Three Lane Highway Cross Section in Germany



In Germany, the highway is designed with two 3.75 m and one 3.5 m lanes. The middle lane of 3.75 m width is provided to facilitate passing in alternate directions shown in figure. The curbs are of 0.25 m each making the width of the highway as 12.0 m. This design is suitable for an ADT less than 2000. Overtaking is prohibited in the opposing lane.

Three Lane Highway Cross Section in Mexico



This design alternative practiced in Mexico consists of three equal lanes of 3.5 m each with a central median of 0.4 m. Here the shoulder in the direction of passing is limited to 0.8 m and that on the reverse direction is 1.5 m as shown in figure. This change in shoulder width may provide some added safety to the driver.

Previous Benefit-Cost Analyses of Super Two Highways

The growing need for the two-lane highways with more capacity, mobility, and safety has lead researchers to put emphasis on alternative designs. On the other hand, limited funding and environmental issues are big concerns in opening new corridors to handle heavy traffic flows. As a result, the Super Two concept has recently started drawing more attention.

There are more than 3 million miles of rural highways in the United States; this figure represents about 97 percent of the total rural system and 80 percent of all U.S. roadways. It is estimated that about 68 percent of the rural transportation and 30 percent of all travel in U.S. is done on the rural two-lane system.

The major benefits of a passing lane are reductions in delay and accidents. In order to evaluate the effectiveness of the passing lanes, the cost savings of the motorists over a wide range of traffic volumes and the construction and maintenance cost of the passing lanes should be compared. The reduction in delay provided by a passing lane results in operational cost savings to the road users. A unit value of time that is usually expressed in dollars per traveler hour is multiplied by the amount of time saved in order to compute the time cost savings. Furthermore, besides the needs for updating these values to current price levels, travel time value is sensitive to trip purpose, travelers' income levels, and the amount of time savings per trip.

According to AASHTO, the time savings is divided into three categories and can be expressed as a function of time saved in a trip and type of a trip.

1. Low time savings (0-5 min): For work trips and average trips, the values of time per traveler hour are suggested as $0.48 (6.4 percent of average hourly family income) and $0.21(2.8 percent of average hourly income), respectively.
2. Medium time savings (5-15 min): For work trips and average trips, the values of time per traveler hour are suggested as $2.40 (32.2 percent of average hourly family income) and $1.80 (24.4 percent of average hourly family income), respectively.
3. High time savings (over 15 minutes): For work trips and average trips, the value of time per traveler hour is suggested as $3.90 (52.3 percent of average hourly income).

Accident Cost Savings

An analysis of accidents on two-lane highways with and without passing lanes determined the effectiveness of a passing lane in reducing accidents. The accident data was obtained from the state file for all two-lane road sections on rural highways throughout Michigan for 5 years, 1983 to 1987. The accident cost savings provided by passing lanes are computed with the following equation.

$$ACS=(AC)(365)(ARF)(ADT)10^{-8}$$

Where: ACS = annual accident cost savings provided by a 1 mile passing lane ($/year/mile)
AC = Average cost of accidents by severity
ARF = Average reduction in accidents by severity for different ADT values (per 100 million vehicle-miles)

The equation above is used to compute the safety benefits of a passing lane on rural two-lane highways in Michigan. The values of average cost of an accident are taken as the total rural accident cost for fatal, injury, and PDO accidents. Direct costs are considered in the equation. Total benefits of the road users are calculated by adding the delay benefits to accident cost savings.

Equivalent uniform annual cost (EUAC) is calculated based on the passing lane of 1.0 mile long. The life of the road is taken as n=15 years. For i=5 and 10, the values of the capital recovery factor are calculated as 0.0964 and 0.1315, respectively.

By using the analysis above, the warrants for a passing lane are met at a 4 percent grade, 10 percent trucks, and average trip type, as the user benefits are greater than construction costs for a passing lane for all ADT values greater than 6500 for a discount rate of 5 percent. Similarly, for the same value of truck percentage, grade, and trip type, the benefits are greater than construction cost for two passing lanes for ADT values greater than 9000 for a 10 percent discount rate.

Super Two Design Alternatives and Classifications

On two-lane rural roads, passing lanes have two important functions. One is to reduce the delay at specific bottleneck locations, such as steep upgrades or locations where trucks frequently travel next to farmland in the rural areas. The second main idea is to improve the overall traffic operations on a two-lane highway by breaking up the traffic platoons and reducing delays caused by inadequate passing opportunities over substantial lengths of highway. The design alternatives that have been evaluated for Super Two highways include many configuration of passing lanes. These alternatives can be classified into four categories according to the passing lane configurations. These categories are detailed in the following figures.

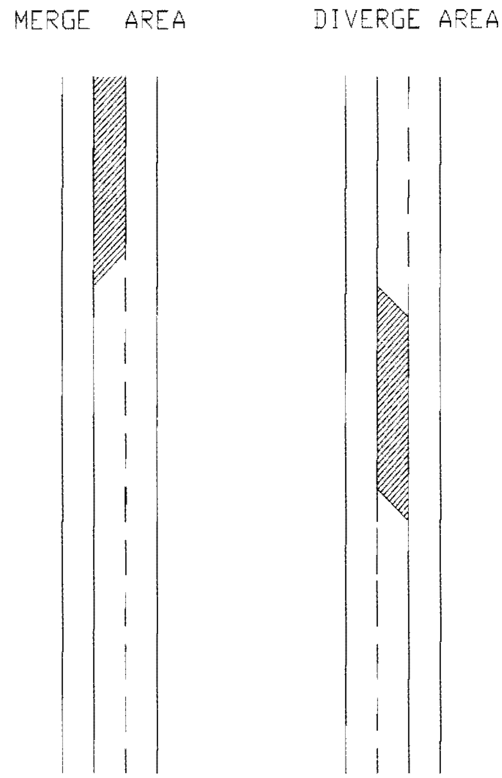


Figure A- 1: Type A- Design with Continuous Interior Alternating Passing Lane

The basic Super Two section with alternate passing lanes in the middle provided in one direction or another. For that specific alternative the main advantage is that there is no added cost of constructing additional lane. The existing pavement width can be modified fulfilling the lane width and shoulder requirements. They may not be suitable for a roadway where traffic volume is even in both direction and where queuing occurs frequently in both directions.

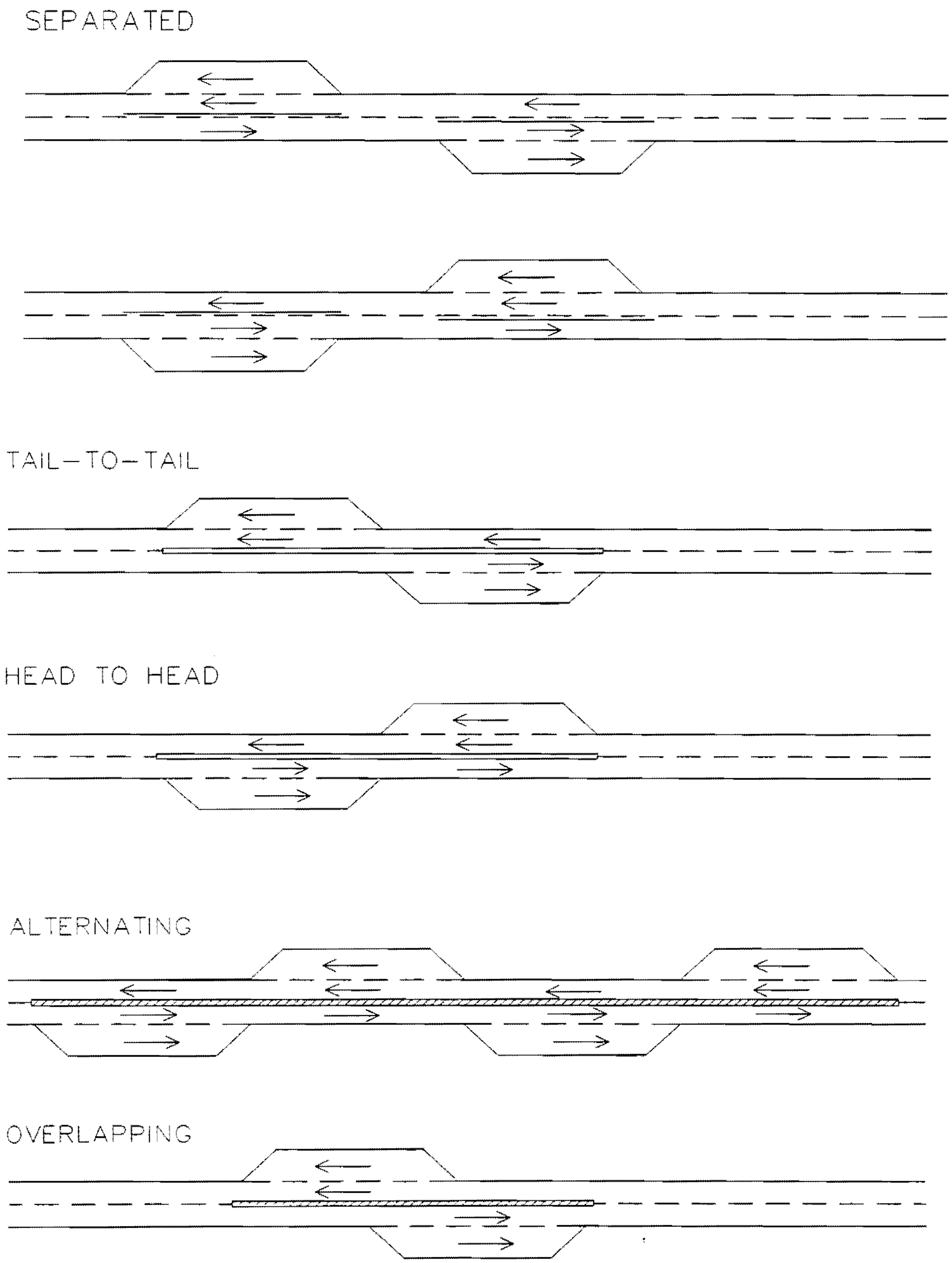
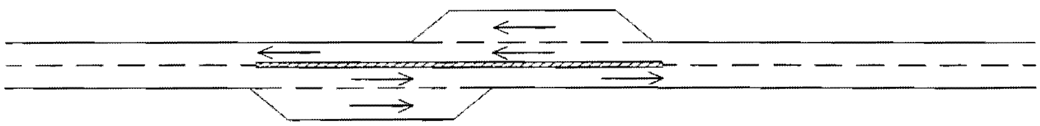


Figure B-2: Type B Design with Separated Passing Sections

Type B is the most common design used to provide passing facilities for the two-way two-lane rural highways. This is suitable for the highway sections having equal ADTs for both directions. The separated designs are often used in pairs, one in each direction at regular intervals along a two-lane highway. Where head-to-head or tail-to- tail sections are used passing by opposing direction vehicle is prohibited. The cost of constructing extra passing lanes should be considered before the final decision. The head-to-head and tail-to-tail sections will handle the platooning in different manners. The head-to-head configuration is preferable because the lane drop areas of the opposing passing lanes are not located adjacent to each other.



SIDE BY SIDE (4 Lane Undivided)

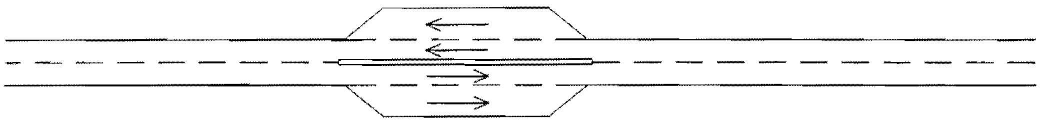


Figure A-3: Type C Design with Overlapping Sections.

Type C is probably the least desired section because of the increased cost of construction due to its increased width, and the need for additional right-of-way. It is included in this discussion to ensure that highway designers have a comprehensive set of alternatives from which to select the optimum condition for each individual project.

ISOLATED

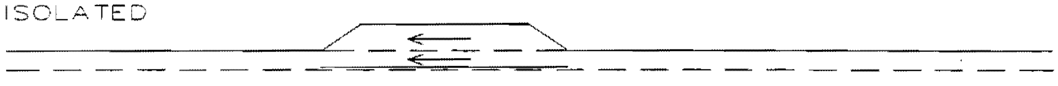


Figure A-4: Type D Design Isolated Passing Section

This kind of isolated passing lane can serve the specific purpose of reducing delay at a specific bottleneck. Their importance may be perceived in an isolated section of a rural two-lane highway where passing opportunities required in an isolated portion of the road, say close to a farmland. A vehicle using the rural road needs some sort of passing facilities where slow moving vehicles like a cotton gin might use the portion of the road frequently. One disadvantage of this kind of isolated passing lane is they will be less traveled because of the seasonal variation of traffic volume. However, from the economic point of view its more cost effective than constructing passing lanes at regular intervals for the full length of the roadway.

Conclusion

After evaluating highway characteristics, Super Two concept is a good approach to the solution of the problem. This type of highway with added passing lanes could provide a cost-effective method for improving the level of service on two-lane highways. Not only can passing lanes improve traffic operations on two-lane roads, but they have also been documented to reduce accidents. However, before the design phase, a thorough analysis of the highway in terms of comparing savings with the construction and maintenance costs is important. In order to come up with a sound analysis, field data revealing the characteristics of a particular highway should be connected. By taking into account all delay and accident savings, Super Two should be considered as a permanent solution or a temporary construction between two-lane highways and four-lane highways.

APPENDIX B: APPLICATION OF QUEUING THEORY IN TWO-WAY-TWO-LANE RURAL HIGHWAYS

Introduction

The congestion of the traffic on urban highways especially during peak hours is a big concern of the traffic engineers. This congestion results in the formation of queues on expressway on-ramps and off-ramps at signalized and unsignalized intersections, and on arterials, where moving queues may occur. On the rural highways the congestion of the traffic is much less frequent than those of the urban highways. However, the formation of the queue is still encountered on the rural highways. Slow moving vehicles preventing other fast moving vehicles from driving at their desired speeds mainly cause that event. This is the case of a platoon of the passenger vehicles being lead by a truck. An understanding of the processes that lead to the occurrence of queues and the subsequent delays on highways is essential for the proper analysis of the effects of queuing. The theory of queuing comprises the mathematical algorithms to describe the processes that result in the formation of the queues, so that a detailed analysis of the effects of queues can be performed.

These mathematical algorithms can be used to determine the probability that an arrival will be delayed, the expected waiting time for all arrivals, the expected waiting time of an arrival that waits, and so forth. Examples where the theory can be applied include vehicles waiting to be served at a gasoline station, passengers or vehicles lined up at a transit terminal, computer jobs awaiting for execution or printing, and so forth.

The service can be provided in a single channel or in several channels. Proper analysis of the effects of such a queue can be carried out only if the queue is fully specified. This requires that the following characteristics of the queue be given.

(1) The characteristic distribution of arrivals such as uniform or Poisson
(2) The methods of service such as first come-first served, random, and priority.
(3) The characteristic of the queue length (finite or infinite)
(4) The distribution of service times
(5) The channel layout (single or multiple channels and series or parallel)

Some terms used to classify the queues are given below.

<u>Arrival Distribution</u>: The arrivals can be described as either a deterministic distribution or a random distribution. A Poisson distribution usually describes light-to-medium traffic, and this is generally used in queuing theories related to traffic flow.

<u>Service Method</u>: Queues can also be classified by the method used in serving the arrivals. These include fist come fist served, where units are served in order of their arrival, and last in-first served, where the service is reversed to the order of arrival. The service method can also be based on priority, where arrivals are directed to specific queues of appropriate priority levels. Queues are then serviced in order of their priority level.

Characteristics of the Queue Length: The maximum length of the queue, or the maximum number of units in the queue, is specified. In this case the queue is a finite or truncated queue, or else there may be no restriction on the length of the queue. Finite queues are sometimes necessary when the waiting area is limited.

Service distribution: This distribution is also usually considered as random, and the Poisson and negative exponential distributions have been used.

Number of Channels: The number of channels usually corresponds to the number of waiting lines and is therefore used to classify queues, for example, as a single-channel or multi-channel queue.

Oversaturated and Undersaturated Queues: Oversaturated queues are those in which the arrival rate is greater than the service rate, and undersaturated queues are those in which the arrival rate is less than the service rate. The length of an oversaturated queue may vary but will reach a steady state with the arrival of units. However, the length of an oversaturated queue will never reach a steady state but will continue to increase with the arrival of units.

Single channel, Undersaturated, Infinite Queues

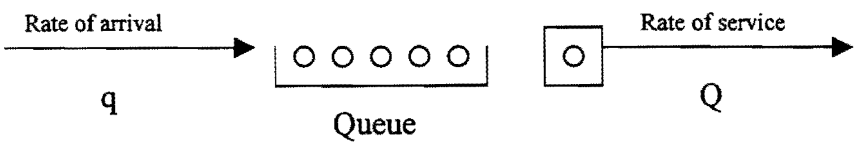


Figure B-1. Queue in a single channel

Figure B-1 represents a single channel queue where service type is FIFO (first in, first out) and with Poisson arrivals and exponentially distributed customer service times. The rate of arrival, q (vph), is less than the rate of service, Q (vph), since it is an undersaturated system. In the system customers are assumed to be patient, in other words they do not leave the system. This system is assumed to have an unlimited holding capacity, which means there is no limit on the number of customers that can be in the waiting line.

For an undersaturated queue ($q<Q$), assuming that both the rate of arrival and the rate of service are random, the following equations are developed. (Nicholas J. Garber, Lester A. Hoel, 1997)

1. Probability of n units in the system

$$P(n) = \left(\frac{q}{Q}\right)^n \left(1 - \frac{q}{Q}\right)$$

Where:n is the number of units in the system, including the unit being serviced.

2. The expected value (the average number of units in the system at any time is)

$$E(n) = \frac{q}{Q-q}$$

3. The expected number of units waiting to be served (the mean queue length) in the system

$$E(m) = \frac{q^2}{Q(Q-q)}$$

4. Average waiting time in the queue

$$E(w) = \frac{q}{Q(Q-q)}$$

5. Average waiting time in the system

$$E(v) = \frac{1}{Q-q}$$

Multi channel, Undersaturated, Infinite Queues

A more complex queuing system is a FIFO system with N identical service counters in parallel. The average service rate per counter is q and Q is the arrival rate. The rate of service rate to the arrival rate is r = q/Q.

In this case probability equation is as follows. (C.S. Papacostas, P.D. Prevedouros, 993).

1. For n = 0

$$p(0) = \left[\left(\sum_{n=0}^{N-1} \frac{r^n}{n!} \right) + \frac{r^N}{(N-1)!(n-r)} \right]^{-1}$$

For $1 \leq n \leq N$

$$p(n) = \frac{r^n}{n!} p(0)$$

For n > N

$$p(n) = \frac{r^n}{N! N^{n-N}} p(0)$$

2. The average number of units in the system

$$E(n) = r + \left[\frac{r^{N+1}}{(N-1)!(N-r)^2}\right]p(0)$$

3. The mean queue length

$$E(m) = \left[\frac{r^{N+1}}{(N-1)!(N-r)^2}\right]p(0)$$

4. The expected time in the queue

$$E(w) = \frac{E(m)}{q}$$

5. The expected time in the system

$$E(v) = \frac{E(n)}{q}$$

Application of the Theory

The major problem that creates the need for two-lane two-way highways to upgrade to Super Two Highways is the lack of the passing opportunities. This event results in the time delay caused by speed difference between the vehicles. In order to compute the average delay, the queuing theory is carried out in this research. The major components of the theory are rate of arrival and rate of service.

<u>The arrival rate</u>

The arrival rate is computed using ADT figures taken from Texas traffic map. On this map a particular section is considered for the calculation of the delay time. This specific section is on highway 87 at Dalhart in Dallam County (Northeast Texas). The ADT ranges from 2400 to 3600 vehicles on that road. On rural roads with average fluctuation in traffic flow, the 30th highest hourly volume of the year approximates 15 percent of ADT. The peak-hour traffic volume is then equal to 15 percent of the ADT. Accordingly, the arrival rates are calculated using the peak-hour traffic volume taking into account a directional distribution coefficient of 0.60 with an increment of 50 vehicle per hour.

The figure includes the number of both cars and trucks traveling on the highway. On the other hand, queuing theory is modeled assuming the trucks are servers and the cars are units being served. In order to come up with a proper value to use in the performing of the queuing theory, number of trucks should be extracted from the total number of vehicles. The deduction of 10 percent of trucks gives the number of passenger cars used for calculating the arrival rate.

The service rate

Two different approaches for calculating the service rate are taken towards the solution of this problem. One is calculating the service rate from the service volume computed directly from capacity under ideal conditions. (Highway Research Board, 1987)

$SV= 2000\ (v/c)\ W_L\ T_L$

Where: (v/c) = volume to capacity ratio
W_L = adjustment for lane width and lateral clearance at any given level of service
T_L = truck factor at given level of service

A typical cross section of the rural highways consists of two 12-foot lanes and two 10-foot shoulders making a 44-foot cross section. For our case we assume 10 percent truck traffic. The section that is considered has a maximum ADT of 3600 vehicles yielding a peak-hour traffic of 540 vehicles for both directions. This figure falls in the proper range (400-900) of service volume for Level of Service B. Therefore, the service rate is calculated for LOS B, as a result the service rate is computed by using proper adjustment factors for a highway constructed on level terrain.

$SV_B = 2000\ (0.45)\ (1.0)\ (0.87) = 783$ vph, total for both directions.

Subsequently, the service rate is the following equation.

Q = 783 x 0.60 = 470 vph = 7.83 veh/min, one direction

The sections without passing lanes are considered as a single channel model. The max arrival rate is the following equation.

q_{max}= 4.86 veh/min (ADT=3600)

The service rate can be considered without truck percentage which is 10%. Q=7.05 veh/min is greater than q_{max}. As a result single channel undersaturated queue model is applicable for computing average delays per vehicle on that road.

Another way of determining the service rate is to find the number of cars that can pass the truck for a unit time. This method is useful since it reflects the real situation on the roadway from a physics standpoint. For that case, a physics problem where the period time for a fast moving vehicle (passenger car) overtakes the slow moving car (truck) is solved. The speed limit of 70 mph and 60 mph are the figures used in calculating the amount of time spent for overtaking the slow moving vehicles leading the platoon. In order to perform a safe passing, for the speed group 60-70 mph, the distance traveled while the passing vehicle occupies the left lane (d_2) is 95.45 ft. The average passing speed for the same speed range is V_{avg}=62.38 mi/hr (8.454 ft/sec). (AASHTO, 1994)

The computations are shown below.

$d_2 = (V_{avg})\ (t_{avg})$

$t_{avg} = 95.45 / 8.454 = 11.3$ sec/veh = 0.188 min/veh

By inverting the average time for a vehicle to pass the truck we can compute the average service rate Q_{avg}.

$Q_{avg} = 1 / t_{avg} = 5.32$ veh/min

<u>Sections With Passing Lane</u>

For the sections of the road with passing lanes, a multiple channel model with two identical channels (N=2) is used.

The average delay time per vehicle, average queue length for sections with and without passing lanes are computed using the formulas given above. The results are given in spreadsheets 1 and 2.

<u>Sample Problem</u>

For a Highway Section where an ADT of 2400 vehicles is observed, the truck percentage is 37%. Determine average delay time per vehicle.

Solution:
Peak-hour traffic: 2400 x 0.15 x 0.60 = 216 veh/hr (Total traffic for one direction)
216-216 x0.37 = 136 veh/hr (Number of cars-units served)
The arrival rate is: q = 2.27 veh/min
The service rate is: Q = 5.32 veh/min

Average delay: $E\ (w) = \dfrac{q}{Q(Q-q)} = \dfrac{2.27}{5.32(5.32-2.27)} x60 = 8.40 \sec/\text{veh}$

Note: Considering a traffic composition with 37% of trucks, the number of trucks is 80 meaning 80 platoons will form on the road. Then, the total delay time of a car to pass all the vehicles will be $T_{tot} = 80 \times 8.4 = 672$ sec = 11.2 min.

Table B-1. Service Rate (5.32 veh/min)

ADT	PEAK	DIRECTIONAL	ARRIVAL RATE	Waiting Time - E(w) No passing Lane(sec)	Waiting Time - E(w) With Passing Lane (sec)	Mean Queue Length Single lane E(m)	Mean Queue Length Passing lane E(m)
2400	360	216	3.24	17.57	1.153	0.95	0.062
2450	368	221	3.31	18.54	1.206	1.02	0.067
2500	375	225	3.38	19.57	1.262	1.10	0.071
2550	383	230	3.44	20.68	1.319	1.19	0.076
2600	390	234	3.51	21.87	1.377	1.28	0.081
2650	398	239	3.58	23.16	1.438	1.38	0.086
2700	405	243	3.65	24.54	1.500	1.49	0.091
2750	413	248	3.71	26.05	1.563	1.61	0.097
2800	420	252	3.78	27.68	1.629	1.74	0.103
2850	428	257	3.85	29.47	1.697	1.89	0.109
2900	435	261	3.92	31.43	1.766	2.05	0.115
2950	443	266	3.98	33.58	1.837	2.23	0.122
3000	450	270	4.05	35.97	1.911	2.43	0.129
3050	458	275	4.12	38.62	1.986	2.65	0.136
3100	465	279	4.19	41.59	2.064	2.90	0.144
3150	473	284	4.25	44.93	2.144	3.18	0.152
3200	480	288	4.32	48.72	2.226	3.51	0.160
3250	488	293	4.39	53.06	2.311	3.88	0.169
3300	495	297	4.46	58.09	2.398	4.31	0.178
3350	503	302	4.52	63.96	2.487	4.82	0.187
3400	510	306	4.59	70.91	2.579	5.42	0.197
3450	518	311	4.66	79.29	2.673	6.15	0.208
3500	525	315	4.73	89.56	2.770	7.05	0.218
3550	533	320	4.79	102.47	2.870	8.18	0.229
3600	540	324	4.86	119.16	2.973	9.65	0.241

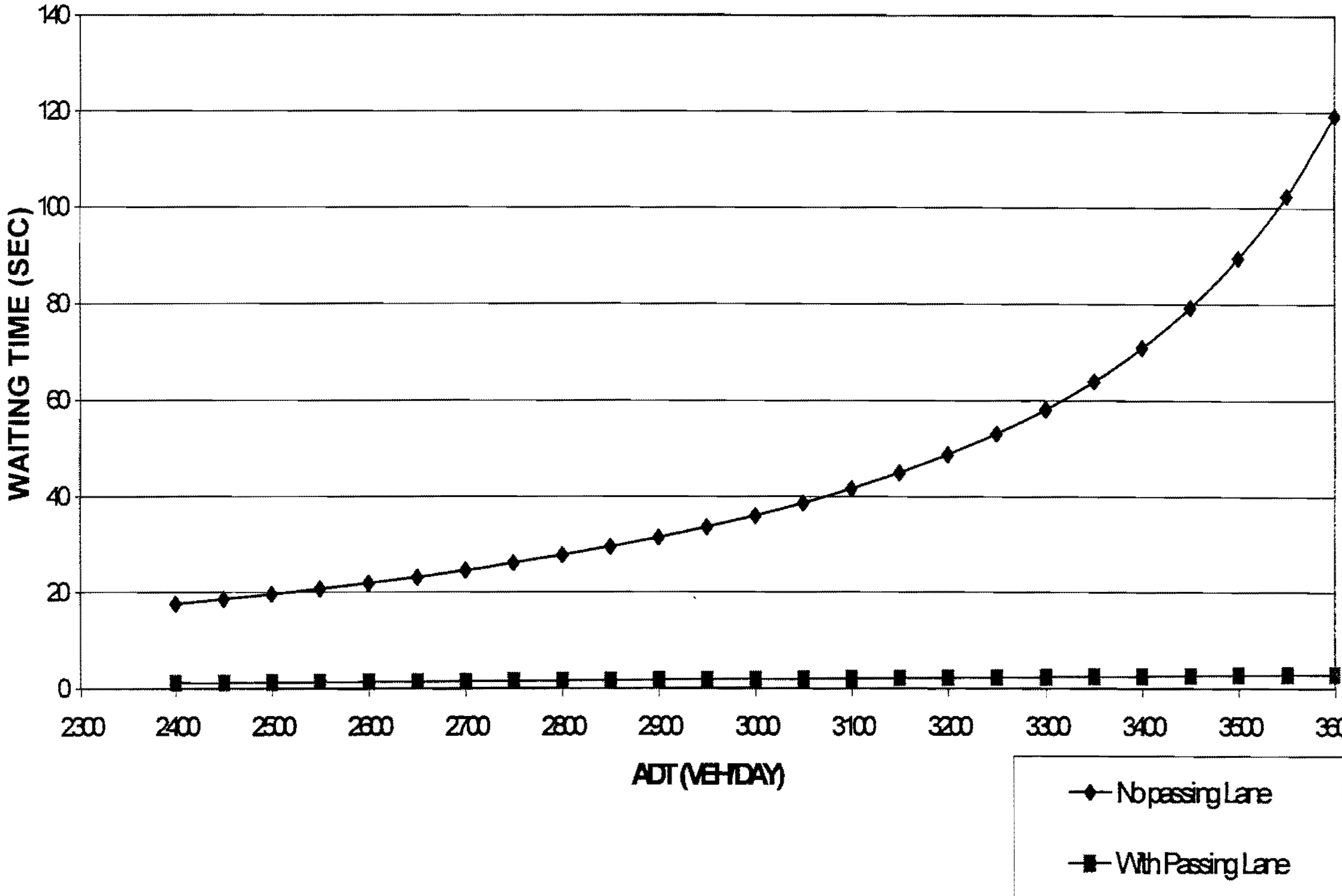


Figure B-2. Waiting Time vs. ADT (Service Rate = 5.32 veh/min)

Table B-2. Service Rate (7.05 veh/min)

ADT	PEAK	DIRECTIONAL	ARRIVAL RATE	Waiting Time - E(w) No passing Lane(sec)	Waiting Time - E(w) With Passing Lane (sec)	Mean Queue Length Single lane E(m)	Mean Queue Length Passing lane E(m)
2400	360	216	3.24	7.24	0.474	0.39	0.026
2450	368	221	3.31	7.52	0.489	0.41	0.027
2500	375	225	3.38	7.72	0.510	0.43	0.029
2550	383	230	3.44	8.02	0.532	0.46	0.031
2600	390	234	3.51	8.33	0.555	0.49	0.032
2650	398	239	3.58	8.66	0.578	0.52	0.034
2700	405	243	3.65	8.99	0.601	0.55	0.037
2750	413	248	3.71	9.34	0.626	0.58	0.039
2800	420	252	3.78	9.71	0.650	0.61	0.041
2850	428	257	3.85	10.09	0.676	0.65	0.043
2900	435	261	3.92	10.48	0.701	0.68	0.046
2950	443	266	3.98	10.90	0.728	0.72	0.048
3000	450	270	4.05	11.33	0.755	0.76	0.051
3050	458	275	4.12	11.78	0.783	0.81	0.054
3100	465	279	4.19	12.25	0.811	0.85	0.057
3150	473	284	4.25	12.75	0.840	0.90	0.060
3200	480	288	4.32	13.26	0.870	0.96	0.063
3250	488	293	4.39	13.81	0.900	1.01	0.066
3300	495	297	4.46	14.38	0.931	1.07	0.069
3350	503	302	4.52	14.99	0.963	1.13	0.073
3400	510	306	4.59	15.62	0.995	1.20	0.076
3450	518	311	4.66	16.29	1.028	1.26	0.080
3500	525	315	4.73	17.00	1.062	1.34	0.084
3550	533	320	4.79	17.75	1.096	1.42	0.088
3600	540	324	4.86	18.55	1.132	1.50	0.092

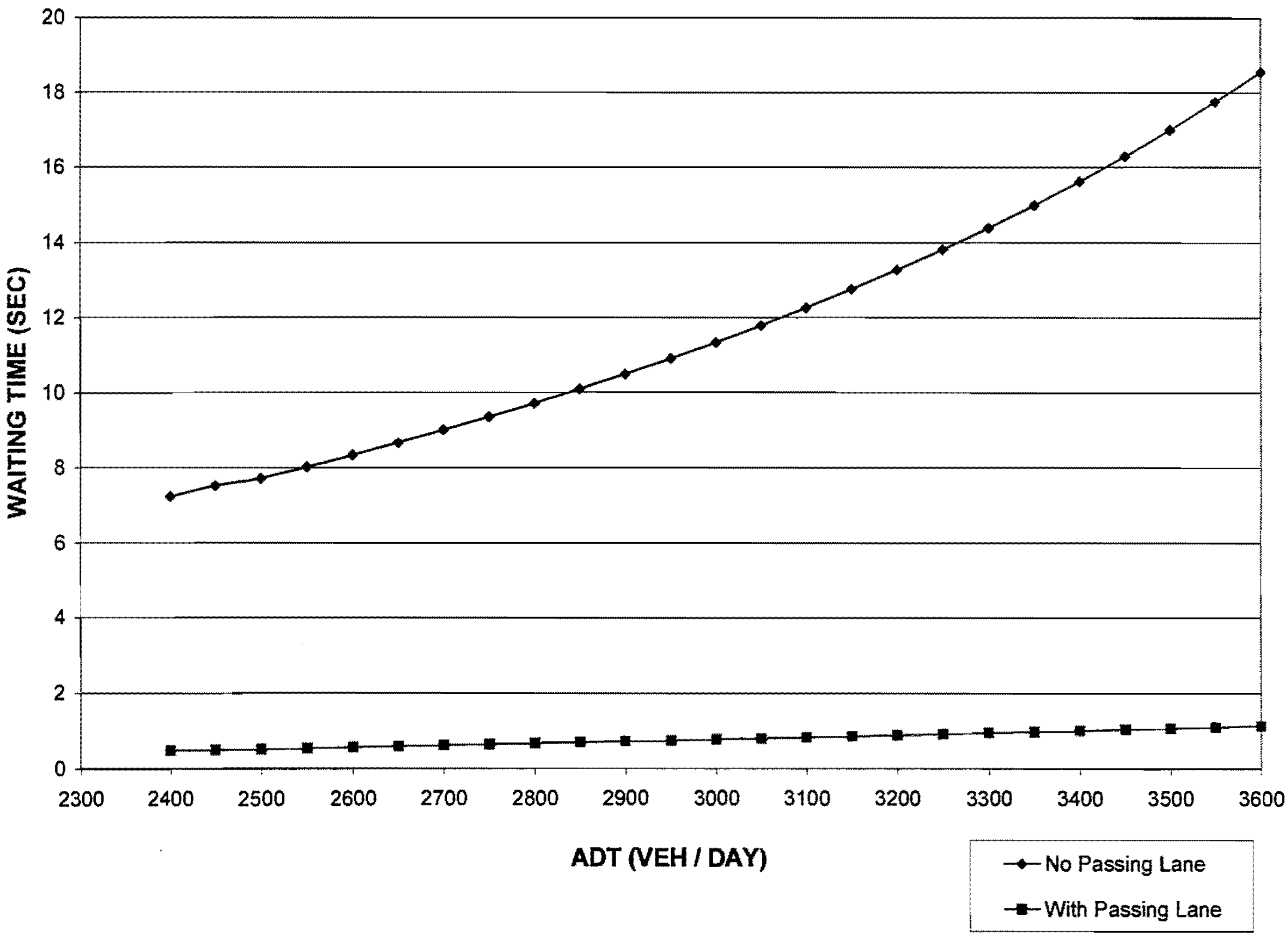


Figure B-3. Waiting Time vs. ADT (Service Rate = 7.05 veh/min)

APPENDIX C: GEOMETRIC DESIGN STANDARDS

Studies show that Super-Two sections can be justified for rural two-lane highways with traffic levels between 1500 and 7000 ADT with composite grades (Mendoza and Mayoral). For a two-lane highway without shoulders and an ADT level below 1500, it is difficult to justify the construction of a Super-Two section from the economic point of view. For ADT greater than 7000 it is more appropriate to consider construction of a four-lane highway. From the accident cost standpoint Super-Two sections are justifiable for an ADT levels of 2500 or over.

Traffic Operation in a Super-Two Section

When vehicles enter the Super-Two section, all the vehicles will be on one lane with slow moving vehicles at the front of the queue. As they enter the Super-Two section, slow vehicles will stay in the right lane and will allow the faster moving vehicles to go through. All the faster moving vehicles will complete passing maneuver using the passing lane within the Super-Two section. At the end of the Super-Two section slow vehicles will merge into the stream of faster moving vehicles while yielding the way.

Spacing

The Super-Two sections should be as regularly spaced as possible. Factors to be considered in the design of Super-Two section are listed below.

(1) ADT
(2) Truck Percentage
(3) Topography
(4) Local needs (presence of off-road vehicles, School busses etc.)

From the case study, for a rural two-lane highway with ADT of 3600 and 10 percent trucks, the frequency of Super-Two section was found to be 20.74 km unless other factors such as topography and local needs dictate. Table C-1 shows how the spacing between Super-Two sections vary for different ADT levels. We can also calculate the total number of Super-Two sections using the same table needed for a given stretch of highway.

Topography of the area is a controlling factor for the placement of Super-Two sections. Super-Two sections can be considered at climbing lanes and at composite grades provided the portion of the highway has adequate sight distance.

Table C-1. Number of Passing Lanes per 100 km according to ADT and Truck Percentage

Truck % / ADT	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
2400	2	2	2	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12
2450	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	11	12
2500	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12
2550	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12
2600	2	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	13
2650	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	11	12	12	12	13
2700	2	2	3	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13
2750	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13
2800	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	12	13	13	14
2850	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13	14
2900	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	14	14
2950	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14
3000	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14
3050	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14	15
3100	2	2	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	15	15
3150	2	3	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	14	15	15
3200	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	15
3250	2	3	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	13	14	14	15	15	16
3300	2	3	3	4	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	15	15	15	16
3350	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	13	14	14	15	15	16	16
3400	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16
3450	2	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	16	16	17
3500	2	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16	17
3550	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17
3600	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	14	15	15	16	16	17	17

Local features such as a factory or a farm may dictate the implementation of Super-Two section at that point of the highway when accompanied with the appropriate levels of traffic.

The design procedure for the spacing of Super-Two section is as follows.

(a) Determine the ADT of the highway concerned and the Percentage of Trucks for the highway.
(b) Determine the total number of Super-Two sections required using Table C-1 of Appendix C.
(c) Identify the number of Super-Two sections needed due to topographical and local requirements and deduct that number from the total in (b).
(d) Distribute the remaining number of Super-Two sections evenly over the highway while trying to maintain the design spacing as much as possible.

Engineering judgment should be used in calculating the positioning and spacing of the Super-Two section. The design engineer's experience should be utilized to determine the local needs of the portion of highway concerned.

Cross Section

The cross section of two-lane arterials and collectors is shown in figure C-1. It shows two lanes of 3.6 m and two shoulders of 3.0 m each. In Texas these shoulders are often used by trucks to provide passing maneuvers for faster vehicles.

Figure C-2 shows the layout of the proposed Texas Super-Two with a 3.6 m lane in one direction and two 3.35 m lane in the other. Widths of shoulders are not the same in this arrangement. In one direction the shoulder width remains same as 3.0 m but it is reduced to 0.6 m on the other side as shown in Figure C-2. A number of sections of primary highways with wide paved shoulders in Western Canada (Frost and Moral, 1995) have been retrofitted with passing lane. Also, different shoulder widths have been used in Mexican Two-lane roads (Mendoza and Mayoral, 1996).

Length, Configuration and Spacing of Super-Two

It is preferable to position the Super-Two section where adequate sight distance is available and platoons can diverge easily. Figure C-3 shows the proposed configuration of Texas Super-Two. A brief description of different portions of the Super-Two section is given in the following paragraphs.

Lane Diverge Taper

The primary function of the diverge area is to direct slow moving vehicles to the outside lane and leave the inside lane free for passing maneuvers. The length of lane merge taper is calculated as a function of the length of lane diverge taper given by equation 29.

$$L_d = (0.65)(L_m) \tag{29}$$

Where L_d and L_m are the lengths of lane diverge and lane merge taper respectively. The value of L_m can be found using Equation (28). Table C-2 shows different values of lane diverge tapers for different lane width and design speed.

Passing Lane

The lengths of passing lanes for different ADT values can be calculated using the following equation.

$$L_{epl} = (t_{acc} + t_{pl})V_{tr} \tag{27}$$

Where: L_{epl} is the effective length (excluding tapers) of passing lane
t_{acc} is the time for acceleration
t_{pl} is the time to pass a vehicle in the queue
V_{tr} is the design speed of truck (or slow moving vehicle)

Here the indicated length of passing lane is from the end of lane diverge taper to the beginning of lane merge taper. Table C-3 shows values of passing lane lengths for different ADT values. From this chart we can see passing lane length increases with increasing ADT and with increasing of percentage of trucks.

Lane Merge Taper

The function of a lane merge taper is to allow the fast and slow moving vehicle streams to form into a single stream. The merge taper lengths may vary with approach speed (S_o) of the faster vehicle and the width of the lane (W). This can be calculated by using the following equation.

$$L_m = (0.62)(S_o)(W) \tag{28}$$

Using Table C-4 we can calculate the lengths of lane merge tapers for different design speeds and lane widths.

Table C-2. Lengths of Passing lane for variable ADT and Truck Percentage

Truck % / ADT	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2400	429	429	429	429	429	429	429	429	429	429	429	430	430	430	430	430
2450	433	433	433	433	433	433	433	433	434	434	434	434	434	434	434	434
2500	437	438	438	438	438	438	438	438	438	438	438	438	438	438	439	439
2550	442	442	442	442	443	443	443	443	443	443	443	443	443	443	443	444
2600	447	448	448	448	448	448	448	448	448	448	448	448	449	449	449	449
2650	453	453	453	453	453	453	454	454	454	454	454	454	454	454	455	455
2700	459	459	459	459	459	460	460	460	460	460	460	460	460	461	461	461
2750	466	466	466	466	466	466	466	466	467	467	467	467	467	467	467	468
2800	473	473	473	473	473	473	473	474	474	474	474	474	474	474	475	475
2850	480	480	481	481	481	481	481	481	481	482	482	482	482	482	482	483
2900	489	489	489	489	489	489	489	490	490	490	490	490	491	491	491	491
2950	498	498	498	498	498	498	499	499	499	499	499	500	500	500	500	500
3000	507	508	508	508	508	508	509	509	509	509	509	510	510	510	510	511
3050	518	518	519	519	519	519	519	520	520	520	520	521	521	521	521	522
3100	530	530	530	531	531	531	531	532	532	532	532	533	533	533	534	534
3150	543	543	543	544	544	544	545	545	545	545	546	546	546	547	547	547
3200	557	558	558	558	558	559	559	559	560	560	560	561	561	562	562	562
3250	573	573	574	574	574	575	575	576	576	576	577	577	577	578	578	579
3300	591	591	592	592	592	593	593	593	594	594	595	595	596	596	597	597
3350	611	611	611	612	612	613	613	614	614	615	615	616	616	617	617	618
3400	633	633	634	634	635	635	636	636	637	637	638	638	639	640	640	641
3450	658	658	659	659	660	660	661	662	662	663	664	664	665	666	666	667
3500	686	687	687	688	689	689	690	691	691	692	693	694	695	695	696	697
3550	719	719	720	721	722	722	723	724	725	726	727	727	728	729	730	731
3600	746	747	748	749	750	751	751	752	753	755	756	757	758	759	760	761
3650	800	801	802	803	804	805	806	807	809	810	811	812	814	815	817	818
3700	852	853	854	855	857	858	859	861	862	864	865	867	868	870	872	873
3750	913	915	916	918	920	921	923	925	926	928	930	932	934	936	938	940
3800	989	990	992	994	996	998	1000	1002	1005	1007	1009	1012	1014	1017	1019	1022
3850	1082	1084	1086	1089	1091	1094	1097	1099	1102	1105	1108	1111	1114	1117	1121	1124
3900	1200	1203	1206	1209	1213	1216	1219	1223	1227	1230	1234	1238	1243	1247	1251	1256
3950	1355	1359	1363	1368	1372	1377	1381	1386	1391	1396	1402	1407	1413	1419	1425	1431
4000	1567	1573	1579	1585	1591	1598	1604	1611	1618	1626	1634	1641	1650	1658	1667	1676

Table C-3. Lengths of Lane Diverge Taper, Ld with respect to Design Speed and Lane Width

Design Speed (km/h) / Lane Width (m)	60	70	80	90	100	110	120	130
	Ld (m)							
2.50	60	71	81	91	101	111	121	131
2.55	62	72	82	92	103	113	123	134
2.60	63	73	84	94	105	115	126	136
2.65	64	75	85	96	107	117	128	139
2.70	65	76	87	98	109	120	131	141
2.75	67	78	89	100	111	122	133	144
2.80	68	79	90	102	113	124	135	147
2.85	69	80	92	103	115	126	138	149
2.90	70	82	94	105	117	129	140	152
2.95	71	83	95	107	119	131	143	155
3.00	73	85	97	109	121	133	145	157
3.05	74	86	98	111	123	135	148	160
3.10	75	87	100	112	125	137	150	162
3.15	76	89	102	114	127	140	152	165
3.20	77	90	103	116	129	142	155	168
3.25	79	92	105	118	131	144	157	170
3.30	80	93	106	120	133	146	160	173
3.35	81	95	108	122	135	149	162	176
3.40	82	96	110	123	137	151	164	178
3.45	83	97	111	125	139	153	167	181
3.50	85	99	113	127	141	155	169	183
3.55	86	100	114	129	143	157	172	186
3.60	87	102	116	131	145	160	174	189
3.65	88	103	118	132	147	162	177	191
3.70	89	104	119	134	149	164	179	194
3.75	91	106	121	136	151	166	181	196
3.80	92	107	123	138	153	168	184	199
3.85	93	109	124	140	155	171	186	202
3.90	94	110	126	141	157	173	189	204
3.95	96	111	127	143	159	175	191	207
4.00	97	113	129	145	161	177	193	210

Table C-4. Lengths of Lane Merge Taper, L_m with respect to Design Speed and Lane Width

Design Speed (km/h) / Lane Width (m)	60	70	80	90	100	110	120	130
	Lm (m)							
2.50	93	109	124	140	155	171	186	202
2.55	95	111	126	142	158	174	190	206
2.60	97	113	129	145	161	177	193	210
2.65	99	115	131	148	164	181	197	214
2.70	100	117	134	151	167	184	201	218
2.75	102	119	136	153	171	188	205	222
2.80	104	122	139	156	174	191	208	226
2.85	106	124	141	159	177	194	212	230
2.90	108	126	144	162	180	198	216	234
2.95	110	128	146	165	183	201	219	238
3.00	112	130	149	167	186	205	223	242
3.05	113	132	151	170	189	208	227	246
3.10	115	135	154	173	192	211	231	250
3.15	117	137	156	176	195	215	234	254
3.20	119	139	159	179	198	218	238	258
3.25	121	141	161	181	202	222	242	262
3.30	123	143	164	184	205	225	246	266
3.35	125	145	166	187	208	228	249	270
3.40	126	148	169	190	211	232	253	274
3.45	128	150	171	193	214	235	257	278
3.50	130	152	174	195	217	239	260	282
3.55	132	154	176	198	220	242	264	286
3.60	134	156	179	201	223	246	268	290
3.65	136	158	181	204	226	249	272	294
3.70	138	161	184	206	229	252	275	298
3.75	140	163	186	209	233	256	279	302
3.80	141	165	188	212	236	259	283	306
3.85	143	167	191	215	239	263	286	310
3.90	145	169	193	218	242	266	290	314
3.95	147	171	196	220	245	269	294	318
4.00	149	174	198	223	248	273	298	322

Signing and Pavement Marking

Figure C-4 shows the proposed Texas Super-Two section with signing and pavement marking used TxDOT. They can be divided into four separate zones as described below.

- Zone 1 provides advanced notification of the Super-Two section
- Zone 2 indicates the diverge area
- Zone 3 provides advance notification of the end of the passing lane
- Zone 4 provides information regarding next Super-Two section and also warns to traffic moving in the opposing direction

In Zone 1 advance notification is posted at 3 km, 2 km and 1 km in advance of the Super-Two section. Zone 2 provides notification of the beginning of the diverge area and the regulatory sign 'SLOWER TRAFFIC KEEP RIGHT'. Zone 3 provides advance notification of the lane merge. Zone 4 provides regulatory signs 'KEEP RIGHT' and 'DO NOT CROSS DOUBLE LINE' for the on coming vehicles and informs about the next Super-Two section.

Double lines and the dotted line along the center of the roadway are yellow lines. Raised pavement marker may be used in between those double yellow lines to discourage accidental crossover. The dotted line marking the passing lane and all other lines are marked by white. All pavement markings should be in agreement with Texas MUTCD.

Case Study Problem

US highway 83 connects Childress and Hamlin and the distance between them is 166.40 km (104 miles). For the purpose of illustration it is assumed that the ADT of this highway is 3500 with 12 percent truck. It passes through the three towns Paducah, Guthrie and Aspermont at distances of 48 km (30 mile), 93 km (58 mile) and 153 km (95 mile) from Childress respectively. Width of passing lane is 3.35 m and the design speed is 120 km/h. Calculate the number of Super-Two sections required to diminish platooning of vehicles in this highway.

Solution:

For 3500 with 12 percent of trucks, using Table C-1 the minimum number of Super-Two sections required per 100 km is found to be 6.

Corresponding minimum number of Super-Two sections required for 166 km is 9.96 ≅ 10.

The three towns Paducah, Guthrie and Aspermont will provide limited passing facilities. Therefore, at least 7 additional passing sections are needed along the rural portions of the highway. One Super-Two section is provided at the outskirts of each cities to minimize Queueing and Platooning caused by low speed low speed limits and traffic lights inside the city limit.

Using Table C-5 the design spacing for the Super-Two sections is found to be 21.33 km (13.33 mile).

Table C-5. Passing Lane Frequency for Variable ADT and Truck Percentage

ADT \ Truck %	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
2400	62.22	51.85	44.44	38.89	34.57	31.11	28.28	25.93	23.93	22.22	20.74	19.44	18.30	17.28	16.37	15.56	14.81	14.14	13.53	12.96	12.44	11.97	11.52	11.11	10.73	10.37	10.04	9.72	9.43	9.15	8.89	8.64
2450	60.95	50.79	43.54	38.10	33.86	30.48	27.71	25.40	23.44	21.77	20.32	19.05	17.93	16.93	16.04	15.24	14.51	13.85	13.25	12.70	12.19	11.72	11.29	10.88	10.51	10.16	9.83	9.52	9.24	8.96	8.71	8.47
2500	59.73	49.78	42.67	37.33	33.19	29.87	27.15	24.89	22.97	21.33	19.91	18.67	17.57	16.59	15.72	14.93	14.22	13.58	12.99	12.44	11.95	11.49	11.06	10.67	10.30	9.96	9.63	9.33	9.05	8.78	8.53	8.30
2550	58.56	48.80	41.83	36.60	32.53	29.28	26.62	24.40	22.52	20.92	19.52	18.30	17.22	16.27	15.41	14.64	13.94	13.31	12.73	12.20	11.71	11.26	10.84	10.46	10.10	9.76	9.45	9.15	8.87	8.61	8.37	8.13
2600	57.44	47.86	41.03	35.90	31.91	28.72	26.11	23.93	22.09	20.51	19.15	17.95	16.89	15.95	15.11	14.36	13.68	13.05	12.49	11.97	11.49	11.05	10.64	10.26	9.90	9.57	9.26	8.97	8.70	8.45	8.21	7.98
2650	56.35	46.96	40.25	35.22	31.31	28.18	25.61	23.48	21.67	20.13	18.78	17.61	16.57	15.65	14.83	14.09	13.42	12.81	12.25	11.74	11.27	10.84	10.44	10.06	9.72	9.39	9.09	8.81	8.54	8.29	8.05	7.83
2700	55.31	46.09	39.51	34.57	30.73	27.65	25.14	23.05	21.27	19.75	18.44	17.28	16.27	15.36	14.55	13.83	13.17	12.57	12.02	11.52	11.06	10.64	10.24	9.88	9.54	9.22	8.92	8.64	8.38	8.13	7.90	7.68
2750	54.30	45.25	38.79	33.94	30.17	27.15	24.68	22.63	20.89	19.39	18.10	16.97	15.97	15.08	14.29	13.58	12.93	12.34	11.81	11.31	10.86	10.44	10.06	9.70	9.36	9.05	8.76	8.48	8.23	7.99	7.76	7.54
2800	53.33	44.44	38.10	33.33	29.63	26.67	24.24	22.22	20.51	19.05	17.78	16.67	15.69	14.81	14.04	13.33	12.70	12.12	11.59	11.11	10.67	10.26	9.88	9.52	9.20	8.89	8.60	8.33	8.08	7.84	7.62	7.41
2850	52.40	43.66	37.43	32.75	29.11	26.20	23.82	21.83	20.15	18.71	17.47	16.37	15.41	14.55	13.79	13.10	12.48	11.91	11.39	10.92	10.48	10.08	9.70	9.36	9.03	8.73	8.45	8.19	7.94	7.71	7.49	7.28
2900	51.49	42.91	36.78	32.18	28.61	25.75	23.41	21.46	19.81	18.39	17.16	16.09	15.15	14.30	13.55	12.87	12.26	11.70	11.19	10.73	10.30	9.90	9.54	9.20	8.88	8.58	8.31	8.05	7.80	7.57	7.36	7.15
2950	50.62	42.18	36.16	31.64	28.12	25.31	23.01	21.09	19.47	18.08	16.87	15.82	14.89	14.06	13.32	12.66	12.05	11.50	11.00	10.55	10.12	9.73	9.37	9.04	8.73	8.44	8.16	7.91	7.67	7.44	7.23	7.03
3000	49.78	41.48	35.56	31.11	27.65	24.89	22.63	20.74	19.15	17.78	16.59	15.56	14.64	13.83	13.10	12.44	11.85	11.31	10.82	10.37	9.96	9.57	9.22	8.89	8.58	8.30	8.03	7.78	7.54	7.32	7.11	6.91
3050	48.96	40.80	34.97	30.60	27.20	24.48	22.26	20.40	18.83	17.49	16.32	15.30	14.40	13.60	12.88	12.24	11.66	11.13	10.64	10.20	9.79	9.42	9.07	8.74	8.44	8.16	7.90	7.65	7.42	7.20	6.99	6.80
3100	48.17	40.14	34.41	30.11	26.76	24.09	21.90	20.07	18.53	17.20	16.06	15.05	14.17	13.38	12.68	12.04	11.47	10.95	10.47	10.04	9.63	9.26	8.92	8.60	8.31	8.03	7.77	7.53	7.30	7.08	6.88	6.69
3150	47.41	39.51	33.86	29.63	26.34	23.70	21.55	19.75	18.23	16.93	15.80	14.81	13.94	13.17	12.48	11.85	11.29	10.77	10.31	9.88	9.48	9.12	8.78	8.47	8.17	7.90	7.65	7.41	7.18	6.97	6.77	6.58
3200	46.67	38.89	33.33	29.17	25.93	23.33	21.21	19.44	17.95	16.67	15.56	14.58	13.73	12.96	12.28	11.67	11.11	10.61	10.14	9.72	9.33	8.97	8.64	8.33	8.05	7.78	7.53	7.29	7.07	6.86	6.67	6.48
3250	45.95	38.29	32.82	28.72	25.53	22.97	20.89	19.15	17.67	16.41	15.32	14.36	13.51	12.76	12.09	11.49	10.94	10.44	9.99	9.57	9.19	8.84	8.51	8.21	7.92	7.66	7.41	7.18	6.96	6.76	6.56	6.38
3300	45.25	37.71	32.32	28.28	25.14	22.63	20.57	18.86	17.40	16.16	15.08	14.14	13.31	12.57	11.91	11.31	10.77	10.28	9.84	9.43	9.05	8.70	8.38	8.08	7.80	7.54	7.30	7.07	6.86	6.65	6.46	6.29
3350	44.58	37.15	31.84	27.86	24.77	22.29	20.26	18.57	17.15	15.92	14.86	13.93	13.11	12.38	11.73	11.14	10.61	10.13	9.69	9.29	8.92	8.57	8.26	7.96	7.69	7.43	7.19	6.97	6.75	6.56	6.37	6.19
3400	43.92	36.60	31.37	27.45	24.40	21.96	19.96	18.30	16.89	15.69	14.64	13.73	12.92	12.20	11.56	10.98	10.46	9.98	9.55	9.15	8.78	8.45	8.13	7.84	7.57	7.32	7.08	6.86	6.65	6.46	6.27	6.10
3450	43.29	36.07	30.92	27.05	24.05	21.64	19.68	18.04	16.65	15.46	14.43	13.53	12.73	12.02	11.39	10.82	10.31	9.84	9.41	9.02	8.66	8.32	8.02	7.73	7.46	7.21	6.98	6.76	6.56	6.37	6.18	6.01
3500	42.67	35.56	30.48	26.67	23.70	21.33	19.39	17.78	16.41	15.24	14.22	13.33	12.55	11.85	11.23	10.67	10.16	9.70	9.28	8.89	8.53	8.21	7.90	7.62	7.36	7.11	6.88	6.67	6.46	6.27	6.10	5.93
3550	42.07	35.05	30.06	26.29	23.37	21.03	19.12	17.53	16.18	15.02	14.02	13.16	12.37	11.68	11.07	10.52	10.02	9.56	9.14	8.76	8.41	8.09	7.79	7.51	7.25	7.01	6.78	6.57	6.37	6.19	6.01	5.84
3600	41.48	34.57	29.63	25.93	23.05	20.74	18.86	17.28	15.95	14.81	13.83	12.96	12.20	11.52	10.92	10.37	9.88	9.43	9.02	8.64	8.30	7.98	7.68	7.41	7.15	6.91	6.69	6.48	6.29	6.10	5.93	5.76
3650	40.91	34.09	29.22	25.57	22.73	20.46	18.60	17.05	15.74	14.61	13.64	12.79	12.03	11.36	10.77	10.23	9.74	9.30	8.89	8.52	8.18	7.87	7.58	7.31	7.05	6.82	6.60	6.39	6.20	6.02	5.84	5.68
3700	40.36	33.63	28.83	25.23	22.42	20.18	18.35	16.82	15.52	14.41	13.46	12.61	11.87	11.21	10.62	10.09	9.61	9.17	8.77	8.41	8.07	7.76	7.47	7.21	6.96	6.73	6.51	6.31	6.12	5.94	5.77	5.61
3750	39.82	33.19	28.44	24.89	22.12	19.91	18.10	16.59	15.32	14.22	13.27	12.44	11.71	11.06	10.48	9.96	9.48	9.05	8.66	8.30	7.96	7.66	7.37	7.11	6.87	6.64	6.42	6.22	6.03	5.86	5.69	5.53
3800	39.30	32.75	28.07	24.56	21.83	19.65	17.86	16.37	15.11	14.04	13.10	12.28	11.56	10.92	10.34	9.82	9.36	8.93	8.54	8.19	7.86	7.56	7.28	7.02	6.78	6.55	6.34	6.14	5.95	5.78	5.61	5.46
3850	38.79	32.32	27.71	24.24	21.55	19.39	17.63	16.16	14.92	13.85	12.93	12.12	11.41	10.77	10.21	9.70	9.24	8.82	8.43	8.08	7.76	7.46	7.18	6.93	6.69	6.46	6.26	6.06	5.88	5.70	5.54	5.39
3900	38.29	31.91	27.35	23.93	21.27	19.15	17.40	15.95	14.73	13.68	12.76	11.97	11.26	10.64	10.08	9.57	9.12	8.70	8.32	7.98	7.66	7.36	7.09	6.84	6.60	6.38	6.18	5.98	5.80	5.63	5.47	5.32
3950	37.81	31.50	27.00	23.63	21.00	18.90	17.18	15.75	14.54	13.50	12.60	11.81	11.12	10.50	9.95	9.45	9.00	8.59	8.22	7.88	7.56	7.27	7.00	6.75	6.52	6.30	6.10	5.91	5.73	5.56	5.40	5.25
4000	37.33	31.11	26.67	23.33	20.74	18.67	16.97	15.56	14.36	13.33	12.44	11.67	10.98	10.37	9.82	9.33	8.89	8.48	8.12	7.78	7.47	7.18	6.91	6.67	6.44	6.22	6.02	5.83	5.66	5.49	5.33	5.19

Therefore,

- Provide 3 Super-Two sections between Childress and Peducah. This will provide a spacing of 15 km (9.35 mile).

- Provide 3 Super-Two sections in between Peducah and Guthrie with a spacing of 14 km (8.70 mile).

- Provide 3 Super-Two sections in between Guthrie and Aspermont with a spacing of 18.50 km (11.50 mile).

- Provide 1 Super-Two sections in between Aspermont and Hamlin with a spacing of 14.40 km (8.94 mile).

Using Table C-2 for the design speed of 120 km/h and lane width of 3.35 m we can find the lengths of Lane Diverge Taper to be 162 m.

From Table C-3 for the ADT of 3500 and 12% trucks we can find lengths of Passing Lane to be 691 m.

Using Table C-4 for the design speed of 120 km/h and lane width of 3.35 m we can find the lengths of Lane Merge Taper to be 249 m.

Therefore, the total length of Super-Two section is 1102 m in detailed layout of the Super-Two sections shown in Figure C-5.

Studies have shown that the inclusion of Super-Two sections can improve the level of service of a standard Two-Lane highway by increasing safety (Frost and Morrall, 1995). From our study it is found that the Super-Two is cost-effective for an ADT range of 2400 to 4200. Beyond this range we need to use computer simulation technique to justify its validity. From our Traffic survey in New Mexico it is found that the Super-Two section is very effective in reducing Queues and Platoons. It is shown that the advent of Super-Two sections reduces Queueing by 55% to 66%. The Super-Two sections will be the suitable solution for Two-Lane roads that need to raise the level of service for the existing traffic and the funds availability.

Figure C-1. Cross Section of a Rural Two-Lane Highway in Texas

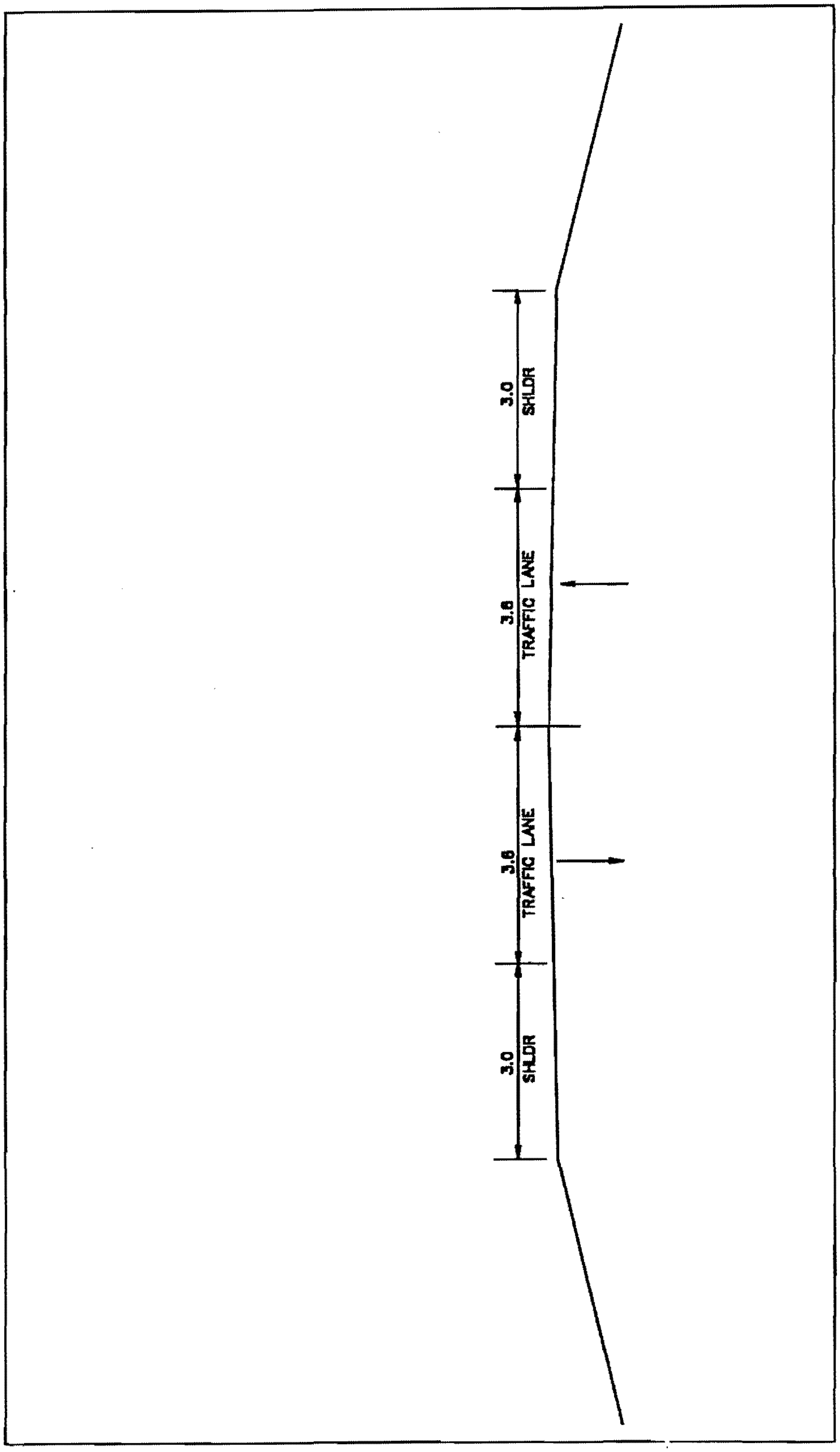


Figure C-2. Cross Section for Texas Super-Two

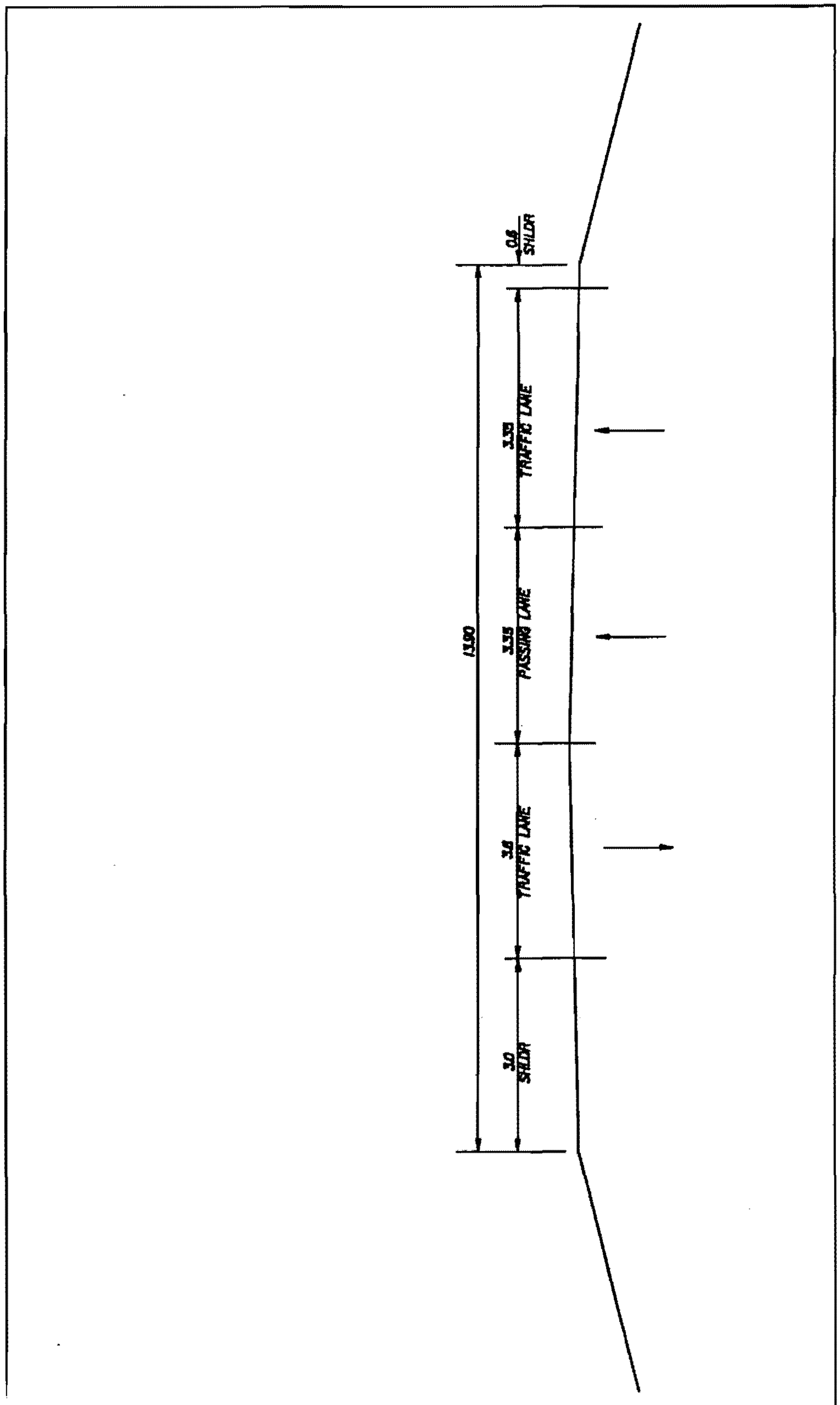


Figure C-3. Lane Configuration for Texas Super-Two

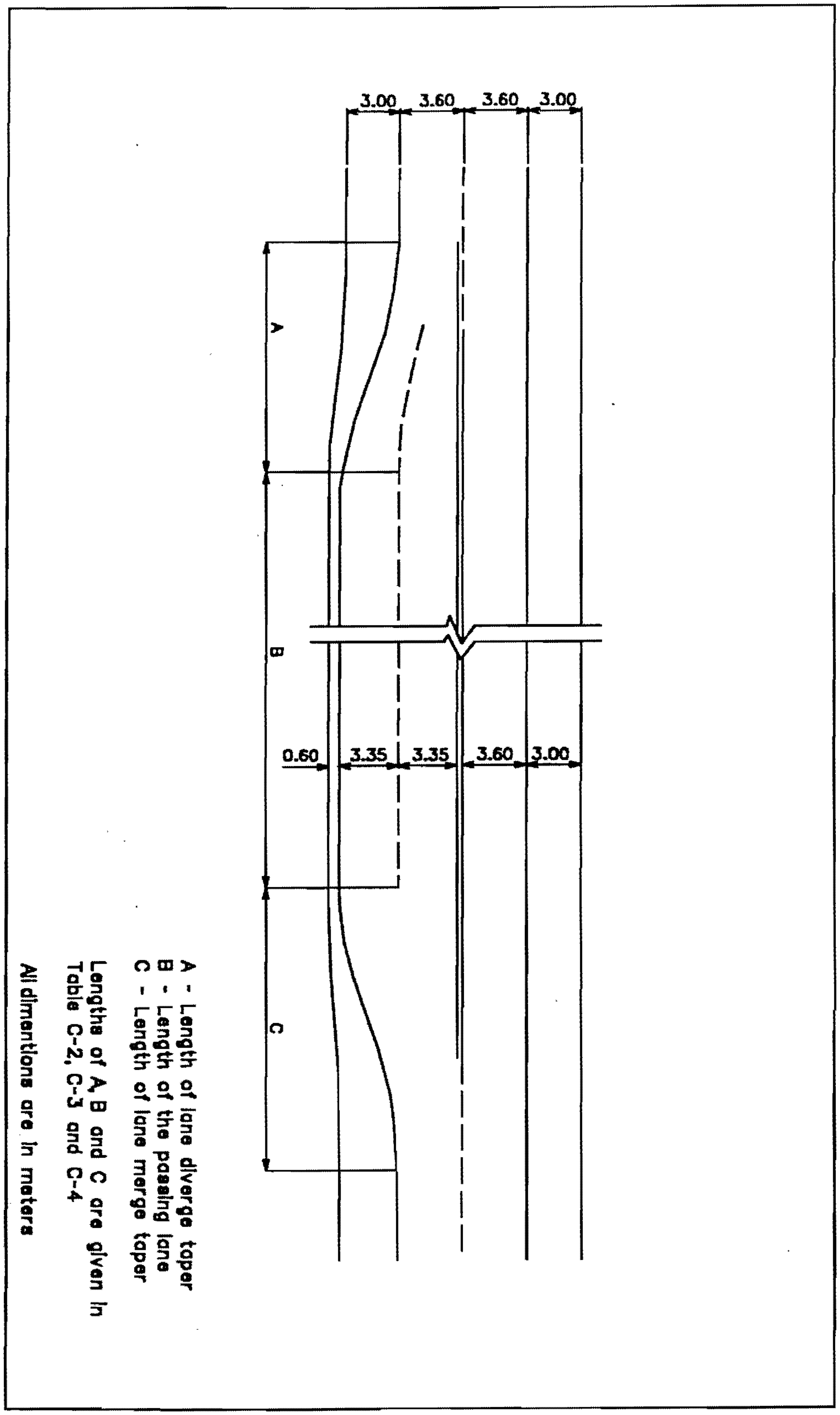


Figure C-4. Signing and Pavement Marking for Texas Super-Two

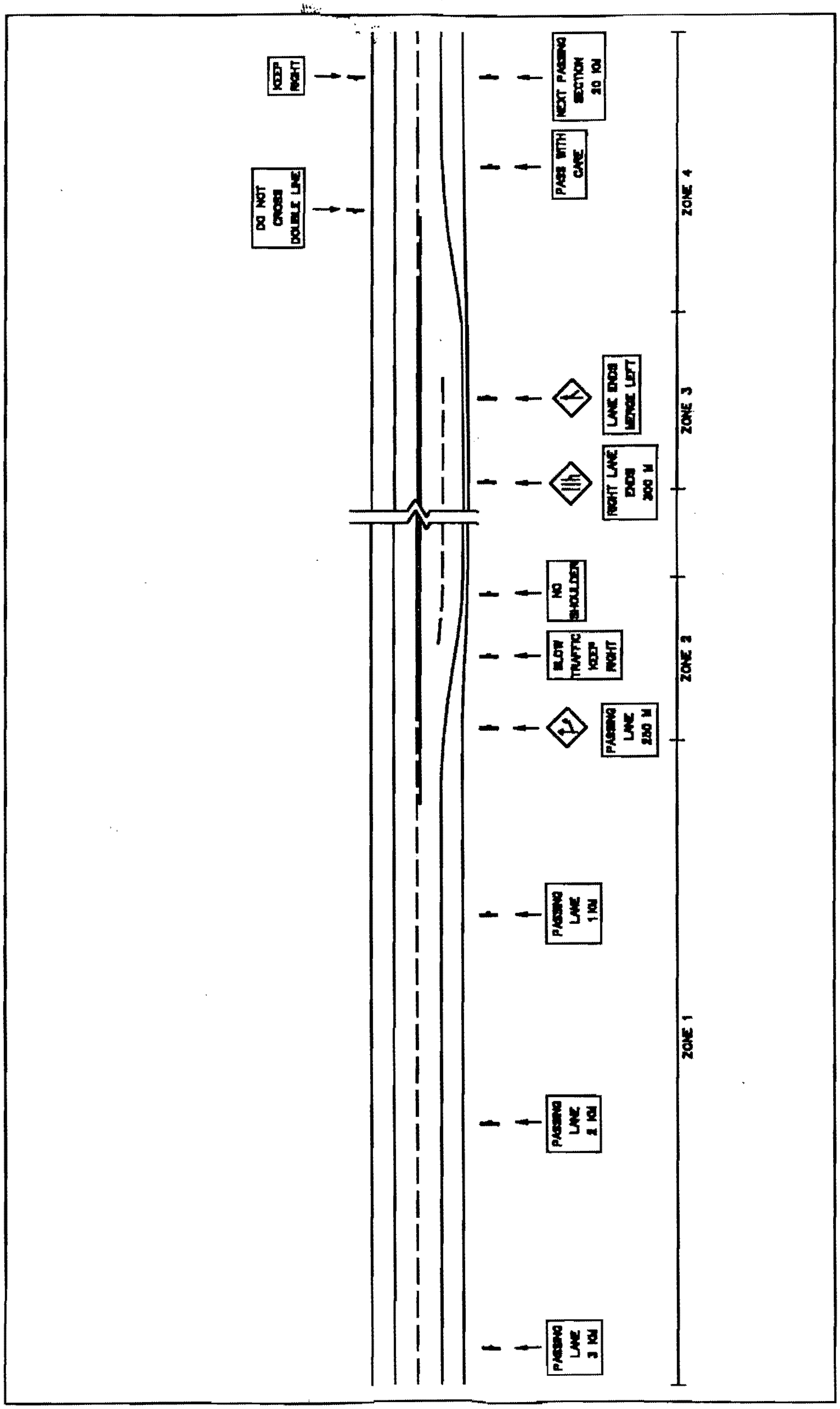
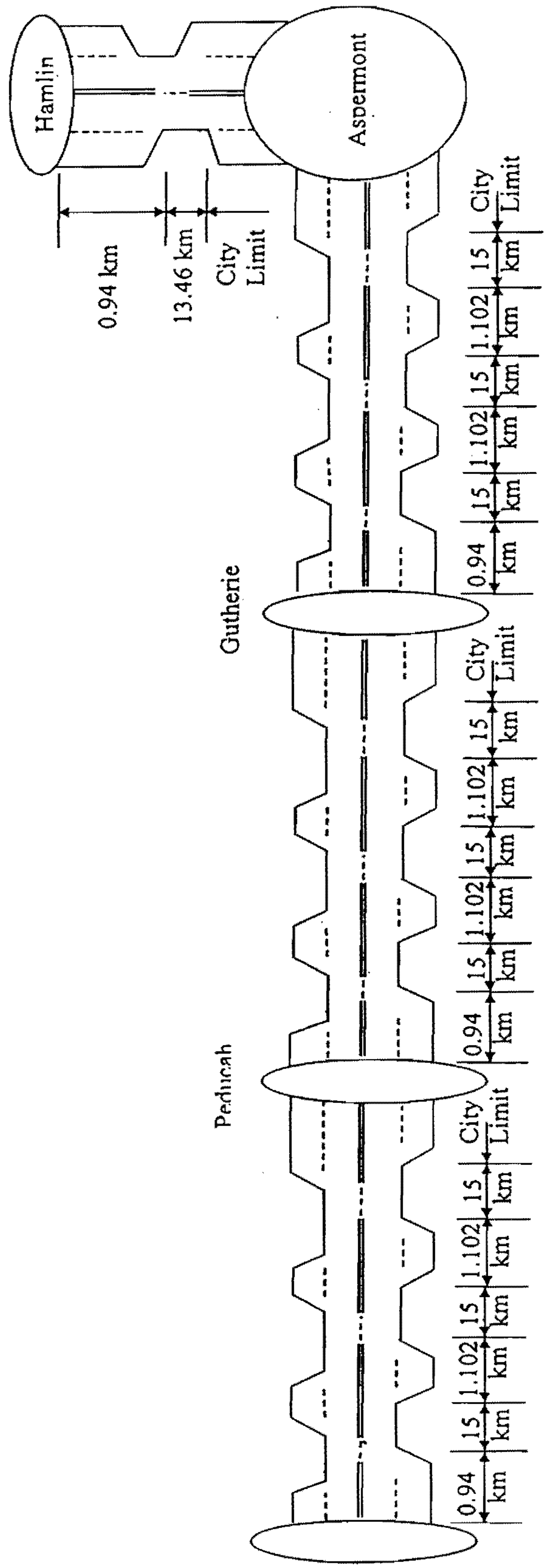


Figure C-5. Layout of Super-Two sections from Childress to Hamlin for the example problem. (Details of signing and pavement markings are shown in Figure C-4.



APPENDIX D: ECONOMIC EVALUATION OF SUPER TWO HIGHWAY DESIGN GEOMOTERY

Introduction

Two-lane, two-way rural roads are of great importance in the American Highway System. There are more than 3 million miles of two-lane rural highways in the United States, and they comprise about 97% of the total rural system and 80% of all U.S. roadways. It is estimated that 68% of rural travel and 30% of all travel occur on these rural two-lane roads. Funding is limited considering the extensiveness of the rural highway system and the environmental concerns, and research for ways to improve the service of these roadways is essential. Because of the low average daily traffic (ADT) levels carried on these rural highways, general low-cost improvements are advantageous over the classical methods involving major modifications such as four-lane sections and extensive modification of road geometrics.

The number of trucks using the rural highways increases the existing safety and operational problems in the design of two-lane, two-way highways. Heavy vehicles create operational problems in terms of delay, a reduced level of service, and an increase in passing attempts, aborted passes, and driver frustration.

The Super Two Highway involves the construction of passing lanes at set intervals to improve the level of service on two-way rural roads. The construction of passing lanes in rural areas where two-lane, two-way highways are provided will result in a benefit to the public. These benefits primarily originate from the delay time savings and prevention of accidents. For the regions such as Texas where the highways are constructed for the most part on level terrain, the savings that could have been benefited from vehicle operation are negligible. These kinds of savings are particularly of great importance in the mountainous areas where the average speed of trucks decreases significantly and passing opportunities are eliminated. Time delays are affected by traffic composition, and the presence of the slow-moving vehicles creates traffic platoons consisting of passenger cars following the trucks. During the time spent in the platoon, passenger cars will have to drive at a lower speed since the speed limit for trucks (60 mph) is lower than that of the passenger cars (70 mph). In addition, the platoons may cause the drivers to be more impatient. Their attempts to overtake the trucks at improper locations or situations may cause unsafe maneuvers, which can result in undesirable circumstances such as traffic accidents and injuries.

The main purpose of the research study is to search for adequate reasoning towards the implementation of passing lanes on rural two-way, two-lane highways where passing opportunities are limited. An economic study is performed to reveal the benefit/cost (B/C) ratios for different situations. As a result of the economic study, it is possible to have the B/C ratios for different ADTs and percentage of trucks. However, the values such as cost data, design period, and interest rates can be modified in order to meet the particular properties of the project.

Another important result of the research is an appropriate methodology that will enable transportation engineers to design the passing lanes. The issues in the design such as the length and intervals of the passing lanes are based on parametric computations. The highway designers will have the flexibility of applying their own considerations or proper figures in the analysis. In addition to having a design method, the engineers will have the capability to evaluate the economic side of their design. The best decision needs to be made after considering the economic outcomes of the project.

<u>Assumptions</u>

The following is a list of assumptions directly related to the construction of a Super Two Highway.

1. The number of cars on a two-lane, two-way highway is modeled with the application of Queuing Theory. Arrival rates of the vehicles on the designed roadway is modeled by a Poisson distribution, but the service rate provided by the road section as a whole is modeled with a negative exponential distribution. All the formulas used in the calculations of the average number of cars in the queue and the average waiting times in the queue are derived from Queuing Theory. These assumptions simulate the real traffic flow with low to medium ADT levels (less than 4200 ADT). High ADT levels are not recommended with these assumptions. These assumptions are not valid for ADTs greater than 4200 vehicles per day. (Garbor and Hoel, 1997)
2. The arrival rate is obtained by considering the maximum hour traffic (ADT x 0.15) with an uneven directional distribution of 60% and 40% in each direction.
3. The trucks are excluded from the arrival rate value because they are assumed to be relatively constant.
4. The service rate of a roadway section is calculated from the formula provided by the Highway Capacity manual. (1987)
5. Service volume capacity (SV) is utilized to find the service rate of the lane to be used in the queuing analysis.
6. Physical conditions on the rural highway that is chosen for the case study is assumed to have a 100% passing sight distance of at least 1500 feet. However, as the ADT value increases, the passing sight distance provided by the opposing traffic will decrease. The cumulative probability of having a time gap that would allow a 1500 feet passing sight distance between consecutive opposing vehicles is calculated. This probability is incorporated in a service volume equation just as the probability of having a physical passing sight distance of 1500 feet. This approach enables the dynamic behavior of service rate, because service rate or service volume decreases with increasing ADT levels.
7. The service rate obtained from Equation (6) gives the total number of vehicles in an hour in both directions. To find the service rate in the critical lane, this service is multiplied with Directional Factor (DF), which is taken as 0.6. (HRB Special Report, 1987)
8. To find the time savings of a Super Two Highway, the number of trucks that a typical passenger car would catch is calculated first. The number of trucks that would be caught will be a function of differential velocity between car and truck and will also depend on the average waiting time in the queue. As the waiting time of a car in the platoon increases, there would be fewer trucks to catch along a certain length of the roadway because the average

velocity of the car would approach the speed of the truck. The average waiting time in each queue per passenger car is then calculated. Time saving calculations were based on the assumption that an ideal Super Two Highway is constructed in such a fashion that would avoid any speed reduction due to the presence of trucks. After the first passing section, passenger cars would be able to travel without reducing their speeds. Hence, each car will benefit from traveling with the design speed during the entire roadway rather than traveling with some reduced speed interruptions when they travel the same speed as the truck where there exist platoon formations. Time saving due to a uniform design speed, rather than a reduced speed while in a platoon and a transition speed during the acceleration to the design speed are calculated as well.

9. The passing lanes are designed in such a manner that they will avoid any interruption of design speed of the passenger car. Therefore, trucks are assumed to be travelling with even distances among them. The time required the first car to overtake a truck and reach the next truck gives the distance between passing lanes.
10. Accident cost reductions and time saving monetary values are modeled with the formula provided in the study implemented by William C. Taylor and Mukesh K. Jain "Warrants for Passing Lanes", Transportation Research Record. (1988)
11. Existing roadway will have a standard 44-foot cross-section as seen in Figure D-1.

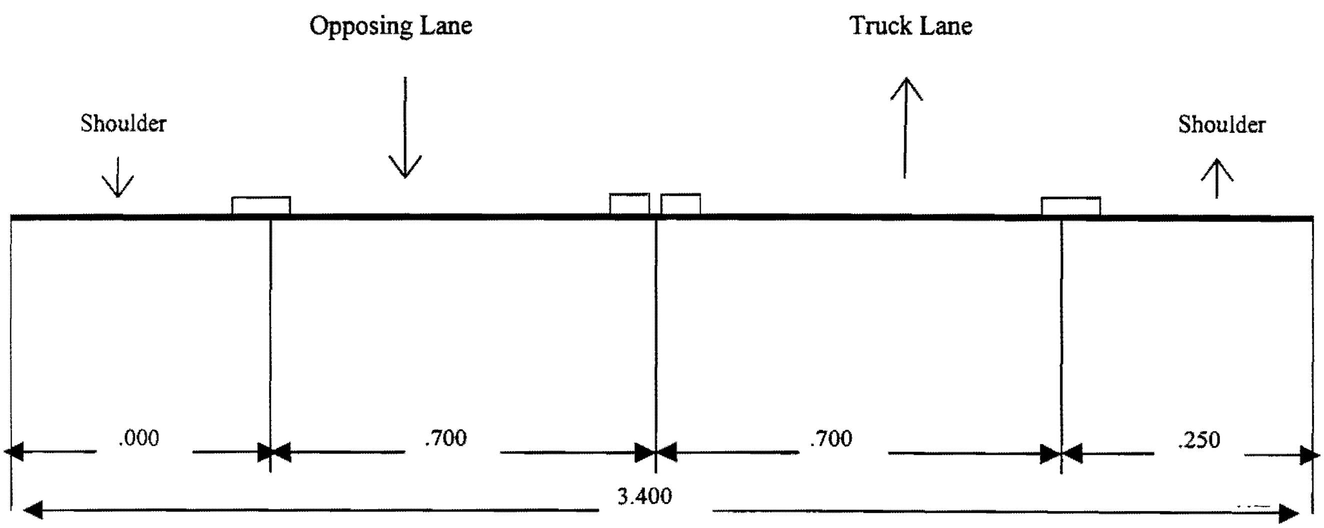


Figure D-1. Current Two-Lane Rural Highway Cross-section

12. A super-two cross section will require widening 60 centimeters. This cross-section is shown in detail in Figure D-2.

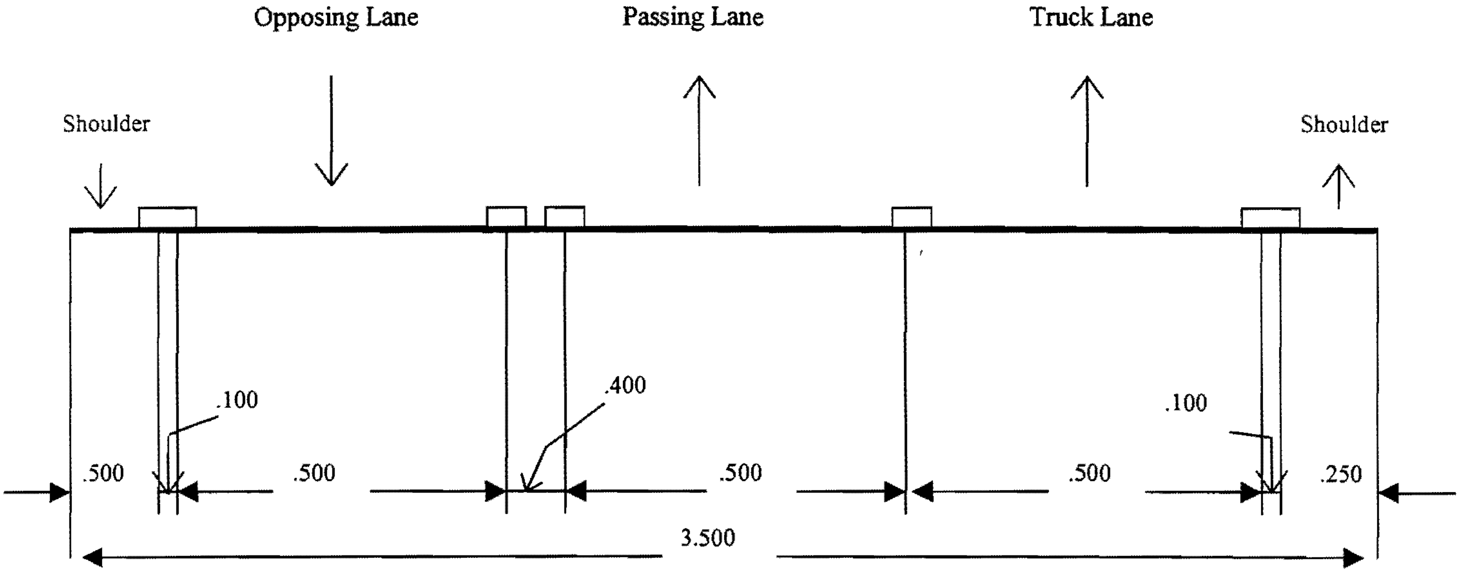


Figure D-2. Proposed Super-Two Cross-section

Assumptions 8 and 9 are an idealized condition with passing sections located at uniform intervals. In practice, this will not be the case. However, the relatively low volumes of traffic allow this simplification without introducing a significant error. For example, at ADTs below 3600 the average queue is less than four cars. Therefore, as the recommended design is based on the average queue length plus one, both the length of the passing lane and the distance between passing sections should be adequate more than 80% of the time. Additionally, this method does not attempt to compensate for the number of vehicles that are able to pass between passing sections. Therefore, an adequate safety factor is inherent to the process.

Design Method

The two main components of the queuing theory are the service and arrival concepts. A major difficulty in the application of the queuing theory on a traffic problem is the dynamic characteristics of the traffic flow. The computation of the service rate (Q) should incorporate the fact that the truck percentage will have an influence on the service rate. Therefore, the service rate, Q, is computed from the equation that is published in the Highway Capacity Manual (1987). This equation gives the maximum service volumes on rural two-lane, two-way highways under uninterrupted flow conditions. Highway Capacity Manual Table 10.7 considers the truck factor (T_L) adjustment for lane width and lateral clearance (W_L). A volume capacity ratio (v/c), depending on a passing site distance of 1500 ft, is considered a sufficient distance to perform a safe passing maneuver. Therefore, a probabilistic method considering the probability of having a safe passing distance in oncoming traffic is integrated into the service rate calculation method. A decrease in the safe passing distance probability will give a lower volume capacity ratio (v/c), therefore yielding a lower service rate. The equation for service volume is given below and explained in greater detail in the following section.

$$SV=2000\ (v/c)\ W_L\ T_L$$

On the highway section where the ADT values are obtained, maximum hourly service volumes are in the range of a level of service (LOS) B. Therefore, the factors taken from the table correspond to that LOS. The W_L parameter has a value of 1.0 since the highway cross section consists of 12-foot lanes with 10-foot shoulders.

The probabilistic approach for the service rate, Q, is implemented in accordance with the following formulas.

$$P(h \geq t)=e^{-\lambda t}$$

$$\lambda= V/T$$

Where: λ = the average numbers of vehicles arriving per second

This equation gives the probability of having a gap of t seconds or greater in the traffic flow assuming a Poisson distribution. The outcome of the equation is used to determine the service volume of the highway by selecting a proper v/c ratio according to the probability of having an adequate passing distance from Table D-1. V/C ratios in the probability ranges given in the table are calculated by interpolating their safe passing sight distance values. This distance is given as 1500 ft. The maximum speed of the vehicles in oncoming traffic is 70 mph. Passing distance of 1500 ft gives a gap of 14.73 seconds. Then different service volumes are determined according to the oncoming traffic.

The oncoming traffic is 40% of the total traffic flow assuming a directional split factor of 60/40. An example for the service volume for a given ADT is shown below using actual data from Highway 87 in Dallam County.

$P(h \geq t)=e^{-\lambda t}$
$\lambda=216/3600=0.06$
$t=14.73$ second
$P(h \geq 14.73)=e^{-0.06x14.73}= 41.32\%$

Where:ADT=3600 vehicles/hour
hourly peak traffic = 540 vehicles/hour (15% of ADT)
oncoming traffic = 216 vehicles/hour (40% of peak volume)

Then, for LOS B, the v/c value is 0.34 (See Table D-1)

T_L= 0.87 (10% truck and level terrain)
W_L= 1.0
SV= 2000 x 0.34 x 0.87 x 1.0 = 592 vehicles/hour (total both directions)

Arrival rates (q) are values taken from the traffic maps prepared on Highway 87 in Dallam County, Texas. The ADT values at the various locations of the map are converted to hourly peak volumes using the AASHTO (1990) standards. An ADT range of 2400 to 3600 passenger cars is observed on that map and utilized in the development of the research study. Hourly peak volume of the road is accepted as fifteen percent of the ADT value. However, another concern is the directional split factor of the roadway, it is known that there will be more traffic flow in the direction towards a major city at certain times than away from that city. Therefore, a directional split factor of sixty percent is used to represent that reasoning.

Application of the queuing theory is possible after calculating the service and arrival rates. The average waiting time in the queue (E (w)) of the roadway used is calculated to predict the delay time savings that will occur after the construction of the passing lanes. Due to the nature of traffic, the average waiting time is not idle as it can be attributed to the example of a customer waiting to place an order at a hamburger restaurant. The waiting time in the traffic situation is the time spent in the queue, but since traffic flow is continuous, time delay can only be attributed to the amount of time lost because of the speed difference between the slow moving trucks and passenger cars. In Texas the truck speed limit is 60 mph, and passenger car speed limit is 70 mph. Another result from the application of the queuing theory is the average number of passenger cars in the queue (E(m)). This value is used to calculate the passing lane length according to changing ADT levels. Table D-1 below explains each LOS. Table D-2 describes lateral clearance and lane width. Table D-3 explains truck adjustment in terms of terrain for each LOS.

Table D-1. Levels of Service and Maximum Service Volumes on Two-Lane Highways under Uninterrupted Flow Conditions (Normally Representative of Rural Operation) (HRB Special Report, 1987)

Level of Service	Traffic Flow Conditions		Passing Sight Distance >1,500 FT (%)	Service Volume/Capacity (v/c) Ratio	Maximum Service Volume Under Ideal Conditions (Total, both directions, per hour)
	Description	Operating Speed (MPH)			
A	Free Flow	≥ 60	100 80 60 40 20 0	≤ 0.20 0.18 0.15 0.12 0.08 0.04	400
B	Stable Flow (upper speed range)	≥50	100 80 60 40 20 0	≤ 0.45 0.42 0.38 0.34 0.30 0.24	900
C	Stable Flow	≥40	100 80 60 40 20 0	≤ 0.70 0.68 0.65 0.62 0.59 0.54	1400

Table D-2. Combined Effect of Lane Width and Restricted Lateral Clearance on Capacity and Service Volume of Two-Lane Highways with Uninterrupted Flow (HRB Special Report, 1987)

Distance From Traffic Lane Edge To Obstruction	Adjustment Factors W_L For Lateral Clearance And Lane Width															
	Obstruction on One Side Only								Obstruction on Both Sides							
	12-FT Lanes		11-FT Lanes		10-FT Lanes		9-FT Lanes		12-FT Lanes		11-FT Lanes		10-FT Lanes		9-FT Lanes	
	Level B	Level E	Level B	Level E	Level B	Level E	Level B	Level E	Level B	Level E	Level B	Level E	Level B	Level E	Level B	Level E
6	1.00	1.00	0.86	0.88	0.77	0.81	0.70	0.76	1.00	1.00	0.86	0.88	0.77	0.81	0.70	0.76
4	0.96	0.97	0.83	0.85	0.74	0.79	0.68	0.74	0.92	0.94	0.79	0.83	0.71	0.76	0.65	0.71
2	0.91	0.93	0.78	0.81	0.70	0.75	0.64	0.70	0.81	0.85	0.70	0.75	0.63	0.69	0.57	0.65
0	0.85	0.88	0.73	0.77	0.66	0.71	0.60	0.66	0.70	0.76	0.60	0.67	0.54	0.62	0.49	0.58

Table D-3. Truck Adjustment Factors for Each Level of Service on Different Terrains

Percentage of Trucks, P_T	Truck adjustment Factor, T_L								
	Level Terrain			Rolling Terrain			Mountainous Terrain		
	Level of Service A	Level of Service B and C	Level of Service D and E	Level of Service A	Level of Service B and C	Level of Service D and E	Level of Service A	Level of Service B and C	Level of Service D and E
1	0.98	0.99	0.99	0.97	0.96	0.96	0.94	0.92	0.90
2	0.96	0.97	0.98	0.94	0.93	0.93	0.89	0.85	0.82
3	0.94	0.96	0.97	0.92	0.89	0.89	0.85	0.79	0.75
4	0.93	0.95	0.96	0.89	0.86	0.86	0.81	0.74	0.69
5	0.91	0.93	0.95	0.87	0.83	0.83	0.77	0.69	0.65
6	0.89	0.92	0.94	0.85	0.81	0.81	0.74	0.65	0.60
7	0.88	0.91	0.93	0.83	0.78	0.78	0.70	0.61	0.57
8	0.86	0.90	0.93	0.81	0.76	0.76	0.68	0.58	0.53
9	0.85	0.89	0.92	0.79	0.74	0.74	0.65	0.55	0.50
10	0.83	0.87	0.91	0.77	0.71	0.71	0.63	0.53	0.48
12	0.81	0.85	0.89	0.74	0.68	0.68	0.58	0.48	0.43
14	0.78	0.83	0.88	0.70	0.64	0.64	0.54	0.44	0.39
16	0.76	0.81	0.86	0.68	0.61	0.61	0.51	0.41	0.36
18	0.74	0.80	0.85	0.65	0.58	0.58	0.48	0.38	0.34
20	0.71	0.77	0.83	0.63	0.56	0.56	0.45	0.36	0.31

The design method seeks to reflect real conditions of the traffic flow. All of the main factors involved in the dynamic structure of the traffic flow are incorporated in the methodology. These factors comprise the effect of road geometrics, truck percentage, and conditions of oncoming traffic. The probabilistic approach that is used to represent the gap acceptance concept provides a simulation of the traffic in terms of passing opportunities. It therefore yields a service rate provided by the roadway on the ability to perform safe passing maneuvers.

Parametric Calculations of Time Savings

This section provides a useful tool to a design engineer for applying the design method. Instead of going through the entire procedure making all of the calculations, it is more practical to follow the steps in the parametric calculations. The type of parameters that will be used should first be determined. The values of the parameters may be different according to different project characteristics such as the speed limit of trucks and passenger cars. Consequently, all the parameters applied with the appropriate units will result in the design components of the roadway that a Super Two Highway is going to be built on. In addition to these design components such as the length and interval of passing lanes, the data that is necessary for the economical feasibility can be obtained. The economic feasibility that is explained in this research includes some assumptions for construction cost and economical figures such as inflation rate. However, using an agency's own cost data and project parameters will result in more realistic analysis. The following equations are the design parameters explained in detail in terms of their use and units.

Arrival rate (q) (vehicles/minute)

$$q = \frac{(PHF)(DF)(ADT)(1-TP)}{60} \qquad (1)$$

Where PHF = Peak Hour Factor
DF = Directional Distribution Factor (major direction)
ADT = Average Daily Traffic
TP = Truck Percentage

Probability of available passing sight distance of 1500 feet during peak hour $P(h \geq t)$

Probability distribution of opposing traffic is assumed to be Poisson distribution. The cumulative probability of having a time gap that would provide a passing sight distance of 1500 ft between two oncoming vehicles is found using Equation (4). Time gap (t) between two oncoming vehicles 1500 ft (450 m) apart is found using Equation (2), and the average number of cars in the opposing direction (λ) is calculated using Equation (3).

$$t = \frac{(0.45)(3600)}{V_{pc}} \qquad (2)$$

$$\lambda = \frac{(ADT)(PHF)(1-DF)}{3600} \qquad (3)$$

$$P(h \geq t) = e^{-\lambda t} \qquad (4)$$

Where h = time gap between two consecutive opposing vehicles (seconds)
t = time gap between two opposing vehicles 1500 ft apart (seconds)
λ = average number of cars in the opposing direction (vehicles/second)

Service Volume (SV) (vehicles/hour)

Service volume is a function of $P(h \geq t)$ and assumes the total mixed vehicles per hour in both directions (HRB Special Report, 1987). Corresponding v/c ratio in the following equation is found according to probabilities of having a passing sight distance of 450 m. Use Table D-1 for appropriate probability values.

$$SV = 2000\ (v/c)\ W_L\ T_L \qquad (5)$$

Where v/c= Volume to capacity ratio (a function of $P(h \geq t)$)

W_L= Adjustment for lane width and lateral clearance at given level of service

T_L= Truck factor at given level of service

Service Rate (Q) (vehicles/minute)

Service value is derived from SV by converting to vehicles/minute and multiplying by Directional Factor (DF).

$$Q = \frac{(SV)(DF)}{60} \qquad (6)$$

Average waiting time in queue (E(w)) (minute/vehicle)

Queuing theory with the assumption of Poisson arrival distribution and exponential service rate distribution would give the average time each car spends in the queue waiting to initiate overtaking the slow-moving truck. It should be kept in mind that the average waiting time in a queue does not include the overtaking duration (5).

$$E(w) = \frac{q}{Q(Q-q)} \qquad (7)$$

Time savings (S) (minute/vehicle/truck)

This parameter shows the amount of time in seconds that can be accrued from the application of the design methodology. The value shows the amount of time that is saved by a passenger car approaching behind a slow moving truck and waiting for a chance to overtake. The average waiting time (E(w)) should be converted to seconds by dividing by 60. The time spent waiting in the queue is not lost completely because time savings considers the fact that a passenger car can travel at a reduced speed while behind a truck. The time spent overtaking the truck is part of the time savings as well. Equations (8) and (9) are used to determine time savings.

$$S = E(w) - E(w)\frac{V_{tr}}{V_{pc}} + \Delta T_{pass} \qquad (8)$$

$$\Delta T_{pass} = t_{ot} - \frac{V_{ot}\, t_{ot}}{V_{pc}} \qquad (9)$$

Where ΔT_{pass} = time saved by not overtaking the truck (seconds)

V_{ot} = average speed of passenger car while overtaking the truck

t_{ot} = time required to overtake the truck by a passenger car (seconds)

Average Speed on the road (V_{avr}) (kilometers/hour)

The parameter indicates the average speed deviates from the speed limit of a passenger car. This is due to the presence of the slow-moving trucks on the roadway. This parameter is the average speed that a passenger car travels before the construction of passing lanes. Equation (10) assumes an average speed equal to the speed limit with the absence of slow moving trucks in the traffic.

$$V_{avg} = \frac{E(w)V_{tr} + T_{pass}V_{pass} + \left(\frac{V_{tr}}{q_{tr}}\frac{3600}{\Delta V_{tr-pc}}\right)V_{pc}}{E(w) + T_{pass} + \left(\frac{V_{tr}}{q_{tr}}\frac{3600}{\Delta V_{tr-pc}}\right)} \qquad (10)$$

$$q_{tr} = (ADT)(PHF)(DF)(TP) \qquad (11)$$

Where q_{tr} = truck arrival rate (vehicles/hour)

Number of trucks a passenger car would catch in 1 hour at V_{avg} before passing lanes are constructed (N_{tr})

The denominator of Equation (12) is the amount of time it takes a passenger car to reach the next slow-moving truck after overtaking one truck. This is done at an average speed per hour (3600 seconds.).

$$N_{tr} = \frac{3600}{E(w) + T_{pass} + \left((\frac{V_{tr}}{q_{tr}})(\frac{3600}{\Delta V_{tr-pc}})\right)} \qquad (12)$$

Conversion Factor to convert per 100 kilometers/vehicle (F_{100})

The previous parameter is an hourly value of the number of trucks that a passenger car can catch. For practical purposes, presenting the values on the basis of distance is more meaningful. Therefore, an interval of 100 kilometers is selected to form that basis. The previous parameter can be converted to a 100 kilometers basis using a F_{100} parameter.

$$F_{100} = \frac{100}{V_{avg}} \qquad (13)$$

Number of trucks a passenger car would catch in per 100 kilometers before passing lanes are constructed (N_{tr100})

This parameter is a result of the two previous calculations. It shows the number of trucks that are caught in a distance of 100 kilometers by modifying the hourly value in Equation (12).

$$N_{tr100} = N_{tr} F_{100} \quad (14)$$

Distance between Passing Lanes (D_{pl}) (kilometers)

The distance from the point where a passenger car overtakes the first truck to the point where it reaches the next truck is the distance between two passing lanes. The distance between the passing lanes assumes an even distribution of the trucks and the trucks do not cause a delay for the passenger cars. This length also includes the passing lane section of the highway.

$$D_{pl} = \frac{\frac{1}{q_{tr}} V_{tr}}{\Delta V_{pc-tr}} V_{pc} \quad (15)$$

Number of Passing Lanes (PS) per 100 kilometers (PL_{100})

Ideally the passing lanes are designed to be at the point when passenger cars reach the next slow moving truck. It is assumed that the queue with an average number of passenger cars E(m) would be formed by the time the platoon reaches the next passing lane.

$$PL_{100} = \frac{100}{D_{pl}} \quad (16)$$

Time Savings for 100 kilometers of Roadway for Passenger Cars (S_{100})

Time savings results from the construction of passing lanes. It is calculated from the number of trucks that a passenger car encounters in a 100 kilometers section of highway. Time savings (S) is the amount of time that a driver in a passenger car will save from the construction of the passing lanes, and it is expressed in seconds.

$$S_{100} = (S) N_{tr100} \quad (17)$$

Summary

Time savings that will be gained from the application of a Super Two section is explained in parametric terms with the number of passing lanes per 100 kilometers. It is assumed that all waiting times are eliminated by the construction of passing lanes. Initially, the average time, E(w), spent in a queue is found from queuing theory. The number of queues in a 100 kilometer stretch of roadway and the times savings for the passenger cars in a 100 kilometer stretch of roadway is essential to constructing a Super Two Highway. The total time savings per year that a Super Two Highway can bring is also important and should be calculated.
The number of passing lanes is found using the distance a passenger car will travel in order to reach the next truck on the highway. The parameter refers to the number of passing lanes that

should be constructed in a 100-kilometer section of the highway in order to avoid the time loss caused by slow moving trucks. It is assumed that the trucks are evenly distributed and the distance between the trucks is a result of the highway's ADT value. The number of passing lanes is an ideal figure that will reflect the objectives of the study on the field. This parameter's value should be rounded to closest integer as an approximation. As a result, this number can be used in finding the number of additional passing lanes that should be constructed after the construction of the necessary ones because of limitations on the highway such as curves and hills.

Parametric Calculations of Passing Lane Length

This section primarily shows the parametric calculations of the roadway geometrics and economic considerations that are associated with a Super Two Highway. Queuing theory is used in computing the number of cars in queues, and those queues will be eliminated after the implementation of a passing lane. Equation (19) is a conservative approach to the number of cars in the design.

Average Queue Length E(m)

This parameter is a result of the queuing theory to obtain a simulation of the traffic pattern that occurs on a highway with a determined ADT. The ADT will yield the arrival (q) and service rates (Q) as explained in the previous section. The average queue length is the number of passenger cars behind a slow-moving truck.

$$E(m) = \frac{q^2}{Q(Q-q)} \qquad (18)$$

Probability of more than N Vehicles in the Queue P(n>N) (5)

The number of vehicles in the queue is the expected value of the number of passenger cars in the platoon. Hence, the probability of having a longer queue should be investigated. The probability of having more than N cars in the platoon is obtained using Equation (19). Since the length of the passing lane is directly effected by the number of waiting cars in the queue, the design of the passing lane should be based on a queue level that is more critical than the average number of cars in the queue. In this analysis the average number of cars in the queue is increased by one to obtain a more critical design parameter. Probability of observing a higher number of cars in the queue is calculated below with a comparative basis between E(m) and E(m)+1 situations (Equation 20). The effect of this operation will not be the same at different levels of ADT. At low ADT levels, the mean number of cars at the queue will be lower when compared to high ADT levels. Therefore the relative effect of adding one to the mean number will be much higher. If the confidence level needs to be high (the design queue length is based on considerably low probability levels of $P(n > N)$), the design of the passing lane should be over conservative because it has been designed for Peak Hourly Volume of ADT.

$$P(n > N) = \left(\frac{q}{Q}\right)^{N+1} \qquad (19)$$

Average Queue Length plus one Vehicle E (m)+1 (number of passenger cars in queue)

The average queue length plus one vehicle is simply a conservative determination of the average queue length. This parameter is expanding from Equation (18).

$$E(m)+1=\frac{q^2}{Q(Q-q)}+1 \tag{20}$$

Platoon Length L_p (m)

The passenger cars that form the platoon behind a slow moving truck are assumed to be 20 ft in length. The headway between the two following cars is assumed to be 40ft, and the truck length is assumed to be 55ft. (HRB Special Report, 1987). The platoon length can then be obtained by multiplying the number of cars in the platoon by the length of the car plus headway distance. These lengths are approximately 18 m and 16.5 m, respectively.

$$L_p=(E(m)+1).18+16.5 \tag{21}$$

While the truck travels in the passing lane, the last passenger car in the platoon should be able to pass the truck. The length of the passing lane is designed in such a way that, the when the passing lane ends, the last car would have just passed the slower moving truck. The movement of the passenger cars is assumed to be in two phases. The first phase begins as soon as the truck pulls into the passing lane, and the platoon accelerates as a whole. The second phase is the platoon overtaking the slower moving truck. The passenger cars travel at the maximum design speed during this phase, and this phase is over when the passing lane ends. Therefore, the total time that the truck should spend in the passing lane should be the sum of t_{acc} and t_{pl}. Equation (22) shows the distance the last car in the platoon must travel to pass the slower moving truck. This distance should be equal to the sum of the platoon length, Lp, and the distance traveled by the truck in the passing lane, L_{epl}. This distance is the effective passing lane length. Equations (22) and (23) represent the physical equilibrium that should exist between the distance traveled by a passenger car and the platoon length and effective passing lane length. Equation (24) will give the amount of time the passenger car spends in the passing lane, t_{pl}, rather than acceleration time, t_{acc}.

$$d_{pc}=L_p+L_{epl} \tag{22}$$

$$0.5a_{pc}t_{acc}{}^2+V_{tr}t_{acc}+V_{pc}t_{pl}=L_p+V_{tr}(t_{acc}+t_{pl}) \tag{23}$$

Where: d_{pc}= distance traveled by the passenger car while the truck is in the passing lane

$t_{pl}+t_{acc}$ = the time spent by the truck in the passing lane (seconds)

t_{acc} = acceleration time of passenger car (seconds)

a_{pc} = acceleration of a passenger car while overtaking a truck. (2.41km/hour/second) (0.67m/sec^2) (AASHTO, 1990)

$$t_{pl}=\frac{L_p-(0.5)a_{pc}t^2{}_{acc}}{V_{pc}-V_{tr}} \tag{24}$$

Acceleration of the vehicle (a_{pc}) (meters/second^2)

The acceleration phase takes place when a passenger car overtakes the slower moving truck after the truck pulls into the passing lane. The time required (Δt) for a passenger car to accelerate to a speed to pass the truck (ideally from 60mph to 70 mph) is given as 4.5 seconds (AASHTO, 1990). Equation (25) converts the speed input in kilometers/hour to an acceleration value in m per square meter.

$$a_{pc} = \frac{\Delta V}{\Delta t} = \frac{V_{pc} - V_{tr}}{\Delta t}\frac{1000}{3600} \qquad (25)$$

Acceleration time of the vehicle (t_{acc}) (seconds)

If an acceleration value of the passenger car is used other than 4.5 seconds, the acceleration time of the passenger car should be determined using Equation (26).

$$t_{acc} = \frac{\Delta V}{a_{pc}} = \frac{V_{pc} - V_{tr}}{a_{pc}} \qquad (26)$$

Effective Length of Passing Lane (L_{epl}) (meters)

An effective length of the passing lane is long enough for the drivers of the passenger cars to feel comfortable overtaking the slower moving truck. There should also be enough provided space for the trucks to ease into the passing lane. Tapered sections at the beginning and end of the passing lane would effectively provide this space. But the tapered sections would not be included in the length of the passing lane. The tapered sections should be equal to the distance traveled by the truck as it moves into and out of the passing lane safely clearing the passenger cars in the queue.

$$L_{epl} = (t_{acc} + t_{pl})V_{tr} \qquad (27)$$

Effective length of Passing Lanes per 100 kilometers (L_{epl100}) (kilometers)

The effective length of the passing lanes should be studied over a 100 kilometer section of the highway to establish a better comparison basis. This parameter expands from Equation (27).

$$L_{epl100} = L_{epl} PL_{100} \qquad (28)$$

Construction Cost per 100km of road section (C_{pl}) ($)

The construction cost of a passing lane is found by multiplying by 2 since the passing lane in the opposite direction must also be considered. Since the length of converge and diverge areas is not a function of the length of a passing lane, the number of passing lanes rather than the length of the passing lane affects the construction cost per 100 kilometer roadway.

$$C_{pl} = 2\left(\frac{UC_{pl} L_{epl100}}{1000} + UC_{cd} PL_{100}\right) \tag{29}$$

Where: UC_{pl} = Construction cost of 1 kilometer of passing lane
UC_{cd} = Construction cost of converge and diverge sections per each passing lane

Annual Construction Cost per 100km of road section (AC_{pl}) ($)

The construction cost is a one-time cost that occurs at the beginning of the project. It should be incorporated into the economical analysis in annual basis so that cost and benefit values can be compared. Equation (30) annualizes the construction cost of the passing lanes using a life cycle of *n* years and an interest value, i. The life cycle period of the project should be estimated according to the characteristics of the roadway.

$$AC_{pl} = C_{pl}(A/P, i\%, n) \tag{30}$$

Where $(A\backslash P, i\%, n)$ = the capital recovery factor for an interest value of $i\%$ and for n years

Annual Time Saving Benefits (B_{time}) ($)

Annual time saving benefits must be multiplied by 365 to incorporate the entire year. The different time costs of business and leisure trips are incorporated into the calculations.

$$B_{time} = (1 - TP)(ADT)(S_{100})(365)(P_{bt}S_{bt} + P_{lt}S_{lt})AN_p \tag{31}$$

Where: S_{100} = Time saving benefits per 100km (seconds)
S_{bt} = Time value of business trips ($/passenger/second)
P_{bt} = Percentage of business trips
S_{lt} = Time value of leisure trips ($/passenger/second)
P_{lt} = Percentage of leisure trips
AN_p = Average number of passengers passenger vehicle

Accident Reduction Benefit (B_{acc}) ($/100km/yr)

Accident cost reductions and time savings in terms of monetary values are modeled using Equation (32).

$$B_{acc} = \frac{(AC)(365)(ARF)(ADT)(10^{-8})(L_{pl100})(1.36)}{1.6} \quad (32)$$

Where: B_{acc} = the annual accident cost savings provided by a 1-mi passing lane
AC = the average cost of accidents by severity
ARF= average reduction in accidents by severity for different ADT values (assumed value of 37.7)

The constant 1.36 in Equation (31) is used to convert 1988 dollars to 1998 dollars. The equatio is further divided by 1.6 to find the cost reduction per kilometer. The equation originally gave the cost reduction per mile.

Total Benefit (TB) ($)

The monetary benefit is the total of time savings that passenger cars will experience and accident reduction benefit on a highway due to the upgrading it to a Super Two Highway.

$$TB = B_{acc} + B_{time} \quad (33)$$

Benefit Cost Ratio (B/C)

The result of the economical analysis is to have a meaningful parameter that will indicate whether the construction of the Super Two Highway is viable or not. Values greater than or equal to 1 prove the application of the project economically feasible.

$$B/C = \frac{TotalBenefits}{TotalCosts} \quad (34)$$

Taper Lengths (L_m), (L_d) (m) (Mendoza and Mayoral, 1996)

The tapered sections at the beginning and end of a passing lane are calculated using the following equations. Equations (27) and (28) must first be used to calculate effective passing lane lengths.

$$L_m = (0.62)(S_o)(W) \quad (35)$$

$$L_d = (0.65)(L_m) \quad (36)$$

Where: L_m = taper length at the merge area
L_d = taper length at the diverge area
S_o = operating speed after installing the extra lane in the given subsegment (kilometers/hour)
W = normal lane width (m)

Total Passing Lane Length L_{pl} (m)

The total passing lane length is the effective passing lane length and the length of the tapered sections of the passing lanes.

$$L_{pl} = L_{epl} + L_m + L_d \qquad (37)$$

Summary

Following the parametric calculations in the previous sections is a practical way to obtain the characteristics of a roadway that is being considered as a Super Two Highway. The second part of the parametric calculations provides the equations that are useful for determining the length of passing lanes. The equations necessary to obtain a benefit/cost ratio will help make a decision while taking into account the economic concerns. Construction costs are the costs related to the widening of the existing roadway, and designers are recommended to use their own cost data to obtain a more appropriate economic analysis. Alternatives without widening the road should also be considered.

Case Study-Parametric Calculations of Time Savings

A case study using actual data from Highway 87 between Dalhart and Texline in Dallam County, Texas is presented in the following two sections to exemplify the proposed equations. The most critical ADT level of 3600 vehicles/day is chosen for the example. Each formula presented in the previous section will be calculated based on assumed parameters. Various calculations for different ADT and truck percentage levels are presented in this report. The design speeds for the passenger cars and slower moving trucks are decided to 70 mph and 60 mph, respectively. However, for the sake of metric unit calculations their speeds are taken as 112 km/h and 96 km/h, respectively. A representative truck percentage of 10% is chosen for this specific case study.

Arrival rate (q) (vehicles/minute)

$$q = \frac{(PHF)(DF)(ADT)(1-TP)}{60} \qquad (1)$$

$$q = \frac{(0.15)(0.6)(3600)(1-0.1)}{60}$$

$$q = 4.86$$

Where: PHF = Peak Hour Factor
DF = Directional Distribution Factor
ADT = Annual Daily Traffic
TP = Truck Percentage

Probability of available passing sight distance of 1500 ft during peak hour *P(h>t)*

$$t = \frac{(0.45)(3600)}{V_{pc}} \quad (2)$$

$$t = 14.5\,\text{sec}$$

$$\lambda = \frac{(ADT)(PHF)(1 - DF)}{3600} \quad (3)$$

$$\lambda = \frac{216}{3600}$$

$$\lambda = 0.06$$

$$P(h \geq t) = e^{-\lambda t} \quad (4)$$

$$P(h \geq 14.5) = e^{-0.06x14.5}$$

$$P(h \geq 14.5) = 0.42$$

Where: h = time gap between two consecutive opposing vehicles (seconds)
t = time gap between two opposing vehicles 1500 ft apart (seconds)
λ = average number of cars in the opposing direction (vehicles/second)

Service Volume (SV) (vehicles/hour) (HRB Special Report, 1987)

$$SV = 2000\ (v/c)\ W_L\ T_L \quad (5)$$

$$SV = 2000\ (0.324)\ (1)\ (0.87)$$

$$SV = 598 \text{ vehicles/hour}$$

Where: SV= Service volume (mixed vehicles per hour, total for both directions)
v/c= Volume to capacity ratio (a function of $P(h \geq t)$)
W_L= Adjustment for lane width and lateral clearance at given level of service
T_L= Truck factor at given level of service

Service Rate *(Q)* (vehicles/minute)

$$Q = \frac{(SV)(DF)}{60} \quad (6)$$

$$Q = \frac{(598)(0.6)}{60}$$

$$Q = 5.98$$

Average waiting time in queue (E(w)) (minute/vehicle)

$$E(w) = \frac{q}{Q(Q-q)} \qquad (7)$$

$$E(w) = \frac{4.86}{5.98(5.98-4.86)}$$

$$E(w) = 0.72\,\text{min}$$

Time savings (S) (minute/vehicle/truck)

$$S = E(w) - E(w)\frac{V_{tr}}{V_{pc}} + \Delta T_{pass} \qquad (8)$$

$$S = (0.72)(60) - (0.72)(60)(\frac{96}{112}) + 1.3$$

$$\Delta T_{pass} = t_{ot} - \frac{V_{ot}\, t_{ot}}{V_{pc}}$$

$$S = 7.5\,\text{sec}$$

ΔT_{pass} = 1.3 seconds

$$\Delta T_{pass} = 11.3 - \frac{(62)(11.3)}{70}$$

Where: ΔT_{pass} = time saved by not overtaking the truck (seconds)
V_{ot} = average speed of passenger car while overtaking the truck
t_{ot} = time required to overtake the truck by a passenger car (seconds)

Average Speed on the road V_{avr} (kilometers/hour)

$$V_{avg} = \frac{E(w)V_{tr} + T_{pass}V_{pass} + \left(\frac{V_{tr}}{q_{tr}}\frac{3600}{\Delta V_{tr-pc}}\right)V_{pc}}{E(w) + T_{pass} + \left(\frac{V_{tr}}{q_{tr}}\frac{3600}{\Delta V_{tr-pc}}\right)} \qquad (10)$$

$$V_{avg} = \frac{(43.2)(96) + (11.3)(100) + \left(\frac{(96)(3600)}{(32.4)(16)}\right)112}{43.2 + 11.3 + \left(\frac{96}{32.4} x \frac{3600}{16}\right)}$$

$$V_{avg} = 111$$

$q_{tr} = (ADT)(PHF)(DF)(TP)$ (11)

$q_{tr} = (3600)(0.15)(0.6)(0.1)$

$q_{tr} = 32.4$

Where q_{tr} = truck arrival rate (vehicles/hour)

Number of trucks a passenger car would catch in 1 hour at V_{avg} before passing lanes are constructed (N_{tr})

$$N_{tr} = \frac{3600}{E(w) + T_{pass} + \left((\frac{V_{tr}}{q_{tr}})(\frac{3600}{\Delta V_{tr-pc}}) \right)} \quad (12)$$

$$N_{tr} = \frac{3600}{43.2 + 11.3 + \left((\frac{96}{32.4})(\frac{3600}{16}) \right)}$$

$$N_{tr} = 4.99$$

Conversion Factor to convert per 100 kilometers/vehicle (F_{100})

$$F_{100} = \frac{100}{V_{avg}} \quad (13)$$

$$F_{100} = \frac{100}{111}$$

$$F_{100} = 0.9$$

Number of trucks a passenger car would catch per 100km before *passing* lanes are constructed (N_{tr100})

$$N_{tr100} = N_{tr} F_{100} \quad (14)$$

$$N_{tr100} = 4.99x0.9$$

$$N_{tr100} = 4.50$$

Distance between Passing Lanes (D_{pl}) (kilometers)

$$D_{pl} = \frac{\frac{1}{q_{tr}} V_{tr}}{\Delta V_{pc-tr}} V_{pc} \qquad (15)$$

$$D_{pl} = \frac{\frac{1}{32.4} x96}{16} x112$$

$$D_{pl} = 20.74 km$$

Number of Passing Lanes (PS) per 100 kilometers (PL_{100})

$$PL_{100} = \frac{100}{D_{pl}} \qquad (16)$$

$$PL_{100} = \frac{100}{20.74}$$

$$PL_{100} = 4.82$$

Time Savings per 100 kilometers for Passenger Cars (S_{100})

$$S_{100} = (S) N_{tr100} \qquad (17)$$

$$S_{100} = (7.50)(4.50)$$

$$S_{100} = 33.8 \text{ seconds}$$

Case Study-Parametric Calculations of Passing Lane Length

Average Queue Length E(m) (passenger cars)

$$E(m) = \frac{q^2}{Q(Q-q)} \qquad (18)$$

$$E(m) = \frac{4.86^2}{5.98(5.98-4.86)}$$

$$E(m) = 3.52$$

Probability of more than N Vehicles in the Queue (P(n>N))

$$P(n > N) = \left(\frac{q}{Q}\right)^{N+1} \qquad (19)$$

$$P(n > 3.52) = \left(\frac{4.86}{5.98}\right)^{3.52+1}$$

$$P(n > 3.52) = 0.39$$

$$P(n > 4.52) = \left(\frac{4.86}{5.98}\right)^{4.52+1}$$

$$P(n > 4.52) = 0.32$$

Average Queue Length plus one Vehicle (E(m)+1) (passenger cars)

$$E(m) + 1 = \frac{q^2}{Q(Q - q)} + 1 \qquad (20)$$

$$E(m) + 1 = 3.52 + 1$$

$$E(m) + 1 = 4.52$$

Platoon Length (L_p) (m)

$$L_p = (E(m) + 1).18 + 16.5 \qquad (21)$$

$$L_p = (4.52)(18) + 16.5$$

$$L_p = 97.86\,\text{m}$$

$$d_{pc} = L_p + L_{epl} \qquad (22)$$

$$0.5a_{pc}t_{acc}^{\ 2} + V_{tr}t_{acc} + V_{pc}t_{pl} = L_p + V_{tr}\left(t_{acc} + t_{pl}\right) \tag{23}$$

Where: d_{pc} = distance traveled by car while truck travels in the passing lane (m)
$t_{pl} + t_{acc}$ = time spent by the truck in the passing lane (seconds)
t_{acc} = acceleration time of passenger car (seconds)
a_{pc} = acceleration of a passenger car while overtaking a truck.

$$t_{pl} = \frac{L_p - (0.5)a_{pc}t^2{}_{acc}}{V_{pc} - V_{tr}} \tag{24}$$

$$t_{pl} = \frac{97.86 - (0.5)(0.98)(4.54)^2}{112 - 96}\frac{3600}{1000}$$

$$t_{pl} = 19.76 \text{ seconds}$$

Acceleration of the vehicle (a_{pc}) (m/sec^2)

$$a_{pc} = \frac{\Delta V}{\Delta t} = \frac{V_{pc} - V_{tr}}{\Delta t}\frac{1000}{3600} \tag{25}$$

$$a_{pc} = \frac{\Delta V}{\Delta t} = \frac{(112) - (96)}{4.5}\frac{1000}{3600} = 0.98 \text{ m/sec}^2$$

Acceleration time of the vehicle (t_{acc}) (seconds)

$$t_{acc} = \frac{\Delta V}{a_{pc}} = \frac{V_{pc} - V_{tr}}{(0.98).(3.6)} \tag{26}$$

$$t_{acc} = \frac{112 - 96}{(0.98)(3.6)}$$

$$t_{acc} = 4.54 \text{ seconds}$$

Effective Length of Passing Lane (L_{epl}) (m)

$$L_{epl} = (t_{acc} + t_{pl})V_{tr} \tag{27}$$

$$L_{epl} = \frac{(4.54 + 19.75)(96)}{3.6}$$

$$L_{epl} = 648 \text{ m}$$

Effective Length of Passing Lanes per 100 kilometers (L_{epl100}) (kilometers)

$$L_{epl100} = L_{epl}PL_{100} \tag{28}$$

$$L_{epl100} = (1.061)(4.82)$$

$$L_{epl100} = 5.11 \text{ kilometers}$$

Construction Cost of Passing Lane Sections per 100km (C_{pl}) ($)

$$C_{pl} = 2\left(\frac{UC_{pl} L_{epl\,100}}{1000} + UC_{cd} PL_{100}\right)$$
$$C_{pl} = 2((30825)(5.11) + (1222)(4.82)) \quad (29)$$
$$C_{pl} = \$326{,}812$$

Where: UC_{pl} = Construction cost of 1 kilometer of passing lane
UC_{pl} = $30,825
UC_{cd} = Construction cost of converge and diverge sections per each passing lane
UC_{cd} = $1,222

Annual Construction Cost per 100km of road section (AC_{pl}) ($)

$$AC_{pl} = C_{pl}(A \backslash P, i\%, n) \quad (30)$$
$$AC_{pl} = (326{,}811)(0.1295)$$
$$AC_{pl} = \$42{,}322$$

Where: *(A\P, i%, n)* = Capital recovery factor for an interest value of *i%* and for *n* years.
(A\P, 5%, 10) = 0.1295

Annual time Saving Benefits (B_{time}) ($)

$$B_{time} = \frac{(1-TP)(ADT)(S_{100})(365)(P_{bt}S_{bt} + P_{lt}S_{lt})AN_p}{3600} \quad (31)$$
$$B_{time} = \frac{(1-0.1)(3600)(33.8)(365)((0.2)(0.48)(1.36) + (0.8)(0.21)(1.36))(2)}{3600}$$
$$B_{time} = \$7{,}956$$

Where S_{100} = Time saving benefits per 100km (seconds)
S_{100} = 33.8 seconds
S_{bt} = Time value of business trips ($/passenger/hour)
S_{bt} = $0.48 /passenger/hour (Taylor, Muckesh, 1988)
P_{bt} = Percentage of business trips
P_{bt} = 20%
S_{lt} = Time value of leisure trips ($/passenger/hour)
S_{lt} = $0.21 /passenger/hour (Taylor, Muckesh, 1988)
P_{lt} = Percentage of leisure trips
P_{lt} = 80%
AN_p = Average number of passengers in a vehicle
AN_p = 2

Accident Reduction Benefit (B_{acc}) ($/100km/yr) (Taylor, Muckesh, 1988)

$$B_{acc} = \frac{(AC)(365)(ARF)(ADT)(10^{-8})(L_{pl100})(1.36)}{1.6} \qquad (32)$$

$$B_{acc} = \frac{(26{,}780)(365)(37.7)(3600)(10^{-8})(5.11)(1.36)}{1.6}$$

$$B_{acc} = \$57{,}622$$

Where: B_{acc} = Annual accident cost savings provided by a 1-mi passing lane ($/yr/mile)
AC = Average cost of accidents by severity (value is taken to be $26,780 in 1988 dollars)
ARF= Average reduction in accidents by severity for different ADT values (value is taken to be 37.7)

Total Benefit (TB) ($)

$$TB = B_{acc} + B_{time} \qquad (33)$$

$$TB = 57{,}622 + 7{,}956$$

$$TB = \$65{,}578$$

Benefit Cost Ratio (B/C)

$$B/C = \frac{TotalBenefits}{TotalCosts} \qquad (34)$$

$$B/C = \frac{65{,}578}{42{,}322}$$

$$B/C = 1.55$$

Taper Lengths (L_m), (L_d) (m) (Mendoza, Mayoral, 1996)

$$L_m = (0.62)(S_o)(W) \qquad (35)$$

$$L_m = (0.62)(112)(3.6) = 250 \text{ m}$$

$$L_d = (0.65)(L_m) \qquad (36)$$

$$L_d = (0.65)(250) = 163 \text{ m}$$

Where L_m = taper length at the merge area
L_d = taper length at the diverge area
S_o = operating speed after installing the extra lane in the given subsegment (kilometers/hour)
S_o = 112 kilometers/hour
W = normal lane width (m)
W = 3.6 m

Total Passing Lane Length L_{pl} (m)

$$L_{pl} = L_{epl} + L_m + L_d \quad (37)$$

$$L_{pl} = 648 + 250 + 163 = 1061\,\text{m}$$

Construction Costs

The upgrade of the existing roadway to a 3-lane pavement with a passing lane is planned with a 60cm pavement widening as shown in Figure D-2. Since the structural capacity of the existing 10ft shoulders is the same with regular lane sections, shoulders should be kept as they are. The 60 cm new construction is foreseen with the same structural capability of present pavement. The existing and proposed sections are comprised of the following layers.

- 0.6m Caliche subbase
- 0.6m fly ash base
- 2 course surface treatment

After the pavement is extended 60 cm, a final seal coat application is designed to cover existing markings. This prepares for the striping of new pavement markings. Another construction activity would be the merge and diverge areas, or the tapered areas of the passing lanes. The cost of these areas does not depend on the length of the passing lane. This is reflected in cost Equation (32). The approximate construction costs are as follows.

- A two-course surface treatment with AC-5, Grade 4 aggregate is needed. Application rate of binder is $2l/m^2$, and distribution rate of aggregate is 137 m^2/m^3. It is calculated to be $1,020/0.6m width/1km length.
- A one-course seal coat application with AC-5, Grade 4 aggregate is needed. The application rate of binder is $2l/m^2$, and the distribution rate of aggregate is 137 m^2/m^3. It is calculated to be $12,309/13.80m width/1km length.
- Fly ash stabilized base construction cost is calculated to be $9,000/0.6m width/1km length.
- Caliche sub-base construction cost is calculated to be $6,000/0.6m width/1km length
- Excavation cost is $1,391/0.6m width/1km length.
- Embankment cost is $1,105/0.6m/1km length.
- Cost of diverge and converge areas is $1,222 / 0.6m width/passing lane.
- Total cost excluding signing cost is $30,825.

Analysis

Various figures obtained from the application of the design methodology show the outcomes of the study for the two-lane two-way rural highways, or Super Two Highway. These figures are the results of applying the design parameters and cost values that are explained previously in the report. They will give a general understanding of the design logic and modifications of the parameter values will show the corresponding study results.

The figures show the variance of the most necessary parameters such as ADT, benefit cost ratio, and the length of passing lanes as other variables change. Therefore, a design engineer can evaluate different aspects of the project and decide on tradeoffs.

Benefit-Cost Ratio vs. ADT

The analysis shown in Figure D-3 is performed at a constant truck percentage of 10% and with varying ADT levels. The B/C ratio increases with increasing ADT levels. The Super Two Highway can be justified from an ADT level of 2500. This justification is mainly caused by the accident cost saving benefits. The equation used in this calculation can be further elaborated or examined to conform to the actual accident cost saving analysis specifically conducted for a roadway section. It is evident that time saving benefits are not adequate to justify the construction of the Super Two Highway (approximately 15% of the savings are contributed by the time saving benefits). However, the construction cost pertaining to the upgrading of the highway is primarily widening cost. Many people with highway construction experience agree that widening is not a necessity. For the segments of the highway with passing lanes, striping will be adequate for safe traffic conditions. The cost of striping is much less than construction cost. If highway agencies can adopt this idea, the construction of passing lanes at given intervals will be a viable solution to the improvement of the two-way two-lane rural highways.

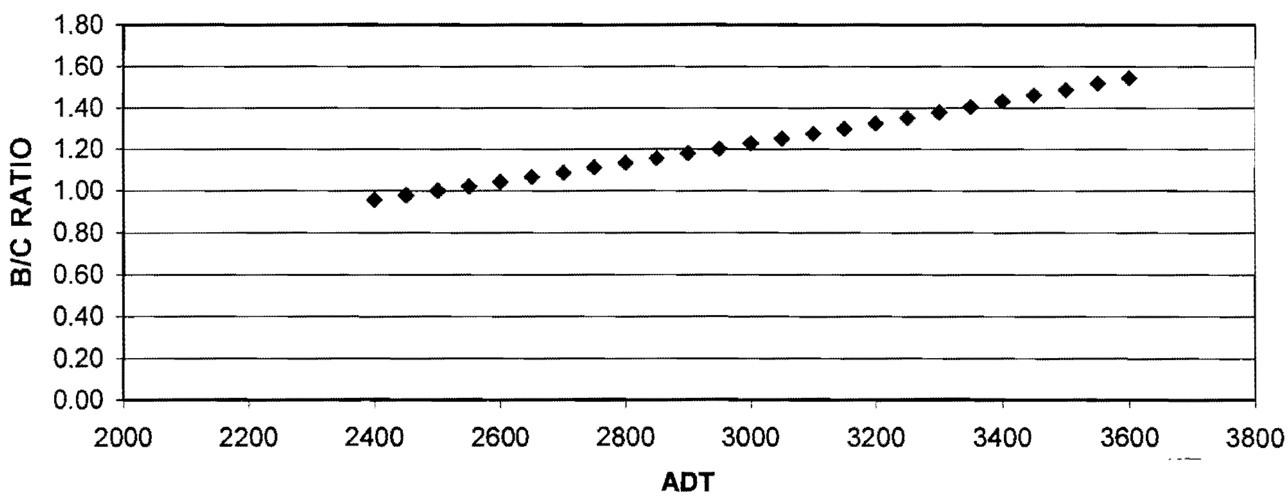


Figure D-3. B/C Ratio to ADT Levels

Benefit-Cost Ratio vs. Truck Percentage

Another outcome of the constant ADT and changing truck percentage analysis is the B/C ratio is not sensitive to truck percentage. This is caused by the structure of the accident cost benefit equation. Figure D-4 is plotted for a constant ADT of 3600 and varying truck percentage. An almost constant line is observed. This is because accident cost savings included in the numerator and construction costs included in the denominator are both functions of the passing lane length, and therefore cancel each other out. This leaves a constant B/C with respect to Truck Percentage.

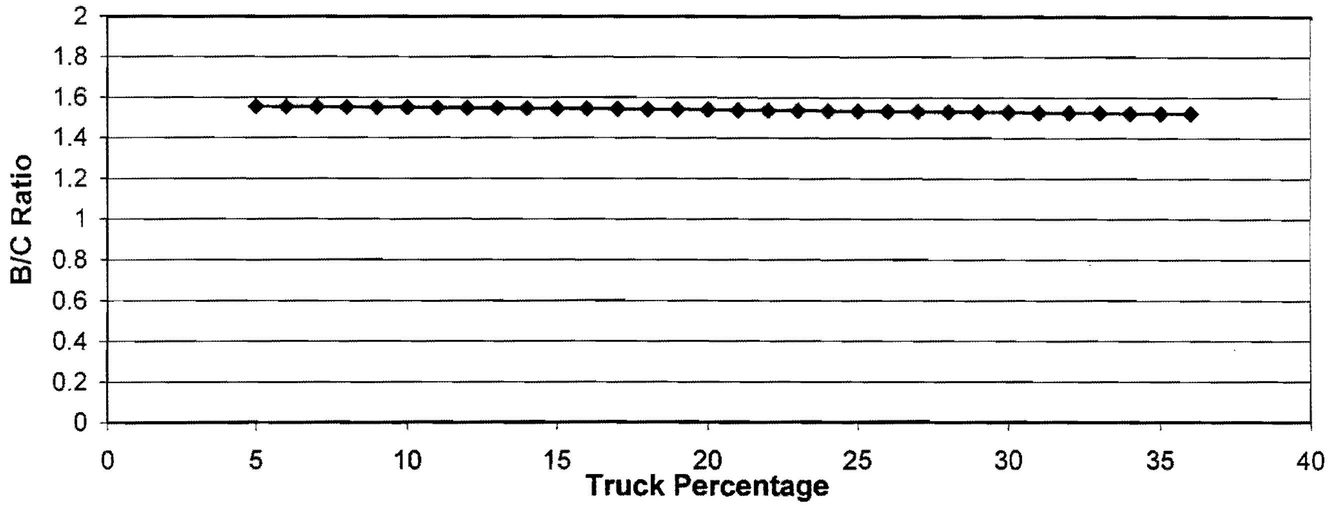


Figure D-4. B/C Ratio to Truck Percentage

Mean Queue Length vs. ADT

The average number of passenger cars in a platoon changes exponentially according to the Poisson distribution. The number of cars in the queue is low, but this is realistic because of the low rural highway traffic volumes. The average number of cars in the platoon for ADT is approximately 3 vehicles. These values will be compared to the actual values that will come from a traffic count on the Highway where the ADT values originated. Consequently, this comparison will be a measure of how realistic the outputs of the study are. Figure D-5 shows the relationship between the mean queue length and ADT.

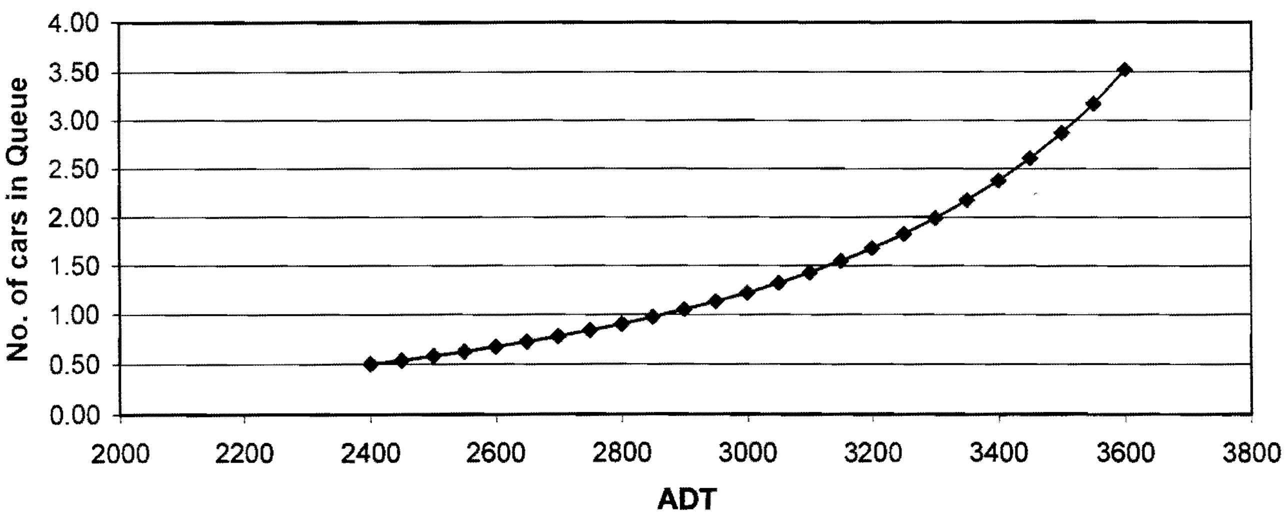


Figure D-5. Number of Cars in Queue at Different ADT Levels (mean queue length) E(m)

Passing Lane Frequency

Figure D-6 shows the passing lane frequency of passing lanes per 100 kilometers and the intervals of the passing lanes as the ADT values change. There will be certain points of the highway where construction of passing lanes will be required regardless of the interval values determined by the design method. The necessary passing lanes may occur where inadequate road geometry impairs traffic conditions. Examples of such locations are places with low sight distances, turns and hills. Figure D-3 can be used in establishing a basis for the selection of the passing lane locations. According to the length of a particular highway, the total number of passing lanes will be known. After selecting the segments of roadway that necessitate the construction of passing lanes, the other passing lanes can be distributed at equal intervals.

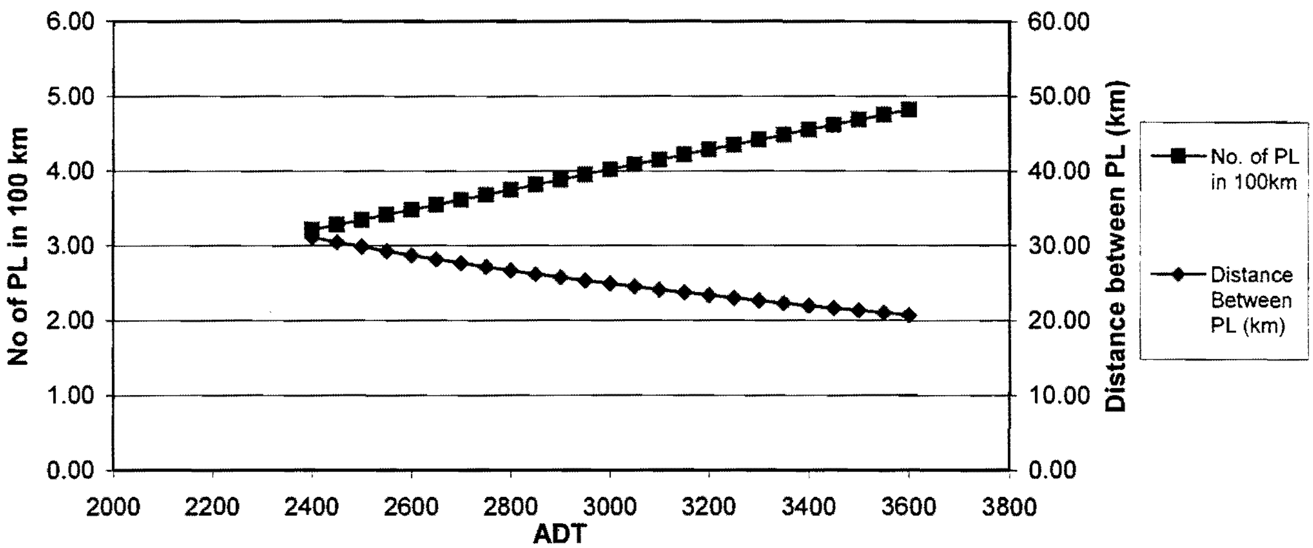


Figure D-6. Passing Lane Frequency

Sensitivity of B/C Ratio to Business Trips

A sensitivity analysis is performed in order to show the effects of business trip percentages on the benefit cost ratio. If the ADT remains at a constant level of 3600 and all other variables are constant, the business-trip percentage increases from 10 percent to 50 percent in increments of 10 percent. The business trips are more critical over the leisure trips because dollar value of business trips per hour is higher than that of leisure trips. Therefore, it is more significant to see the effects of a changing volume of vehicles that are using the roadway for business purposes. Figure D-7 shows an upward trend in B/C ratio with increasing business trip percentages in the traffic volume as delay savings increases more rapidly.

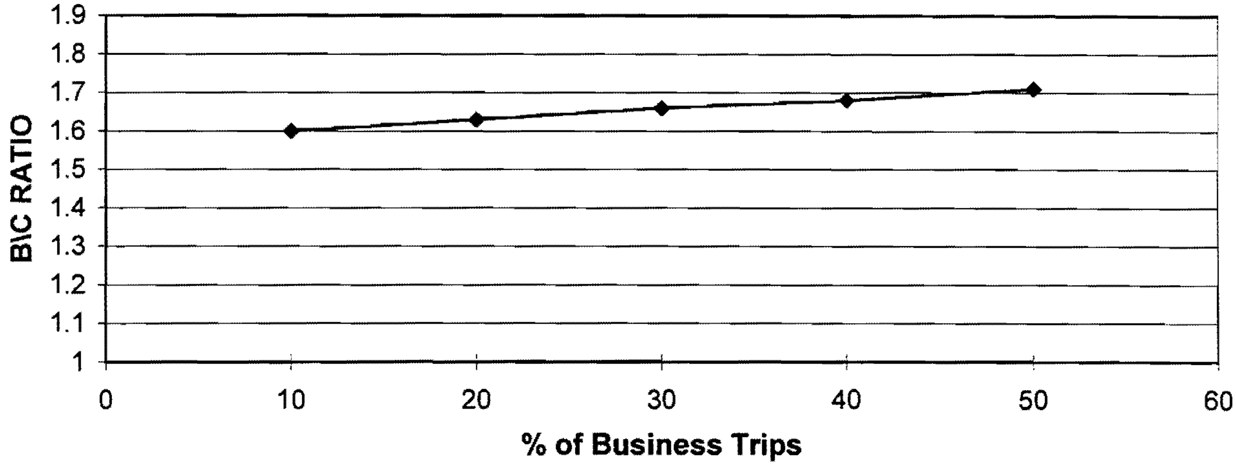


Figure D-7. Sensitivity of B/C Ratio (ADT = 3600)

Passing Lane Length/100 kilometers vs. ADT

Figure D-8 shows passing lane lengths and the number of passing lanes with respect to ADT values. In addition, the product of these two numbers gives the total length of passing lanes in 100 kilometers. These values can be used in estimating the construction or striping costs of the highway to be upgraded. The number of passing lanes and the passing lane lengths increase with ADT to meet the assumptions of preventing platoon forming on the highway. Because of the queuing theory's nature, the increase of total passing lane length has an exponential pattern.

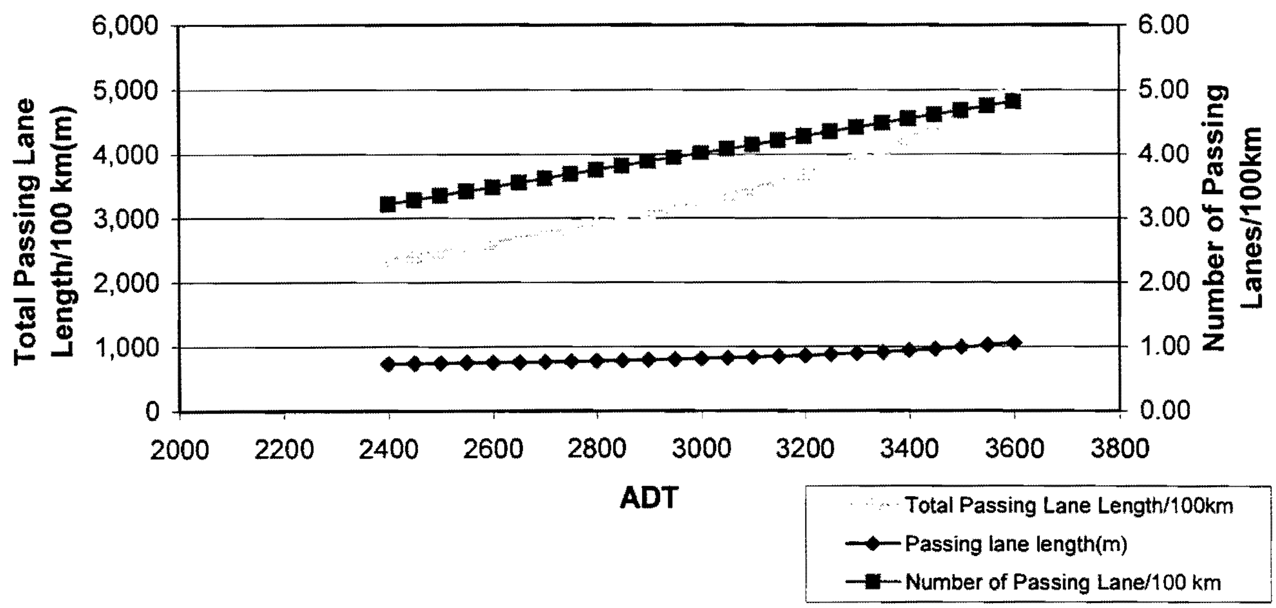


Figure D-8. Passing Lane Lengths

Passing Lane Length and Number of Passing Lane for Different ADT and Truck Percentage Values

Table D-4 shows passing lane length for various ADT and truck percentage combinations. This table is obtained from the case study performed on a rural two-way two-lane highway at Dalhart in Dallam County (Northwest Texas). It is observed that passing lane lengths slightly increase with increasing ADT values. The overriding factor is the level of ADT where passing lane lengths increase significantly.

Table D-5 is a chart where one can see the number of passing lanes per 100 kilometers of roadway with varying ADT and truck percentage. This chart may be used as a reference before starting the upgrading process of the roadways. The percentage of trucks, rather than the ADT levels determine the number of passing lanes.

Table D-4. Passing Lane Length according to ADT and Truck Percentage

Truck % / ADT	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2400	735	735	735	735	735	735	735	735	735	735	735	735	735	735	735	736
2450	739	739	739	739	739	739	739	739	739	739	739	739	740	740	740	740
2500	743	743	743	743	743	743	744	744	744	744	744	744	744	744	744	744
2550	746	748	748	748	748	746	746	746	746	749	749	749	749	749	749	749
2600	753	753	753	753	753	753	753	754	754	754	754	754	754	754	754	754
2650	758	758	759	759	759	759	759	759	759	759	759	760	760	760	760	760
2700	764	764	765	765	765	765	765	765	765	765	765	766	766	766	766	766
2750	771	771	771	771	771	771	771	772	772	772	772	772	772	772	773	773
2800	778	778	778	778	778	778	778	779	779	779	779	779	779	779	780	780
2850	785	785	785	786	786	786	786	786	786	786	787	787	787	787	787	788
2900	793	793	794	794	794	794	794	794	795	795	795	796	796	796	796	796
2950	802	802	803	803	803	803	803	803	804	804	804	804	804	805	805	805
3000	812	812	812	812	813	813	813	813	813	814	814	814	814	815	815	815
3050	823	823	823	823	823	824	824	824	824	824	825	825	826	826	826	826
3100	834	834	835	835	835	836	836	836	836	836	837	837	837	837	838	838
3150	847	847	847	848	848	848	848	849	849	849	850	850	850	851	851	851
3200	861	861	862	862	862	862	863	863	863	864	864	864	865	865	866	866
32[illegible]	877	877	877	878	878	878	879	879	879	880	880	880	881	881	882	882
3300	894	894	895	895	895	896	896	897	897	897	898	898	899	899	900	900
3350	913	914	914	915	915	915	916	916	917	917	918	918	919	919	920	921
3400	935	936	936	937	937	938	938	939	939	940	940	941	941	942	943	943
3450	960	960	961	961	962	963	963	964	964	965	966	966	967	968	968	969
3500	988	988	989	990	990	991	992	992	993	994	994	995	996	997	998	999
3550	1020	1020	1021	1022	1023	1023	1024	1025	1026	1027	1028	1029	1029	1030	1031	1032
3600	1057	1058	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1071	1072

Truck % / ADT	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
2400	736	736	736	736	736	736	736	736	736	736	737	737	737	737	737	737
2450	740	740	740	740	740	740	740	741	741	741	741	741	741	741	741	742
2500	744	744	745	745	745	745	745	745	745	745	746	748	748	746	746	746
2550	749	749	749	750	750	750	750	750	750	750	750	751	751	751	751	751
2600	754	755	755	755	756	756	755	755	756	756	756	756	758	756	757	757
2650	760	760	760	761	761	761	761	761	761	761	762	762	762	762	762	763
2700	766	766	767	767	767	767	767	767	768	768	768	768	768	769	769	769
2750	773	773	773	773	773	774	774	774	774	774	775	775	775	775	776	776
2800	780	780	780	781	781	781	781	781	782	782	782	782	782	783	783	783
2850	788	788	788	788	789	789	789	789	789	790	790	790	791	791	791	791
2900	796	796	797	797	797	797	798	798	798	798	799	799	799	800	800	800
2950	805	805	806	806	806	807	807	807	807	808	808	808	809	809	809	810
3000	815	816	816	816	816	817	817	817	818	818	818	819	819	820	820	820
3050	826	827	827	827	828	828	828	829	829	829	830	830	831	831	831	832
3100	838	839	839	839	840	840	841	841	841	842	842	843	843	844	844	845
3150	852	852	852	853	853	854	854	855	855	855	856	856	857	858	858	859
3200	866	867	867	868	868	869	869	870	870	871	871	872	872	873	874	874
32[illegible]	883	883	884	884	885	885	886	886	887	887	888	889	889	890	891	892
3300	901	901	902	902	903	904	904	905	906	906	907	908	908	909	910	911
3350	921	922	922	923	924	924	925	926	927	927	928	929	930	931	932	933
3400	944	945	945	946	947	948	949	949	950	951	952	953	954	955	956	957
3450	970	971	972	972	973	974	975	976	977	978	979	980	981	983	984	985
3500	1000	1000	1001	1002	1003	1004	1006	1007	1008	1009	1010	1012	1013	1014	1016	1017
3550	1034	1035	1036	1037	1038	1039	1041	1042	1043	1045	1046	1048	1049	1051	1053	1054
3600	1073	1074	1076	1077	1078	1080	1081	1083	1084	1086	1088	1090	1092	1094	1096	1098

Table D-5. Number of Passing Lanes per 100 kilometers according to ADT and Truck Percentage

Truck % / ADT	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
2400	2	2	2	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12
2450	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	11	12
2500	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12
2550	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12
2600	2	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	11	12	12	
2650	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	11	12	12	12	13
2700	2	2	3	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13
2750	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13
2800	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	12	13	13	14
2850	2	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	11	12	12	13	13	13	14
2900	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	14	14
2950	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14
3000	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14
3050	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14	15
3100	2	2	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	12	13	13	14	14	15	15
3150	2	3	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	14	15	15
3200	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	15
3250	2	3	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	13	14	14	15	15	16
3300	2	3	3	4	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	15	15	15	16
3350	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	13	14	14	15	15	16	16
3400	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16
3450	2	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	16	16	17
3500	2	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	15	16	16	17
3550	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17
3600	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	14	15	15	16	16	17	17

Conclusions and Recommendations

The following conclusions and recommendations can be made.

- This methodology can be used to justify the Super Two Highway at ADT levels less than 4200 vehicles per day.
- A Super Two section that requires a 60-centimeter widening is economically feasible at ADT levels greater than 2400 vehicles per day.
- If no widening is required (i.e. no shoulder on passing section side), then Super Two is economically justified at much lower ADT levels.
- Super Two B/C ratio is insensitive to truck percentage.
- Typical queues will contain less then four vehicles.
- Designing for the number of passing lanes per 100 kilometers of road provides high design flexibility without introducing significant error.
- If ADT levels exceed 4200 vehicles per day, the passing lane design should be based on simulations or other appropriate urban design methods.

A critical issue that we should make comments on is the ADT range where the feasibility study is applicable. After a certain level of ADT, waiting times of the passenger car in the queue become very large and then the values drop below zero. This drastic change in the values is caused by the characteristic of the Queuing theory, the theory is valid for the arrival rates (q) less than service rate (Q). However, the research model has increasing arrival rates with ADT, and service rate decreases as ADT values become larger because of the physical limitations of the highway. The point where two values intersect there is an infinite queue, this is obviously not an appropriate situation for the rural highways. The limiting ADT value for the application of the model is 4200. For the upper traffic levels other techniques like simulation programs may be used to model the real traffic conditions. This kind of methods, however, is not in the scope of that research.

List of Variables

AC	Average Cost of Accidents by Severity
AC_{pl}	Annual Construction Cost per 100 kilometers of Roadway ($)
ADT	Average Daily Traffic
AN_p	Average Number of Passengers per Passenger Vehicle
(A/P, i%, n)	The Capital Recovery Factor for an Interest Value of i% and for n Years.
a_{pc}	Acceleration of the Vehicle (meters/second^2)
ARF	Average Reduction in Accidents by Severity for different ADT values
B/C	Benefit Cost Ratio
B_{acc}	Annual Accident Cost Savings provided by a one-mile Lane
B_{time}	Annual Time Saving Benefits ($)
C_{pl}	Construction Cost per 100 kilometers of Roadway ($)
DF	Directional Distribution Factor (major direction)
d_{pc}	Distance Traveled by the Passenger Car while the Truck is in the Passing Lane
D_{pl}	Distance Between Passing Lanes (kilometers)
ΔT_{pass}	Passing Time Saved (seconds)
E(m)	Average Queue Length
E(m) + 1	Average Queue Length plus one
E(w)	Average Waiting Time in Queue (minute/vehicle)
F_{100}	Conversion Factor to Convert per 100 kilometers/vehicle
h	Time Gap between Two Consecutive Opposing Vehicles (seconds)
L_d	Taper Length at the Diverge Section of the Passing Lane
L_{epl}	Effective Length of Passing Lane (meters)
L_{epl100}	Effective Length of Passing Lanes per 100 kilometers (kilometers)
L_m	Taper Length at the Merge Section of the Passing Lane
L_p	Platoon Length (meters)
L_{pl}	Total Passing Lane Length (meters)
N_{tr}	Number of Trucks a Passenger Car would catch in One Hour at V_{avg} before Passing Lanes are Constructed
N_{tr100}	Number of Trucks a Passenger would Catch per 100 kilometers before Passing Lanes are Constructed

$P(h \geq t)$	Probability of Available Passing Sight Distance of 1500 feet during Peak Hour
P_{bt}	Percentage of Business Trips
PHF	Peak Hour Factor
PL_{100}	Number of Passing Lanes per 100 kilometers
P_{lt}	Percentage of Leisure Trips
λ	Average Number of Cars in the Opposing Direction (vehicles/second)
q	Arrival Rate (vehicles/minute)
Q	Service Rate (vehicle/minute)
q_{tr}	Truck Arrival Rate (vehicles/hour)
S	Time Savings (minute/vehicle/truck)
S_{100}	Time Savings for 100 kilometers of roadway for Passenger Cars
S_{bt}	Time Value of Business Trips ($/passenger/second)
S_{lt}	Time Value of Leisure Trips ($/passenger/second)
S_o	Operating Speed after installing the Extra Lane in the Given Subsegment (kilometers/hour)
SV	Service Volume (vehicles/hour)
t	Time Gap between Two Opposing Vehicles 1500 feet apart (seconds)
t_{acc}	Acceleration Time of the Vehicle (seconds)
TB	Total Benefit ($)
T_L	Truck Factor at a given Level of Service
t_{ot}	Time Required to overtake the Truck by a Passenger Car (seconds)
TP	Truck Percentage
t_{pl}	Amount of Time a Passenger Car spends in the Passing Lane (seconds)
UC_{cd}	Construction Cost of Converge and Diverge Sections for each Passing Lane ($)
UC_{pl}	Construction Cost of one kilometer of Roadway ($)
v/c	Volume to Capacity Ratio (a function of $P(h \geq t)$)
V_{avg}	Average Speed on the Road (kilometers/hour)
V_{ot}	Average Speed of Passenger Car while overtaking the Truck
W	Normal Lane Width (meters)
W_L	Adjustment for Lane Width and Lateral Clearance at a given Level of Service

APPENDIX E: TRAFFIC STUDY

The goal of this study is to evaluate the effect of a Super-Two section in an existing highway. The traffic study was made on US 87 highway. The portion of the highway (for this study) starts from Dalhart to a few miles north of Clayton close to the border of Texas and New Mexico. The selections of the highway sections were made to get the best set of data that will depict the Super-Two effect. Analysis based on these data was made to show the significance of a Super-Two section in reducing queuing.

Data Collection Process

Traffic data was accumulated for two days, from 6 a.m. to 6 p.m. evening, in two different sections of Highway 87. Two teams were involved in collecting data and they were engaged on those two different sections alternately to minimize the error. Each team consisted of two people to count traffic in both directions. Both of them counted traffic sitting on both sides of a particular point of the highway. The different aspects of traffic count focused were:

- Number of vehicles
- Number of queues
- Number of vehicles in a queue and
- Number of Trucks (or slow vehicles)

Detailed data accumulated is attached in Appendix F.

Factors Involved In Data Collection

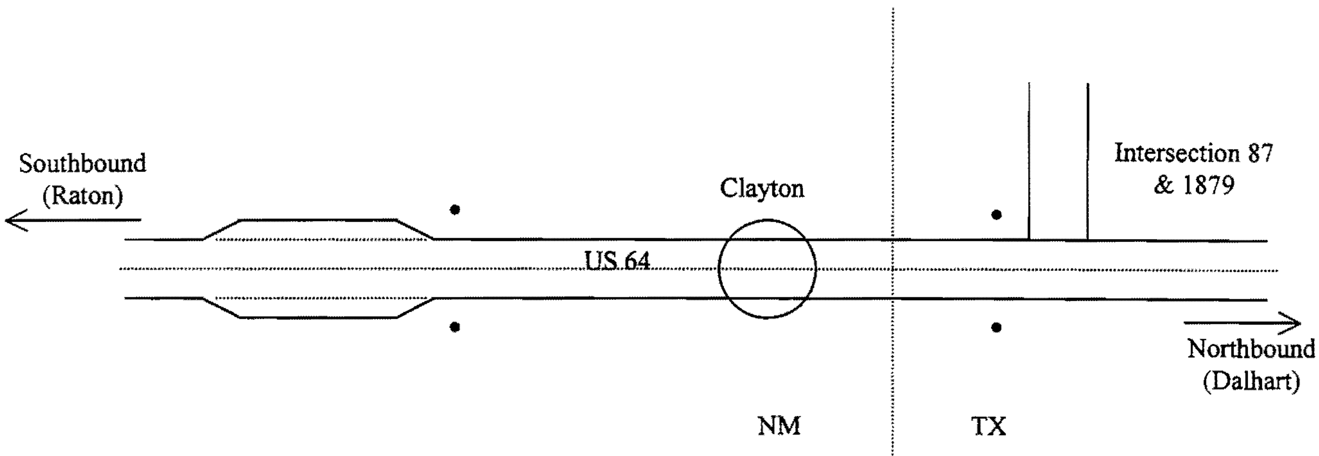
In general a truck or any slow moving vehicle followed by at least one passenger car was considered as the definition of a queue. The maximum distance between a fast and a slow moving vehicle to be considered in a queue was taken as 12.20 m (40 ft). Speed of the vehicles involved in a queue wasn't considered to be a deciding factor in queue formation. In general any big truck, a pickup or any passenger car driven slowly was considered to be a slow moving vehicle. Traffic was counted using human eye. Subjective judgment used by the people collecting the data was an important factor in this study.

Synopsis of Traffic Data

The traffic data was collected on an hourly basis starting from 6 a.m. to 6 p.m. Data was collected on separate sheets for different hours, directions and dates. The following is a synopsis of the accumulated data:

Reduction in Number of Queues Due To Passing Lanes

The sketch of the area where traffic data is collected is shown below:



Clayton is a small town with a population around 2000. The locations of the data collection points are at both sides of Clayton. One is on the south direction at the intersection of US 87 and 1879, the other is on the opposite direction and just before first passing lane section. The passing lanes are constructed on the northern part of Clayton towards Raton.

On the first day of traffic count (07/17/98 Friday) on US 64 and towards Clayton, the number of queues in traffic after the first passing lane is 146. This number has the effect of Super 2 in it because certain number of queues is eliminated because of the passing opportunities provided by passing lane. At the opposite direction towards Dalhart, there is no passing lanes provided, the road is only a two-way two-lane rural road and the effect of the Super 2 can no longer be seen. The number of queues then becomes 382. There is a 62 percent reduction in number of queues.

The number of vehicles in the queue is 357 after first passing lane whereas the same number is 796 at the other data collection point. As a result there is a 55 percent reduction in the number of vehicles per queue.

Another way to measure the effect of Super-Two is to count traffic in between two Super-Two sections. In this way we can measure the queues developed between passing sections and the effect of the section to eliminate queues. This is left for future study.

Traffic Count and Design Method

One result of the traffic study is to determine how good the real traffic conditions match the idealized traffic conditions. The key terms in understanding and revealing the consistency between the real and computed traffic characteristics are the parameters. The parameter that we can compare is the average number of vehicles on the Highway. It should be noted that the traffic count is a very long and vigorous job that involved a substantial amount of personal judgement in determining the queue formation and number of vehicles per queue. In addition, to reflect the dynamic characteristics of the traffic, the design methodology that is used for Super-

Two sections was based on probabilistic approach. Therefore, the parameters that are found at the end of the study are the average or expected numbers, having the most probability to occur. It is never possible to find the exact numbers in a traffic count study. Nor, is it possible to observe the same traffic conditions on another day.

The design methodology utilizes ADT values only as a way to calculate the hourly peak volume, the design and the other computations such as those that are involved in benefit/cost analysis are based on this hourly traffic volume. Therefore, a comparison can be possible since the traffic count also has the hourly traffic volumes.

The maximum traffic volume in the Summary sheet for both directions is selected as the peak hour volume for comparison purpose. Since the design method only computes the average number of vehicles per queue before the construction of passing lanes, we should compare the traffic volumes on the direction where there is no effect of Super-Two passing lanes. Because of the inherent limitations due to the Queuing theory when the arrival and service rates come closer, the design method is applicable up to a certain traffic levels. The traffic count shows that these traffic levels are exceeded for the data collected on Saturdays. As a result of this increase in traffic in weekend, the comparison is done according to Friday's data collection.

The observed peak hour volume on 07/17/98 is 532, the average number of vehicles for the same hour is counted as 3.00 according to Traffic Count Summary Sheet *(Table 1)*. The same parameter can be found from the design method as described earlier in the Case Study portion of the report. The peak hour corresponds to an ADT of 3547 by using a peak hour factor of 0.15. As a result, the average number of vehicles per queue calculated in the case study is 3.15 vehicles per queue.

The observed field values and computed analytic values show significant consistency. It is also important to remember that for safety reasons, the number of average vehicles per queue is increased by one.

Reduction in the number of vehicles in the queue is main objective of the study. In order to understand the benefits of the Super-Two, it is also possible to examine how the Super-Two sections affect the platooning of passenger cars. For instance, the tables that provide information on the queuing formation will be useful to determine the change in average number of vehicles in queues caused by passing lanes. On Friday, 07/17/98 the average number of vehicles in queues northbound Texas (Data Collection point is Intersection at US 87 and FM 1879) is 2.55 (Taken from *Table 2*). From this point the vehicles go towards north and they enter Clayton, a small town with a population of 2500. This small town has a main avenue of about 1 mile with four-lanes, and a few traffic lights. This main avenue serves as a passing lane, because the passenger cars will have enough opportunities to overtake the slow moving vehicles at traffic lights, as well as on four-lane main avenue. Therefore, the town itself is considered as passing lane section. After leaving the town, the vehicles will pass through the other data collection point in New Mexico. The average number of vehicles in queues is then observed 2.25 (Taken from *Table 4*). The reduction rate in the average number of vehicles in queue is 12 percent.

On the other hand, the traffic conditions change during weekends, the total number of vehicles that travel increase significantly compared to weekdays. Therefore, in our traffic count study also, there is an increase in traffic due to weekend. The total number of vehicles observed during 12 hours is 4761 for Friday and 5856 for Saturday. This numbers are the average of the total traffic volumes coming from the data collected in two different collection points in the same day as presented in *Tables 1,3,5,7*. The fact that there is a town between the two data collection points is the major reason of the difference between the two numbers. The increase in the traffic volume on Saturday compared to Friday is calculated as 23 percent.

The increase in the traffic volumes on weekends has also effect in the reduction of the average number of vehicles in queues. On Saturday, from *Table 6*, it is noticed that the average number of vehicles in queues going towards North at the data collection point in Texas is 3.54. Whereas, the same parameter becomes 2.40 after vehicles cross Clayton where the effects of passing lane sections occur. The reduction rate is 32 percent. In the other direction, the following numbers are observed. In New Mexico, the average number of vehicles in queue is 1.81 (Taken from *Table 8*) for the vehicles leaving the passing lane where this number has direct effect of passing lane. The same parameter becomes 3.73 (Taken from *Table 6*). Then, the corresponding reduction rate in the average number of vehicles in queues is 52 percent.

As a result of comparing the reduction rates for Friday and Saturdays, the reduction rates are much higher for Saturday than they are for Friday. We can conclude that the Super Two sections are more effective in the weekends when there is more traffic using the roadway. More important point to make is that Super Two Highways are successful in reducing the queues and providing a higher level of service for two-way two-lane rural highways.

Table E-1. Traffic Count Summary Sheet on 07/17/98 Friday - Intersection at US 87 & 1879 (TX)

Time	Number of Cars		Number of Trucks		Total Number of Vehicles		Hourly Volume (2 Directions)
	Northbound	Southbound	Northbound	Southbound	Northbound	Southbound	
6:00-7:00	86	48	29	18	115	66	181
7:00-8:00	129	48	42	29	171	77	248
8:00-9:00	157	83	56	33	213	116	329
9:00-10:00	220	64	48	15	268	79	347
10:00-11:00	190	133	44	33	234	166	400
11:00-12:00	205	206	40	42	245	248	493
12:00-13:00	218	178	46	61	264	239	503
13:00-14:00	208	188	72	59	280	247	527
14:00-15:00	206	208	53	57	259	265	524
15:00-16:00	206	233	47	46	253	279	532
16:00-17:00	164	234	48	55	212	289	501
17:00-18:00	227	199	38	53	265	252	517
Total	2216	1822	563	501	2779	2323	5102

Table E-2. Summary of Queue Formation on 07/17/98 Friday - Intersection at US 87 & 1879 (TX)

Time	Number of Queues		Number of queues per Hour	Vehicles / Queue		Average # of Vehicles in Queue	
	Northbound	Southbound		Northbound	Southbound	Northbound	Southbound
6:00-7:00	10	5	15	22	6	2.20	1.20
7:00-8:00	23	13	36	40	19	1.74	1.46
8:00-9:00	31	16	47	70	27	2.26	1.69
9:00-10:00	45	9	54	117	14	2.60	1.56
10:00-11:00	28	25	53	64	48	2.29	1.92
11:00-12:00	34	38	72	77	93	2.26	2.45
12:00-13:00	29	43	72	92	84	3.17	1.95
13:00-14:00	32	37	69	96	80	3.00	2.16
14:00-15:00	38	38	76	109	114	2.87	3.00
15:00-16:00	35	43	78	101	87	2.89	2.02
16:00-17:00	38	52	90	81	127	2.13	2.44
17:00-18:00	39	46	85	107	95	2.74	2.07
Total	382	365	747	976	794	2.55	2.18

Table E-3. Traffic Count Summary Sheet on 07/17/98 Friday US 64 Before 1st Passing Lane (NM)

Time	Number of Cars		Number of Trucks		Total Number of Vehicles		Hourly Volume (2 Directions)
	South bound	North bound	South bound	North bound	South bound	North bound	
6:00-7:00	18	45	5	19	23	64	87
7:00-8:00	34	101	19	33	53	134	187
8:00-9:00	65	143	30	46	97	191	288
9:00-10:00	102	144	44	55	146	199	345
10:00-11:00	160	182	39	73	199	255	454
11:00-12:00	182	168	41	59	223	227	450
12:00-13:00	157	170	68	46	225	216	441
13:00-14:00	163	154	58	55	221	209	430
14:00-15:00	154	198	48	56	202	254	456
15:00-16:00	179	195	69	56	248	251	499
16:00-17:00	159	150	62	43	221	193	414
17:00-18:00	143	132	62	31	205	163	368
Total	1516	1782	545	572	2063	2356	4419

Table E-4. Summary of Queue Formation on 07/17/98 Friday - US 64 Before 1st Passing Lane (NM)

Time	Number of Queues		Number of queues per Hour	Vehicles / Queue		Average # of Vehicles in Queue	
	South bound	North bound		South bound	North bound	South bound	North bound
6:00-7:00	1	3	4	1	7	1.00	2.33
7:00-8:00	3	13	16	4	22	1.33	1.69
8:00-9:00	8	27	35	11	43	1.38	1.59
9:00-10:00	12	25	37	17	55	1.42	2.20
10:00-11:00	15	46	61	29	110	1.93	2.39
11:00-12:00	22	32	54	48	96	2.18	3.00
12:00-13:00	23	22	45	50	55	2.17	2.50
13:00-14:00	20	31	51	62	62	3.10	2.00
14:00-15:00	6	45	51	21	94	3.50	2.09
15:00-16:00	16	30	46	61	77	3.81	2.57
16:00-17:00	10	29	39	21	71	2.10	2.45
17:00-18:00	12	20	32	43	34	3.58	1.70
Total	148	323	471	368	726	2.49	2.25

Table E-5. Traffic Count Summary Sheet on 07/18/98 Saturday - Intersection at US 87 & 1879 (TX)

Time	Number of Cars		Number of Trucks		Total Number of Vehicles		Hourly Volume (2 Directions)
	North bound	South bound	North bound	South bound	North bound	South bound	
6:00-7:00	102	37	70	26	172	63	235
7:00-8:00	156	45	72	30	228	75	303
8:00-9:00	226	90	73	24	299	114	413
9:00-10:00	306	125	93	31	399	156	555
10:00-11:00	256	143	104	47	360	190	550
11:00-12:00	267	213	94	47	361	260	621
12:00-13:00	279	231	77	61	356	292	648
13:00-14:00	226	237	64	44	290	281	571
14:00-15:00	280	252	72	48	352	300	652
15:00-16:00	264	249	65	46	329	295	624
16:00-17:00	200	218	48	48	248	266	514
17:00-18:00	137	208	35	40	172	248	420
Total	2699	2048	867	492	3566	2540	6106

Table E-6. Summary of Queue Formation on 07/18/98 Saturday - Intersection at US 87 & 1879 (TX)

Time	Number of Queues		Number of queues per Hour	Vehicles / Queue		Average # of Vehicles in Queue	
	North bound	South bound		North bound	South bound	North bound	South bound
6:00-7:00	19	5	24	39	6	2.05	1.20
7:00-8:00	24	7	31	46	14	1.92	2.00
8:00-9:00	32	9	41	73	19	2.28	2.11
9:00-10:00	36	19	55	118	68	3.28	3.58
10:00-11:00	40	23	63	132	70	3.30	3.04
11:00-12:00	39	26	65	120	105	3.08	4.04
12:00-13:00	33	33	66	130	143	3.94	4.33
13:00-14:00	18	31	49	86	107	4.78	3.45
14:00-15:00	27	28	55	146	124	5.41	4.43
15:00-16:00	25	25	50	113	87	4.52	3.48
16:00-17:00	17	19	36	86	97	5.06	5.11
17:00-18:00	11	16	27	48	59	4.36	3.69
Total =	321	241	562	1137	899	3.54	3.73

Table E-7. Traffic Count Summary Sheet on 07/18/98 Saturday - US 64 Before 1st Passing Lane (NM)

Time	Number of Cars		Number of Trucks		Total Number of Vehicles		Hourly Volume (2 Directions)
	Southbound	Northbound	Southbound	Northbound	Southbound	Northbound	
6:00-7:00	32	68	11	22	43	90	133
7:00-8:00	47	124	11	42	58	166	224
8:00-9:00	78	213	19	60	97	273	370
9:00-10:00	119	243	42	55	161	298	459
10:00-11:00	162	275	40	65	202	340	542
11:00-12:00	239	235	60	55	299	290	589
12:00-13:00	292	256	68	68	360	324	684
13:00-14:00	207	252	48	51	255	303	558
14:00-15:00	205	250	57	61	262	311	573
15:00-16:00	192	245	49	45	241	290	531
16:00-17:00	222	225	52	39	274	264	538
17:00-18:00	162	162	43	37	205	199	404
Total	1957	2548	500	600	2457	3148	5605

Table E-8. Summary of Queue Formation on 07/18/98 Saturday US 64 Before 1st Passing Lane (NM)

Time	Number of Queues		Number of queues per Hour	Vehicles / Queue		Average # of Vehicles in Queue	
	Southbound	Northbound		Southbound	Northbound	Southbound	Northbound
6:00-7:00	2	11	13	2	17	1.00	1.55
7:00-8:00	3	31	34	4	53	1.33	1.71
8:00-9:00	6	44	50	9	109	1.50	2.48
9:00-10:00	17	44	61	26	107	1.53	2.43
10:00-11:00	20	50	70	39	128	1.95	2.56
11:00-12:00	25	44	69	46	134	1.84	3.05
12:00-13:00	48	52	100	80	112	1.67	2.15
13:00-14:00	11	53	64	21	115	1.91	2.17
14:00-15:00	18	49	67	37	143	2.06	2.92
15:00-16:00	20	42	62	44	110	2.20	2.62
16:00-17:00	21	41	62	44	81	2.10	1.98
17:00-18:00	14	23	37	19	53	1.36	2.30
Total	205	484	689	371	1162	1.81	2.40

APPENDIX F: TRAFFIC DATA SHEETS

DATA COLLECTION SHEET FROM 6 AM TO 7 AM

Southbound (Highway 87 Direction DALHART 07/17/98)

	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	1	1	1	1	2
	10	10			20
	10	1			11
	1	1	1	1	2
	7	2			9
	10				10
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	5				5
Total:	48	18	5	6	66

DATA COLLECTION SHEET FROM 7 AM TO 8 AM

Southbound (Highway 87 Direction DALHART 07/17/98)

Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	5			15
2	1	1	2	3
2	1	1	2	3
1	1	1	1	2
10	6			16
2	2	1	3	4
1	1	1	1	2
1	1	1	1	2
	2	1	1	2
10	1			11
1	2	1	2	3
1	1	1	1	2
1	1	1	1	2
2	1	1	2	3
1	1	1	1	2
2	1			3
1	1	1	1	2

Total: 48 29 13 19 77

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
		2	1	1	2
	1	2	1	2	3
	3	1	1	3	4
	10	1			11
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	10	4			14
	2	1	1	2	3
		2	1	1	2
	1	3	1	3	4
	10	6			16
	2		1	1	2
	3		1	2	3
	2		1	1	2
	2	2	1	3	4
	10				10
	2		1	1	2
	2		1	1	2
	7	1			8
	3		1	3	3
Total:	83	33	16	27	116

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	10			20
	10	1			11
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	1	1	1	1	2
	10				10
	3		1	2	3
	3	2	1	4	5
	10				10
	3		1	2	3
	5				5
	2		1	1	2
	2		1	1	2
Total:	64	15	9	14	79

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	2	1	1	2	3
	1	1	1	1	2
	4	2	1	5	6
	7	1			8
	2		1	1	2
	10	1			11
	1	3	1	3	4
	3	1	1	3	4
	3		1	2	3
	10	3			13
	1	1	1	1	2
	3		1	2	3
	2		1	1	2
	10	3			13
	4	1	1	4	5
	2		1	1	2
	10	1			11
	3		1	2	3
	2	2	1	3	4
	10	4			14
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	10	2			12
	2		1	1	2
	2		1	1	2
	3		1	2	3
	1	1	1	1	2
	5		1	4	5
	2	1	1	2	3
	2		1	1	2
	3		1	2	3
Total:	133	33	25	48	166

DATA COLLECTION SHEET FROM 11 AM TO 12 PM

Southbound (Highway 87 Direction DALHART 07/17/98)

Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	4			14
4		1	3	4
3	2	1	4	5
2		1	1	2
10				10
3	1	1	3	4
10				10
1	1	1	1	2
1	1	1	1	2
3		1	2	3
3		1	2	3
2	1	1	2	3
2		1	1	2
3		1	2	3
10	1			11
1	2	1	2	3
2		1	1	2
1	1	1	1	2
1	1	1	1	2
14	1	1	14	15
2	1	1	2	3
3		1	2	3
10	3			13
2		1	1	2
5	2	1	6	7
4		1	3	4
2		1	1	2
1	1	1	1	2
10	5			15
4		1	3	4
5		1	4	5
2	1	1	2	3
10				10
5		1	4	5
3	1	1	3	4
3		1	2	3
10	3			13

	1	1	1	1	2
	5		1	4	5
	10	1			11
	1	1	1	1	2
	9	1			10
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	4	1	1	4	5
	4		1	3	4
Total:	206	42	38	93	248

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	3		1	2	3
	3		1	2	3
	2		1	1	2
	3		1	2	3
	1	1	1	1	2
	5	1	1	5	6
	3		1	2	3
		4	1	3	4
	2		1	1	2
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	2		1	1	2
	10				10
	10				10
	1	3	1	3	4
	2	1	1	2	3
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	4		1	3	4
	2		1	1	2
	5	3	1	7	8
	2		1	1	2
	4		1	3	4
		2	1	1	2
	3		1	2	3
	10	5			15
	1	1	1	1	2
	3		1	2	3
	2		1	1	2
	3		1	2	3
	10	5			15

	4	1	1	4	5
	10				10
	2		1	1	2
	1	2	1	2	3
		2	1	1	2
	5	1	1	5	6
	10	9			19
	3		1	2	3
	2	2	1	3	4
	3		1	2	3
	2		1	1	2
	2		1	1	2
	3				3
	2	1	1	2	3
Total:	178	61	43	84	239

DATA COLLECTION SHEET FROM 1 PM TO 2 PM

Southbound (Highway 87 Direction DALHART 07/17/98)

Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	5			15
	4	1	3	4
2		1	1	2
2		1	1	2
4	2	1	5	6
2	1	1	2	3
10	1			11
1	1	1	1	2
3		1	2	3
1	1	1	1	2
	2	1	1	2
2		1	1	2
2		1	1	2
10				10
1	1	1	1	2
4		1	3	4
10	5			15
2	1	1	2	3
1	2	1	2	3
3		1	2	3
5	3	1	7	8
4	2	1	5	6
2	2	1	3	4
2	2	1	3	4
3		1	2	3
2		1	1	2
3		1	2	3
5	5			10
1	2	1	2	3
3		1	2	3
10	5			15
4	1	1	4	5
2		1	1	2
2		1	1	2
1	1	1	1	2
10	2			12
1	1	1	1	2
5	1	1	5	6

	1	1	1	1	2
	10				10
	2	1	1	2	3
	10				10
	2		1	1	2
	10				10
	2	2	1	3	4
	10	1			11
	3	1	1	3	4
	1				1
	2		1	1	2
Total:	188	59	37	80	247

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	6	1	1	6	7
		3	1	2	3
	10	1			11
	3	1	1	3	4
	7	3	1	9	10
	10				10
	1	1	1	1	2
	10				10
	3		1	3	3
	12	1	1	12	13
	2	2	1	3	4
	1	1	1	1	2
		2	1	1	2
	10	4			14
	4	1	1	4	5
	3		1	2	3
	1	1	1	1	2
	3	1	1	3	4
	10	3			13
	2	1	1	2	3
	1	1	1	1	2
	8	3	1	10	11
	2	1	1	2	3
	3	3	1	5	6
	4	2	1	5	6
	10				10
	5				5
	3		1	2	3
	2		1	1	2
	10	6			16
	1	1	1	1	2
	2		1	1	2
	1	1	1	1	2
	1	1	1	1	2
	5		1	4	5
	10				10
	3	2	1	4	5
	4	1	1	4	5

	2		1	1	2
	1	1	1	1	2
	3		1	2	3
	4		1	3	4
	2		1	1	2
	3		1	2	3
	10				10
	3	1	1	3	4
	2	3			5
	3	2	1	4	5
	2	1	1	2	3
	208	57	38	114	265

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	2		1	1	2
	4	2	1	5	6
	6	1	1	6	7
	2		1	1	2
	10				10
	5		1	4	5
	2		1	1	2
	2	1	1	2	3
	2		1	1	2
	3		1	2	3
	1	1	1	1	2
	2		1	1	2
	10				10
	1	2	1	2	3
	10	1			11
	4		1	3	4
	1	1	1	1	2
	2		1	1	2
	10	1			11
	8		1	7	8
	3		1	2	3
	2		1	1	2
	10				10
	2	1	1	2	3
	4		1	3	4
	1	1	1	1	2
	10	1			11
	10	4			14
	1	1	1	1	2
	2		1	1	2
	4		1	3	4
	10				10
	2	1	1	2	3
	1	2	1	2	3
	2		1	1	2
	1	1	1	1	2
	2		1	1	2

	2		1	1	2
	10				10
	1	2	1	2	3
	1	2	1	2	3
	2		1	1	2
	10	1			11
	4	1	1	4	5
	1	1	1	1	2
		2	1	1	2
	2	1	1	2	3
	10				10
	1	1	1	1	2
	3	1	1	3	4
	4		1	3	4
	2	1	1	2	3
	10	3			13
	1	2	1	2	3
	2	1	1	2	3
	3				3
Total:	233	46	43	87	279

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	4			14
	6		1	5	6
	1	1	1	1	2
	10	1	1	10	11
	3		1	2	3
	7	2	1	8	9
	10				10
	1	1	1	1	2
	3		1	2	3
	1	2	1	2	3
	1	1	1	1	2
	4	1	1	4	5
	10				10
	3	1	1	3	4
	2	1	1	2	3
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	10	2			12
	5	1	1	5	6
	2		1	1	2
	1	1	1	1	2
	1	1	1	1	2
	3		1	2	3
	2		1	1	2
	2	1	1	2	3
	3		1	2	3
	2		1	1	2
					0
	2	2	1	3	4
	10	3			13
	2	1	1	2	3
	3		1	2	3
	2	1	1	2	3
	6		1	5	6
	1	1	1	1	2
	3	2	1	4	5
	2	1	1	2	3

	2		1	1	2
	2		1	1	2
	3	1	1	3	4
	1	1	1	1	2
	4	3	1	6	7
	10				10
	3	1	1	3	4
	2		1	1	2
	10	1			11
	1	1	1	1	2
	2		1	1	2
	1	1	1	1	2
	3	1	1	3	4
	2	1	1	2	3
	2	3	1	4	5
	5	1	1	5	6
	4		1	3	4
	10	1			11
	3		1	2	3
	2	1	1	2	3
	6				6
	10	3			13
	3	1	1	3	4
	2	1	1	2	3
	2		1	1	2
Total:	234	55	52	127	289

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Southbound (Highway 87 Direction DALHART 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	1	2	1	2	3
	3		1	2	3
	3	1	1	3	4
	10	3			13
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	10				10
		3	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	10	1			11
	2		1	1	2
	2		1	1	2
	2		1	1	2
	3	1	1	3	4
	2	1	1	2	3
	3		1	2	3
	10				10
	1	1	1	1	2
	3		1	2	3
	3		1	2	3
	2		1	1	2
	2	1	1	2	3
					0
	10	5			15
	3	2	1	4	5
	1	1	1	1	2
	2		1	1	2
	10				10
	5	1	1	5	6
	3		1	2	3
	2		1	2	2
	3	1	1	3	4

	2		1	1	2
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	10				10
	7		1	6	7
	3	1	1	3	4
	10				10
	3		1	2	3
	2		1	1	2
	2		1	1	2
	1	1	1	1	2
	2	1	1	2	3
	2		1	1	2
	5	3	1	7	8
	2	2	1	3	4
	6	2			8
	3	2	1	4	5
	3		1	2	3
Total:	199	53	46	95	252

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	5	2			6
	1	1	1	1	2
	10	1			11
	3	1			4
	2	1	1	2	3
	10	3			13
	4	1	1	5	5
	10	4			14
	5				5
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	3	2			5
	3	1	1	3	4
	10	3			13
	2	1	1	2	3
	2	1	1	2	3
Total:	86	29	10	22	115

		DATA COLLECTION SHEET FROM 7 AM TO 8 AM			
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10				10
	1	1	1	1	2
	2	1	1	2	3
	10	3			13
	1	1	1	1	2
	10	3			13
	2	2	1	3	4
	1	1	1	1	2
	10	3			13
	10	1			11
	1	1	1	1	2
	1	1	1	1	2
	10	1			11
	3	2	1	4	5
	2	1	1	2	3
	2	1	1	2	3
	10	2			12
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	10	3			13
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	2	2	1	3	4
	10				10
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	2				2
Total:	129	42	23	40	171

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	3	2			5
	3	1	1	3	4
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	10	2			12
	8	1	1	8	9
	10	3			13
	1	1	1	1	2
	1	1	1	1	2
	6	1	1	6	7
	4		1	3	4
	5	1			6
	1	1	1	1	2
	1	1	1	1	2
	2	2	1	3	4
	10	3			13
	2	1	1	2	3
	10				10
	3	1	1	3	4
	1	1	1	1	2
	10	1			11
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	2	1	3	4
	10	3			13
	3	1	1	3	4
	1	1	1	1	2
	10	4			14
	1	1	1	1	2
	1	1	1	1	2
	4	1	1	4	5
	10	5			15
	1	1	1	1	2
	3	1	1	3	4

	2	1	1	2	3
	5	1	1	5	6
	3	1	1	3	4
Total:	157	56	31	70	213

		DATA COLLECTION SHEET FROM 9 AM TO 10 AM			
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10				10
	1	1	1	1	2
	10	2			12
	1	1	1	1	2
	1	3	1	3	4
	3	1	1	4	4
	10				10
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	10	2			12
	3		1	2	3
	1	1	1	1	2
	1	1	1	1	2
	2		1	1	2
	2		1	1	2
	2		1	1	2
	10	1			11
	4	2	1	5	6
	4	1	1	4	5
	10	3			13
	3		1	2	3
	2	1	1	2	3
	3		1	2	3
	3		1	2	3
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	10	1			11
		2	1	1	2
	3		1	2	3
	5		1	4	5
		2	1	1	2
	10	1	1	10	11
	7	1	1	7	8
	2		1	1	2

	4		1	3	4
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	10	1			11
		2	1	1	2
	3	1	1	3	4
	2	1	1	2	3
	11	2	1	12	13
	2	1	1	1	3
	3		1	2	3
	7	2	1	8	9
	2		1	1	2
	10				10
	2		1	1	2
	5				5
	5	2	1	6	7
	4		1	3	4
	4		1	2	4
Total:	220	48	45	117	268

		DATA COLLECTION SHEET FROM 10 AM TO 11 AM			
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	7	4			11
	10	2			12
	4		1	3	4
	2	1	1	2	3
	4	1	1	4	5
	10	2			12
	3	1	1	3	4
	2		1	1	2
	1	1	1	1	2
	4		1	3	4
	10	1			11
	1	1	1	1	2
	4	1	1	4	5
	10	4			14
	2		1	1	2
	5				5
	2		1	1	2
	2		1	1	2
	4	1	1	4	5
	5	1			6
	3	1	1	3	4
Total :	95	22	14	32	117
Corrected	190	44	28	64	234
Note: This hourly traffic is corrected assuming linear traffic distribution					

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	2	1	1	2	3
	1	1	1	1	2
	4		1	3	4
	10	2			12
	3		1	2	3
	10				10
	2		1	1	2
	10	2			12
	5		1	4	5
	1	1	1	1	2
		2	1	1	2
	2		1	1	2
	6		1	5	6
	3		1	2	3
	1	1	1	1	2
	10	2			12
	5	1	1	5	6
	3		1	2	3
	5		1	4	5
	5		1	4	5
	10	2			12
	1	1	1	1	2
	9	3			12
	5	1	1	5	6
	1	1	1	1	2
	7		1	6	7
	10				10
	2	2	1	3	4
	10				10
	1	2	1	2	3
	10				10
	1	1	1	1	2
	2		1	1	2
	10	5			15
	2		1	1	2
	2		1	1	2
	2		1	1	2

	2		1	1	2
	3		1	2	3
	2	2	1	3	4
	3		1	2	3
	2	1	1	2	3
	1	2	1	2	3
	5	1			6
	4		1	3	4
Total :	205	40	34	77	245

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	3		1	2	3
	3		1	2	3
	10	1			11
	4		1	3	4
	2	1	1	2	3
	3		1	2	3
	7	1	1	7	8
	10	4			14
	1	1	1	1	2
	2	1			3
	14	3	1	16	17
	10	2			12
	6		1	5	6
	7	2	1	8	9
	4	1	1	4	5
	3	1	1	3	4
	10	1			11
	3	1	1	3	4
	1	1	1	1	2
	3	2	1	4	5
	5		1	4	5
	1	1	1	1	2
	3	4	1	6	7
	10	2			12
	10	3			13
	7				7
	1	1	1	1	2
	6	1	1	5	7
	2	1	1	2	3
	10	1			11
	3		1	2	3
	10	1			11
	3		1	2	3
	1	1	1	1	2
	10	1			11
	1	1	1	1	2
	1	1	1	1	2

	10				10
	2		1	1	2
	4				4
	1	1	1	1	2
	1	1	1	1	2
Total :	218	46	29	92	264

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	4	2	1	5	6
	4	2	1	5	6
	10	3			13
	3		1	2	3
	3		1	2	3
	1	1	1	1	2
	10	3			13
	4	1	1	4	5
	1	1	1	1	2
	10				10
	2	1	1	2	3
	3	2	1	4	5
	4	1	1	4	5
	3	1	1	3	4
	9	2			11
	3	4	1	6	7
	1	1	1	1	2
	2	1	1	2	3
	3	1	1	3	4
	4	1	1	4	5
	10	1			11
	8	1	1	8	9
	4	1	1	4	5
	1	1	1	1	2
	10	2			12
	10	3			13
	4	2	1	5	6
	5	1	1	5	6
	10				10
	2	1	1	2	3
	10	4			14
	2	1	1	2	3
	1	1	1	1	2
	10	1			11

	1	1	1	1	2
	2	2	1	3	4
	10	9			19
	2	1	1	2	3
	1	2	1	2	3
	7	1	1	7	8
	2	1	1	2	3
Total :	208	72	32	96	280

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	5		1	4	5
	10	1	1	10	11
	4		1	3	4
	10	3			13
	1	1	1	1	2
	5		1	4	5
	10				10
	3	2	1	4	5
	5		1	4	5
	5	2	1	6	7
	8				8
	3		1	2	3
	10	1			11
	3		1	2	3
	10	1			11
	4		1	3	4
	10	4			14
	4	1	1	3	5
	1	1	1	1	2
	2	1	1	2	3
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	4	1	1	4	5
	7	3			10
	3		1	2	3
	10	2	1	11	12
	3		1	2	3
	2	3	1	4	5
	1	1	1	1	2
	4		1	3	4
	1	1	1	1	2
	5	1			6
	1	1	1	1	2
	9	6			15
	5	2	1	6	7

	1	1	1	1	2
	2	3	1	4	5
	4		1	3	4
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	4		1	3	4
	2		1	1	2
	1	2	1	2	3
	2	1	1	2	3
	3		1	2	3
Total :	206	53	38	109	259

DATA COLLECTION SHEET FROM 3 PM TO 4 PM

Northbound (Highway 87 Direction CLAYTON 07/17/98)

Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	2			12
2	1	1	2	3
3	1	1	3	4
7	1	1	7	8
3	1	1	3	4
1	1	1	1	2
4	1	1	4	5
2	1	1	2	3
1	1	1	1	2
10				10
3		1	3	3
3	2	1	4	5
10	1			11
10				10
3		1	2	3
1	1	1	1	2
10	2			12
4	1	1	4	5
2	2	1	3	4
2		1	1	2
3		1	2	3
10	2			12
3		1	2	3
2	1	1	2	3
2		1	1	2
10	4	1	13	14
1	1	1	1	2
10	1			11
10	2			12
4		1	4	4
2	1	1	2	3
4		1	3	4
10				10
1	2	1	2	3
1	1	1	1	2
2		1	1	2
2		1	1	2
10	1			11

	7		1	6	7
	1	4	1	4	5
	5		1	4	5
	1	1	1	1	2
	2	2	1	3	4
	1	1	1	1	2
	2	2			4
	6	1	1	6	7
	3	1			4
Total :	206	47	35	101	253

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	5	5			10
	1	1	1	1	2
	5	3	1	7	8
	5	1			6
	1	1	1	1	2
	3		1	2	3
	3		1	2	3
	7	1	1	7	8
	2	1	1	2	3
	1	1	1	1	2
	10	1			11
	2	1	1	2	3
	2		1	1	2
	3		1	2	3
	3		1	2	3
	10	1			11
	5	1	1	4	6
	3	1	1	3	4
	4	1	1	4	5
	10				10
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	10	4			14
		4	1	3	4
	5		1	4	5
	1	1	1	1	2
	7	2			9
	2		1	1	2
	1	2	1	2	3
	2	1	1	2	3
	10	2			12
		2	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	6		1	5	6
	1	1	1	1	2
	1	1	1	1	2

	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	1	1	1	1	2
	9				9
	4		1	3	4
Total :	164	48	38	81	212

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Northbound (Highway 87 Direction CLAYTON 07/17/98)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10				10
	10	3	1	12	13
		2			2
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	5	1	1	5	6
	4		1	3	4
	10	1			11
	7	1	1	7	8
	4		1	3	4
	4		1	3	4
	3		1	2	3
	10	2			12
	4		1	3	4
	2	1	1	2	3
	2		1	1	2
	10				10
	3		1	2	3
	2		1	1	2
	4		1	3	4
	3				3
	7	3	1	9	10
	3	1	1	3	4
	3		1	2	3
	7				7
	2		1	1	2
	4	1	1	4	5
	1	1	1	1	2
	10	1			11
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	10				10
	2		1	1	2
	3		1	2	3
	2		1	1	2

	2		1	1	2
	10	1			11
	2		1	1	2
	1	1	1	1	2
	10	1			11
	2		1	1	2
	4	1	1	4	5
	8	1	1	8	9
	10	3			13
	3		1	2	3
	3	1	1	3	4
	2	1	1	2	3
	5	3			8
	3		1	2	3
Total :	227	38	39	107	265

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	10	4			14
	10				10
	1	1	1	1	2
Total:	32	11	2	2	43

	DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	4			14
	10				10
	10				10
		2	1	1	2
	1	1	1	1	2
	10				10
	5	1			6
	1	3	1	2	4
Total:	47	11	3	4	58

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10				10
	2		1	1	2
	10				10
	2	2	1	3	4
		2	1	1	2
	10	4			14
	2	1	1	2	3
	1	1	1	1	2
	10	5			15
	10				10
	10	2			12
		2	1	1	2
	10				10
	1				1
Total:	78	19	6	9	97

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	7			17
	2		1	1	2
	10	4			14
	10	10			20
	5	1	1	4	6
		2	1	1	2
	10				10
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	10				10
	2		1	1	2
		2	1	1	2
	10	2			12
	1	1	1	1	2
	1	1	1	1	2
	2		1	1	2
	10	6			16
	3	1	1	3	4
		2	1	1	2
	4		1	3	4
	3		1	2	3
	10				10
	3		1	2	3
		2	1	1	2
	8				8
Total:	119	42	17	26	161

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	10	1			11
	4		1	3	4
	1	1	1	1	2
	2		1	1	2
	10	2			12
	4		1	3	4
	3		1	2	3
	10	2			12
	10	2			12
	4		1	3	4
		3	1	2	3
	5		1	4	5
	2		1	1	2
	2		1	1	2
	2		1	1	2
	10	2			12
	2		1	1	2
	10	2			12
		3	1	2	3
	4		1	3	4
	1	1	1	1	2
	4	1	1	4	5
	10	4			14
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
	7	1			8
	10				10
	2		1	1	2
	8	4			12
	2	1	1	2	3
Total:	162	40	20	39	202

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	2	1	1	2	3
	2	1	1	2	3
	10				10
	2				2
	3	1	1	3	4
	5				5
	10				10
	3		1	2	3
	10	2			12
	3		1	2	3
	10				10
	2		1	1	2
	10	4			14
	7				7
	4		1	3	4
	10	2			12
	4	1	1	4	5
	1	1	1	1	2
	10				10
	4		1	3	4
	4	1			5
	2		1	1	2
	3		1	2	3
	2		1	1	2
					0
	4	2	1	5	6
	10	10			20
	1	3			4
	1	1	1	1	2
	10	3			13
	2		1	1	2
	10	7			17
	10	2			12
		2	1	1	2
	10				10
	10	4			14

	2	1	1	2	3
	10	2			12
	1	1	1	1	2
	2		1	1	2
	3		1	2	3
	9	2			11
		2	1	1	2
	2	1	1	2	3
	6				6
	2		1	1	2
	1	1	1	1	2
Total :	239	60	25	46	299

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	1	3	1	3	4
	2		1	1	2
	2	2	1	3	4
	2	1	1	2	3
	2		1	1	2
	10	6			16
	2		1	1	2
	1	1	1	1	2
	3		1	2	3
	10	1			11
	3		1	2	3
	3		1	2	3
	10	1			11
	3				3
	2		1	1	2
	2		1	1	2
	2		1	1	2
	2		1	1	2
	1	1	1	1	2
Total :	73	17	15	23	90
Corrected:	292	68	48	80	360

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	6			16
	2	1	1	2	3
	2	1	1	2	3
	3				3
	10	3			13
	10	3			13
	1	1	1	1	2
	10				10
	10	1			11
	10	2			12
		2	1	1	2
	10	4			14
	10				10
	5				5
	1	2	1	2	3
	10	3			13
	5				5
	10	2			12
		4	1	3	4
	10	3			13
	2		1	1	2
	10	1			11
	10	5			15
	2		1	1	2
	10	1			11
	4	1	1	4	5
	10				10
	10				10
	2		1	1	2
	10				10
	4	2			6
	4		1	3	4
Total:	207	48	11	21	255

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	10	2			12
	2	1	1	2	3
	10				10
	10	4			14
	2	2	1	3	4
		2	1	1	2
	10	8			18
	3		1	2	3
		2	1	1	2
	4	1	1	4	5
	2		1	1	2
		3	1	2	3
	10	2			12
	3				3
	3	2	1	4	5
	10	1			11
	10	2			12
	10	1			11
	10	2			12
	10	1			11
	10	2			12
		2	1	1	2
	2		1	1	2
	5				5
	1	1	1	1	2
	3		1	2	3
	10	1			11
	1	1	1	1	2
	10	4			14
	6	1	1	6	7
	10				10
	3		1	2	3
	10	8			18
	3		1	2	3
	2		1	1	2

Total:	205	57	18	37	262

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	4			14
	3	1	1	3	4
	2		1	1	2
	10	2			12
	8				8
	2	1	1	2	3
	10	3			13
	3		1	2	3
	2	1	1	2	3
	10	5			15
	2		1	1	2
	2	1	1	2	3
	2		1	1	2
	10	2			12
	10	6			16
	3		1	2	3
	10	2			12
	3	3	1	5	6
	10				10
	2		1	1	2
	2	1	1	2	3
	2	1	1	2	3
	10	1			11
	2		1	1	2
	3	1	1	3	4
	10	1			11
	5				5
	4		1	3	4
	2		1	1	2
	10	1			11
	4	2	1	5	6
	2	2	1	3	4
	10	4			14
	10	3			13
	2	1	1	2	3
Total:	192	49	20	44	241

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	10	2			12
	2		1	1	2
		2	1	1	2
	10	2			12
	2	1	1	2	3
	1	1	1	1	2
	2		1	1	2
	2		1	1	2
	10				10
	2		1	1	2
	10	2			12
	3	1	1	3	4
	10				10
	5	2	1	6	7
	10				10
	10				10
	5	2	1	6	7
	10	1			11
	3		1	2	3
	2	1	1	2	3
	10	4			14
	2		1	1	2
	4	1	1	4	5
	2		1	1	2
	1	1	1	1	2
	2		1	1	2
	10	2			12
	10	6			16
	10				10
	10	5			15
	2		1	1	2
	2		1	1	2
	2	4	1	5	6
	10	7			17
	1	2	1	2	3
	10				10

	10				10
	5				5
Total:	222	52	21	44	274

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Southbound (US 64 Direction CLAYTON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	7			17
	10	1			11
		2	1	1	2
	2		1	1	2
	2	2	1	3	4
	10	2			12
	10	2			12
	2		1	1	2
	10	3			13
		2	1	1	2
	3		1	2	3
	10				10
	2		1	1	2
	2	1	1	2	3
	10	3			13
	10	1			11
	10	2			12
		2	1	1	2
	10	4			14
	2		1	1	2
	2		1	1	2
	10				10
	3		1	2	3
	1	1	1	1	2
	10	7			17
	9	1			10
	10				10
	2		1	1	2
Total:	162	43	14	19	205

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	2		1	1	2
	10	5			15
	1	1	1	1	2
	3	1	1	3	4
	10	4			14
	2		1	1	2
	2		1	1	2
	2		1	1	2
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	10				10
	2	1	1	2	3
	3		1	2	3
	6	2			8
Total:	68	22	11	17	90

DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	5			15
2		1	1	2
2	1	1	2	3
2	1	1	2	3
2		1	1	2
2		1	1	2
10				10
	2	1	1	2
2		1	1	2
10	5			15
2	1	1	2	3
3		1	2	3
2		1	1	2
5		1	4	5
10	4			14
2	1	1	2	3
4	1	1	4	5
2	2	1	3	4
1	1	1	1	2
1	1	1	1	2
2		1	1	2
1	1	1	1	2
1	1	1	1	2
10	1			11
4		1	3	4
1	1	1	1	2
1	1	1	1	2
1	2	1	2	3
3	1	1	3	4
1	1	1	1	2
1	1	1	1	2
2	1	1	2	3
2		1	1	2
2		1	1	2
5				5
	2	1	1	2
10	2			12

	3	2	1	4	5
Total:	124	42	31	53	166

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	2	1	1	2	3
	4	1	1	4	5
	5		1	4	5
	2	1	1	2	3
	2		1	1	2
	2	2	1	3	4
	4		1	3	4
	3		1	2	3
	1	1	1	1	2
	1	1	1	1	2
	10	5			15
	3	1	1	3	4
	10				10
	1	1	1	1	2
	3		1	2	3
	1	3	1	3	4
	10				10
		3	1	2	3
	2	2	1	3	4
	2		1	1	2
	4	1	1	4	5
	2		1	1	2
	2		1	1	2
	2	2	1	3	4
	10				10
	4	1	1	4	5
	2		1	1	2
					0
	3	1	1	3	4
		2	1	1	2
	10	4			14
	2	1	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	2	1	1	2	3
	10				10

	3		1	2	3
	2	1	1	2	3
	5	1	1	5	6
	3		1	2	3
	3	1	1	3	4
	1	1	1	1	2
	3	1	1	3	4
	2		1	1	2
	10	2			12
	10				10
	4	1	1	4	5
		2	1	1	2
	2	1	1	2	3
	10				10
	2	1	1	2	3
	3		1	2	3
	4				4
	1	2	1	2	3
	12	3	1	14	15
Total:	213	60	44	109	273

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	2		1	1	2
	2		1	1	2
	10				10
	10	5			15
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	2	2	1	3	4
	10				10
	3	1	1	3	4
	1	1	1	1	2
	3	1	1	3	4
	3	1	1	3	4
	3	1	1	3	4
	10	3			13
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	5	1	1	5	6
	10				10
	4		1	3	4
	3		1	2	3
	2	1	1	2	3
	5		1	4	5
	3	1	1	3	4
	2		1	1	2
	1	1	1	1	2
	4	1	1	4	5
	10	5			15
	8	5	1	12	13
	3		1	2	3
	2		1	1	2
	1	1	1	1	2
	10				10
	4		1	3	4

	4		1	3	4
	4		1	3	4
	10	4			14
	2		1	1	2
	2		1	1	2
	2		1	1	2
	10				10
	2		1	1	2
	2		1	1	2
	10				10
	4		1	3	4
	1	1	1	1	2
	9	2	1	10	11
	10				10
	3		1	2	3
	3		1	2	3
	5		1	4	5
	1	1	1	1	2
		2	1	1	2
	3	2			5
Total:	243	55	44	107	298

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	7	1	1	7	8
	2		1	1	2
	1	1	1	1	2
	3		1	2	3
	10	3			13
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	1	2	1	2	3
	3		1	2	3
	3	1	1	3	4
	10				10
	10				10
	2		1	1	2
	3		1	2	3
	10	5			15
	2	1	1	2	3
	3		1	2	3
	2	1	1	2	3
	1	1	1	1	2
	2		1	1	2
	3	1	1	3	4
	5	2	1	6	7
	10				10
	3		1	2	3
	8				8
	2	1	1	2	3
					0
	1	1	1	1	2
	10	5			15
	1	2	1	2	3
	3		1	2	3
	5	3	1	7	8
	10				10
	6		1	5	6
	10	4			14

	2		1	1	2
	2		1	1	2
	3		1	2	3
	8		1	7	8
	3	1	1	3	4
	2		1	1	2
	3	1	1	3	4
	3	1	1	3	4
	2	1	1	2	3
	5	1	1	5	6
	4	1	1	4	5
	10				10
	4	1	1	4	5
	4	1	1	4	5
	1	1	1	1	2
	3	1	1	3	4
	10	5			15
	1	1	1	1	2
	3	1	1	3	4
	10				10
	3	1	1	3	4
	3		1	2	3
	2	1	1	2	3
	4	1	1	4	5
	7				7
	1	1	1	1	2
	3	1	1	3	4
	3		1	2	3
Total:	275	65	50	128	340

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	3	1	1	3	4
	10	5			15
	4	1	1	4	5
	2		1	1	2
	10				10
	1	1	1	1	2
	10				10
	1	1	1	1	2
	6	3	1	8	9
	10		1	9	10
		2	1	1	2
	6	6	1	11	12
	2		1	1	2
	10				10
	2	1	1	2	3
	2	1	1	2	3
	2		1	1	2
	3		1	2	3
	2	1	1	2	3
	3		1	2	3
	4		1	3	4
	3	1	1	3	4
	10	2			12
	3		1	3	3
	1	1	1	1	2
	10	1			11
	1	2	1	2	3
	7		1	6	7
	3		1	2	3
	11		1	10	11
	5		1	4	5
	2	2	1	3	4
	3	5	1	7	8
	2		1	1	2
	3	1	1	3	4
	2	1	1	2	3
	2		1	1	2

	10	2			12
	2	1	1	2	3
	10				10
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	10	6			16
	9		1	8	9
	3		1	2	3
	3	1	1	3	4
	4		1	3	4
	2		1	1	2
	4	1	1	4	5
	2	1	1	2	3
	1	1	1	1	2
	3		1	2	3
	7				7
Total:	235	55	44	134	290

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	2	1	1	2	3
	3		1	2	3
	2	1	1	2	3
	10	3			13
	4	3	1	6	7
	2		1	1	2
	2		1	1	2
	2	1	1	2	3
	1	1	1	1	2
	2		1	1	2
	10	4			14
	1	1	1	1	2
	4		1	3	4
	2		1	1	2
	6		1	5	6
	1				1
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	2	2	1	3	4
	1	1	1	1	2
	10	3			13
	3	1	1	3	4
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	10				10
	4		1	3	4
	3	1	1	3	4
	2	1	1	2	3
	3	1	1	3	4
	10				10
	6				
Total:	128	34	26	56	156
Corrected:	256	68	52	112	324

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	2		1	1	2
	2	1	1	2	3
	1	1	1	1	2
	10	4			14
	5	1	1	5	6
	3		1	2	3
	5	2	1	6	7
	2		1	1	2
	10				10
	5		1	4	5
	1	1	1	1	2
	2		1	1	2
	2		1	1	2
	5		1	4	5
	10	2			12
	2	3	1	4	5
	2		1	1	2
	4	1	1	4	5
	10	4			14
	2		1	1	2
	4		1	3	4
	2		1	1	2
	3	1	1	3	4
	2		1	1	2
	2		1	1	2
	9	1			10
	2	1	1	1	3
					0
	1	1	1	1	2
	2		1	1	2
	3	1	1	3	4
	10	5			15
	5		1	4	5
	2		1	1	2
	5		1	4	5
	2		1	1	2

	2		1	1	2
	3		1	2	3
	3		1	2	3
	8	2	1	9	10
	10				10
	2	1	1	2	3
	3		1	2	3
	1	1	1	1	2
	4	1	1	4	5
	2		1	1	2
	10	1			11
	2	1	1	2	3
	10	3			13
	2		1	1	2
	3		1	2	3
	2	1	1	2	3
	3	2	1	4	5
		2	1	1	2
	4		1	3	4
	1	1	1	1	2
	2		1	1	2
	2		1	1	2
	4		1	3	4
	10				10
	3				3
	3		1	2	3
	1	1	1	1	2
		2	1	1	2
	3		1	2	3
Total:	252	51	53	115	303

DATA COLLECTION SHEET FROM 2 PM TO 3 PM Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
Cars	Trucks	Queues	Vehicles per Queue	Total DT
10	2			12
5	3	1	7	8
5		1	4	5
4		1	3	4
5		1	4	5
3	1	1	3	4
10				10
2	2	1	3	4
1	1	1	1	2
3		1	2	3
6	1	1	6	7
4		1	3	4
10	3			13
2	1	1	2	3
3		1	2	3
3		1	2	3
2	1	1	2	3
1	1	1	1	2
3	1	1	3	4
5	1	1	5	6
3		1	2	3
10	2			12
3		1	2	3
4		1	3	4
3	2	1	4	5
3		1	2	3
10	5			15
3	1	1	3	4
5	2	1	6	7
7	2	1	8	9
3		1	2	3
2		1	1	2
10	7			17
8		1	7	8
5		1	4	5
2	1	1	2	3
1	1	1	1	2

	2	2	1	3	4
	1	1	1	1	2
	2	1	1	2	3
	2		1	1	2
	10				10
	4		1	3	4
	2		1	1	2
	3		1	2	3
	2	2	1	3	4
	2	1	1	2	3
	3	1	1	3	4
	10	1			11
	5		1	4	5
	5	2	1	6	7
	3	2	1	4	5
	2		1	1	2
	2	1	1	2	3
	10	2			12
	2	1	1	2	3
	5	2			7
	2		1	1	2
	2	1	1	2	3
Total:	250	61	49	143	311

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	1	1	1	1	2
	3		1	2	3
		2	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	3		1	2	3
	2		1	1	2
	10				10
	4	1	1	4	5
	3		1	2	3
	3	1	1	3	4
	2		1	1	2
	2		1	1	2
	10	5			15
	10				10
	2		1	1	2
	10	5			15
	2		1	1	2
	2	2	1	3	4
	5	1	1	5	6
	5		1	4	5
	3		1	2	3
	1	1	1	1	2
	10				10
	3		1	2	3
	9				9
	2		1	1	2
	2		1	1	2
	10				10
	4	2	1	5	6
	3	1	1	3	4
	6		1	5	6
	2		1	1	2
	6	1	1	6	7
	5	1	1	5	6
	4	2	1	5	6

	3	2	1	4	5
	3	1	1	3	4
	10				10
	4		1	3	4
	2	1	1	2	3
	10	2			12
	3	4	1	6	7
	10				10
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	10	1			11
	3		1	2	3
	3		1	2	3
	5	1	1	5	6
	5		1	4	5
	3		1	2	3
	4				4
Total:	245	45	42	110	290

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	2		1	1	2
	3		1	2	3
	3		1	2	3
	1	1	1	1	2
	10	1			11
	2		1	1	2
	2		1	1	2
	5		1	4	5
	3		1	2	3
	4		1	3	4
	3	1	1	3	4
	2		1	1	2
	10	1			11
	3		1	2	3
	3	1	1	3	4
	1	1	1	1	2
	2		1	1	2
					0
	10				10
	4		1	3	4
	3		1	2	3
	9	4			13
	5		1	4	5
	1	1	1	1	2
	1	1	1	1	2
		2	1	1	2
	1	1	1	1	2
	2		1	1	2
	6		1	5	6
	10	4			14
	4	1	1	4	5
	1	1	1	1	2
	1	1	1	1	2
	2		1	1	2
	10	1			11
	4		1	3	4

	2	1	1	2	3
	10				10
	3		1	2	3
	10	1			11
	2		1	1	2
	1	1	1	1	2
	10				10
	1	1	1	1	2
	5	1	1	5	6
	10	3			13
	3	1	1	3	4
	10	1			11
	4		1	3	4
	2	1	1	2	3
	1	1	1	1	2
	2		1	1	2
	4	2			6
	2	1	1	2	3
Total:	225	39	41	81	264

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Northbound (US 64 Direction RATON Before 1st Passing Lane 07/18/98 Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	2		1	1	2
	3	2	1	4	5
	4		1	3	4
	10				10
	4	1	1	4	5
	10	3			13
	1	1	1	1	2
	2		1	1	2
	10	4			14
		3	1	2	3
	10				10
	2		1	1	2
	2	1	1	2	3
	2	2	1	3	4
	10				10
	3		1	2	3
	4	1	1	4	5
	3		1	2	3
	10	4			14
	6		1	5	6
	2		1	1	2
	4		1	3	4
	10	2			12
	1	1	1	1	2
	2		1	1	2
	3		1	2	3
	10	2			12
	6	1	1	6	7
	1	2	1	2	3
	10				10
	3				3
Total:	162	37	23	53	199

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	2	1			3
	1	1			2
		2	1	1	2
	5				5
	2				2
	8	1			9
Total:	18	5	1	1	23

	DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	4	3			7
		3	1	2	3
	10	2			12
	3				3
		2	1	1	2
	3	2			5
		2	1	1	2
	4	3			7
Total:	34	19	3	4	53

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	1				1
	1	1	1	1	2
	4	2			6
		2	1	1	2
	5	6			11
		3	1	2	3
	2	1			3
		2	1	1	2
	2	2			4
	3	1	1	3	4
	10	1			11
	10	4			14
	9	2			11
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	5				5
Total:	65	30	8	11	97

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	4	2			6
	4		1	3	4
	10				10
	2	2			4
		2	1	1	2
	5	4			9
	1	1	1	1	2
	6	2			8
	1	1	1	1	2
	10	1			11
	1	2	1	2	3
	10	7			17
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
	5	1			6
	1	1	1	1	2
	10	4			14
	2	1	1	2	3
	11	1			12
	1	1	1	1	2
	3	2			5
	1	1	1	1	2
	1	1	1	1	2
Total:	102	44	12	17	146

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	2		1	1	2
	10				10
	10	2			12
	2	1			3
	1	1	1	1	2
	5				5
	1	1	1	1	2
	10	3			13
	8	1	1	8	9
	10				10
		3	1	2	3
	10	5			15
	1	1	1	1	2
	8	1			9
	4	1	1	4	5
	1	1	1	1	2
	10	2			12
	10				10
	10	1			11
	2	1	1	2	3
	10	1			11
	1	1	1	1	2
	5				5
	1	1	1	1	2
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	10	2			12
	2				2
Total:	160	39	15	29	199

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	2	1	1	2	3
	1	1	1	1	2
	4		1	3	4
	10	2			12
	3		1	2	3
	10				10
	2		1	1	2
	10	2			12
	1	1	1	1	2
		2	1	1	2
	2		1	1	2
	6		1	5	6
	3		1	2	3
	1	1	1	1	2
	10	2			12
	5	1	1	5	6
	5		1	4	5
	5		1	4	5
	10	2			12
	1	1	1	1	2
	9	3			12
	10				10
	2	2	1	3	4
	10				10
	10				10
	2		1	1	2
	10	5			15
	2		1	1	2
	3		1	2	3
	5	5			10
	3		1	2	3
	1	2	1	2	3
	10	5			15
	4		1	3	4
Total:	182	41	22	48	223

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	1	1	1	1	2
	3	1	1	3	4
	5	5			10
	1	1	1	1	2
	3	1	1	3	4
	10	5			15
	7	2	1	8	9
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	2	1	1	2	3
	5	1	1	5	6
	10	5			15
	10	2			12
	1	1	1	1	2
	10	5			15
	10				10
	10	5			15
	3	1	1	3	4
	2	1	1	2	3
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
	1	1	1	1	2
	3	1	1	3	4
	10				10
	1	1	1	1	2
	4	1	1	4	5
		2	1	1	2
	1	1	1	1	2
	5	4			9
		2	1	1	2
Total:	157	68	23	50	225

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	10	5			15
	5	1	1	5	6
	1	2	1	2	3
	10	5			15
	3	1	1	3	4
	10	5			15
		2	1	1	2
	1	1	1	1	2
	5	2	1	6	7
	2	1	1	2	3
	10	5			15
	1	1	1	1	2
		2	1	1	2
		2	1	1	2
	10	5			15
	3	1	1	3	4
	7	2	1	8	9
	7	1	1	7	8
	4	1	1	4	5
	10	1			11
	1	1	1	1	2
	10	1			11
	3	1	1	3	4
	10				10
	1	1	1	1	2
	2	1	1	2	3
	7	1	1	7	8
	10				10
	7				7
	3	1	1	3	4
Total:	163	58	20	62	221

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	10	5			15
	10				10
	3	1	1	3	4
	10	5			15
	10	5			15
		2	1	1	2
	8	3	1	10	11
	10	5			15
	4	1	1	4	5
	10	5			15
	10	5			15
	10	4			14
	10				10
	10				10
	10				10
	10				10
	1	1	1	1	2
	6				6
	2	1	1	2	3
Total:	154	48	6	21	202

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	4	2	1	5	6
	10	5			15
	10	5			15
	2	2	1	3	4
	10	5			15
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	10	5			15
	3	2	1	4	5
	10	5			15
	11	5	1	15	16
	10	3			13
	1	2	1	2	3
	3	3	1	5	6
	6	5	1	10	11
	10				10
	10				10
	5	1	1	5	6
	10				10
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	2	1	3	4
	10				10
	10				10
	3				3
Total:	179	69	16	61	248

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	2	1	1	2	3
	10	5			15
	10	5			15
		3	1	2	3
	1	3	1	3	4
	10	5			15
	3	1	1	3	4
	1	1	1	1	2
	3	1	1	3	4
	10	4			14
	2	1	1	2	3
	10	1			11
	6				6
		3	1	2	3
	10	5			15
	10				10
	10	5			15
	10	5			15
	10	1			11
	1	1	1	1	2
	10	1			11
		3	1	2	3
	5				5
	10	2			12
	5				5
Total:	159	62	10	21	221

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Southbound (Highway 64 Direction CLAYTON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	1			11
	7	1	1	7	8
	5	1	1	5	6
	10	5			15
	1	5	1	5	6
	2	1	1	2	3
	1	1	1	1	2
	10	1			11
	2	5	1	6	7
	10	5			15
	4	1	1	4	5
	10	5			15
	2	1	1	2	3
	10	5			15
	10	5			15
	1	1	1	1	2
	4	3	1	6	7
	10	5			15
	10	1			11
	2	1	1	2	3
	2	1	1	2	3
	10	5			15
	10	2			12
Total:	143	62	12	43	205

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	2			12
	1	3	1	3	4
	8	2			10
	2	2	1	3	4
	21	9			30
	2		1	1	2
	1	1			2
Total:	45	19	3	7	64

	DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	2		1	1	2
	17	3			20
	2		1	1	2
	2		1	1	2
		2	1	1	2
		1			1
		3	1	2	3
		2	1	1	2
	2	1			3
	3		1	2	3
	1	1			2
	2		1	1	2
	1	2	1	2	3
	21	8			29
	2	1	1	2	3
	7	3			10
	3	1	1	3	4
	19	2			21
	4	1	1	4	5
	12	1			13
	1	1	1	1	2
Total:	101	33	13	22	134

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	9	1			10
	2	1	1	2	3
	3				3
	1	1	1	1	2
	3				3
		2	1	1	2
	14	3			17
	1	3	1	3	4
	2				2
	1	1	1	1	2
		2	1	1	2
	5	2			7
	2	1	1	2	3
	2	1	1	2	3
	5				5
	2	1	1	2	3
	2	2			4
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	9				9
	1	1	1	1	2
	7				7
	2	1	1	2	3
	1	1	1	1	2
	3				3
	1	1	1	1	2
	1	2			3
	1	1	1	1	2
	11	1			12
	2	2	1	3	4
	5				5
	2	1	1	2	3
	10	1			11
	3	1	1	3	4
	14				14
	2	1	1	2	3
		2	1	1	2

	1	1	1	1	2
		2	1	1	2
	3				3
	1	1	1	1	2
	1	2			3
	1	1	1	1	2
	2	1	1	2	3
Total:	143	46	27	43	191

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
		2			2
	4	1	1	4	5
	5	4			9
	1	1	1	1	2
	2				2
	3	1	1	3	4
	4	1			5
	2	1	1	2	3
	15				15
	1	1	1	1	2
	1	2	1	2	3
	5	4			9
	1	1	1	1	2
	10				10
	4	2	1	5	6
	1	1	1	1	2
	15	1			16
	2	1	1	2	3
	1	1	1	1	2
		2	1	1	2
	12	6			18
	1	2	1	2	3
	1				1
	1	1	1	1	2
	21	6			27
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	3	1	1	3	4
	1	1	1	1	2
	2	1	1	2	3
	5	2	1	6	7
	1	1	1	1	2
	3	1	1	3	4
	4	1	1	4	5
	5				5
	2	2	1	3	4
Total:	144	55	25	55	199

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	3			13
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	4	2	1	5	6
	4	1	1	4	5
	1	1	1	1	2
	7				7
	3	1	1	3	4
	1	1	1	1	2
	10	1			11
	2	1	1	2	3
	2	1	1	2	3
	3	1	1	3	4
	15	3			18
	1	2	1	2	3
	8	2	1	9	10
	2	1	1	2	3
	16	9			25
	1	1	1	1	2
	1	1	1	1	2
		2	1	1	2
	6	1	1	6	7
	2	2	1	3	4
	2	1	1	2	3
	2	1	1	2	3
	4	1	1	4	5
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	3	1	1	3	4
	3	1	1	3	4
	1	1	1	1	2

	1	2	1	2	3
	6	1	1	5	7
	14	2			16
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	9	3	1	11	12
	7	1			8
	2	1	1	2	3
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
Total:	182	73	46	110	255

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	5			30
	8	1	1	8	9
	4	3	1	6	7
	25	5			30
		2	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	2	2	2	3
	2	1	1	2	3
	7	1	1	7	8
	3	1	1	3	4
	4	1	1	4	5
	4	1	1	4	5
	2	2	1	3	4
	5	2	1	6	7
	5	1	1	5	6
	7	2	1	8	9
	2	1	1	2	3
	25	1			26
	3	1	1	3	4
	1	1	1	1	2
	1	2	2	2	3
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	10	5			15
	3	1	1	3	4
	6	3	1	8	9
	1	1	1	1	2
	1	1	1	1	2
	3	4	1	6	7
Total:	168	59	32	96	227

	DATA COLLECTION SHEET FROM 12 AM TO 1 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	1	1	1	1	2
	23	2			25
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	25	1			26
	1	3	1	3	4
	8	3	1	10	11
	1	1	1	1	2
	16	4			20
	2	1	1	2	3
	1	1	1	1	2
	20	8			28
	5	1	1	5	6
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	20	3			23
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	15	2			17
	1	1	1	1	2
	2	1	1	2	3
	14	1	1	14	15
Total:	170	46	22	55	216

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	20	11			31
	1	2	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	2	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	4	1	1	4	5
	21	1			22
	1	1	1	1	2
	1	1	1	1	2
	3	2	1	3	5
	4	1	1	4	5
	1	1	1	1	2
	2	1	1	2	3
	30				30
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	5	1	1	5	6
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	25	7			32
	1	1	1	1	2
	4	1	1	4	5
	3	2	1	4	5
	1	1	1	1	2
	3	2	1	4	5
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	3	1	1	3	4
Total:	154	55	31	62	209

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	1			26
	1	1	1	1	2
	2	2	1	3	4
	1	1	1	1	2
	5	1	1	5	6
	1	1	1	1	2
	5	1	1	5	6
	25	2			27
	2	1	1	2	3
	1	1	1	1	2
	3	1	1	3	4
	4	1	1	4	5
	1	1	1	1	2
	1	1	1	1	2
	6	1	1	6	7
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	25				25
	3	1	1	3	4
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	3	1	4	5
	2	1	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	6	1	1	6	7
	1	1	1	1	2
	5				5
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2

	29	3			32
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	5	2	1	6	7
Total:	198	56	45	94	254

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25				25
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	5	1	1	5	6
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	30	6			36
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	4	2	1	5	6
	3	1	1	3	4
	25	15			40
	3	1	1	3	4
	2	1	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	4	2	1	5	6
	3	1	1	3	4
	30	3			33
	2	1	1	2	3
	2	1	1	2	3
	4		1	3	4
	1	1	1	1	2
	3	1	1	3	4
	2	1	1	2	3
	10				10
	4	1	1	4	5
	12	1	1	12	13
	2	1	1	2	3
	3	1	1	3	4
Total:	195	56	30	77	251

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	3			33
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	30	2			32
	2	1	1	2	3
		2	1	1	2
	1	1	1	1	2
	4	1	1	4	5
	1	3	1	3	4
	5	3	1	7	8
	3	1	1	3	4
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	8	3	1	10	11
	2	1	1	2	3
	3	1	1	3	4
	2	1	1	2	3
	27	1			28
	3	1	1	3	4
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	2	2	1	3	4
	1	1	1	1	2
	1	1	1	1	2
Total:	150	43	29	71	193

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Northbound (Highway 64 Direction RATON 7/17/1998)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	1	1	1	1	2
	25	2			27
	3	1	1	3	4
	3	1	1	3	4
	4	1	1	4	5
	2	1	1	2	3
		2	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	25	4			29
	1	1	1	1	2
	1	1	1	1	2
	1	2	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	25	2			27
	3	1	1	3	4
	1	1	1	1	2
	1	1	1	1	2
	25	1			26
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
Total:	132	31	20	34	163

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	2	2	1	3	4
		3	1	2	3
	4	1	1	4	5
	10	5			15
		3	1	2	3
	1	2	1	2	3
		2	1	1	2
	10	5			15
	2	1	1	2	3
	4	1	1	4	5
	10	1			11
	1	1	1	1	2
	9				9
	10	5			15
	2	1	1	2	3
	1	1	1	1	2
	4	1	1	4	5
	2	1	1	2	3
	10	13			23
	1	3	1	3	4
	4	7			11
	2	1	1	2	3
	1	1	1	1	2
		2	1	1	
	1	1	1	1	2
Total:	102	70	19	39	172

	DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	10	5			15
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	10	5			15
	1	1	1	1	2
	1	5			6
	1	2	1	2	3
	10	5			15
	10	1			11
	2	1	1	2	3
	10	5			15
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	10	5			15
	1	2	1	2	3
	2	2	1	3	4
	1	1	1	1	2
	2	2	1	3	4
	5	1	1	5	6
	1	1	1	1	2
	10	5			15
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	10	1			11
	1	1	1	1	2
	10				10
	15				15
	2	3	1	4	5
	2	1	1	2	3
	1	1	1	1	2

Total:	156	72	24	46	228

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	15	5			20
	15	5			20
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	15	5			20
	4	1	1	4	5
	1	1	1	1	2
	15	5			20
	1	1	1	1	2
	10	3			13
	1	3	1	3	4
		2	1	1	2
	15	1			16
	2	1	1	2	3
	1	1	1	1	2
	15				15
	1	1	1	1	2
	15	1			16
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	5	3	1	7	8
	1	2	1	2	3
	4	3	1	6	7
	6	1	1	6	7
	3	2	1	4	5
	2	1	1	2	3
	3	1	1	3	4
	15	1			16
		3	1	2	3
		2	1	1	2
	3	1	1	3	4
	2	1	1	2	3
	10				10
	7	2	1	8	9

	2	1	1	2	3
	10	2			12
	1	1	1	1	2
	1	1	1	1	2
	6				6
	6	1	1	6	7
	1	1	1	1	2
Total:	226	73	32	73	299

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	5	1	1	5	6
	2	1	1	2	3
	2	1	1	2	3
	10				10
	2	1	1	2	3
	2	1	1	2	3
	3	1	1	3	4
	10	5			15
	10	5			15
	10				10
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
	10	5			15
	17	2	1	18	19
	1	1	1	1	2
	10	1			11
	1	1	1	1	2
	3	1	1	3	4
	1	1	1	1	2
	10	1			11
	4	1	1	4	5
	2	4	1	5	6
	1	2	1	2	3
	10				10
	1	1	1	1	2
	1	2	1	2	3
	10	1			11
	10	1			11
	1	1	1	1	2
	10				10
	4	1	1	4	5
	6				6
	6	2	1	7	8

	10	5			15
	3	2	1	4	5
	10	5			15
	1	1	1	1	2
	10				10
	10				10
	3	1	1	3	4
	2	1	1	2	3
	1	2	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	10				10
	4	4	1	7	8
	1	1	1	1	2
	10				10
	5	4	1	8	9
	8	2			10
	5	1	1	5	6
	6	2	1	7	8
	3	1	1	3	4
Total:	306	93	36	118	399

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	3	4	1	6	7
	15	5			20
	15	5			20
	15	5			20
	3	1	1	3	4
	1	1	1	1	2
	1	2	1	2	3
	3	1	1	3	4
	10	4			14
	10				10
	4	1	1	4	5
	2	1	1	2	3
	1	1	1	1	2
	5	1	1	5	6
	3	2	1	4	5
	10				10
	3	1	1	3	4
	2	1	1	2	3
	2	1	1	2	3
	4	3	1	6	7
	1	3	1	3	4
	9	2	1	10	11
	1	1	1	1	2
	1	1	1	1	2
	7	3	1	9	10
	3	1	1	3	4
	15	5			20
	4	1	1	4	5
	15	5			20
	1	1	1	1	2
	10	3			13
	15	1			16
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	4	3	1	6	7
	6	1	1	6	7

	3	2	1	4	5
	2	1	1	2	3
	3	1	1	3	4
	15	10			25
	5	1	1	5	6
	1	1	1	1	2
	2	1	1	2	3
	4	1	1	4	5
	2	4	1	5	6
	1	2	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	6	2	1	7	8
	1	1	1	1	2
Total:	256	104	40	132	360

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	5			15
	1	1	1	1	2
	10	5			15
	2	1	1	2	3
		2	1	1	2
	2	1	1	2	3
	10	3			13
	3	1	1	3	4
	4	1	1	4	5
	3	1	1	3	4
	10	1	1	10	11
	10				10
	2	1	1	2	3
	2	1	1	2	3
	1	2	1	2	3
	2	1	1	2	3
	7				7
	3	1	1	3	4
	5	1	1	5	6
	2	1	1	2	3
	10				10
	2	1	1	2	3
	10	5			15
	2	1	1	2	3
	10	5			15
	4	1	1	4	5
	2	4	1	5	6
	1	2	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	6	2	1	7	8
	15				15
	15	1			16
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	3	1	1	3	4

	15	1			16
	10	5			15
	7	2	1	8	9
	2	1	1	2	3
	10	2			12
	2	2	1	3	4
	1	1	1	1	2
	5	1	1	5	6
	1	1	1	1	2
	10	4	1	13	14
	10	1			11
	2	1	1	2	3
	10	7			17
	2	1	1	2	3
	1	2	1	2	3
	2	2	1	3	4
	1	1	1	1	2
Total:	267	94	39	120	361

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	8			38
	7	1	1	7	8
	35	5			40
	2	1	1	2	3
	3	1	1	3	4
	3	1	1	3	4
	10	2	1	11	12
	30	5			35
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	30	5			35
	2	1	1	2	3
	3	1	1	3	4
	1	2	1	2	3
	1	1	1	1	2
	6	1	1	6	7
	1	1	1	1	2
	2	2	1	3	4
	5	6	1	10	11
	2	1	1	2	3
	8	1	1	8	9
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	2	1	2	3
	3	1	1	3	4
	7	1	1	7	8
	6		1	5	6
	2	1	1	2	3
	3	2	1	4	5
	40	5			45
	6	2	1	7	8
	4	2	1	5	6
	2	1	1	2	3
	16	6	1	21	22

	1	1	1	1	2
Total:	279	77	33	130	356

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	5			30
	8	1	1	8	9
	4	3	1	6	7
	25	5			30
		2	1	1	2
	25	5			30
	7	1	1	7	8
		2	1	1	2
	4	5	1	8	9
	3	1	1	3	4
	2	3	1	4	5
	25	5			30
	8	4	1	11	12
	10	1	1	10	11
	1	1	1	1	2
	25	5			30
	2	1	1	2	3
	25	1			26
	3	3	1	5	6
	10				10
	3	1	1	3	4
	6	3	1	8	9
	1	1	1	1	2
	1	1	1	1	2
	3	4	1	6	7
Total:	226	64	18	86	290

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	5			30
	4	1	1	4	5
	3	1	1	3	4
	2	1	1	2	3
	3	2	1	4	5
	4	1	1	4	5
	11	2	1	12	13
	10	2	1	11	12
	25	5			30
	7	1	1	7	8
	8	1	1	8	9
	2	2	1	3	4
	25	5			30
	2	1	1	2	3
	1	1	1	1	2
	25	5			30
	3	1	1	3	4
	26	5			31
	4	1	1	4	5
	4	1	1	4	5
	4	1	1	4	5
	2	2	1	3	4
	5	2	1	6	7
	5	1	1	5	6
	7	2	1	8	9
	25	3			28
	3	2	1	4	5
	2	1	1	2	3
	2	2	1	3	4
	5	2	1	6	7
	13	5	1	17	18
	5	4	1	8	9
	8	1	1	8	9
Total:	280	72	27	146	352

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	1	2	1	2	3
	1	2	1	2	3
	25	5			30
	4	2	1	5	6
	3	2	1	4	5
	25	5			30
	7	2	1	8	9
	5	3	1	7	8
	25	5			30
	6	1	1	6	7
	5	1	1	5	6
	2	1	1	2	3
	1	1	1	1	2
	1	2	1	2	3
	25	5			30
	1	1	1	1	2
	5	1	1	5	6
	25				25
	4	3	1	6	7
	10	1	1	10	11
	4	1	1	4	5
	7	2	1	8	9
	2	1	1	2	3
	3	1	1	3	4
	1	1	1	1	2
	25	5			30
	3	1	1	3	4
	2	2	1	3	4
	13	3			16
	2	1	1	2	3
	6	1	1	6	7
	15	1	1	15	16
Total:	264	65	25	113	329

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	20	5			25
	2	1	1	2	3
	20	5			25
	2	1	1	2	3
	3	1	1	3	4
	5	4	1	8	9
	1	1	1	1	2
	2	1	1	2	3
	20	5			25
	1	1	1	1	2
	20	4	1	23	24
	20	5			25
	4	2	1	5	6
	5	1	1	5	6
	20	1			21
	3	1	1	3	4
	2	2	1	3	4
	1	1	1	1	2
	11	2	1	12	13
	6	1	1	6	7
	20				20
		2	1	1	2
	8	1	1	8	9
	4				4
Total:	200	48	17	86	248

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Northbound (Highway 87 Direction Clayton 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	10	4	1	13	14
	20	5			25
	3	1	1	3	4
	6	1	1	6	7
	20	5			25
		2	1	1	2
	20	5			25
	1	1	1	1	2
	4	1	1	4	5
	5	3	1	7	8
	4	3	1	6	7
	4	1	1	4	5
	20	1			21
	2	1	1	2	3
	17				17
	1	1	1	1	2
Total:	137	35	11	48	172

	DATA COLLECTION SHEET FROM 6 AM TO 7 AM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	20	10			30
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	10	5			15
	1	1	1	1	2
	2	5			7
		2	1	1	2
Total:	37	26	5	6	63

	DATA COLLECTION SHEET FROM 7 AM TO 8 AM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	15			45
		2	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	1	2	1	2	3
	1	1	1	1	2
	7	2			9
	1	2	1	2	3
	3	4	1	6	7
Total:	45	30	7	14	75

	DATA COLLECTION SHEET FROM 8 AM TO 9 AM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	5			35
	2	1	1	2	3
	1	1	1	1	2
	30	5			35
	5	2	1	6	7
	1	1	1	1	2
	2	1	1	2	3
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	14	2			16
	2	3	1	4	5
Total:	90	24	9	19	114

	DATA COLLECTION SHEET FROM 9 AM TO 10 AM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	1			31
	5	2	1	6	7
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	5	1	1	5	6
	2	1	1	2	3
	4	1	1	4	5
	1	1	1	1	2
	25	3			28
	6	3	1	8	9
	4	2	1	5	6
	1	3	1	3	4
	1	1	1	1	2
	2	2	1	3	4
	1	1	1	1	2
	7	1	1	7	8
	3	1	1	3	4
	1	1	1	1	2
	9	1			10
	7	1	1	7	8
	5	1	1	5	6
Total:	125	31	19	68	156

	DATA COLLECTION SHEET FROM 10 AM TO 11 AM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	1	1	1	1	2
	25	3			28
	3	1	1	3	4
	3	1	1	3	4
	1	1	1	1	2
	6	3	1	8	9
	3	1	1	3	4
	1	1	1	1	2
	6	1	1	6	7
	15	1			16
	2	2	1	3	4
	2	3	1	4	5
	2	1	1	2	3
	3	1	1	3	4
	15	5			20
	4	1	1	4	5
	1	1	1	1	2
	15	5			20
	1	1	1	1	2
	10	3			13
	1	1	1	1	2
	6	1	1	6	7
	1	1	1	1	2
	2	1	1	2	3
	2	1	1	2	3
	5	3	1	7	8
	3	2	1	4	5
	4		1	3	4
Total:	143	47	23	70	190

	DATA COLLECTION SHEET FROM 11 AM TO 12 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	4			29
	2	1	1	2	3
	3	1	1	3	4
	3	1	1	3	4
	6	1	1	6	7
	2	1	1	2	3
	5	1	1	5	6
	4	1	1	4	5
	5				5
	6	1	1	6	7
	3				3
	3	1	1	3	4
	12	2			14
	5	1	1	5	6
	3	1	1	3	4
	6	1	1	6	7
	3	1	1	3	4
	2	3	1	4	5
	25	5			30
	1	1	1	1	2
	4	1	1	4	5
	22				22
	8	3	1	10	11
	10	1	1	10	11
	1	1	1	1	2
	25	1			26
	3	2	1	4	5
	3	1	1	3	4
	6	3	1	8	9
	1	1	1	1	2
	1	1	1	1	2
	3	2	1	4	5
	2	2	1	3	4
Total:	213	47	26	105	260

	DATA COLLECTION SHEET FROM 12 PM TO 1 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	30	5			35
	2	2	1	3	4
	2	1	1	2	3
	9	3	1	11	12
	3	1	1	3	4
	4	1	1	4	5
	6		1	5	6
	1	1	1	1	2
	2	1	1	2	3
		4	1	3	4
	8	1	1	8	9
	7	3	1	9	10
	1	1	1	1	2
	1	1	1	1	2
	7	1	1	7	8
	25	2			27
	1	1	1	1	2
	1	1	1	1	2
	14	1	1	14	15
	1	1	1	1	2
	4	3	1	6	7
	5	2	1	6	7
	25	1			26
	7	1	1	7	8
	2	2	1	3	4
	4	1	1	4	5
	2	1	1	2	3
	2	1	1	2	3
	2	1	1	2	3
	6	1	1	6	7
	3	1	1	3	4
	25				25
	1	2	1	2	3
	1	2	1	2	3
	2	1	1	2	3
	10	8	1	17	18
	2	1	1	2	3

	3				3
Total:	231	61	33	143	292

	DATA COLLECTION SHEET FROM 1 PM TO 2 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	1			26
	13	1	1	13	14
	1	1	1	1	2
	4	1	1	4	5
	2	1	1	2	3
	25				25
	4	1	1	4	5
	1	1	1	1	2
	10	1	1	10	11
	3	1	1	3	4
	25	1			26
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	2	1	1	2	3
	3	1	1	3	4
	25				25
	1	1	1	1	2
	3	2	1	4	5
	4	3	1	6	7
	2	1	1	2	3
	4		1	3	4
	1	2	1	2	3
	7	1	1	7	8
	6		1	5	6
	4	2	1	5	6
	2	4	1	5	6
	25	3			28
	3	1	1	3	4
	3	1	1	3	4
	2	1	1	2	3
	12	1			13
	1	1	1	1	2
	4	2	1	5	6
	2	1	1	2	3
	4	1	1	4	5
	1	1	1	1	2

Total:	237	44	31	107	281

	DATA COLLECTION SHEET FROM 2 PM TO 3 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	2			27
	2	1	1	2	3
	2	2	1	3	4
	1	1	1	1	2
	5	1	1	5	6
	3	3	1	5	6
	2	1	1	2	3
	25	2			27
	4	1	1	4	5
	2	1	1	2	3
	4	4	1	7	8
	22				22
	2	1	1	2	3
	25	1	1	25	26
	2	2	1	3	4
	1	1	1	1	2
	5	1	1	5	6
	1	1	1	1	2
	25				25
	3	1	1	3	4
	3	1	1	3	4
	4	1	1	4	5
	3	1	1	3	4
	5	2	1	6	7
	6	1	1	6	7
	5	2	1	6	7
	25	4			29
	7	1	1	7	8
	3	1	1	3	4
	17	1			18
	3	2	1	4	5
	1	1	1	1	2
	4	2	1	5	6
	5	1	1	5	6
Total:	252	48	28	124	300

	DATA COLLECTION SHEET FROM 3 PM TO 4 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25				25
	4	1	1	4	5
	4	1	1	4	5
	1	2	1	2	3
	25	4			29
	2	1	1	2	3
	2	1	1	2	3
	1	1	1	1	2
	2	1	1	2	3
	3	1	1	3	4
	5	3	1	7	8
	3	1	1	3	4
	25	2			27
	5	4	1	8	9
	1	2	1	2	3
	2	1	1	2	3
	3	3	1	5	6
	4	2	1	5	6
	4	1	1	4	5
	25	2			27
	9	1	1	9	10
	25				25
	3	2	1	4	5
	1	1	1	1	2
	4	1	1	4	5
	25	3			28
	3	1	1	3	4
	2	1	1	2	3
	3	1	1	3	4
	5		1	4	5
	22				22
	1	1	1	1	2
Total:	249	46	25	87	295

	DATA COLLECTION SHEET FROM 4 PM TO 5 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	4			29
	2	1	1	2	3
	2	1	1	2	3
	10	2	1	11	12
	25	5			30
	2	1	1	2	3
	1	1	1	1	2
	19	6	1	24	25
	11	2	1	12	13
	25	5			30
	7	1	1	7	8
	3	1	1	3	4
	1	1	1	1	2
	5	3	1	7	8
	25	2			27
	3	1	1	3	4
	1	1	1	1	2
	3	1	1	3	4
	25	4			29
	1	1	1	1	2
	1	1	1	1	2
	1	1	1	1	2
	3	1	1	3	4
	5				5
	12	1	1	12	13
Total:	218	48	19	97	266

	DATA COLLECTION SHEET FROM 5 PM TO 6 PM				
	Southbound (Highway 87 Direction DALHART 7/18/1998 - Saturday)				
	Cars	Trucks	Queues	Vehicles per Queue	Total DT
	25	2			27
	2	1	1	2	3
	1	2	1	2	3
	1	1	1	1	2
	25	2			27
	3	3	1	5	6
	2	2	1	3	4
	3	1	1	3	4
	1	1	1	1	2
	25	1			26
	8	4			12
	1	1	1	1	2
	5	3	1	7	8
	25	2			27
	25	1			26
	3	1	1	3	4
	11	2	1	12	13
	3		1	2	3
	5	1	1	5	6
	25	2			27
	1	2	1	2	3
	1	2	1	2	3
	6	3	1	8	9
	1				1
Total:	208	40	16	59	248

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