DEPARTMENT OF TRANSPORTATION

ROAD USER COST MANUAL

THE STATE OF NEW JERSEY

June 2001

New Jersey
Department of Transportation

Road User Cost Manual

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EXECUTIVE SUMMARY

The Road User Cost manual provides the Department with a method to quantify road user costs to the traveling public based on operating and time delays. Based on this information, the Department can determine the cost effectiveness of various alternatives including detours, temporary roadway or shoulder construction, off-peak hour day work, night work, and the most appropriate project delivery method (i.e., Incentive/Disincentive, A+B Bidding, etc.). Finally, it can be used to quantify the road user costs incurred by the traveling public for cases when the contract provisions for allowable working hours and completion dates are not adhered to (i.e., Liquidated Damages).

INTRODUCTION

Road User Costs in the work zone are added vehicle operating costs and delay costs to highway users resulting from construction, maintenance, or rehabilitation activity. They are a function of the timing, duration, frequency, scope, and characteristics of the work zone; the volume and operating characteristics of the traffic affected; and the dollar cost rates assigned to vehicle operations and delays.

This manual will familiarize the analyst with work zone and traffic characteristics, explain the possible work zone related road user cost components that can occur, and provide a step by step procedure to determine road user costs. Example problems, default hourly traffic percentages, and computation worksheets are also provided to aid the analyst with the road user cost computations. The worksheets and sample problems are calculated using English units of feet and miles. For users utilizing Metric units, the following conversions are applicable: 1 meter = 3.2808 feet & 1 kilometer = 0.62137 miles. The Metric units must be converted to English units prior to using the charts and worksheets.

Designers should consider road user costs when determining the most appropriate construction staging and final design. This should be done early in the design process while there is still flexibility in the design. The optimal design will mitigate or avoid disruptions before they can be created. In addition to considering road user costs for the present construction needs, the analysis procedure provides the tools to determine future road user costs based on future construction needs. By understanding the major factors influencing road user costs, the analyst can take steps to minimize the effect of planned future rehabilitation activities on highway users.

Road User Costs play an important role in computing Liquidated Damages. The contractor's failure to complete a contract or reopen a lane of traffic on time results in damages in terms of delay and cost to the motoring public and the Department. The procedures in this manual will establish how to calculate and apply these damages. Desirably, these damages will never be imposed because it is preferable to avoid high road user costs by adhering to the completion dates and allowable work hours provided in the contract. The methods of computing liquidated damages have taken into account input by the Construction Industry and reflect that road user costs are in fact real, but difficult to accurately calculate given the many factors involved and the different variables that exist on a given day in the life of a construction project.

Road user costs can be used in Benefit/Cost ratios, Life Cycle Cost Analyses, and selecting the most appropriate project delivery method (i.e., Incentive/Disincentive, A+B Bidding, etc.).

Road User Costs are not direct costs to the Department's budget, but they do directly affect the public it serves. For example, the construction of a $1 million full width shoulder to reduce Road User Costs by $2 million increases Department costs to reduce road user costs. This manual is an excellent tool in helping to determine the appropriate capital investment on a project.

SECTION 1

Work Zone and Traffic Characteristics

1.1 DEFINITIONS

Work Zone is defined in the Highway Capacity Manual as an area of a highway in which maintenance and construction operations are taking place that impinge on the number of lanes available to traffic or affect the operational characteristics of traffic flowing through the area.

Road User Costs in the work zone are added vehicle operating costs, delay costs, and crash costs to highway users resulting from construction, maintenance, or rehabilitation activity.

1.2 WORK ZONE CHARACTERISTICS

In order to calculate work zone related road user costs the characteristics of the work zone must be defined. Work zone characteristics of concern include such factors as work zone length, number and capacity of lanes open, duration of lane closures, timing (hours of the day and days of the week) of lane closures, posted speed, and the availability and traffic characteristics of alternative routes. The strategy for the maintenance of traffic should include any anticipated restrictions on contractor's or maintenance force's hours of operations or ability to establish lane closures.

Each work zone established over the analysis period can have different impacts on traffic flow and the associated user costs. Whenever characteristics of the work zone or the characteristics of the affected traffic change, a separate work zone must be defined and evaluated as a separate event.

The duration of a work zone (i.e. the overall length of time a facility or portion of a facility is out of service) can range from sporadic daily lane closures for maintenance to several months for bridge deck replacements.

1.3 TRAFFIC DIVERSION

Traffic demand is generally determined based on the need to use the facility. Traffic volume during work zone operations may or may not be the same. Some portion of the traffic normally wanting to use the facility may divert to other routes when work zones are established.

Vehicles use a given facility because it offers, what the vehicle operators perceive to be, the least expensive combination of vehicle operating and time delay costs, consistent with safety requirements. When faced with restricted flow, or even the anticipation of restricted flow, vehicle operators who normally use a facility will exercise one of several options. The potential vehicle operator responses are categorized as follows:

Hang Toughers - This group continues to use the facility as they always have. They are primarily users with little, or no, option. They (1) must make the trip, (2) they must make it at a specific time, and (3) either don't know of, or don't have, alternative routes or modes to choose from. These users pay the full price of the work zone and have little effect on other facilities in the corridor. In rural areas the predominate choice of through traffic will be to tough it out, as these users generally must make the trip and do not have available alternative routes unless formal detours are established.

Time Shifters - Time Shifters have the "luxury" to travel on the facility or other route at a different time - generally a time well outside of the restricted flow period. These users lessen their impact by sharing the impact with other vehicles by "invading" their time slot. These users also have little effect on other facilities in the corridor, but do impact hourly traffic distribution.

Detourees - Detourees either seek out and use alternate routes, or are forced to negotiate detours established by the highway agency. These operators also lessen their impact by sharing the impact with other vehicles by "invading" their routes. They tend to trade off anticipated time delay for additional travel distances and associated vehicle operating costs. In urban areas this could include users who switch modes. Detourees can have significant impact on overall road user costs of alternative routes.

Trip Swappers - Trip swappers have the "luxury" of totally abandoning the trip or seeking other destinations when the cost, in terms of time and money, becomes too great. Historically, this group consists primarily of shopping and social/recreational trip makers. While their behavior may diminish the road user costs impact in the work zone they adversely impact businesses along the route in question. More recent trends in people working out of the home and Telecommuting may have a significant effect on work trips in the future.

In simple cases, where either work zone disruption is tolerable or alternative routes are limited, the estimated Average Daily Traffic (ADT) during the duration of the work zone can be anticipated to continue on the facility and the work zone analysis can be limited to the existing facility.

In more complex situations where existing traffic would face intolerable work zone disruptions, it is entirely possible that total travel demand and hourly distribution on the facility may change when the work zone is established. When demand changes, the road user cost analysis may have to expand beyond the existing facility and include road user costs on major alternative routes. When preliminary analyses of travel demand show that work zone related road user costs are unreasonably high, allowable work hours may need to be restricted, early contract completion incentives may be appropriate, or an alternative design may need to be considered.

1.4 TRAFFIC CHARACTERISTICS

Road user costs are directly dependent on the volume and operating characteristics of the traffic on the facility. Each construction, maintenance, and rehabilitation activity generally involves some temporary impact on traffic using the facility. The impact can vary from insignificant for minor work zone restrictions on low volume facilities to highly significant for major lane closures on high volume facilities.

The major traffic characteristics of interest for each work zone include such factors as the overall projected Average Daily Traffic (ADT) volumes, the associated 24-hour hourly traffic distributions, and the vehicle classification distribution within the traffic stream. Each of the major traffic characteristics is discussed in the sections that follow.

1.5 AVERAGE DAILY TRAFFIC (ADT)

Current weekday and weekend ADT volumes can be obtained from the traffic monitoring section. When using projected ADT volumes, it is generally assumed traffic patterns remain the same. However, consideration should be given as to whether traffic using the facility will continue to use the facility when work zones are established and traffic flow is restricted.

1.6 HOURLY TRAFFIC DISTRIBUTION (BY DIRECTION)

The 24-hour hourly traffic distribution during work zone operations is essential to be able to compare the unrestricted demand on the facility with the facility's ability to carry that traffic through the work zone. On all routes, distinctions between weekday and weekend traffic hourly distributions are important. Further, when work zones are proposed on recreational routes during seasonal peak periods, seasonal ADT traffic distribution is important.

If current 24-hour hourly traffic distributions are not available default values may be used. The New Jersey Department of Transportation has developed hourly traffic percentages for various functional classes of roadway for each County. These values are based on existing 24-hour weekday traffic volumes and are provided in Appendix B. It should be noted that the use of these percentages is most appropriate for preliminary analyses.

1.7 VEHICLE CLASSIFICATIONS

Road user costs are a composite of the costs of all affected highway users. Highway users are not a homogeneous group. They include commercial and non-commercial vehicles ranging from motorcycles and passenger cars through the heaviest trucks. Appendix A of the FHWA Traffic Monitoring Guide, Third Edition (February 1995) includes 13 different vehicle classifications. These different vehicle types have different operating characteristics and associated operating costs. Further, the value of time differs between vehicle classes. As a result, road user costs need to be analyzed for each major vehicle class present in the traffic stream.

- *Road user cost analysis based on 13 vehicle classifications would be laborious and require extensive traffic data. For simplification of vehicle classifications and consistency with available traffic data, it is recommended to use* ***Car*** *and* ***Truck*** *classifications only.*

SECTION 2

Road User Cost Components

2.1 COST COMPONENTS

Before addressing road user cost calculation procedures, it is helpful to understand the Road User Cost Components. There are a total of ten potential work zone related road user cost components that can occur. Three components are associated with a "Base Case" situation where traffic operates under "Unrestricted Flow" conditions. Four components are associated with a "Queue" situation where traffic operates under "Forced Flow" (Level of Service "F") conditions. Two components are associated with a "Circuity" situation where traffic is forced to utilize a detour to avoid a highway work zone, and the final component is associated with "Crash Costs". Each of the potential road user cost components is discussed in the sections that follow.

2.2 UNRESTRICTED FLOW

Work zones restrict traffic flow either by restraining the capacity of the roadway or, as a minimum, by posting lower speed limits. Figure 2.1 shows unrestricted flow conditions at a work zone. All traffic that flows through the work zone, at a minimum, must slow down while traveling through it and then accelerate back to normal operating speed. This is commonly referred to as a speed change and results in three work zone related road user cost components. The cost components associated with the unrestricted flow case in Figure 2.1 are described below.

Speed Change VOC (Vehicle Operating Cost) - This is the additional vehicle operating cost associated with decelerating from the unrestricted upstream approach speed to the work zone speed and then accelerating back to the unrestricted approach speed from the work zone speed after traversing the work zone.

Speed Change Delay - This is the additional time necessary to decelerate from the unrestricted upstream approach speed to the work zone speed and then to accelerate back to the unrestricted approach speed after traversing the work zone.

Work Zone Delay - This is the additional time necessary to traverse the work zone at the lower posted speed. This depends on the normal and work zone speed differential and length of the work zone.

If traffic volume remains below work zone capacity, the added road user costs are limited to the above three components and the analysis is relatively simple. In most cases delay times remain relatively low and represent more of a minor irritation and inconvenience than a serious problem.

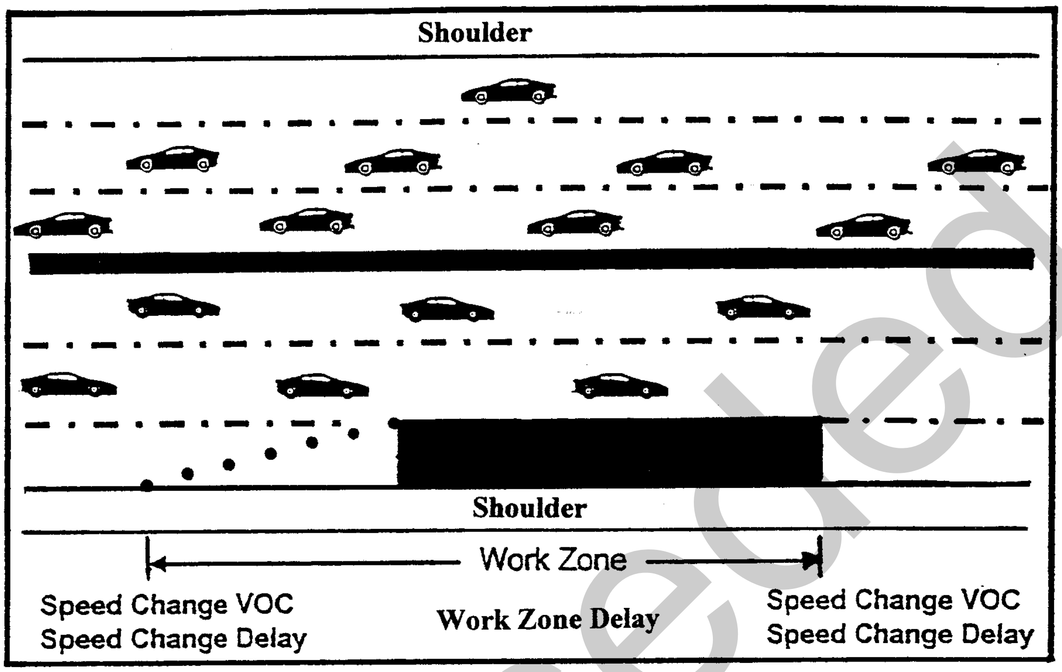

Figure 2.1 - Road User Cost Components (Unrestricted Flow)

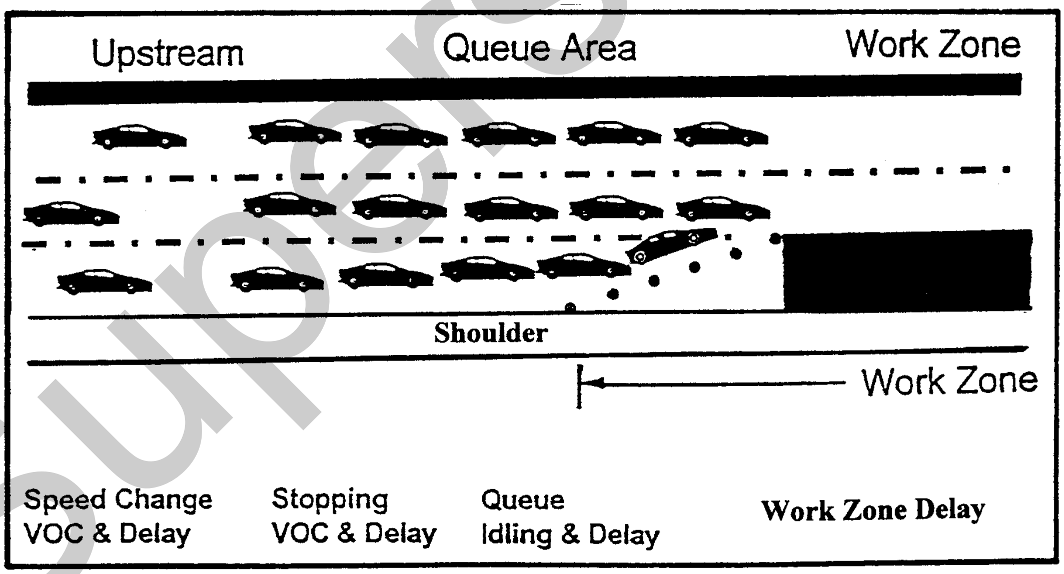

Figure 2.2 - Road User Cost Components (Forced Flow)

- *Department analyses have shown that the **Work Zone Delay** component accounts for approximately 90% of the total road user costs associated with the "Unrestricted Flow" situation. For simplification of calculations, it is recommended to only calculate the costs associated with the **Work Zone Delay** component.*

2.3 FORCED FLOW (Level of Service "F")

When traffic demand exceeds work zone capacity, traffic flow breaks down and a queue of vehicles develops as shown in Figure 2.2. It is important to note that the queue does not form in the work zone itself, but in the upstream approach to the work zone. Once a queue develops, all approaching vehicles must stop at the approach to the work zone and creep through the length of the physical queue under forced flow conditions at significantly reduced speeds. As long as the traffic volume exceeds the work zone capacity, the length of the queue grows. When the traffic volume eventually falls below the work zone capacity, vehicles then leave the queue faster than they arrive and the length of the queue shrinks and eventually dissipates over time. When capacity is reduced on high traffic facilities, it is not uncommon for queues to develop in the morning peak traffic period, dissipate, and then redevelop in the afternoon peak traffic period.

Queuing situations impose four more work zone related road user cost components that are a direct result of the queue. They are in addition to the "Unrestricted Flow" added road user costs and only apply to vehicles that encounter a physical queue. The cost components associated with the forced flow case in Figure 2.2 are described below.

Stopping VOC - This is additional vehicle operating cost associated with stopping and accelerating back up to work zone speed.

Stopping Delay - This is additional time necessary to come to a complete stop (instead of just slowing to the work zone speed) and then accelerating back to the work zone speed.

Queue Delay - This is additional time necessary to creep through the queue under forced flow conditions.

Queue Idling VOC - This is the additional vehicle operating costs associated with "stop and go" driving in the queue. The operating costs include fuel, engine oil, maintenance, and depreciation.

- *Department analyses have shown that the **Queue Delay** and **Queue Idling VOC** components account for approximately 90% of the total road user costs associated with the "Forced Flow" situation. For simplification of calculations, it is recommended to only calculate the costs associated with the **Queue Delay** and **Queue Idling VOC** components.*

The conceptual analysis presented in Figure 2.1 and Figure 2.2 is geared primarily to freeway conditions. Conceptual analysis of facilities with at-grade intersections would also incur speed change, stopping, delay, and idling costs, but at a much higher frequency due to intersection control devices and turning movements.

2.4 CIRCUITY

Circuity is a term used to describe the additional mileage that users travel, either voluntarily or involuntarily, on a detour to avoid a highway work zone or queue situation. Circuity situations impose two more work zone related road user cost components that are a direct result of the detour. They can be in addition to or in lieu of the "Unrestricted Flow" and "Forced Flow" components. If traffic is forced to detour, the associated cost components are described below.

Circuity VOC - This is the additional vehicle operating cost associated with traveling the excess distance the detour imposes.

Circuity (Detour) Delay - This is the additional time necessary to travel the excess distance the detour imposes and this depends on the travel time and travel length differentials.

- *For simplification of calculations, it is recommended to only calculate the **Circuity VOC** and **Circuity Delay** components when a formal detour is established. For non-detour cases, it is assumed the traffic will remain on the roadway and travel the queue and/or work zone situations.*

2.5 CRASH COSTS

Crash Costs are a function of the crash rate for the work zone and for the facility in absence of work zones. Crash rates are typically based on the number of crashes per vehicle miles of travel. Crash rates are commonly specified as crashes per 100 million vehicle miles of travel (100 M VMT).

Overall crash rates for the various functional classes of roadway are fairly well established. Crash rates for work zones, however, are not. While there is a limited amount of work zone crash data, the validity of the data used to compute the crash rates is sometimes suspect. Crashes that occur in work zone generated queues are not always classified as "Work Zone" crashes. Probably even more importantly, it is difficult to accurately quantify the work zone exposure rate (i.e. the length of the work zone and the hours and days the work zone queues are in place). Further, the crash rate, while generally higher in work zones than non-work zones, is still low enough that there may not be any crashes in a given work zone because the exposure period is just too short to allow for statistically valid results. Finally, the problem is compounded by the fact that work zones differ in the way they treat maintenance of traffic. For example, some work zones use permanent barriers, while others use cones or drums; some narrow the lanes, while others maintain lane width and shoulders, etc.

- *The Department considers the human and financial factors associated with crash costs during the project development phase. However, due to the limited availability of work zone crash cost data, the inclusion of* ***Crash Costs*** *as part of the road user costs is* <u>*not*</u> *recommended.*

SECTION 3

Road User Cost Computations

3.1 COMPUTATIONAL ANALYSIS

Once the individual work zones have been identified, each is evaluated separately. This is the point at which individual road user cost components are quantified and converted to dollar cost values. The following sections provide an approach for quantifying and costing the individual road user cost components encountered. The potential work zone related road user cost components were discussed in the previous section and are listed below.

1. Speed Change VOC
2. Speed Change Delay
3. **Work Zone Delay**
4. Stopping VOC
5. Stopping Delay
6. **Queue Delay**
7. **Queue Idling VOC**
8. **Circuity VOC**
9. **Circuity Delay**
10. Crash Costs

The road user cost components shown as **bold** are computed fairly accurately and account for the majority of the total road user costs. Computations for each bolded component will be discussed in detail in the following sections. Worksheets have been developed to aid in organizing and calculating the necessary data and are included in Appendix C. It is recommended that these worksheets be used for the actual computations.

3.2 ANALYSIS OF THE WORK ZONE

The traffic demand and the capacity of individual work zones are important parts in calculating work zone related road user costs. Worksheet 3.1 has been developed to aid the analyst in comparing the traffic volume to the available capacity for each hour of the day. Worksheet 3.1 will provide the total affected traffic to be used in the computations and is discussed below.

Work Zone

Provides all relevant information pertaining to each work zone operation such as the number of lanes closed, the direction of travel, the day(s) of the week and the hours the work zone is in place.

Worksheet 3.1: Analysis of the Work Zone

Work Zone: ____________________ Normal Capacity: ________

Percent Trucks: ________ Percent Cars: ________ Work Zone/Detour Capacity: ________

Directional ADT: ________ Year: ________ Lanes Under Normal Operation: ________

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	Hourly Traffic (%)	Vehicle Demand (vph)	Lanes Open (#)	Roadway Capacity (vph)	Queue Rate (vph)	Queued Vehicles (vph)	Average Queued Vehicles (vph)	Vehicles that Travel Work Zone (vph)	Vehicles that Travel Detour (vph)	Vehicles that Travel Queue (vph)
12-1 AM										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12 PM										
12-1										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12										
TOTALS										

Project: ____________________ Date: ________

Description: ____________________

Directional ADT & Year

The current or future directional ADT, based on the desired construction year, should be obtained from the traffic monitoring section. If future ADT is not readily available, the following formula can be used:

$$\textbf{Future Year ADT} = \textbf{Base Year ADT} \times (1 + \textbf{Growth Rate})^{(\textbf{Future Yr.} - \textbf{Base Yr.})}$$

Percent Trucks & Cars

Provide the percent of each vehicle class that is present in the traffic stream.

Normal / Work Zone / Detour Capacity

The appropriate capacity is related to the allowable lane closure schedule and each is discussed in the Roadway Capacity section.

Lanes Under Normal Operation

The lanes under normal operation are the available number of traffic lanes per direction when no roadway restrictions are present.

Time Period - *Column 3.1 (A)*

The time period generally is shown as one-hour intervals over a 24-hour period. Intervals less than one hour can be used and require that the hourly traffic distribution and roadway capacity be revised accordingly.

Hourly Traffic - *Column 3.1 (B)*

The hourly traffic percent distribution can be determined from traffic data obtained from the traffic monitoring section. If such data can not be determined, the default hourly traffic percentages for various roadway classes (Statewide Averages and by County) can be used and are provided in Appendix B.

Vehicle Demand - *Column 3.1 (C)*

The hourly vehicle demand is calculated by multiplying the directional ADT by the hourly traffic percent distribution.

Lanes Open - *Column 3.1 (D)*

The number of lanes open on the facility varies directly with the allowable work zone lane closure hours provided in the contract.

Roadway Capacity - *Column 3.1 (E)*

Capacity is the maximum number of vehicles passing a point on the facility at established roadway conditions. In analyzing work zone related road user costs, there are three possible capacities that could be utilized and need to be determined. They include: (1) the capacity of the facility under normal operating conditions, (2) the capacity of the facility when the work zone is in place, and (3) the capacity of the facility to dissipate traffic from a queue condition. Each of these is discussed in turn.

(1) Normal Capacity

Normal Capacity is the maximum traffic volume a facility can handle under normal roadway conditions. Table 3.1 provides the ideal capacity a facility type can handle. Chapter 3 of the Highway Capacity Manual (HCM) points out that these capacities under ideal conditions must be adjusted for such real world factors as restricted lane widths, reduced lateral clearances, the presence of trucks and recreational vehicles, and the presence of a driver population unfamiliar with the area. The normal capacity of the facility is used during the non-work zone hours when all traffic lanes are open.

Table 3.1
Capacity by Facility Type

Facility Type	Ideal Capacity
Freeway – 4 lanes	2,200 Passenger Cars per hour per lane
Freeway – 6 or more lanes	2,300 Passenger Cars per hour per lane
Multilane Highway	2,200 Passenger Cars per hour per lane
Two-Lane Highway	1,400 Passenger Cars per hour per lane (*)
Signalized Intersection	1,900 Passenger Cars per hour of green per lane

Source: 1994 HCM Table 2-14

(*) For 50/50 volume split by direction

(2) Work Zone / Detour Capacity

Capacity in the work zone can be estimated from research studies. Table 3.2 reflects average vehicle flow capacities at several real world work zones under several lane closure scenarios. These average capacities are 50% reliable. This means that the work zone capacity will be at least equal to the Table Value 50% of the time. On the other hand it also means the capacity of the work zone will be less than the Table Value 50% of the time.

Table 3.2
Measured Work Zone Capacities – Freeway Section

Number of Directional Lanes		Number Of Studies	Average Capacity		Recommended Value (*) veh/lane/hour
Normal	Open		vehicles per hour	vehicles per lane per hour	
3	1	7	1,170	1,170	**1,200**
2	1	8	1,340	1,340	**1,300**
5	2	8	2,740	1,370	**1,400**
4	2	4	2,960	1,480	**1,500**
3	2	9	2,980	1,490	**1,500**
4	3	4	4,560	1,520	**1,500**

Source: 1994 HCM Fig. 6-11, Fig. 6-12, and Table 6.1

(*) Value may be increased 100 veh/lane/hour when the work zone is protected with Jersey barrier.

The recommended values in Table 3.2 are based on average capacities and a freeway type of facility. These values can be adjusted to reflect other facility types and changes in reliability (i.e., as the reliability increases the capacity decreases). The appropriate work zone and/or detour capacity would be used during the hours that lane restrictions are permitted.

(3) Dissipation Capacity

Capacity during queue dissipation may be less than the capacity during normal conditions, even though the lanes are unrestricted. According to the Highway Capacity Manual "various observations of freeway queue departure rates range from as low as 1500 pcphpl to as high as 2000 pcphpl". When compared to a capacity of 2000 pcphpl, this effect ranges from a significant reduction in capacity of 25% to virtually no reduction at all. This implies that a separate and distinct temporary "dissipation capacity" may exist after a work zone is removed. The appropriate dissipation capacity would only be used during the hours all traffic lanes are open with a physical queue present.

- *Although a dissipation capacity may exist, in the case of a slow moving queue, it is recommended to use the normal capacity in lieu of the dissipation capacity as soon as the work zone is removed. However, in the case of traffic dissipating from a true stop condition such as a bridge opening, it is recommended to use a dissipation capacity that is 85% of the normal capacity (15% reduction).*

Queue Rate - *Column 3.1 (F)*

The queue rate is the difference between hourly capacity of the facility and the unrestricted hourly demand (demand minus capacity) during each hour of the day. The queuing rate is the hourly rate at which vehicles accumulate to, or, if negative, dissipate from any queue that may exist. A physical queue develops when the queue rate is greater than zero.

Queued Vehicles - *Column 3.1 (G)*

The number of queued vehicles are the vehicles "backed up" in the queue at the end of each hour. Once a queue develops, the number of queued vehicles equals the queue rate at the end of the first hour. The next hours' queue rate is then added to the previous queued vehicles total until all the queued vehicles have been dissipated.

Average Queued Vehicles - *Column 3.1 (H)*

The average number of queued vehicles in the queue for each hour is computed by averaging the number of queued vehicles at the beginning and end of each hour.

Vehicles That Travel Work Zone - *Column 3.1 (I)*

Under unrestricted flow conditions, the number of vehicles that travel the work zone is generally the traffic demand on the facility during the hours the work zone is in place. Under forced flow conditions, the number of vehicles that travel the work zone is limited to the capacity of the work zone.

Vehicles That Travel Detour - *Column 3.1 (J)*

The number of vehicles that travel the detour are those vehicles that are forced to use the alternate route during the hours the detour is in effect.

Vehicles That Travel Queue - *Column 3.1 (K)*

A physical queue develops when demand exceeds capacity (i.e. queue rate greater than zero). All vehicles that approach the work zone when a physical queue exists must stop and work their way through the queue before entering the work zone. Traffic that arrives as the queue starts to develop will have a rather short queue to work through, while traffic arriving when the queue is fully developed will have a much longer queue to travel. On the other hand, vehicles arriving as the queue is dissipating will have a continually shrinking queue to deal with. It is important to note that since the facility is operating under forced flow condition, the hourly volume of vehicles traveling the queue is limited to the capacity of the work zone. This is because the only way out of the queue is through the work zone.

Once the analysis of the work zone has been completed, the 24-hour totals should be entered for Hourly Traffic, Vehicle Demand, Vehicles That Travel Work Zone, Vehicles That Travel Detour, and Vehicles That Travel Queue. The affected traffic has now been determined and the analyst should now identify the road user cost components to be computed.

3.3 QUEUE DELAY

The queue delay per vehicle is only computed during forced flow conditions. Before computing the actual road user cost, the delay time through the queue (if applicable) must be known. Although the number of vehicles that travel the queue has been determined, the amount of delay can only be computed after knowing the queue length and queue speed. It is therefore necessary to determine the queue length and queue speed for each time period where a queue exists.

The delay time through the queue is determined by subtracting the time it takes to travel the queue length when it is present, from the time it takes to travel the same distance when it is not present. Worksheet 3.2 has been developed to aid the analyst in computing the overall queue delay per vehicle and is discussed below.

Queue Period - ***Column 3.2 (A)***

A queue period is generally the hours a physical queue exists. It is not uncommon to have several queue periods within a 24-hour period. A physical queue develops when vehicle demand exceeds the roadway capacity and continues until all queued vehicles have been dissipated. The actual queue period(s) can be determined from the results of Worksheet 3.1.

Queue Volume - ***Column 3.2 (B)***

The only way for traffic to exit the queue is through the work zone and therefore the volume through the queue section is limited to the capacity of the work zone.

Normal Capacity - ***Column 3.2 (C)***

The normal capacity of the facility is the capacity of the roadway section operating in an unrestricted flow condition.

V/C Ratio - ***Column 3.2 (D)***

The volume to capacity (V/C) ratio is calculated by dividing Column 3.2 (B) by Column 3.2 (C) for each queue period.

Worksheet 3.2: Queue Delay

	3.2(A) Queue Period (hour)	3.2(B) Queue Volume (veh/hr)	3.2(C) Normal Capacity (veh/hr)	3.2(D) V/C Ratio	3.2(E) Average Queue Speed (mph)	3.2(F) Unrestricted Speed (mph)	3.2(G) Average Queued Vehicles per Queue Period (#)	3.2(H) Queue Lanes (#)
1								
2								
3								
4								
5								

	3.2(I) Average Vehicle Length (feet/veh)	3.2(J) Average Queue Length (mile)	3.2(K) Queue Travel Time at Unrestricted Speed (hr/veh)	3.2(L) Queue Travel Time at Queue Speed (hr/veh)	3.2(M) Added Time to Travel Queue (hr/veh)	3.2(N) Affected Vehicles per Queue Period (#)	3.2(O) Added Time per Queue Period (hour)
1							
2							
3							
4							
5							
			Totals				
			Added Time Weighted Average				hr/veh

Project: ______________________ Date: ______________

Description: ______________________

Average Queue Speed - ***Column 3.2 (E)***

The average queue speed for each queue period is determined by using the V/C Ratio and the graph in Figure 3.1 shown below.

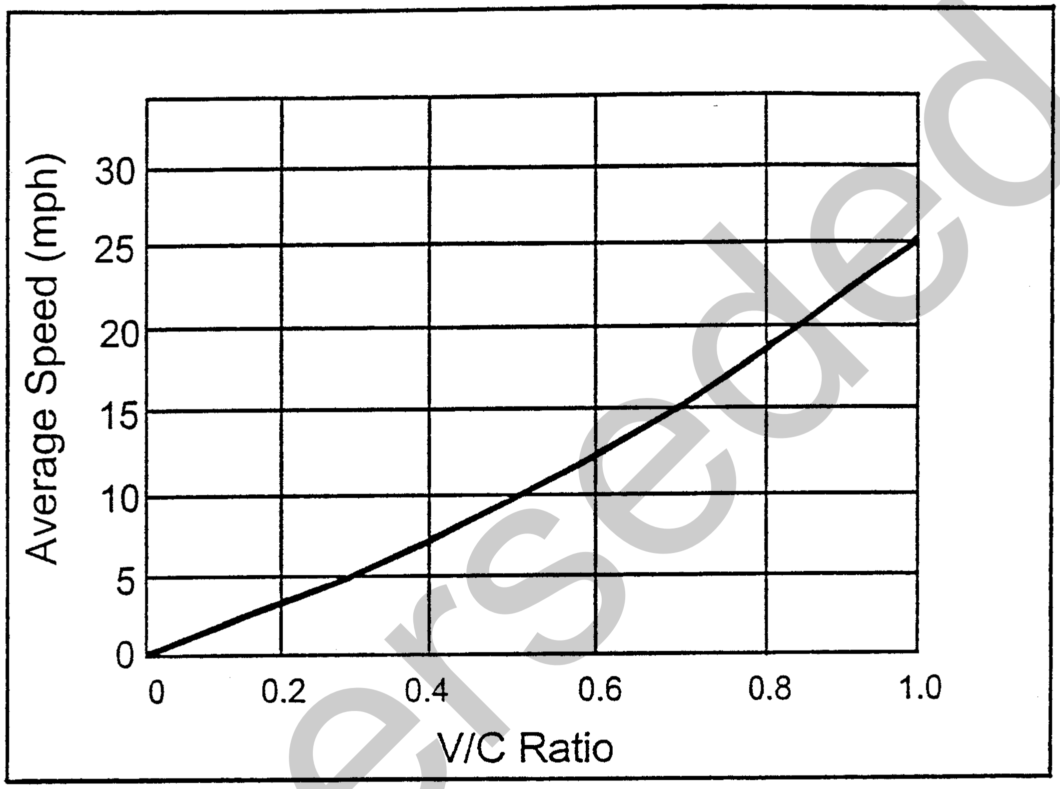

Figure 3.1 - Average Queue Speed Versus V/C Ratio (Source: NCHRP 133)

Unrestricted Speed - ***Column 3.2 (F)***

The unrestricted speed of the facility is generally the posted speed limit of the section operating in an unrestricted flow condition.

Average Queued Vehicles per Queue Period - ***Column 3.2 (G)***

The average number of queued vehicles for each queue period is computed by averaging the Average Queued Vehicles (Worksheet 3.1) over the duration of each queue period.

Queue Lanes - *Column 3.2 (H)*

The number of queue lanes for each queue period is the available lanes upstream of the work zone that are used by vehicles when a physical queue develops.

Average Vehicle Length - *Column 3.2 (I)*

The average vehicle length for each queue period includes an assumed vehicle length (VL) and the space between vehicles. The mixed flow VL is 25 feet. The space between vehicles is computed as one VL for every 10 mph of queue speed. Therefore, a general rule-of-thumb is used: "The average vehicle length = One VL + One VL for every 10 mph of queue speed". For queue speeds up to 6 mph, use an average vehicle length of 40 feet.

Average Queue Length - *Column 3.2 (J)*

The average queue length for each queue period is computed by multiplying Column 3.2 (G) with Column 3.2 (I) and then dividing by Column 3.2 (H) and 5280 feet/mile.

Queue Travel Time At Unrestricted Speed - *Column 3.2 (K)*

This is the time necessary to travel the average queue length at the unrestricted speed and is computed by dividing Column 3.2 (J) by Column 3.2 (F).

Queue Travel Time At Queue Speed - *Column 3.2(L)*

This is the time necessary to travel the average queue length at the average queue speed and is computed by dividing Column 3.2 (J) by Column 3.2 (E).

Added Time To Travel Queue - *Column 3.2 (M)*

The added time to travel the queue for each queue period is computed by subtracting Column 3.2 (K) from Column 3.2 (L).

Affected Vehicles per Queue Period- *Column 3.2 (N)*

The affected vehicles per queue period is the number of vehicles that travel the queue during that period and is only required if there is more than one queue period in 24 hours.

Added Time per Queue Period - ***Column 3.2 (O)***

The added time per queue period is computed by multiplying Column 3.2 (M) and Column 3.2 (N) and is only required if there is more than one queue period in 24 hours.

Added Time Weighted Average

The added time weighted average is computed by dividing the **total** of Column 3.2 (O) by the **total** of Column 3.2 (N).

3.4 QUEUE IDLING VOC

The queue idling VOC is only computed during forced flow conditions. At this point, an overall queue delay per vehicle has been determined. The queue idling VOC is computed by multiplying the number of vehicles that travel the queue, the overall queue delay per vehicle, and the current idling cost rate associated with "stop and go" driving in the queue. The current idling cost rate is computed in Section 3.7.

3.5 WORK ZONE & CIRCUITY (DETOUR) DELAYS

Before computing the actual road user cost, the delay time through both the work zone and detour (if applicable) must be known. Although the number of vehicles delayed through the work zone and/or the detour have been determined, the amount of delay can only be computed after knowing the work zone and/or detour lengths and the times through them. The circuity delay is only computed when a formal detour route has been established. The delay time through the work zone and through the detour are computed in the same manner. In each case, the delay is determined by subtracting the time it takes to travel either the work zone and/or detour when they are present, from the time it takes to travel the same distance when they are not present. Worksheet 3.3 has been developed to aid the analyst in computing the Work Zone and Circuity delays and is discussed below.

Work Zone Length - ***Column 3.3 (A)***

The work zone length is generally the length of lane restrictions including transitions.

Work Zone Speed - ***Column 3.3 (B)***

The work zone speed is generally a 10 mph-15 mph reduction in the unrestricted speed.

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A)	3.3(B)	3.3(C)	3.3(D)	3.3(E)	3.3(F)
Work Zone Length (mile)	Work Zone Speed (mph)	Unrestricted Speed (mph)	Work Zone Travel Time at Unrestricted Speed (hr/veh)	Work Zone Travel Time at Work Zone Speed (hr/veh)	Added Time to Travel Work Zone (hr/veh)

Circuity (Detour) Delay

3.3(G)	3.3(H)	3.3(I)	3.3(J)	3.3(K)	3.3(L)
Travel Length without Detour (mile)	Travel Length with Detour (mile)	Added Travel Length (mile)	Travel Time without Detour (hr/veh)	Travel Time with Detour (hr/veh)	Added Time to Travel Detour (hr/veh)

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)

Project: ______________________ Date: __________

Description: ______________________

Unrestricted Speed - *Column 3.3 (C)*

The unrestricted speed of the facility is generally the posted speed limit of the section operating in an unrestricted flow condition.

Work Zone Travel Time At Unrestricted Speed - *Column 3.3 (D)*

This is the time necessary to travel the work zone length at the unrestricted speed and is computed by dividing Column 3.3 (A) by Column 3.3 (C).

Work Zone Travel Time At Work Zone Speed - *Column 3.3 (E)*

This is the time necessary to travel the work zone length at the work zone speed and is computed by dividing Column 3.3 (A) by Column 3.3 (B).

Added Time To Travel Work Zone - *Column 3.3 (F)*

The added time to travel the work zone is computed by subtracting Column 3.3 (D) from Column 3.3 (E).

Travel Length Without Detour - *Column 3.3 (G)*

This is the existing travel length prior to any lane restrictions or road closures.

Travel Length With Detour - *Column 3.3 (H)*

This is the length of the proposed detour or alternate route.

Added Travel Length - *Column 3.3 (I)*

The added travel length is computed by subtracting Column 3.3 (G) from Column 3.3 (H).

Travel Time Without Detour - *Column 3.3 (J)*

This is the time necessary to travel the existing facility prior to the proposed detour.

Travel Time With Detour - *Column 3.3 (K)*

This is the time necessary to travel the detour route.

Added Time To Travel Detour - *Column 3.3 (L)*

The added time to travel the detour is computed by subtracting Column 3.3 (J) from Column 3.3 (K).

Alternating Traffic (Flagging) Delay can be determined by utilizing Worksheet 3.3. The delay is determined by subtracting the time it takes to travel the flagging zone when it is present, from the time it takes to travel the same distance when it is not. Flagging work zones are generally up to a 1/3 mile in length and limited to a travel speed of 25 mph.

An additional component necessary to determine the road user cost associated with an Alternating Traffic (Flagging) work zone is the amount of time the approach vehicles are delayed while the opposing approach vehicles are traveling the flagging zone. The approach vehicle wait time should be based on the number of arriving vehicles during a given period and should not exceed five minutes per vehicle.

3.6 CIRCUITY (DETOUR) VOC

The circuity VOC is only computed when a formal detour route has been established. At this point, an overall added travel length per vehicle has been determined. The circuity VOC is computed by multiplying the number of vehicles that travel the detour, the overall added travel length per vehicle, and the current VOC cost rate associated with driving the added distance. The current VOC cost rate is computed in Section 3.7.

3.7 ESCALATION FACTORS & COST RATES

The National Cooperative Highway Research Program (NCHRP) Report 133, Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects, provides 1970 travel time values of $3.00/hour for cars and $5.00/hour for trucks. The 1970 Idling Costs are provided in Table 5 of the same report and the average 1970 VOC values are derived from Figures A-13, A-14, and A-15 of the same report. The 1970 values are generally accepted to provide reliable costs although changes may have occurred regarding trip purpose and driving habits.

- *To escalate the values shown in NCHRP Report 133 to reflect current year dollars, it is recommended to use the unadjusted **Consumer Price Index for All Urban Consumers (CPI-U): U.S. City Average, by expenditure category and commodity and service group.***

The CPI-U is an accepted escalation tool and the values are available in Almanacs or at the Bureau of Labor Statistics web site (http://stats.bls.gov/news.release/cpi.t01.htm). Also, in the event that research studies update or supercede the NCHRP Report 133 values, the use of the CPI-U for escalation purposes remains applicable. Worksheet 3.4 has been developed to aid the analyst in computing the appropriate escalation factors and current cost rates and is discussed below.

Cost Factors - *Column 3.4 (A)*

The Idling and VOC cost factors are based on the "Transportation Component" of the CPI-U. The Time Value cost factor is based on the "All Items Component" of the CPI-U.

1970 (CPI-U) - *Column 3.4 (B)*

The "Transportation Component" of the CPI-U was 37.5 in 1970. The "All Items Component" of the CPI-U was 38.8 in 1970.

Current (CPI-U) - *Column 3.4 (C)*

The "Transportation Component" and "All Items Component" of the CPI-U should be determined for the current or desired year.

Escalation Factor - *Column 3.4 (D)*

The escalation factor for each cost factor is computed by dividing the Current CPI-U in Column 3.4 (C) by the 1970 CPI-U in Column 3.4 (B).

Vehicle Class - *Column 3.4 (E)*

Section 1.7 of this manual stated that 13 different vehicle classifications exist. "Car" and "Truck" classifications are only considered in the road user cost computations.

1970 Time Value Cost Rate - *Column 3.4 (F)*

NCHRP Report 133 reflects 1970 travel time value cost rates as $3.00/hour for cars and $5.00/hour for all trucks.

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	1970 (CPI-U)	Current (CPI-U)*	Escalation Factor
IDLING and VOC (transportation component)	37.5		
TIME VALUE (all components)	38.8		

* CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	1970 Time Value Cost Rate ($/veh-hr)	1970 Idling Cost Rate ($/veh-hr)	1970 VOC Cost Rate ($/mile)	Current Time Value Cost Rate ($/veh-hr)	Current Idling Cost Rate ($/veh-hr)	Current VOC Cost Rate ($/mile)
CAR	3.00	0.1819	0.06			
TRUCK	5.00	0.2092	0.12			

Project: ______________________ Date: ______________

Description: ______________________

1970 Idling Cost Rate - ***Column 3.4 (G)***

NCHRP Report 133 reflects 1970 Idling cost rates as $0.1819/veh-hr for cars, $0.2017/veh-hr for single unit trucks, and $0.2166/veh-hr for combination trucks. The cost rate for single unit trucks and combination trucks has been averaged to reflect $0.2092/veh-hr for all trucks.

1970 VOC Cost Rate - ***Column 3.4 (H)***

NCHRP Report 133 reflects average 1970 VOC cost rates as $0.06/mile for cars, $0.09/mile for single unit trucks, and $0.14/mile for combination trucks. The cost rate for single unit trucks and combination trucks has been averaged to reflect $0.12/mile for all trucks.

Current Time Value Cost Rate - ***Column 3.4 (I)***

The current time value cost rate for each vehicle class is computed by multiplying the 1970 time value cost rate in Column 3.4 (F) by the Time Value escalation factor in Column 3.4 (D).

Current Idling Cost Rate - ***Column 3.4 (J)***

The current idling cost rate for each vehicle class is computed by multiplying the 1970 idling cost rate in Column 3.4 (G) by the Idling escalation factor in Column 3.4 (D).

Current VOC Cost Rate - ***Column 3.4 (K)***

The current VOC cost rate for each vehicle class is computed by multiplying the 1970 VOC cost rate in Column 3.4 (H) by the VOC escalation factor in Column 3.4 (D).

- *For simplification of calculations, the Department will calculate the* ***Current Time Value Cost Rate,*** *the* ***Current Idling Cost Rate****, and the* ***Current VOC Cost Rate*** *on a yearly basis and provide them to interested users.*

Table 5 from NCHRP Report 133 is also designed to determine speed change costs. Speed change costs are the added costs (VOC and Delay) of slowing/stopping from one speed to another and returning to the original speed. Speed change costs are calculated by subtracting the cost and time factors of slowing/stopping at one speed from the cost and time factors of slowing/stopping at another speed. The road user cost components associated with slowing/stopping are discussed in Section 2 and will not be computed in this manual.

3.8 ROAD USER COSTS

At this point, all the necessary data to compute road user costs has been compiled. It is now necessary to distribute the traffic impacted by the various road user cost components to the appropriate vehicle classes. Worksheet 3.5 has been developed to aid the analyst in computing the road user costs and is discussed below.

Road User Cost Component - *Column 3.5 (A)*

There are ten potential work zone related road user cost components that can occur. The five components shown are generally computed fairly accurately and account for the majority of the road user costs.

Vehicle Class - *Column 3.5 (B)*

"Car" and "Truck" vehicle classifications are only considered for each road user cost component.

Percent Class - *Column 3.5 (C)*

The percent of each vehicle class in the traffic stream should be part of the data obtained from the traffic monitoring section. The percent class is entered at the bottom left corner of the worksheet and for each appropriate road user cost component.

Total Vehicles - *Column 3.5 (D)*

The number of total vehicles that travel the queue, work zone or detour over a 24 hour period are obtained from Worksheet 3.1. The total vehicles are entered at the bottom left corner of the worksheet and for each appropriate road user cost component.

Added Travel Length - *Column 3.5 (E)*

The appropriate value for added travel length is obtained from Worksheet 3.3.

Added Time - *Column 3.5 (F)*

The appropriate values for added time are obtained from Worksheets 3.2 & 3.3.

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	**Vehicle Class**	**Percent Class (%)**	**Total Vehicles (#)**	**Added Travel Length (mile/veh)**	**Added Time (hr/veh)**	**Cost Rate ($/veh-hr, $/mile)**	**Road User Cost ($)**
Queue Delay (Added Time)	CAR						
	TRUCK						
Queue Idling VOC (Added Cost)	CAR						
	TRUCK						
Work Zone Delay (Added Time)	CAR						
	TRUCK						
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue: ____________

Total Vehicles that Travel Work Zone: ____________

Total Vehicles that Travel Detour: ____________

Percent Passenger Cars: ____________

Percent Trucks: ____________

Daily Road User Cost	
Calculated Road User Cost (CRUC)	
Number of Work Zone Days	
Total Road User Cost	

Project: ____ **Date:** ____________

Description: ____

Cost Rate - ***Column 3.5 (G)***

The appropriate cost rates for time, idling, and VOC are obtained from Worksheet 3.4.

Road User Cost - Column 3.5 ***(H)***

The road user cost associated with each component is obtained by multiplying the values across each row for each vehicle class and rounding to the nearest dollar.

Daily Road User Cost

The daily road user cost is computed by totaling the road user costs for each component.

Calculated Road User Cost (CRUC)

The calculated road user cost is computed by multiplying the daily road user cost by a 50% reduction factor. The reduction factor is used to accommodate for variations in traffic data, roadway capacities, and cost rates.

Number of Work Zone Days

The number of work zone days is the anticipated number of days that the work zone or detour will be in effect.

Total Road User Cost

The total road user cost is computed by multiplying the calculated road user cost by the number of work zone days.

SECTION 4

Road User Cost Applications

4.1 GENERAL

The calculation of road user costs provides information enabling the designer to make better informed decisions in regards to staging, allowable work hours, project delivery method, and the actual design itself. Therefore, before a scheme is finalized, traffic volumes should be evaluated on a 7 day 24 hour basis. Staging should be evaluated for potential queues. Often, queues can be avoided by simply allowing lane closures only during non-peak hours. If the proposed design reveals substantial road user costs, an alternative scheme that reduces these costs may be a better choice. At other times, the queues are not avoidable, and thus an alternative project delivery method (i.e., A+B Bidding, Incentive/Disincentive) should be considered. In all cases, the significant risks and costs associated with night operations including safety, quality, and productivity should be considered. The many applications of road user costs in projects will be discussed in the following sections.

4.2 LIQUIDATED DAMAGES

A failure to complete a project or portion of a project on time results in damages in terms of delay on the use of the Project and delay to the traveling public using the facility. A failure to complete on time also results in additional costs to the Department for engineering, inspection, and administration of the Contract.

A "liquidated damage" is a liquidated sum or specified amount of damages in the event of a noncompliance with the specifications where it is difficult or impossible to accurately estimate the damages incurred. The liquidated damages a contractor may pay include the Construction Engineering Charge, the Road User Charge, and the Lane Occupancy Charge. The purpose of these charges is intended to constitute a reasonable liquidated sum designed to compensate for the damages incurred by the traveling public and the Department. The charges are not imposed for the purpose of ensuring timely compliance with the lane closure time limits or project completion requirements in the contract documents. The charges collected are in turn intended to be used in conjunction with future capital transportation projects so as to help relieve traffic congestion and to improve travel time and convenience for the traveling public. Each component of the liquidated damages is discussed in the following sections.

4.3 CONSTRUCTION ENGINEERING CHARGE

Construction engineering costs are the costs incurred by the Department for engineering, inspection, and administration of a project. Prior to the Substantial Completion Date, the Department does not require the contractor to pay these costs. For each day of overrun in the Substantial Completion Date, the contractor will pay a Construction Engineering Charge in accordance with Subsection 108.16 of the Specifications. For each day of overrun in the Completion Date, the contractor will pay a Construction Engineering Charge equal to one-half of the value used for Substantial Completion.

4.4 ROAD USER CHARGE

Road user costs are added vehicle operating costs (VOC) and delay costs to the traveling public resulting from the establishment of construction, maintenance, or rehabilitation work zones. The procedures in this manual provide a reasonable estimate of the added VOC and delay in terms of dollars per day. If a highway facility is nearing or exceeding capacity prior to construction, only the road user costs associated with the proposed construction activity are considered. Prior to the Substantial Completion Date, the Department does not require the contractor to pay the road user costs incurred by the traveling public. For each day of overrun in the Substantial Completion Date, the contractor will pay a Road User Charge in accordance with Subsection 108.16 of the Specifications, if applicable. The Road User Charge is in addition to the Construction Engineering Charge.

- *The road user costs incurred by the traveling public during a Project can be extremely high.* ***Therefore, the Department has determined that the Maximum Allowable Road User Charge (MARC) to be collected from the contractor for any one day will be $5,000.*** *If the Calculated Road User Costs (CRUC) are less than the MARC value, use the CRUC value rounded to the nearest hundred dollars.*

4.5 LANE OCCUPANCY CHARGE

The contract documents provide allowable lane closure time limits for the contractor's use and occupancy of a lane or lanes to perform work. During the allowable lane closure time limits, the Department does not require the contractor to pay lane occupancy charges.

In the event that the contractor fails to reopen a lane or lanes of traffic on time, the contractor will pay a Lane Occupancy Charge (per direction) for the period of time a lane is unavailable to the traveling public beyond the allowable lane closure time limits. A Lane Occupancy Charge will not be collected when a lane or lanes are closed by extraordinary circumstances as defined in Subsection 108.19 of the Specifications.

If the allowable lane closure time limits permit the contractor to close lanes more than once a day, several occupancy charges are possible. For example, if a contractor must maintain all lanes open for traffic from 6 AM to 9 AM and 4 PM to 7 PM, an occupancy charge may be collected for the overrun of time beyond 6 AM and the overrun of time beyond 4 PM. Each occupancy charge is calculated by multiplying the overrun of time, in minutes, by the chargeable rate per minute. The chargeable rate per minute is based on using the procedures in this manual to calculate the road user costs incurred by the traveling public during the <u>first hour</u> of each period the contractor fails to open a lane or lanes.

For the example above, the road user costs would be calculated for 6 AM to 7 AM and 4 PM to 5 PM and then divided by 60 to obtain the chargeable rate per minute (rounded to the nearest ten dollars). The Lane Occupancy Charge is calculated using 1/2 the chargeable rate for the first 15 minutes of overrun, and shall only be charged if the entire 15 minute period is used. For every subsequent minute after the first 15 minutes, the chargeable rate shall be used.

- ***The Department has determined that the maximum Lane Occupancy Charge to be collected from the contractor for any one day will be $5,000.***

4.6 INTERIM COMPLETION DATES

Contract documents may require a portion of work, stage of construction, or critical path item to be completed on or before a specified interim date or number of days. In these cases, only the applicable Road User Charge and Lane Occupancy Charge can be included as part of the Liquidated Damages for that interim requirement. These charges will be different than those calculated for the entire project completion, depending on what work is being specified for the interim date or time.

4.7 ALTERNATIVE PROJECT DELIVERY METHODS

A contract that establishes proper completion dates for a construction project is more important today than ever before. Most construction projects now involve the reconstruction of existing highways, which means that traffic is often maintained with lane and shoulder restrictions while the reconstruction takes place. A standard contract completion date should be based on the shortest practical duration of construction to minimize road user costs while allowing the contractor a reasonable amount of time to complete the work. When accelerated construction periods are desired to reduce high road user costs productivity and alternative project delivery methods should be considered.

Table 4.1 provides guidelines for the recommended Project Delivery Method for a particular project or stage of construction based on a comparison between the Calculated Road User Cost (CRUC) and the Maximum Allowable Road User Charge (MARC). The designer shall consider road user costs and any other pertinent factors to determine the most appropriate project delivery method. Each Project Delivery Method is discussed in the sections that follow.

Table 4.1
Project Delivery Method
Based on Production Rate and Road User Costs

Comparison Condition	Production Rate	Recommended Project Delivery Method	Road User Charge Value
CRUC≤MARC	1.00	Standard	CRUC
CRUC>MARC	1.00	Standard	MARC
CRUC>2 x MARC	1.20	Increased Production Rate	MARC
CRUC>3 x MARC	1.25	A + B Bidding	MARC
CRUC>4 x MARC	1.33	Incentive/Disincentive	I/D = 0.25 CRUC (*)

(*) Utilize the calculated I/D value, rounded to the nearest hundred dollars, up to a maximum I/D value of 0.1% of the estimated contract amount. The total accumulated I/D payment is generally limited to 5% of the estimated contract amount based on FHWA Technical Advisory T5080.10, dated February 8, 1989.

4.8 INCREASED PRODUCTION RATE

An Increased Production Rate project delivery method speeds up the construction process by utilizing multiple crews, longer workdays, night work, and/or an around-the-clock work schedule. A production rate of 1.20 times the standard production rate would be utilized to establish the contract completion date.

4.9 A+B BIDDING

An A+B Bidding project delivery method is a cost plus time bidding procedure which selects the low bidder based on a monetary combination of the contract bid items (A) and the time (B) needed to complete the project or a critical portion of the project. The award is based on the lowest combined bid using the following formula.

Bid Amount for Evaluation = A + (B x MARC). Where:

A = Bidder's Estimate of Contract Bid Items ($)
B = Bidder's Estimate of Construction Time (Days)
MARC = Maximum Allowable Road User Charge ($/day)

- *Consideration may be given to limiting the (B) value so that the (A) value accounts for at least 80% of the total bid amount for evaluation. However, a limited value reduces the opportunity for minimizing the construction schedule.*

For example, a project's CRUC value is $18,000/day and MARC value is $5,000/day. Since CRUC = 3.6 MARC, An A+B Bidding project delivery method is recommended with a pre-bid completion date based on a production rate of 1.25 times the standard production rate. The bid information received is as follows:

Bidder	ABC Company	DEF Company	GHI Company
(A) Value	$2,500,000	$2,600,000	$2,700,000
MARC VALUE	$5,000/day	$5,000/day	$5,000/day
(B) Value	140 Days	110 Days	95 Days
Time Value	$700,000	$550,000	$475,000
Combined Cost	**$3,200,000**	**$3,150,000**	**$3,175,000**

Therefore, the DEF Company would be awarded the contract based on it being the lowest combined bid. The contract amount for payment purpose is the (A) value ($2,600,000). The project completion date will be based on the (B) value (110 days).

4.10 INCENTIVE AND DISINCENTIVE (I/D)

An Incentive/Disincentive project delivery method is intended to motivate the contractor to complete the project, or a particular construction stage, on or ahead of an accelerated schedule. I/D projects compensate the contractor a daily amount for completing the work ahead of the I/D completion date or assess a daily amount for finishing later than the I/D completion date.

For example, a $10 million project's CRUC value is $25,000/day and MARC value is $5,000/day. Since CRUC > 4 MARC, as per Table 4.1, an Incentive/Disincentive project delivery method is recommended with an I/D value of $6,300/day [0.25 x CRUC value, rounded to the nearest hundred dollars, up to a maximum of 0.1% of the project cost ($10,000)]. The I/D production rate is 1.33 times the standard production rate. The project would be awarded to the low bidder. The contractor would receive a $6,300/day incentive bonus for each day he finishes prior to the contract completion date up to a maximum of 5% of the project cost ($500,000). Conversely, the contractor would be charged $6,300/day for each day of overrun in the contract completion date.

4.11 BENEFIT / COST RATIO

The Benefit/Cost (B/C) Ratio is a useful tool for the designer to measure the benefits of transportation improvements and increase the value of a project. They are also useful in comparing the value of two or more alternative projects. The B/C Ratios of approved, dormant, and rejected projects should be documented and maintained to aid the Department in prioritizing project needs. The user benefits are defined as the savings in vehicle operating costs and travel time that the facility users will enjoy.

For example, an intersection improvement project is being designed. Exclusive right turn lanes (RTL) are being considered for the northbound and westbound approaches. The calculated B/C ratio without exclusive right turn lanes is 2.5:1 and the overall intersection LOS is 'C'. The specific improvement information is shown below.

Northbound RTL	Exclusive Right Turn Lane	Westbound RTL
300	Projected Peak Hour Volume	150
E	Projected Peak Hour LOS (No Build)	C
C	Projected Peak Hour LOS (Build)	A
$3 Million	User Benefits	$1 Million
$1 Million	ROW and Construction Costs	$0.2 Million
3:1	**Benefit/Cost Ratio**	**5:1**

The results show that the B/C for each improvement exceeds the 2.5:1 ratio established from the original design. Therefore, adding either of these elements to the project would increase the B/C ratio for the project.

An additional example shows two separate projects having equal support to replace an existing signalized intersection with a grade-separated interchange. The specific information regarding the projects is shown below.

Main Street	Project	Central Boulevard
D	No Build Level of Service	E
C	Build Level of Service	C
50,000	Projected Average Daily Traffic	30,000
$25 Million	User Benefits	$18 Million
$10 Million	ROW and Construction Costs	$10 Million
2.5:1	**Benefit/Cost Ratio**	**1.8:1**

The results show that the Main Street Project has the highest B/C ratio and therefore should be chosen. Although the Main Street Project under no build conditions has a better Level of Service than the Central Boulevard Project (D Versus E), constructing the Main Street Project provides a better benefit/cost ratio to the public.

4.12 LANE RENTAL

Lane Rental is a form of innovative contracting which charges a contractor daily or hourly fees for occupying lanes or shoulders to perform work. The rental fee is based on road user costs and the daily costs incurred by the Department. Lane rental is applicable to projects where the contractor can adjust the traffic control plans to reduce lane closure duration, or to take lanes out of service during periods when traffic impacts are minimal.

- *In general, the Department uses allowable lane closure hours, A+B Bidding, or Incentive/Disincentive projects in lieu of **Lane Rental**.*

SECTION 5

Road User Cost Implementation

5.1 POLICY IMPLEMENTATION

The reliability of Road User Cost calculations is greatly dependent on good traffic data. Ideally, this information should include 24-hour traffic counts for a full 7-day period, the existing and 20 year projected traffic volumes, the percent of passenger cars and trucks in the traffic stream, and the directional hourly distribution of the facility. The traffic data at the anticipated beginning of construction should be supplied if the existing traffic data is more than two years old before the anticipated contract award date. The following units should be contacted to obtain the best available traffic information.

Transportation Data Development
Mobility Strategies
Intelligent Transportation Services
Major Access Permits
Scope Development

Other pertinent information required to perform Road User Cost calculations includes:

- Existing and affected number of lanes per direction of the facility.
- Length of work zone or detour in miles.
- Allowable lane closure schedule.
- Number of work zone days.
- Work zone and non-work zone posted speeds.
- Work zone and normal capacity of the facility.
- Construction costs of alternative schemes.
- Construction costs of specific project elements.

Designers should consider Road User Costs during the scoping and design process as key decision making opportunities occur concerning such items as the following:

- Calculating the benefit/cost ratio for a project or project element.
- Determining the preferred scheme.
- Determining the Allowable Lane Closure Schedule.
- Determining construction staging (the use of shoulders, moveable barrier, detour routes, diversionary roads, etc.).
- Calculating the Road User Charge and Lane Occupancy Charge.
- Determining the appropriate project delivery method.

5.2 SUMMARY

This manual provides guidelines and procedures to compute Road User Costs via a modeled approach that provides the analyst with consistent and quantifiable results. Road User Costs are directly related to the current and future traffic demand, facility capacity, and the timing, duration and frequency of work zone induced capacity restrictions.

As long as work zone capacity exceeds vehicle demand on the facility, road user costs are normally not a serious cost to the traveling public. Under such circumstances, the roadway operates under free flow conditions and road user costs are dominated by delay costs in traveling the work zone.

When vehicle demand on the facility exceeds work zone capacity, the facility operates under forced flow conditions and road user costs can be immense. Queuing costs can account for over 90% of road user costs with the majority of the cost being the delay time of crawling through long slow moving queues. Project improvements and work zones that reduce the users actual and perceived costs may be expected to induce traffic to stay on their originally intended or preferred route rather than utilizing other state or local routes. Alternatives available to reduce work zone related road user costs include; carefully selecting the preferred scheme and frequency of rehabilitation activities, restricting the allowable work hours to avoid queuing, adding capacity prior to the development of large traffic demands, accelerating contractor production rates to reduce the overall work zone duration, and utilizing alternative project delivery methods.

The road user costs incurred by the traveling public during project improvements can be extremely high. This manual provides a reasonable measurement of costs incurred by the traveling public to be paid in lieu of timely performance by the contractor in the form of Liquidated Damages.

The quantification of road user costs in both time and money provides the designer with a valuable decision making tool. The examples in this manual illustrate many practical and real life applications.

5.3 RESOURCE DOCUMENTS

1. National Cooperative Highway Research Program (NCHRP) Report 133:

   Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects (1972)

2. American Association of State Highway and Transportation Officials (AASHTO):

   A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (1977)

3. Transportation Research Board (TRB) & National Research Council (NRC) Special Report 209:

   Highway Capacity Manual, Third Edition (1994)

4. Federal Highway Administration (FHWA) Pavement Divisions Interim Technical Bulletin:

   Life Cycle Cost Analysis in Pavement Design (1998)

5. New Jersey Department of Transportation:

   Standard Specifications for Road and Bridge Construction (1996)
   Supplemental Specifications to the 1996 Standard Specifications (1998)
   Standard Input (SI98 DOT1)
   Other Department Documents

APPENDIX A

Example Problems

EXAMPLE PROBLEM 1

Road User Costs in the Work Zone
24 Hour Lane Reduction - Freeway

One eastbound lane of a six-lane facility is undergoing rehabilitation. The eastbound lanes carry 50,000 vehicles per day of which 90% are passenger cars and 10% are trucks. A 3.0 mile work zone will be in place 24 hours a day until construction is complete. It is estimated to take 75 days to complete construction. The unrestricted upstream approach speed is posted at 55 mph and the speed through the work zone is posted at 45 mph. The normal capacity of the roadway is estimated at 6,300 vehicles per hour while the work zone capacity is estimated at 3,000 vehicles per hour. Compute the total road user cost for the project.

ANSWER: **The Calculated Road User Cost is $25,813 per day. The Total Road User Cost is $1,935,938 for the Project.**

Worksheet 3.1: Analysis of the Work Zone

Work Zone: 24 Hour Lane Reduction
Percent Trucks: 10% **Percent Cars:** 90%
Directional ADT: 50,000 **Year:** 1999
Normal Capacity: 6,300
Work Zone/Detour Capacity: 3,000
Lanes Under Normal Operation: 3

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	Hourly Traffic (%)	Vehicle Demand (vph)	Lanes Open (#)	Roadway Capacity (vph)	Queue Rate (vph)	Queued Vehicles (vph)	Average Queued Vehicles (vph)	Vehicles that Travel Work Zone (vph)	Vehicles that Travel Detour (vph)	Vehicles that Travel Queue (vph)
12-1 AM	0.7	350	2	3,000	-2,650	0	0	350	0	0
1-2	0.5	250	2	3,000	-2,750	0	0	250	0	0
2-3	0.4	200	2	3,000	-2,800	0	0	200	0	0
3-4	0.6	300	2	3,000	-2,700	0	0	300	0	0
4-5	1.8	900	2	3,000	-2,100	0	0	900	0	0
5-6	4.4	2,200	2	3,000	-800	0	0	2,200	0	0
6-7	6.2	3,100	2	3,000	100	100	50	3,000	0	3,000
7-8	7.2	3,600	2	3,000	600	700	400	3,000	0	3,000
8-9	5.6	2,800	2	3,000	-200	500	600	3,000	0	3,000
9-10	5.0	2,500	2	3,000	-500	0	250	3,000	0	3,000
10-11	4.8	2,400	2	3,000	-600	0	0	2,400	0	0
11-12 PM	5.1	2,550	2	3,000	-450	0	0	2,550	0	0
12-1	5.3	2,650	2	3,000	-350	0	0	2,650	0	0
1-2	5.5	2,750	2	3,000	-250	0	0	2,750	0	0
2-3	5.6	2,800	2	3,000	-200	0	0	2,800	0	0
3-4	6.4	3,200	2	3,000	200	200	100	3,000	0	3,000
4-5	7.0	3,500	2	3,000	500	700	450	3,000	0	3,000
5-6	6.4	3,200	2	3,000	200	900	800	3,000	0	3,000
6-7	5.9	2,950	2	3,000	-50	850	875	3,000	0	3,000
7-8	4.9	2,450	2	3,000	-550	300	575	3,000	0	3,000
8-9	4.0	2,000	2	3,000	-1,000	0	150	2,300	0	900
9-10	3.0	1,500	2	3,000	-1,500	0	0	1,500	0	0
10-11	2.1	1,050	2	3,000	-1,950	0	0	1,050	0	0
11-12	1.6	800	2	3,000	-2,200	0	0	800	0	0
TOTALS	100.0	50,000						50,000	0	27,900

Project: EXAMPLE #1 **Date:** July 1999
Description: 24 Hour Lane Reduction

Worksheet 3.2: Queue Delay

	3.2(A)	3.2(B)	3.2(C)	3.2(D)	3.2(E)	3.2(F)	3.2(G)	3.2(H)
	Queue Period (hour)	Queue Volume (veh/hr)	Normal Capacity (veh/hr)	V/C Ratio	Average Queue Speed (mph)	Unrestricted Speed (mph)	Average Queued Vehicles per Queue Period (#)	Queue Lanes (#)
1	6AM - 10AM	3,000	6,300	0.48	10	55	325	3
2	3PM - 9PM	3,000	6,300	0.48	10	55	492	3
3								
4								
5								

	3.2(I)	3.2(J)	3.2(K)	3.2(L)	3.2(M)	3.2(N)	3.2(O)
	Average Vehicle Length (feet/veh)	Average Queue Length (mile)	Queue Travel Time at Unrestricted Speed (hr/veh)	Queue Travel Time at Queue Speed (hr/veh)	Added Time to Travel Queue (hr/veh)	Affected Vehicles per Queue Period (#)	Added Time per Queue Period (hour)
1	50.0	1.03	0.019	0.103	0.084	12,000	1008.000
2	50.0	1.55	0.028	0.155	0.127	15,900	2019.300
3							
4							
5							
				Totals		27,900	3027.300
				Added Time Weighted Average		0.109	**hr/veh**

Project: EXAMPLE #1 **Date:** July 1999

Description: 24 Hour Lane Reduction

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A)	3.3(B)	3.3(C)	3.3(D)	3.3(E)	3.3(F)
Work Zone Length (mile)	Work Zone Speed (mph)	Unrestricted Speed (mph)	Work Zone Travel Time at Unrestricted Speed (hr/veh)	Work Zone Travel Time at Work Zone Speed (hr/veh)	Added Time to Travel Work Zone (hr/veh)
3.0	45	55	0.055	0.067	0.012

Circuity (Detour) Delay

3.3(G)	3.3(H)	3.3(I)	3.3(J)	3.3(K)	3.3(L)
Travel Length without Detour (mile)	Travel Length with Detour (mile)	Added Travel Length (mile)	Travel Time without Detour (hr/veh)	Travel Time with Detour (hr/veh)	Added Time to Travel Detour (hr/veh)
0.0	0.0	0.0	0.000	0.000	0.000

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)
0.0	0	0	0.000	0.000	0.000	0.000

Project: EXAMPLE #1 **Date:** July 1999

Description: 24 Hour Lane Reduction

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	1970 (CPI-U)	Current (CPI-U)*	Escalation Factor
IDLING and VOC (transportation component)	37.5	140.6	3.75
TIME VALUE (all components)	38.8	165.0	4.25

* CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average, March 1999

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	1970 Time Value Cost Rate ($/veh-hr)	1970 Idling Cost Rate ($/veh-hr)	1970 VOC Cost Rate ($/mile)	Current Time Value Cost Rate ($/veh-hr)	Current Idling Cost Rate ($/veh-hr)	Current VOC Cost Rate ($/mile)
CAR	3.00	0.1819	0.06	12.75	0.6821	0.225
TRUCK	5.00	0.2092	0.12	21.25	0.7845	0.450

Project: EXAMPLE #1 **Date:** July 1999

Description: 24 Hour Lane Reduction

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	**Vehicle Class**	**Percent Class (%)**	**Total Vehicles (#)**	**Added Travel Length (mile/veh)**	**Added Time (hr/veh)**	**Cost Rate ($/veh-hr, $/mile)**	**Road User Cost ($)**
Queue Delay (Added Time)	CAR	90	27,900		0.109	12.75	34,897
	TRUCK	10	27,900		0.109	21.25	6,462
Queue Idling VOC (Added Cost)	CAR	90	27,900		0.109	0.6821	1,867
	TRUCK	10	27,900		0.109	0.7845	239
Work Zone Delay (Added Time)	CAR	90	50,000		0.012	12.75	6,885
	TRUCK	10	50,000		0.012	21.25	1,275
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue: 27,900

Total Vehicles that Travel Work Zone: 50,000

Total Vehicles that Travel Detour: 0

Percent Passenger Cars: 90%

Percent Trucks: 10%

Daily Road User Cost	51,625
Calculated Road User Cost (CRUC)	25,813
Number of Work Zone Days	75
Total Road User Cost	1,935,938

Project: EXAMPLE #1 **Date:** July 1999

Description: 24 Hour Lane Reduction

EXAMPLE PROBLEM 2

Road User Costs in the Work Zone
Off-Peak Hour Lane Reductions - Freeway

Using the information from Example 1, Compute the following:

A) The road user costs when the work zone remains in place and the allowable lane closure hours are changed to off-peak hours of 9 AM to 3 PM and 8 PM to 6 AM.

B) The Lane Occupancy Charge associated with a 1-hour overrun in the allowable hours in part A.

ANSWER:

Part A) **The Calculated Road User Cost is $4,080 per day.**
The Total Road User Cost is $306,000 for the project.
Note the large reduction in Road User Costs when work is not permitted during the peak hours:
CRUC = $4,080 versus $25,813 and the Total Road User Cost = $306,000 versus $1,935,938.

Part B) **The Calculated Road User Cost for 6 AM to 7 AM is $524 for the hour.**
The chargeable rate is $10 per minute
($524/60 = $8.73, then rounded to nearest ten dollars).
The Lane Occupancy Charge for the 1-hour overrun is $525
($10/2 x 15 minutes + $10 x 45 minutes).

The Calculated Road User Cost for 3 PM to 4 PM is $803 for the hour.
The chargeable rate is $10 per minute
($803/60 = $13.38, then rounded to nearest ten dollars).
The Lane Occupancy Charge for the 1-hour overrun is $525
($10/2 x 15 minutes + $10 x 45 minutes).

Worksheet 3.1: Analysis of the Work Zone

Work Zone: Off-Peak Hour Lane Reduction
Percent Trucks: 10% **Percent Cars:** 90%
Directional ADT: 50,000 **Year:** 1999

Normal Capacity: 6,300
Work Zone/Detour Capacity: 3,000
Lanes Under Normal Operation: 3

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	Hourly Traffic (%)	Vehicle Demand (vph)	Lanes Open (#)	Roadway Capacity (vph)	Queue Rate (vph)	Queued Vehicles (vph)	Average Queued Vehicles (vph)	Vehicles that Travel Work Zone (vph)	Vehicles that Travel Detour (vph)	Vehicles that Travel Queue (vph)
12-1 AM	0.7	350	2	3,000	-2,650	0	0	350	0	0
1-2	0.5	250	2	3,000	-2,750	0	0	250	0	0
2-3	0.4	200	2	3,000	-2,800	0	0	200	0	0
3-4	0.6	300	2	3,000	-2,700	0	0	300	0	0
4-5	1.8	900	2	3,000	-2,100	0	0	900	0	0
5-6	4.4	2,200	2	3,000	-800	0	0	2,200	0	0
6-7	6.2	3,100	3	6,300	-3,200	0	0	3,100	0	0
7-8	7.2	3,600	3	6,300	-2,700	0	0	3,600	0	0
8-9	5.6	2,800	3	6,300	-3,500	0	0	2,800	0	0
9-10	5.0	2,500	2	3,000	-500	0	0	2,500	0	0
10-11	4.8	2,400	2	3,000	-600	0	0	2,400	0	0
11-12 PM	5.1	2,550	2	3,000	-450	0	0	2,550	0	0
12-1	5.3	2,650	2	3,000	-350	0	0	2,650	0	0
1-2	5.5	2,750	2	3,000	-250	0	0	2,750	0	0
2-3	5.6	2,800	2	3,000	-200	0	0	2,800	0	0
3-4	6.4	3,200	3	6,300	-3,100	0	0	3,200	0	0
4-5	7.0	3,500	3	6,300	-2,800	0	0	3,500	0	0
5-6	6.4	3,200	3	6,300	-3,100	0	0	3,200	0	0
6-7	5.9	2,950	3	6,300	-3,350	0	0	2,950	0	0
7-8	4.9	2,450	3	6,300	-3,850	0	0	2,450	0	0
8-9	4.0	2,000	2	3,000	-1,000	0	0	2,000	0	0
9-10	3.0	1,500	2	3,000	-1,500	0	0	1,500	0	0
10-11	2.1	1,050	2	3,000	-1,950	0	0	1,050	0	0
11-12	1.6	800	2	3,000	-2,200	0	0	800	0	0
TOTALS	100.0	50,000						50,000	0	0

Project: EXAMPLE #2 **Date:** July 1999
Description: Off-Peak Hour Lane Reduction, Part A

Worksheet 3.1: Analysis of the Work Zone

Work Zone: One Hour Overrun in AM Lane Reduction
Percent Trucks: 10% **Percent Cars:** 90%
Directional ADT: 50,000 **Year:** 1999

Normal Capacity: 6,300
Work Zone/Detour Capacity: 3,000
Lanes Under Normal Operation: 3

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	Hourly Traffic (%)	Vehicle Demand (vph)	Lanes Open (#)	Roadway Capacity (vph)	Queue Rate (vph)	Queued Vehicles (vph)	Average Queued Vehicles (vph)	Vehicles that Travel Work Zone (vph)	Vehicles that Travel Detour (vph)	Vehicles that Travel Queue (vph)
12-1 AM										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7	6.2	3,100	2	3,000	100	100	50	3,000	0	3,000
7-8										
8-9										
9-10										
10-11										
11-12 PM										
12-1										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12										
TOTALS	6.2	3,100						3,000	0	3,000

Project: EXAMPLE #2 **Date:** July 1999
Description: Off-Peak Hour Lane Reduction, Part B (AM)

Worksheet 3.1: Analysis of the Work Zone

Work Zone: One Hour Overrun in PM Lane Reduction
Percent Trucks: 10% **Percent Cars:** 90%
Directional ADT: 50,000 **Year:** 1999
Normal Capacity: 6,300
Work Zone/Detour Capacity: 3,000
Lanes Under Normal Operation: 3

3.1(A) Time Period (hour)	3.1(B) Hourly Traffic (%)	3.1(C) Vehicle Demand (vph)	3.1(D) Lanes Open (#)	3.1(E) Roadway Capacity (vph)	3.1(F) Queue Rate (vph)	3.1(G) Queued Vehicles (vph)	3.1(H) Average Queued Vehicles (vph)	3.1(I) Vehicles that Travel Work Zone (vph)	3.1(J) Vehicles that Travel Detour (vph)	3.1(K) Vehicles that Travel Queue (vph)
12-1 AM										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12 PM										
12-1										
1-2										
2-3										
3-4	6.4	3,200	2	3,000	200	200	100	3,000	0	3,000
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12										
TOTALS	6.4	3,200						3,000	0	3,000

Project: EXAMPLE #2 **Date:** July 1999
Description: Off-Peak Lane Reduction, Part B (PM)

Worksheet 3.2: Queue Delay

	3.2(A) Queue Period (hour)	3.2(B) Queue Volume (veh/hr)	3.2(C) Normal Capacity (veh/hr)	3.2(D) V/C Ratio	3.2(E) Average Queue Speed (mph)	3.2(F) Unrestricted Speed (mph)	3.2(G) Average Queued Vehicles per Queue Period (#)	3.2(H) Queue Lanes (#)
1	0	0	0	0.00	0	0	0	0
2								
3								
4								
5								

	3.2(I) Average Vehicle Length (feet/veh)	3.2(J) Average Queue Length (mile)	3.2(K) Queue Travel Time at Unrestricted Speed (hr/veh)	3.2(L) Queue Travel Time at Queue Speed (hr/veh)	3.2(M) Added Time to Travel Queue (hr/veh)	3.2(N) Affected Vehicles per Queue Period (#)	3.2(O) Added Time per Queue Period (hour)
1	0.0	0.00	0.000	0.000	0.000	0	0.000
2							
3							
4							
5							
			Totals			0	0.000
			Added Time Weighted Average			0.000	hr/veh

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Hour Lane Reduction, Part A

Worksheet 3.2: Queue Delay

	3.2(A)	3.2(B)	3.2(C)	3.2(D)	3.2(E)	3.2(F)	3.2(G)	3.2(H)
	Queue Period (hour)	Queue Volume (veh/hr)	Normal Capacity (veh/hr)	V/C Ratio	Average Queue Speed (mph)	Unrestricted Speed (mph)	Average Queued Vehicles per Queue Period (#)	Queue Lanes (#)
1	6AM - 7AM	3,000	6,300	0.48	10	55	50	3
2								
3								
4								
5								

	3.2(I)	3.2(J)	3.2(K)	3.2(L)	3.2(M)	3.2(N)	3.2(O)
	Average Vehicle Length (feet/veh)	Average Queue Length (mile)	Queue Travel Time at Unrestricted Speed (hr/veh)	Queue Travel Time at Queue Speed (hr/veh)	Added Time to Travel Queue (hr/veh)	Affected Vehicles per Queue Period (#)	Added Time per Queue Period (hour)
1	50.0	0.16	0.003	0.016	0.013	3,000	39.000
2							
3							
4							
5							
					Totals	3,000	39.000
					Added Time Weighted Average	0.013	**hr/veh**

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Hour Lane Reduction, Part B (AM)

Worksheet 3.2: Queue Delay

	3.2(A) Queue Period (hour)	3.2(B) Queue Volume (veh/hr)	3.2(C) Normal Capacity (veh/hr)	3.2(D) V/C Ratio	3.2(E) Average Queue Speed (mph)	3.2(F) Unrestricted Speed (mph)	3.2(G) Average Queued Vehicles per Queue Period (#)	3.2(H) Queue Lanes (#)
1	3PM - 4PM	3,000	6,300	0.48	10	55	100	3
2								
3								
4								
5								

	3.2(I) Average Vehicle Length (feet/veh)	3.2(J) Average Queue Length (mile)	3.2(K) Queue Travel Time at Unrestricted Speed (hr/veh)	3.2(L) Queue Travel Time at Queue Speed (hr/veh)	3.2(M) Added Time to Travel Queue (hr/veh)	3.2(N) Affected Vehicles per Queue Period (#)	3.2(O) Added Time per Queue Period (hour)
1	50.0	0.32	0.006	0.032	0.026	3,000	78.000
2							
3							
4							
5							
				Totals		3,000	78.000
				Added Time Weighted Average		0.026	**hr/veh**

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Lane Reduction, Part B (PM)

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A) Work Zone Length (mile)	3.3(B) Work Zone Speed (mph)	3.3(C) Unrestricted Speed (mph)	3.3(D) Work Zone Travel Time at Unrestricted Speed (hr/veh)	3.3(E) Work Zone Travel Time at Work Zone Speed (hr/veh)	3.3(F) Added Time to Travel Work Zone (hr/veh)
3.0	45	55	0.055	0.067	0.012

Circuity (Detour) Delay

3.3(G) Travel Length without Detour (mile)	3.3(H) Travel Length with Detour (mile)	3.3(I) Added Travel Length (mile)	3.3(J) Travel Time without Detour (hr/veh)	3.3(K) Travel Time with Detour (hr/veh)	3.3(L) Added Time to Travel Detour (hr/veh)
0.0	0.0	0.0	0.000	0.000	0.000

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)
0.0	0	0	0.000	0.000	0.000	0.000

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Hour Lane Reduction, Part A and Part B

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	1970 (CPI-U)	Current (CPI-U)*	Escalation Factor
IDLING and VOC (transportation component)	37.5	140.6	3.75
TIME VALUE (all components)	38.8	165.0	4.25

* CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average, March 1999

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	1970 Time Value Cost Rate ($/veh-hr)	1970 Idling Cost Rate ($/veh-hr)	1970 VOC Cost Rate ($/mile)	Current Time Value Cost Rate ($/veh-hr)	Current Idling Cost Rate ($/veh-hr)	Current VOC Cost Rate ($/mile)
CAR	3.00	0.1819	0.06	12.75	0.6821	0.225
TRUCK	5.00	0.2092	0.12	21.25	0.7845	0.450

Project: EXAMPLE #2 **Date:** July 1999
Description: Off-Peak Hour Lane Reduction, Part A and Part B

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	**Vehicle Class**	**Percent Class (%)**	**Total Vehicles (#)**	**Added Travel Length (mile/veh)**	**Added Time (hr/veh)**	**Cost Rate ($/veh-hr, $/mile)**	**Road User Cost ($)**
Queue Delay (Added Time)	CAR						
	TRUCK						
Queue Idling VOC (Added Cost)	CAR						
	TRUCK						
Work Zone Delay (Added Time)	CAR	90	50,000		0.012	12.75	6,885
	TRUCK	10	50,000		0.012	21.25	1,275
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue: 0

Total Vehicles that Travel Work Zone: 50,000

Total Vehicles that Travel Detour: 0

Percent Passenger Cars: 90%

Percent Trucks: 10%

Daily Road User Cost	8,160
Calculated Road User Cost (CRUC)	4,080
Number of Work Zone Days	75
Total Road User Cost	306,000

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Hour Lane Reduction, Part A

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	Vehicle Class	Percent Class (%)	Total Vehicles (#)	Added Travel Length (mile/veh)	Added Time (hr/veh)	Cost Rate ($/veh-hr, $/mile)	Road User Cost ($)
Queue Delay (Added Time)	CAR	90	3,000		0.013	12.75	448
	TRUCK	10	3,000		0.013	21.25	83
Queue Idling VOC (Added Cost)	CAR	90	3,000		0.013	0.6821	24
	TRUCK	10	3,000		0.013	0.7845	3
Work Zone Delay (Added Time)	CAR	90	3,000		0.012	12.75	413
	TRUCK	10	3,000		0.012	21.25	77
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue:	3,000
Total Vehicles that Travel Work Zone:	3,000
Total Vehicles that Travel Detour:	0
Percent Passenger Cars:	90%
Percent Trucks:	10%

Daily Road User Cost	1,048
Calculated Road User Cost (CRUC)	524
Number of Work Zone Days	1
Total Road User Cost	524

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Hour Lane Reduction, Part B (AM)

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	Vehicle Class	Percent Class (%)	Total Vehicles (#)	Added Travel Length (mile/veh)	Added Time (hr/veh)	Cost Rate ($/veh-hr, $/mile)	Road User Cost ($)
Queue Delay (Added Time)	CAR	90	3,000		0.026	12.75	895
	TRUCK	10	3,000		0.026	21.25	166
Queue Idling VOC (Added Cost)	CAR	90	3,000		0.026	0.6821	48
	TRUCK	10	3,000		0.026	0.7845	6
Work Zone Delay (Added Time)	CAR	90	3,000		0.012	12.75	413
	TRUCK	10	3,000		0.012	21.25	77
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue: 3,000

Total Vehicles that Travel Work Zone: 3,000

Total Vehicles that Travel Detour: 0

Percent Passenger Cars: 90%

Percent Trucks: 10%

Daily Road User Cost	1,605
Calculated Road User Cost (CRUC)	803
Number of Work Zone Days	1
Total Road User Cost	803

Project: EXAMPLE #2 **Date:** July 1999

Description: Off-Peak Lane Reduction, Part B (PM)

EXAMPLE PROBLEM 3

Road User Costs in the Work Zone
Road Closure - Detour in Effect

A one-mile section of a two-lane coastal facility will be closed during a $15 million bridge replacement project. The facility carries 22,000 vehicles per day of which 80% are passenger cars and 20% are trucks. A 9.0 mile detour will be in effect until construction is completed. It is estimated to take 100 days to complete construction. The existing facility is posted at 50 mph and the average speed through the detour route is 35 mph. The normal capacity of the existing facility is 2,400 vehicles per hour and the detour capacity is estimated at 1,900 vehicles per hour. Compute the following:

A) The road user costs incurred by the traffic traveling the detour for the project.

B) The recommended Project Delivery Method based on the results of Part A.

ANSWER:

Part A) The Calculated Road User Cost $61,432 per day.
The Total Road User Cost is $6,143,150 for the project.

Part B) The Calculated Road User Cost (CRUC = $61,432/day) is greater than 4 times the Maximum Allowable Road User Cost (MARC = $5,000/day). Therefore, based on Table 4.1 of this manual, an Incentive/ Disincentive project delivery method is recommended. The daily I/D rate (0.25 x CRUC value) equals $15,400 when rounded to the nearest hundred dollars. The maximum allowable daily I/D value is calculated as 0.1 times the $15 million project cost, or $15,000. Therefore, an I/D value of $15,000/day should be used with a total accumulated maximum I/D payment of 5% of the project cost, or $750,000.

Worksheet 3.1: Analysis of the Work Zone

Work Zone: 9 Mile Detour
Percent Trucks: 20% **Percent Cars:** 80%
Directional ADT: 22,000 (2-way) **Year:** 1999

Normal Capacity: 2,400
Work Zone/Detour Capacity: 1,900
Lanes Under Normal Operation: 2

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	**Hourly Traffic (%)**	**Vehicle Demand (vph)**	**Lanes Open (#)**	**Roadway Capacity (vph)**	**Queue Rate (vph)**	**Queued Vehicles (vph)**	**Average Queued Vehicles (vph)**	**Vehicles that Travel Work Zone (vph)**	**Vehicles that Travel Detour (vph)**	**Vehicles that Travel Queue (vph)**
12-1 AM	0.7	154	0	1,900	-1,746	0	0	0	154	0
1-2	0.6	132	0	1,900	-1,768	0	0	0	132	0
2-3	0.4	88	0	1,900	-1,812	0	0	0	88	0
3-4	0.4	88	0	1,900	-1,812	0	0	0	88	0
4-5	0.6	132	0	1,900	-1,768	0	0	0	132	0
5-6	1.6	352	0	1,900	-1,548	0	0	0	352	0
6-7	4.4	968	0	1,900	-932	0	0	0	968	0
7-8	6.0	1,320	0	1,900	-580	0	0	0	1,320	0
8-9	5.3	1,166	0	1,900	-734	0	0	0	1,166	0
9-10	5.1	1,122	0	1,900	-778	0	0	0	1,122	0
10-11	5.2	1,144	0	1,900	-756	0	0	0	1,144	0
11-12 PM	5.7	1,254	0	1,900	-646	0	0	0	1,254	0
12-1	6.3	1,386	0	1,900	-514	0	0	0	1,386	0
1-2	6.5	1,430	0	1,900	-470	0	0	0	1,430	0
2-3	6.4	1,408	0	1,900	-492	0	0	0	1,408	0
3-4	6.2	1,364	0	1,900	-536	0	0	0	1,364	0
4-5	6.2	1,364	0	1,900	-536	0	0	0	1,364	0
5-6	6.3	1,386	0	1,900	-514	0	0	0	1,386	0
6-7	6.5	1,430	0	1,900	-470	0	0	0	1,430	0
7-8	6.0	1,320	0	1,900	-580	0	0	0	1,320	0
8-9	4.6	1,012	0	1,900	-888	0	0	0	1,012	0
9-10	3.8	836	0	1,900	-1,064	0	0	0	836	0
10-11	2.9	638	0	1,900	-1,262	0	0	0	638	0
11-12	2.3	506	0	1,900	-1,394	0	0	0	506	0
TOTALS	100.0	22,000						0	22,000	0

Project: EXAMPLE #3 **Date:** July 1999
Description: 9 Mile Detour in Effect

Worksheet 3.2: Queue Delay

	3.2(A) Queue Period (hour)	3.2(B) Queue Volume (veh/hr)	3.2(C) Normal Capacity (veh/hr)	3.2(D) V/C Ratio	3.2(E) Average Queue Speed (mph)	3.2(F) Unrestricted Speed (mph)	3.2(G) Average Queued Vehicles per Queue Period (#)	3.2(H) Queue Lanes (#)
1	0	0	0	0.00	0	0	0	0
2								
3								
4								
5								

	3.2(I) Average Vehicle Length (feet/veh)	3.2(J) Average Queue Length (mile)	3.2(K) Queue Travel Time at Unrestricted Speed (hr/veh)	3.2(L) Queue Travel Time at Queue Speed (hr/veh)	3.2(M) Added Time to Travel Queue (hr/veh)	3.2(N) Affected Vehicles per Queue Period (#)	3.2(O) Added Time per Queue Period (hour)
1	0.0	0.00	0.000	0.000	0.000	0	0.000
2							
3							
4							
5							
			Totals			0	0.000
			Added Time Weighted Average			0.000	**hr/veh**

Project: EXAMPLE #3 **Date:** July 1999

Description: 9 Mile Detour in Effect

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A)	3.3(B)	3.3(C)	3.3(D)	3.3(E)	3.3(F)
Work Zone Length (mile)	Work Zone Speed (mph)	Unrestricted Speed (mph)	Work Zone Travel Time at Unrestricted Speed (hr/veh)	Work Zone Travel Time at Work Zone Speed (hr/veh)	Added Time to Travel Work Zone (hr/veh)
0.0	0	0	0.000	0.000	0.000

Circuity (Detour) Delay

3.3(G)	3.3(H)	3.3(I)	3.3(J)	3.3(K)	3.3(L)
Travel Length without Detour (mile)	Travel Length with Detour (mile)	Added Travel Length (mile)	Travel Time without Detour (hr/veh)	Travel Time with Detour (hr/veh)	Added Time to Travel Detour (hr/veh)
1.0	9.0	8.0	0.020	0.257	0.237

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)
0.0	0	0	0.000	0.000	0.000	0.000

Project: EXAMPLE #3 **Date:** July 1999

Description: 9 Mile Detour in Effect

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	1970 (CPI-U)	Current (CPI-U)*	Escalation Factor
IDLING and VOC (transportation component)	**37.5**	140.6	3.75
TIME VALUE (all components)	**38.8**	165.0	4.25

*** CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average, March 1999**

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	1970 Time Value Cost Rate ($/veh-hr)	1970 Idling Cost Rate ($/veh-hr)	1970 VOC Cost Rate ($/mile)	Current Time Value Cost Rate ($/veh-hr)	Current Idling Cost Rate ($/veh-hr)	Current VOC Cost Rate ($/mile)
CAR	**3.00**	**0.1819**	**0.06**	12.75	0.6821	0.225
TRUCK	**5.00**	**0.2092**	**0.12**	21.25	0.7845	0.450

Project: EXAMPLE #3 **Date:** July 1999

Description: 9 Mile Detour in Effect

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	Vehicle Class	Percent Class (%)	Total Vehicles (#)	Added Travel Length (mile/veh)	Added Time (hr/veh)	Cost Rate ($/veh-hr, $/mile)	Road User Cost ($)
Queue Delay (Added Time)	CAR						
	TRUCK						
Queue Idling VOC (Added Cost)	CAR						
	TRUCK						
Work Zone Delay (Added Time)	CAR						
	TRUCK						
Circuity Delay (Added Time)	CAR	80	22,000		0.237	12.75	53,183
	TRUCK	20	22,000		0.237	21.25	22,160
Circuity VOC (Added Cost)	CAR	80	22,000	8.0		0.225	31,680
	TRUCK	20	22,000	8.0		0.450	15,840

Daily Road User Cost	122,863
Calculated Road User Cost (CRUC)	61,432
Number of Work Zone Days	100
Total Road User Cost	6,143,150

Total Vehicles that Travel Queue: 0

Total Vehicles that Travel Work Zone: 0

Total Vehicles that Travel Detour: 22,000

Percent Passenger Cars: 80%

Percent Trucks: 20%

Project: EXAMPLE #3 **Date:** July 1999

Description: 9 Mile Detour in Effect

EXAMPLE PROBLEM 4

Road User Costs in the Work Zone
Alternating Traffic Pattern - Two-Lane Highway

A two-lane facility in a central business district is undergoing resurfacing. The facility carries 26,000 vehicles per day of which 90% are passenger cars and 10% are trucks. A 0.5 mile alternating traffic pattern with flagmen will be in place 10 PM to 6 AM until the resurfacing is completed. It is estimated to take 10 days to complete the resurfacing. The facility is posted at 30 mph and the speed through the flagging zone is limited to 15 mph. Traffic Engineering estimates an average wait time of 3 minutes (0.050 hr) per vehicle while the opposing traffic is moving. The normal capacity of the two-lane facility is estimated at 2,200 vehicles per hour while the work zone capacity is estimated at 700 vehicles per hour. Compute the total road user cost for the project.

ANSWER: **The Calculated Road User Cost is $922 per day.**
The Total Road User Cost is $9,220 for the project.

Worksheet 3.1: Analysis of the Work Zone

Work Zone: Alternating Traffic Pattern
Percent Trucks: 10% **Percent Cars:** 90%
Directional ADT: 26,000 **Year:** 1999

Normal Capacity: 2,200
Work Zone/Detour Capacity: 700
Lanes Under Normal Operation: 2

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	**Hourly Traffic (%)**	**Vehicle Demand (vph)**	**Lanes Open (#)**	**Roadway Capacity (vph)**	**Queue Rate (vph)**	**Queued Vehicles (vph)**	**Average Queued Vehicles (vph)**	**Vehicles that Travel Work Zone (vph)**	**Vehicles that Travel Detour (vph)**	**Vehicles that Travel Queue (vph)**
12-1 AM	0.8	208	1	700	-492	0	0	208	0	208
1-2	0.4	104	1	700	-596	0	0	104	0	104
2-3	0.3	78	1	700	-622	0	0	78	0	78
3-4	0.3	78	1	700	-622	0	0	78	0	78
4-5	0.4	104	1	700	-596	0	0	104	0	104
5-6	1.3	338	1	700	-362	0	0	338	0	338
6-7	4.0	1,040	2	2,200	-1,160	0	0	0	0	0
7-8	6.4	1,664	2	2,200	-536	0	0	0	0	0
8-9	5.7	1,482	2	2,200	-718	0	0	0	0	0
9-10	4.8	1,248	2	2,200	-952	0	0	0	0	0
10-11	4.9	1,274	2	2,200	-926	0	0	0	0	0
11-12 PM	5.6	1,456	2	2,200	-744	0	0	0	0	0
12-1	6.0	1,560	2	2,200	-640	0	0	0	0	0
1-2	5.9	1,534	2	2,200	-666	0	0	0	0	0
2-3	6.3	1,638	2	2,200	-562	0	0	0	0	0
3-4	7.6	1,976	2	2,200	-224	0	0	0	0	0
4-5	8.3	2,158	2	2,200	-42	0	0	0	0	0
5-6	8.0	2,080	2	2,200	-120	0	0	0	0	0
6-7	6.2	1,612	2	2,200	-588	0	0	0	0	0
7-8	5.1	1,326	2	2,200	-874	0	0	0	0	0
8-9	4.3	1,118	2	2,200	-1,082	0	0	0	0	0
9-10	3.4	884	2	2,200	-1,316	0	0	0	0	0
10-11	2.4	624	1	700	-76	0	0	624	0	624
11-12	1.6	416	1	700	-284	0	0	416	0	416
TOTALS	100.0	26,000						1,950	0	1,950

Project: Example #4 **Date:** July 1999
Description: Alternating Traffic Pattern

Worksheet 3.2: Queue Delay

	3.2(A)	3.2(B)	3.2(C)	3.2(D)	3.2(E)	3.2(F)	3.2(G)	3.2(H)
	Queue Period (hour)	Queue Volume (veh/hr)	Normal Capacity (veh/hr)	V/C Ratio	Average Queue Speed (mph)	Unrestricted Speed (mph)	Average Queued Vehicles per Queue Period (#)	Queue Lanes (#)
1	0	0	0	0.00	0	0	0	0
2								
3								
4								
5								

	3.2(I)	3.2(J)	3.2(K)	3.2(L)	3.2(M)	3.2(N)	3.2(O)
	Average Vehicle Length (feet/veh)	Average Queue Length (mile)	Queue Travel Time at Unrestricted Speed (hr/veh)	Queue Travel Time at Queue Speed (hr/veh)	Added Time to Travel Queue (hr/veh)	Affected Vehicles per Queue Period (#)	Added Time per Queue Period (hour)
1	0.0	0.00	0.000	0.000	0.000	0	0.000
2							
3							
4							
5							
			Totals			0	0.000
			Added Time Weighted Average			0.000	**hr/veh**

Project: Example #4 **Date:** July 1999

Description: Alternating Traffic Pattern

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A)	3.3(B)	3.3(C)	3.3(D)	3.3(E)	3.3(F)
Work Zone Length (mile)	Work Zone Speed (mph)	Unrestricted Speed (mph)	Work Zone Travel Time at Unrestricted Speed (hr/veh)	Work Zone Travel Time at Work Zone Speed (hr/veh)	Added Time to Travel Work Zone (hr/veh)
0.0	0	0	0.000	0.000	0.000

Circuity (Detour) Delay

3.3(G)	3.3(H)	3.3(I)	3.3(J)	3.3(K)	3.3(L)
Travel Length without Detour (mile)	Travel Length with Detour (mile)	Added Travel Length (mile)	Travel Time without Detour (hr/veh)	Travel Time with Detour (hr/veh)	Added Time to Travel Detour (hr/veh)
0.0	0.0	0.0	0.000	0.000	0.000

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)
0.5	15	30	0.016	0.033	0.017	0.050

Project: Example #4 **Date:** July 1999

Description: Alternating Traffic Pattern

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	**1970 (CPI-U)**	**Current (CPI-U)***	**Escalation Factor**
IDLING and VOC (transportation component)	**37.5**	140.6	3.75
TIME VALUE (all components)	**38.8**	165.0	4.25

*** CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average, March 1999**

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	**1970 Time Value Cost Rate ($/veh-hr)**	**1970 Idling Cost Rate ($/veh-hr)**	**1970 VOC Cost Rate ($/mile)**	**Current Time Value Cost Rate ($/veh-hr)**	**Current Idling Cost Rate ($/veh-hr)**	**Current VOC Cost Rate ($/mile)**
CAR	**3.00**	**0.1819**	**0.06**	12.75	0.6821	0.225
TRUCK	**5.00**	**0.2092**	**0.12**	21.25	0.7845	0.450

Project: Example #4 **Date:** July 1999

Description: Alternating Traffic Pattern

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	**Vehicle Class**	**Percent Class (%)**	**Total Vehicles (#)**	**Added Travel Length (mile/veh)**	**Added Time (hr/veh)**	**Cost Rate ($/veh-hr, $/mile)**	**Road User Cost ($)**
Queue Delay (Added Time)	**CAR**	90	1,950		0.050	12.75	1,119
	TRUCK	10	1,950		0.050	21.25	207
Queue Idling VOC (Added Cost)	**CAR**	90	1,950		0.050	0.6821	60
	TRUCK	10	1,950		0.050	0.7845	8
Work Zone Delay (Added Time)	**CAR**	90	1,950		0.017	12.75	380
	TRUCK	10	1,950		0.017	21.25	70
Circuity Delay (Added Time)	**CAR**						
	TRUCK						
Circuity VOC (Added Cost)	**CAR**						
	TRUCK						

Total Vehicles that Travel Queue:	1,950
Total Vehicles that Travel Work Zone:	1,950
Total Vehicles that Travel Detour:	0
Percent Passenger Cars:	90%
Percent Trucks:	10%

Daily Road User Cost	1,844
Calculated Road User Cost (CRUC)	922
Number of Work Zone Days	10
Total Road User Cost	9,220

Project: Example #4 **Date:** July 1999

Description: Alternating Traffic Pattern

EXAMPLE PROBLEM 5

Liquidated Damages

The reconstruction of the southbound lanes of a four-lane facility costs an estimated $7 million. All work must be completed at night with one lane open at all times. The contractor must have both southbound lanes open for traffic at 6 AM each morning. The calculated daily road user costs are $6,000 per day and the calculated road user costs associated with closing a lane from 6 AM to 7 AM are $4,800 for the hour ($80/minute). The Department's costs for engineering, inspection, and administration of the project are estimated at $1,000 per day. The project's substantial and final completion dates are June 30, 1999 and August 30,1999 respectively. Compute the liquidated damages for the following situations:

Date	Situation
June 29	1 lane open until 6:10 AM
June 30	1 lane open until 6:20 AM
July 1	1 lane open until 7:15 AM
July 2	1 lane open until 6:05 AM
August 31	Project Completed

ANSWER:

The liquidated damages that may apply are the Construction Engineering Charge, the Road User Charge, and the Lane Occupancy Charge. As per this manual, the Maximum Allowable Road User Charge is $5,000 per day and the Maximum Allowable Lane Occupancy Charge is $5,000 per day. The liquidated damages associated with the above dates are as follows:

Calendar Date	Construction Engineering Charge	Road User Charge ($5,000/day maximum)	Lane Occupancy Charge ($5,000/day maximum)	Total Liquidated Damages
June 29	$0	$0	$0	$0
June 30	$0	$0	$40/min x 15 min $80/min x 5 min = $1,000	$1,000
July 1	$1,000	$6,000 ($5,000 max)	$40/min x 15 min $80/min x 60 min = $5,400 ($5,000 max)	$11,000
July 2	$1,000	$6,000 ($5,000 max)	$0	$6,000
August 31	$500	$0	$0	$500

EXAMPLE PROBLEM 6

Road User Costs at a Signalized Intersection

A recently installed traffic signal at the intersection of a land service highway and a local street has a total approach volume of 54,200 vehicles per day in the 1st year and a projected 67,200 vehicles per day in the 20th year. The traffic composition is 90% passenger cars and 10% trucks. The value of time is $12.75/hour for passenger cars and $21.25/hour for trucks. The idling cost rate is $0.68/hour for passenger cars and $0.78/hour for trucks. Compute the intersection road user cost for the 1st year and 20th year of operation.

ANSWER:

The Calculated Road User Cost in the 1st year of operation is $376,935.
The Calculated Road User Cost in the 20th year of operation is $603,646.

The following table is developed by performing a separate Signalized Intersection Analysis for each hour in a 24 hour period and then computing a weighted average daily delay.

1st Year		Time	20th Year	
Volume	**Delay (sec)**	**Period**	**Delay (sec)**	**Volume**
433	8.7	12-1AM	8.7	538
217	8.5	1-2	8.6	271
164	8.5	2-3	8.5	203
163	8.5	3-4	8.5	202
219	8.5	4-5	8.6	270
704	8.9	5-6	9.1	875
2167	10.5	6-7	11.3	2687
3487	13.3	7-8	19.1	4299
3088	12.2	8-9	14.8	3828
2601	11.2	9-10	12.5	3225
2656	11.3	10-11	12.7	3291
2979	11.9	11-12PM	14.2	3695
3250	8.0	12-1	9.2	4030
3089	7.8	1-2	8.8	3829
3413	8.2	2-3	9.7	4231
4171	9.5	3-4	14.3	5172
4550	10.7	4-5	19.2	5641
4388	10.1	5-6	17.3	5441
3358	8.1	6-7	9.5	4184
2763	7.4	7-8	8.2	3426
2329	7.0	8-9	7.6	2888
1842	6.7	9-10	7.0	2285
1302	6.4	10-11	6.5	1613
867	6.1	11-12	6.3	1076
54,200	**Total Volume in 24 Hours**			**67,200**
9.6	**Weighted Average Daily Delay (sec/veh)**			**12.4**

1st YEAR INTERSECTION ROAD USER COST

9.6 sec/veh/day x 1 hour/3600 sec x 54,200 veh x 365 days = 52,755 hours

Delay Cost

Passenger Cars:	52,755 hours x 90% x $12.75/hour = $605,364
Trucks:	52,755 hours x 10% x $21.25/hour = $112,104
	Total Delay Cost = $717,468

Idling Cost

Passenger Cars:	52,755 hours x 90% x $0.68/hour = $ 32,286
Trucks:	52,755 hours x 10% x $0.78/hour = $ 4,115
	Total Idling Cost = $ 36,401
	Subtotal = $753,869
	Calculated Road User Cost (Includes 50% Reduction Factor) = $376,935

1st Year Total Estimated Intersection Road User Cost = $376,935

20th YEAR INTERSECTION ROAD USER COST

12.4 sec/veh/day x 1 hour/3600 sec x 67,200 veh x 365 days = 84,485 hours

Delay Cost

Passenger Cars:	84,485 hours x 90% x $12.75/hour = $ 969,465
Trucks:	84,485 hours x 10% x $21.25/hour = $ 179,531
	Total Delay Cost = $1,148,996

Idling Cost

Passenger Cars:	84,485 hours x 90% x $0.68/hour = $ 51,705
Trucks:	84,485 hours x 10% x $0.78/hour = $ 6,590
	Total Idling Cost = $ 58,295
	Subtotal = $1,207,291
	Calculated Road User Cost (Includes 50% Reduction Factor) = $ 603,646

20th Year Total Estimated Intersection Road User Cost = $603,646

EXAMPLE PROBLEM 7

Present Worth and Benefit/Cost Ratio at a Signalized Intersection

A State Highway Agency utilizes an empirically based systematic approach to compute road user costs. This simplified method is used to determine the Net Present Worth of road user costs for signalized intersections based on the Level of Service and Traffic Volumes over a 20 year period. The Agency utilizes these figures as a tool to compare benefits to costs and to help determine the appropriate level of investment for various proposed improvements. The construction costs for schemes A and B and road user costs for scheme A are shown in the table below.

Proposed Scheme	Road User Costs ($)	Construction Costs ($)
A	3,900,000	1,200,000
B	X	1,000,000

Determine the following:

A) The Net Present Worth of road user costs for proposed intersection Scheme B utilizing the empirically based approach.

B) The Benefit / Cost ratio of road user costs to construction costs for Scheme B compared to Scheme A.

ANSWER:

Part A) The Net Present Worth of road user costs is $4,540,200 for the 20-year period.

Part B) For the twenty-year period, road user costs in Scheme B are increased by $3.20 for every dollar saved in construction compared to Scheme A. Therefore, the Benefit / Cost ratio is –3.20/1.

PART A

STEP 1 Gather traffic data for Year 20 and compute AM and PM peak hour Level of Service analysis.

Traffic Data	Delay/Vehicle (LOS)	Number of Vehicles
Year 20 AM Weekday Peak	33.0 sec (D)	5,371
Year 20 PM Weekday Peak	21.2 sec (C)	5,444
Year 20 Average Daily Traffic	N/A	72,580

STEP 2 Compute Year 20 Daily Delay.
(AM Peak Delay + PM Peak Delay)/2 x 0.7 Average Daily Delay Empirical Factor
(33.0 seconds/vehicle + 21.2 seconds/vehicle)/2 x 0.7 = 18.97 seconds/vehicle

STEP 3 Compute Year 20 Yearly Delay.
18.97 seconds/vehicle x 1 hour/3600 seconds x 6.5***** days/week x 52 weeks/year x 72,580 vehicles/day = 129,270 hours/year

***** Based on peak weekday traffic volumes, Saturday and Sunday traffic volumes are equivalent to 1.5 weekdays.

STEP 4 Compute Year 20 Road User Cost.
129,270 hours/year x $14/hour Vehicle Weighted Time Value = $1,816,080/year
Calculated Road User Cost (Includes 50% Reduction Factor) = $ 908,040/year

STEP 5 Convert 20 Year Period Cost to Net Present Worth.
$908,040/year x 0.5 Average Year Factor x 20 years x 0.5 Present Worth Factor
= $4,540,200 (Present Worth Value of 20 years of Road User Costs)

PART B

Alternative	Road User Costs ($)	Construction Costs ($)	Comparison to Scheme A		
			ΔRUC	ΔCC	B/C Ratio
Scheme A	3,900,000	1,200,000	N/A	N/A	N/A
Scheme B	4,540,200	1,000,000	+640,000	-200,000	-3.20 / 1

Notes: ΔRUC = Change in Road User Costs between evaluated scheme and scheme A.
ΔCC = Change in Construction Costs between evaluated scheme and scheme A.
B/C ratio = (ΔRUC) x (-1)/(ΔCC) x (-1)

Benefit / Cost Ratio analysis:

a) If both the B and C values are positive, it is a win-win alternative scheme.
b) If both the B and C values are negative, it is a lose-lose alternative.
c) If one of the B or C values is negative and one of the B or C values is positive, it is beneficial if the benefits outweigh the costs.

EXAMPLE PROBLEM 8

Road User Costs and Life Cycle Costs

A State Highway Agency is conducting a Life Cycle Cost Analysis (LCCA) of a proposed six lane facility. The LCCA is utilizing the initial construction costs, future rehabilitation costs, and road user costs to determine the preferred alternative. Compute the total Net Present Worth (NPW) for each alternative based on the project data below.

	ALTERNATIVE A		ALTERNATIVE B	
Project Data	**Initial Construction**	**Future Rehab.**	**Initial Construction**	**Future Rehab.**
Design Period	20	10	20	10
Agency Cost ($ million)	15	10	20	5
Road User Costs ($ million)	30	10	10	2

General Data

Analysis Period = 30 years
Real Discount Rate (i) = 4%
Present Worth Factor at year 20 = 0.4564
Net Present Worth = Initial Cost + $\sum$ Future Cost $[1/(1+i)^N]$
Agency Weighted Value of Project Costs Versus Road User Costs = 1:1/3

ANSWER: **NPW for Alternative A = $25.32 Million**
NPW for Alternative B = $24.10 Million

ALTERNATIVE A

Agency Cost

Year 0		= $15.00 million
Year 20	$10.0 million x 0.4564	= $ 4.56 million
Total		= $19.56 million

Road User Cost

Year 0		= $30.00 million
Year 20	$10.0 million x 0.4564	= $ 4.56 million
Total		= $34.56 million

Calculated Road User Cost (Includes 50% Reduction Factor) = $17.28 million
Agency Weighted Value (1:1/3) = $ 5.76 million

Total NPW = $19.56 million + $5.76 million = $25.32 million

ALTERNATIVE B

Agency Cost

Year 0		= $20.00 million
Year 20	$5.0 million x 0.4564	= $ 2.28 million
Total		= $22.28 million

Road User Cost

Year 0		= $10.00 million
Year 20	$2.0 million x 0.4564	= $ 0.91 million
Total		= $10.91 million

Calculated Road User Cost (Includes 50% Reduction Factor) = $ 5.46 million
Agency Weighted Value (1:1/3) = $ 1.82 million

Total NPW = $22.28 million + $1.82 million = $24.10 million

The results of the LCCA show that Alternative A has the lowest agency costs. However, Alternative B is the preferred option (lowest NPW) when road user costs are considered. Therefore, Alternative B would be the preferred alternative.

EXAMPLE PROBLEM 9

Bridge Opening and Waterway Vessel User Costs

An existing movable bridge has 300 openings per month and each opening lasts 10 minutes. A planned rehabilitation of the movable span will close the navigational channel to all waterway vessels for an entire month which will require an alternate waterway route of 26.75 nautical miles. The four-lane facility carries 20,000 vehicles per day in each direction. The average non-peak and peak hour volumes are 1,350 and 2,400 vehicles per hour respectively. Compute the following:

A) The monthly user costs incurred by the waterway vessels during the navigational channel closure.

B) The monthly road user costs incurred by the roadway traffic during bridge openings assuming that 75% occur during non-peak hours and 25% occur during peak hours.

ANSWER:

Part A) The Calculated User Costs for the waterway vessels is $42,152 for the month.

Part B) The Calculated Road User Cost is $296 per each non-peak hour opening.
The Calculated Road User Cost is $919 per each peak hour opening.

The Total Road User Cost is $135,349 for the month
($88,607 x 75% + $275,576 x 25%).

A) WATERWAY USER COSTS
Due to Navigational Channel Closure

A	B	C	D	E	F	G	H	I	J	K
Vessel Class	Percent Vessel Class	Average Speed	Average Fuel Usage	Average Number of People on Vessel	Time Value	Added Travel Distance	Added Travel Time	Added Fuel Usage	Added Fuel Cost	Added Time Cost
(type)	(%)	(knots)	(gal/hr)	(#)	($/hr)	(nautical mile)	(hour)	(gallon)	($)	($)
Sport Fishing	65	15 - 25 (20)	10 - 25 (15)	6 - 8 (6)	51	26.75	1.34	20.10	24.12	68.34
Sailboat	18	5 - 8 (6)	1 - 3 (2)	3 - 8 (4)	34	26.75	4.46	8.92	10.70	151.64
Tug/Towing	12	5 - 10 (7)	30 - 70 (50)	3 - 4 (3)	250	26.75	3.82	191.00	229.20	955.00
Party Boat	5	8 - 12 (10)	20 - 30 (25)	30 - 60 (40)	340	26.75	2.68	67.00	80.40	911.20

Weighted Average per Vessel	**49.13**	**231.88**
Monthly Added Fuel Cost	**$14,739**	
Monthly Added Time Cost	**$69,564**	
Total Monthly Added Cost	**$84,303**	
Total Waterway User Costs*	**$42,152**	

( ) Represents value used in calculations

1 knot = 1 nautical mile/hour

1 nautical mile = 6080 feet

*** Includes 50% reduction Factor**

A) The **Vessel Class** is the type of vessels requiring openings.

B) The **Percent Vessel Class** is calculated from bridge opening survey data.

C) The **Average Speed** is obtained from the vessel manufacturers.

D) The **Average Fuel Usage** is obtained from the vessel manufacturers.

E) The **Average Number of People on Vessel** is based on estimates during the channel closure.

F) NCHRP Report 133 provides $2.00/hour time value per person. The consumer price index is used to escalate to current value of $8.50/hour. The **Time Value** is the **Average Number of People on Vessel** multiplied by the $8.50/hr rate. The **Time Value** for tug/towing is based on an 8 hour workday of $2000.

G) The **Added Travel Distance** is the length of the waterway alternate route.

H) The **Added Travel Time** is the **Added Travel Distance** divided by the **Average Speed**.

I) The **Added Fuel Usage** is the **Added Travel Time** multiplied by the **Average Fuel Usage**.

J) The **Added Fuel Cost** is the **Added Fuel Usage** multiplied by $1.20/gallon.

K) The **Added Time Cost** is the **Added Travel Time** multiplied by the **Time Value**.

B) ROADWAY USER COSTS
Due to Bridge openings

A	B	C	D	E	F	G	H	I	J	K	L (Both Approaches)	M (Both Approaches)
Traffic Volume per Approach	Vehicle Approach Rate	Vehicle Dissipation Rate	Net Dissipation Rate	Vehicles Queued per Opening	Average Queue Length	Queue Dissipation Time	Approach Vehicles that Travel Queue	Average Queued Vehicle Delay per Opening	Approach Vehicle Queue Delay per Opening	Total Delay per Opening	Monthly Delay	Monthly Road User Cost
(veh/hr)	(veh/min)	(veh/min)	(veh/min)	(vehicles)	(miles)	(minutes)	(vehicles)	(veh-hr)	(veh-hr)	(veh-hr)	(veh-hr)	($)
1,350	22	-51	-29	220	0.42	8	176	18.33	2.11	20.44	12,264	88,607
2,400	**40**	**-51**	**-11**	**400**	**0.76**	**36**	**1,440**	**33.33**	**30.24**	**63.57**	**38,142**	**275,576**

Note: Peak hours are shown in **bold.**

A) The **Traffic Volume Per Approach** is given.
B) The **Vehicle Approach Rate** is the free flow capacity.
C) The **Vehicle Dissipation Rate** is the dissipation capacity.
D) The **Net Dissipation Rate** is the addition of the **Vehicle Approach Rate** and the **Vehicle Dissipation Rate**.
E) The **Vehicles Queued Per Opening** is the **Vehicle Approach Rate** multiplied by the 10 minute bridge opening time.
F) The **Average Queue Length** is the maximum queue length divided by two. The maximum queue length is the **Vehicles Queued Per Opening** multiplied by a 40 foot average vehicle length then divided by the number of lanes and 5,280 feet/mile.
G) The **Queue Dissipation Time** is the **Vehicles Queued Per Opening** divided by the **Queue Dissipation Time**.
H) The **Approach Vehicles that Travel Queue** is the **Vehicle Approach Rate** multiplied by the **Queue Dissipation Rate**.
I) The **Average Queued Vehicle Delay Per Opening** is the **Vehicles Queued Per Opening** multiplied by an average waiting time of 5 minutes.
J) The **Approach Vehicle Queue Delay Per Opening** is the **Approach Vehicles that Travel Queue** multiplied by the additional time to traverse the **Average Queue Length** at 20 mph versus 45 mph. The 20 mph average queue speed is obtained from the V/C Ratio for LOS-F Versus Average Queue Speed chart in the NCHRP Report 133.
K) The **Total Delay Per Opening** is the addition of the **Average Queued Vehicle Delay Per Opening** and the **Approach Vehicle Queue Delay Per Opening**.
L) The **Monthly Delay** is the **Total Delay Per Opening** multiplied by two approaches and 300 openings.
M) The **Monthly Road User Cost** is the **Monthly Delay** multiplied by an hourly weighted time value cost of $14.45/hour (1999 Dollars) and the 50% reduction factor. The hourly cost is based on $12.75/hour for passenger cars (80% of traffic) and $21.25/hour for trucks (20% of traffic).

EXAMPLE PROBLEM 10

Allowable Work Hours for Highway Lane Closures

A 24 hour traffic count for a highway in Mercer County was obtained from the traffic monitoring section. The directional traffic is 80,000 vehicles per day. Management will not accept work zone and construction related queues on the facility. Provide the allowable work hours when queues will not be present for the following three conditions: No lane reduction, 1 lane reduction and 2 lane reduction work zones.

ANSWER: As per the chart, the allowable work hours are as follows:

4 Lanes Maintained (No Lane Reduction)	**= 24 hours a day**
3 Lanes Maintained (One Lane Reduction)	**= 10 AM to 11 AM**
	= 6 PM to 7 AM (Next Day)
2 Lanes Maintained (Two Lane Reduction)	**= 8 PM to 7 AM (Next Day)**

8 Lane Highway (4 Lanes Each Direction) - 80,000 ADT (one-way)

Route: 2 **Highway Type:** Freeway **County:** Mercer **Peak Type:** Balanced

Freeway Section						
			Hourly Reserve Capacity or **Hourly Queue (-)**			
			Standard Capacity	**Work Zone Capacity**		
Hour	**Hourly % of ADT**	**Actual Hourly Traffic Volume** based on 80,000 ADT	**Ideal Capacity** 4 lanes x 2300 veh/lane = 9,200 veh/hour	**No Lane Reduction** 4 lanes x 1800 veh/lane = 7,200 veh/hour	**1 Lane Reduction** 3 lanes x 1500 veh/lane = 4,500 veh/hour	**2 Lane Reduction** 2 lanes x 1500 veh/lane = 3,000 veh/hour
	Standard Table	(ADT x hourly %)	(9,200 - hourly ADT)	(7,200 - hourly ADT)	(4,500 - hourly ADT)	(3,000 - hourly ADT)
	%	veh/hour	veh/hour	veh/hour	veh/hour	veh/hour
12-1 AM	1.0	800	8,400	6,400	3,700	2,200
1-2	0.7	560	8,640	6,640	3,940	2,440
2-3	0.6	480	8,720	6,720	4,020	2,520
3-4	0.6	480	8,720	6,720	4,020	2,520
4-5	0.8	640	8,560	6,560	3,860	2,360
5-6	1.9	1,520	7,680	5,680	2,980	1,480
6-7	3.7	2,960	6,240	4,240	1,540	40
7-8	6.5	5,200	4,000	2,000	**-700**	**-2,200**
8-9	6.9	5,520	3,680	1,680	**-1,020**	**-2,520**
9-10	5.8	4,640	4,560	2,560	**-140**	**-1,640**
10-11	5.5	4,400	4,800	2,800	100	**-1,400**
11-12	6.0	4,800	4,400	2,400	**-300**	**-1,800**
12-1 PM	6.5	5,200	4,000	2,000	**-700**	**-2,200**
1-2	6.2	4,960	4,240	2,240	**-460**	**-1,960**
2-3	6.4	5,120	4,080	2,080	**-620**	**-2,120**
3-4	6.9	5,520	3,680	1,680	**-1,020**	**-2,520**
4-5	7.2	5,760	3,440	1,440	**-1,260**	**-2,760**
5-6	6.9	5,520	3,680	1,680	**-1,020**	**-2,520**
6-7	5.4	4,320	4,880	2,880	180	**-1,320**
7-8	4.1	3,280	5,920	3,920	1,220	**-280**
8-9	3.3	2,640	6,560	4,560	1,860	360
9-10	2.8	2,240	6,960	4,960	2,260	760
10-11	2.5	2,000	7,200	5,200	2,500	1,000
11-12	1.8	1,440	7,760	5,760	3,060	1,560
24 hour Totals	100.0	80,000				
24 hour Total Capacity (hourly capacity x 24 hours)			220,800	172,800	108,000	72,000
24 hour Total Reserve Capacity (total capacity - ADT)			140,800	92,800	28,000	**-8,000**

Note: The negative bold values indicate queue conditions based on an individual hour.

APPENDIX B

Hourly Traffic Percentages
(Statewide Averages & by County)

New Jersey Department of Transportation
Statewide Average Hourly Traffic Percentages

Hour	Interstates, Freeways, and Other Expressways			Principal Arterials			Major Arterials			Minor Arterials		
	AM Peak	PM Peak	Balanced	AM Peak	PM Peak	Balanced	AM Peak	PM Peak	Balanced	AM Peak	PM Peak	Balanced
12-1AM	1.0	1.5	1.3	0.8	1.5	1.2	1.0	1.0	0.7	0.8	1.0	0.8
1-2	0.8	0.9	0.8	0.4	0.9	0.6	0.5	0.5	0.4	0.4	0.5	0.4
2-3	0.7	0.7	0.7	0.4	0.7	0.5	0.5	0.3	0.3	0.3	0.3	0.2
3-4	0.9	0.6	0.7	0.4	0.6	0.5	0.5	0.3	0.3	0.3	0.3	0.2
4-5	1.4	0.7	0.9	0.8	0.8	0.8	0.9	0.4	0.4	0.5	0.4	0.4
5-6	3.4	1.2	1.9	2.7	1.1	1.9	2.5	0.9	1.1	1.2	1.0	1.2
6-7	8.1	2.5	4.6	6.5	2.6	4.1	6.5	2.9	3.6	4.5	3.5	4.6
7-8	10.7	4.4	6.6	9.6	4.3	6.4	9.7	4.9	6.8	9.5	5.5	7.7
8-9	8.9	4.5	6.8	9.2	4.7	7.0	9.2	5.2	7.4	9.2	5.2	7.3
9-10	5.6	4.0	5.4	6.1	4.1	5.6	6.4	4.8	5.9	5.6	4.4	5.3
10-11	4.8	4.4	4.9	5.2	4.2	5.2	5.4	4.8	5.6	4.9	4.5	4.7
11-12	4.7	4.9	5.1	5.4	4.8	5.7	5.5	5.6	5.9	5.3	5.5	5.3
12-1PM	4.6	5.3	5.2	5.4	5.2	5.8	5.5	6.1	6.2	6.1	6.2	5.8
1-2	4.6	5.4	5.2	5.4	5.4	6.0	5.6	6.0	6.1	5.8	5.8	5.8
2-3	5.0	5.9	5.6	5.5	6.2	5.9	5.7	6.5	6.6	6.0	6.3	6.2
3-4	5.5	7.5	6.5	6.0	8.0	6.3	5.8	7.9	7.3	6.9	7.7	7.4
4-5	6.2	9.2	7.4	6.1	9.7	6.5	6.0	9.2	7.5	6.9	9.7	8.0
5-6	6.3	9.2	7.5	6.2	9.7	6.8	5.9	8.9	7.3	6.7	9.2	7.1
6-7	4.7	7.4	6.1	5.0	7.2	5.9	4.5	7.1	6.0	5.4	6.7	6.1
7-8	3.5	5.7	4.6	4.0	5.4	5.0	3.6	5.1	4.7	4.2	5.1	4.9
8-9	2.7	4.6	3.9	2.9	4.3	4.1	2.9	3.8	3.4	3.5	4.0	3.6
9-10	2.5	4.0	3.4	2.5	3.6	3.6	2.5	3.3	2.9	2.6	3.2	3.1
10-11	2.0	3.1	2.8	2.1	2.8	2.7	2.1	2.6	2.1	2.0	2.2	2.3
11-12	1.4	2.4	2.1	1.4	2.2	1.9	1.3	1.9	1.5	1.4	1.8	1.6
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Congestion Management System (CMS)
PERCENT HOURLY DISTRIBUTION DATA (1997)

COUNTY CODE (CC):

1	Atlantic	15	Gloucester	29	Ocean
3	Bergen	17	Hudson	31	Passaic
5	Burlington	19	Hunterdon	33	Salem
7	Camden	21	Mercer	35	Somerset
9	Cape May	23	Middlesex	37	Sussex
11	Cumberland	25	Monmouth	39	Union
13	Essex	27	Morris	41	Warren

FACILITY TYPE (FT):

1 Interstate, Freeway and other Expressway
3 Principal Arterial
5 Major Arterial
7 Minor Arterial

PEAK TYPE (PT):

1 AM high
2 PM high
3 Balanced

NOTES:

1) This data is not intended to replace the actual traffic counts that may be necessary for specific job sites.

2) The Bureau of Technical Analysis may supply updated yearly data.

3) The facility type "Major Arterial" includes County Route 500 Series and other non-continuous Principal Arterials.

4) Hours shown on chart are for the hour ending the period (i.e. If 4 is shown, the traffic volume is for the period 3 AM-4 AM).

Hourly Traffic Percentages

by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1	1	1.0	0.6	0.4	0.9	0.4	0.9	2.7	5.5	7.8	5.5	6.6	7.1	5.8	6.1	6.6	6.4	6.4	6.4	5.6	5.3	3.5	3.5	2.9	2.0
1	1	2	2.4	1.7	1.3	1.0	1.4	1.1	2.1	3.0	3.4	3.1	3.9	4.5	4.7	4.4	4.7	5.7	6.3	8.5	7.7	7.3	6.6	5.8	5.2	4.4
1	1	3	1.5	0.8	0.6	0.7	0.5	0.7	1.7	4.0	6.1	5.9	6.3	7.1	6.5	5.9	6.4	6.5	6.1	5.9	5.8	5.6	4.7	4.3	3.5	2.8
1	3	1	1.2	0.6	0.4	0.4	0.5	0.9	2.8	6.1	8.7	6.3	6.2	6.6	5.9	6.3	6.5	7.0	6.4	6.3	5.1	4.8	3.2	2.9	2.6	2.1
1	3	2	2.9	2.0	1.7	1.5	2.2	0.8	1.6	3.2	4.0	3.6	3.7	4.4	4.8	5.1	5.8	7.9	9.5	9.0	6.2	4.9	4.4	3.8	3.8	3.5
1	3	3	1.3	0.6	0.4	0.3	0.4	0.9	2.4	5.1	7.4	5.6	5.0	5.6	5.3	5.5	6.0	7.0	6.1	6.6	5.8	5.9	5.3	4.9	3.6	2.7
1	5	1	1.3	0.6	0.6	0.7	1.1	3.0	6.3	8.6	5.7	5.9	5.6	5.0	5.4	5.9	6.0	6.3	6.5	6.8	5.0	3.8	2.9	2.5	2.5	1.9
1	5	2	1.6	1.1	0.9	0.9	1.1	0.6	1.1	3.0	4.2	4.8	5.5	6.5	7.4	7.2	7.5	7.9	8.4	8.2	6.2	4.6	3.8	3.0	2.5	2.0
1	5	3	1.1	0.6	0.4	0.5	0.5	0.9	1.8	4.7	6.3	4.5	5.9	6.9	7.2	7.3	7.4	7.6	7.3	6.5	5.7	4.9	3.7	3.7	2.6	2.0
1	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
1	7	2	1.2	0.6	0.5	0.4	0.5	1.1	4.9	5.5	4.9	4.0	4.7	5.9	6.1	5.6	6.2	8.2	11.4	9.1	5.4	3.6	3.1	2.8	2.0	2.0
1	7	3	1.0	0.4	0.3	0.3	0.5	0.7	3.9	10.2	8.8	5.6	5.1	6.2	6.6	5.4	5.8	9.0	7.9	5.9	4.3	3.5	2.5	2.6	2.0	1.6
3	1	1	1.5	1.2	1.2	1.2	1.7	3.6	7.2	9.6	9.9	5.9	4.8	4.6	4.6	4.7	5.0	4.8	5.1	5.5	4.7	3.6	2.9	2.5	2.4	1.8
3	1	2	1.7	1.2	1.0	0.9	1.0	1.6	3.0	4.5	4.7	4.0	4.4	4.9	5.1	5.5	6.0	6.5	7.7	8.8	6.8	5.8	4.6	4.0	3.4	2.7
3	1	3	2.4	1.9	1.9	1.8	1.9	2.6	4.5	6.2	6.5	5.1	5.0	5.0	4.9	5.1	5.2	5.5	5.9	6.3	5.7	4.6	3.7	3.1	2.8	2.4
3	3	1	0.9	0.6	0.5	0.5	0.9	2.5	7.4	11.2	10.7	6.1	4.6	4.5	4.9	4.7	4.9	5.4	5.6	6.5	5.2	3.9	2.9	2.4	2.1	1.6
3	3	2	1.4	0.8	0.5	0.4	0.4	0.8	2.6	4.8	5.6	4.1	3.9	4.2	4.7	4.9	5.7	7.5	9.5	10.7	8.1	5.7	4.4	3.9	3.0	2.2
3	3	3	2.5	1.5	0.8	0.5	0.8	0.9	1.6	2.8	4.0	5.6	7.1	7.9	8.3	8.1	7.2	6.1	5.4	5.0	5.1	5.5	4.4	3.6	3.2	2.1
3	5	1	0.5	0.3	0.2	0.3	0.8	2.6	7.2	10.5	10.7	7.2	5.2	5.1	5.2	4.9	5.3	6.4	6.6	6.0	4.7	3.2	2.4	2.1	1.7	1.1
3	5	2	0.9	0.4	0.3	0.3	0.4	1.1	3.0	5.3	5.4	4.6	4.3	4.6	4.9	5.3	5.8	6.6	8.7	9.7	10.4	6.1	4.4	3.2	2.6	1.8
3	5	3	0.7	0.3	0.2	0.2	0.3	1.5	5.7	9.4	9.5	6.9	4.9	5.2	5.7	4.6	5.0	6.1	8.0	6.7	5.6	3.8	2.8	2.4	2.3	2.2
3	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
3	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
3	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4
5	1	1	1.0	0.7	0.6	0.8	1.1	2.7	7.5	10.9	7.8	5.2	4.6	4.6	4.7	4.7	5.0	6.0	7.0	7.4	5.1	3.6	2.8	2.5	2.0	1.8
5	1	2	1.2	0.9	0.8	0.8	0.9	1.7	3.6	6.1	5.8	4.7	4.8	5.1	5.3	5.3	6.1	7.5	9.0	9.8	6.6	4.0	3.1	2.7	2.4	1.7
5	1	3	1.2	0.9	0.9	0.9	1.0	1.8	4.5	7.9	7.4	4.5	4.1	4.3	4.7	4.5	5.5	7.3	9.6	9.7	6.5	3.4	3.2	2.4	2.1	1.7
5	3	1	0.9	0.5	0.6	0.7	1.0	2.4	4.9	9.6	8.1	5.7	5.2	5.6	5.9	5.7	5.6	6.1	6.1	6.1	5.1	4.1	3.3	3.0	2.2	1.4
5	3	2	1.2	0.7	0.4	0.4	0.6	1.1	3.2	6.4	5.8	4.4	4.3	4.9	5.5	5.4	5.8	7.6	9.9	10.7	7.1	4.9	3.4	2.7	2.1	1.5
5	3	3	1.1	0.6	0.4	0.6	0.7	1.9	5.4	8.8	8.1	5.5	4.5	4.7	4.7	5.2	5.3	6.2	7.3	7.9	5.9	4.2	3.7	3.3	2.4	1.6
5	5	1	0.8	0.6	0.6	0.7	1.3	3.0	6.6	9.4	7.9	6.1	6.0	5.6	5.4	5.5	5.4	5.5	5.7	5.1	4.9	4.1	3.3	2.6	2.3	1.4
5	5	2	1.3	0.8	0.6	0.5	0.7	0.9	2.6	4.4	4.5	4.6	5.2	5.5	5.6	5.7	6.2	8.4	10.2	9.8	6.9	4.3	3.7	3.1	2.7	1.7
5	5	3	0.3	0.2	0.1	0.3	0.4	1.3	3.6	9.7	8.2	6.0	6.1	5.7	5.6	6.5	7.4	9.1	8.8	7.5	5.2	2.5	2.2	1.2	1.0	1.0
5	7	1	0.7	0.5	0.4	0.3	0.6	1.8	5.5	8.3	6.4	5.4	5.2	5.5	6.1	6.3	6.3	6.2	5.8	6.1	6.0	5.3	4.5	3.2	2.2	1.5
5	7	2	0.7	0.4	0.2	0.1	0.3	1.3	3.5	6.1	6.4	5.3	5.6	6.5	7.0	6.5	6.2	7.1	8.2	7.9	5.7	5.0	4.0	2.9	1.7	1.2
5	7	3	0.7	0.3	0.2	0.2	0.4	1.2	3.5	5.7	6.7	5.0	5.0	5.6	6.3	6.3	6.5	7.6	8.1	7.9	6.6	5.1	4.1	3.5	2.2	1.4

Hourly Traffic Percentages

by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
7	1	1	0.8	0.6	0.5	0.7	1.0	2.0	6.3	12.0	10.4	4.6	4.1	4.4	4.3	4.0	4.5	5.9	7.3	9.2	5.4	3.3	2.7	2.5	1.9	1.4
7	1	2	1.5	0.8	0.6	0.4	0.5	0.9	1.8	3.4	3.8	4.2	5.1	6.0	6.7	6.4	6.5	8.0	9.6	9.4	6.8	5.2	4.5	3.8	2.5	1.7
7	1	3	1.0	0.7	0.6	0.6	0.8	1.9	3.7	6.5	6.9	5.8	5.5	6.0	6.5	6.2	6.4	6.9	7.2	6.9	5.4	4.1	3.3	2.8	2.5	1.8
7	3	1	0.8	0.5	0.4	0.3	0.5	1.6	6.1	11.1	9.6	5.3	4.5	4.4	4.8	5.1	5.2	6.4	7.3	7.6	5.3	4.0	3.0	2.7	2.0	1.5
7	3	2	1.1	0.8	0.5	0.4	0.5	1.1	3.6	6.2	5.9	4.1	4.1	4.5	5.2	5.2	5.9	7.7	9.9	10.5	7.0	4.7	3.6	3.2	2.5	1.9
7	3	3	1.1	0.6	0.4	0.6	0.7	1.9	5.4	8.8	8.1	5.5	4.5	4.7	4.7	5.2	5.3	6.2	7.3	7.9	5.9	4.2	3.7	3.3	2.4	1.6
7	5	1	1.0	0.5	0.4	0.3	0.7	1.6	5.9	10.2	8.4	5.7	4.7	4.7	5.0	4.6	5.8	6.5	7.2	7.6	5.8	4.3	3.1	2.6	1.8	1.5
7	5	2	0.7	0.4	0.2	0.2	0.4	0.9	3.2	5.5	5.8	4.4	4.3	5.2	6.0	5.4	5.9	8.0	12.1	10.5	6.9	5.0	3.0	2.9	1.9	1.3
7	5	3	1.1	0.7	0.5	0.4	0.7	1.4	4.5	7.5	6.3	5.1	5.0	5.6	5.8	5.6	6.0	6.5	7.2	7.4	6.4	5.3	3.6	2.9	2.5	2.0
7	7	1	0.7	0.5	0.4	0.3	0.6	1.8	5.5	8.3	6.4	5.4	5.2	5.5	6.1	6.3	6.3	6.2	5.8	6.1	6.0	5.3	4.5	3.2	2.2	1.5
7	7	2	1.2	0.6	0.5	0.3	0.4	0.7	1.7	4.0	4.2	4.2	4.6	5.6	6.1	6.0	6.4	8.0	9.1	8.8	7.3	6.0	5.0	4.3	3.0	2.1
7	7	3	0.7	0.6	0.4	0.4	0.6	1.6	4.4	6.0	5.3	5.1	5.2	5.7	6.3	6.5	6.4	6.2	6.2	6.3	6.5	6.0	4.6	3.8	2.9	2.3
9	1	1	1.0	0.6	0.4	0.9	0.4	0.9	2.7	5.5	7.8	5.5	6.6	7.1	5.8	6.1	6.6	6.4	6.4	6.4	5.6	5.3	3.5	3.5	2.9	2.0
9	1	2	2.4	1.7	1.3	1.0	1.4	1.1	2.1	3.0	3.4	3.1	3.9	4.5	4.7	4.4	4.7	5.7	6.3	8.5	7.7	7.3	6.6	5.8	5.2	4.4
9	1	3	1.5	0.8	0.6	0.7	0.5	0.7	1.7	4.0	6.1	5.9	6.3	7.1	6.5	5.9	6.4	6.5	6.1	5.9	5.8	5.6	4.7	4.3	3.5	2.8
9	3	1	1.2	0.6	0.4	0.4	0.5	0.9	2.8	6.1	8.7	6.3	6.2	6.6	5.9	6.3	6.5	7.0	6.4	6.3	5.1	4.8	3.2	2.9	2.6	2.1
9	3	2	2.9	2.0	1.7	1.5	2.2	0.8	1.6	3.2	4.0	3.6	3.7	4.4	4.8	5.1	5.8	7.9	9.5	9.0	6.2	4.9	4.4	3.8	3.8	3.5
9	3	3	1.3	0.6	0.4	0.3	0.4	0.9	2.4	5.1	7.4	5.6	5.0	5.6	5.3	5.5	6.0	7.0	6.1	6.6	5.8	5.9	5.3	4.9	3.6	2.7
9	5	1	1.3	0.6	0.6	0.7	1.1	3.0	6.3	8.6	5.7	5.9	5.6	5.0	5.4	5.9	6.0	6.3	6.5	6.8	5.0	3.8	2.9	2.5	2.5	1.9
9	5	2	0.5	0.2	0.2	0.3	0.3	1.1	3.8	7.4	7.4	5.8	5.0	5.9	5.8	6.3	6.3	7.4	9.7	8.2	5.6	4.4	2.7	2.6	1.7	1.3
9	5	3	0.5	0.2	0.2	0.2	0.4	1.0	3.4	7.7	7.7	5.8	5.7	6.2	6.2	6.3	6.5	7.8	8.5	7.7	5.7	3.9	2.8	2.7	1.7	1.2
9	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
9	7	2	1.2	0.6	0.5	0.4	0.5	1.1	4.9	5.5	4.9	4.0	4.7	5.9	6.1	5.6	6.2	8.2	11.4	9.1	5.4	3.6	3.1	2.8	2.0	2.0
9	7	3	1.0	0.4	0.3	0.3	0.5	0.7	3.9	10.2	8.8	5.6	5.1	6.2	6.6	5.4	5.8	9.0	7.9	5.9	4.3	3.5	2.5	2.6	2.0	1.6
11	1	1	1.0	0.7	0.6	0.8	1.1	2.7	7.5	10.9	7.8	5.2	4.6	4.6	4.7	4.7	5.0	6.0	7.0	7.4	5.1	3.6	2.8	2.5	2.0	1.8
11	1	2	0.7	0.3	0.4	0.4	0.6	2.0	3.9	6.1	5.0	4.7	5.3	6.1	5.8	6.6	6.6	6.9	8.4	7.8	5.3	4.8	3.8	4.2	2.6	1.7
11	1	3	1.2	0.9	0.9	0.9	1.0	1.8	4.5	7.9	7.4	4.5	4.1	4.3	4.7	4.5	5.5	7.3	9.6	9.7	6.5	3.4	3.2	2.4	2.1	1.7
11	3	1	1.2	0.6	0.4	0.4	0.5	0.9	2.8	6.1	8.7	6.3	6.2	6.6	5.9	6.3	6.5	7.0	6.4	6.3	5.1	4.8	3.2	2.9	2.6	2.1
11	3	2	2.9	2.0	1.7	1.5	2.2	0.8	1.6	3.2	4.0	3.6	3.7	4.4	4.8	5.1	5.8	7.9	9.5	9.0	6.2	4.9	4.4	3.8	3.8	3.5
11	3	3	1.3	0.6	0.4	0.3	0.4	0.9	2.4	5.1	7.4	5.6	5.0	5.6	5.3	5.5	6.0	7.0	6.1	6.6	5.8	5.9	5.3	4.9	3.6	2.7
11	5	1	1.3	0.6	0.6	0.7	1.1	3.0	6.3	8.6	5.7	5.9	5.6	5.0	5.4	5.9	6.0	6.3	6.5	6.8	5.0	3.8	2.9	2.5	2.5	1.9
11	5	2	0.4	0.2	0.2	0.1	0.3	1.4	6.2	7.2	6.3	5.2	5.1	5.5	5.1	5.8	7.6	10.2	9.1	5.9	5.0	3.3	2.2	2.0	4.3	1.3
11	5	3	0.3	0.2	0.1	0.3	0.4	1.3	3.6	9.7	8.2	6.0	6.1	5.7	5.6	6.5	7.4	9.1	8.8	7.5	5.2	2.5	2.2	1.2	1.0	1.0
11	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
11	7	2	1.2	0.6	0.5	0.4	0.5	1.1	4.9	5.5	4.9	4.0	4.7	5.9	6.1	5.6	6.2	8.2	11.4	9.1	5.4	3.6	3.1	2.8	2.0	2.0
11	7	3	1.0	0.4	0.3	0.3	0.5	0.7	3.9	10.2	8.8	5.6	5.1	6.2	6.6	5.4	5.8	9.0	7.9	5.9	4.3	3.5	2.5	2.6	2.0	1.6

Hourly Traffic Percentages
by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
13	1	1	1.0	0.7	0.6	0.7	1.1	2.8	8.0	12.1	11.1	6.4	4.6	4.2	4.0	3.9	4.3	5.0	6.5	7.1	5.0	3.3	2.4	2.1	1.8	1.4
13	1	2	1.2	0.6	0.4	0.3	0.3	0.8	2.0	4.4	4.8	4.1	4.3	4.9	5.6	5.9	6.4	8.0	8.9	8.5	7.9	6.4	5.1	4.2	2.9	2.1
13	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
13	3	1	0.7	0.4	0.3	0.3	0.6	1.8	5.2	8.4	8.1	5.8	5.1	5.3	5.7	5.6	5.7	6.2	6.6	6.9	5.9	4.9	3.7	3.1	2.3	1.5
13	3	2	1.4	0.8	0.7	0.4	0.5	1.2	2.9	4.7	5.2	4.7	5.1	5.6	6.1	6.1	6.4	7.3	8.1	7.9	6.7	5.5	4.4	3.5	2.7	2.1
13	3	3	1.0	0.5	0.4	0.3	0.6	1.6	4.2	7.2	7.6	5.6	5.1	5.4	5.7	5.6	6.0	6.8	7.3	7.1	6.0	5.0	3.9	3.2	2.4	1.8
13	5	1	1.8	0.7	0.8	0.5	1.0	2.3	6.9	10.2	12.6	7.5	4.5	5.2	5.0	5.4	6.4	5.7	6.0	5.3	3.8	2.6	1.9	1.4	1.4	1.1
13	5	2	1.2	0.7	0.4	0.3	0.3	0.7	1.7	3.4	4.5	5.1	5.4	6.1	6.7	7.0	7.0	7.1	7.5	7.7	7.1	6.0	5.1	4.2	2.8	1.9
13	5	3	1.1	0.6	0.4	0.3	0.4	1.3	3.6	6.0	6.8	5.6	5.4	5.6	6.1	5.8	6.1	6.7	7.0	7.3	6.3	5.4	4.2	3.5	2.7	1.9
13	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
13	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
13	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4
15	1	1	1.0	0.7	0.6	0.8	1.1	2.7	7.5	10.9	7.8	5.2	4.6	4.6	4.7	4.7	5.0	6.0	7.0	7.4	5.1	3.6	2.8	2.5	2.0	1.8
15	1	2	1.2	0.8	0.8	0.8	1.1	1.8	4.6	7.6	6.5	4.6	4.1	4.2	4.3	4.4	5.2	7.5	11.8	9.4	6.2	3.8	2.7	2.6	2.5	1.6
15	1	3	1.2	0.9	0.9	0.9	1.0	1.8	4.5	7.9	7.4	4.5	4.1	4.3	4.7	4.5	5.5	7.3	9.6	9.7	6.5	3.4	3.2	2.4	2.1	1.7
15	3	1	0.9	0.5	0.6	0.7	1.0	2.4	4.9	9.6	8.1	5.7	5.2	5.6	5.9	5.7	5.6	6.1	6.1	6.1	5.1	4.1	3.3	3.0	2.2	1.4
15	3	2	1.2	0.7	0.4	0.4	0.6	1.1	3.2	6.4	5.8	4.4	4.3	4.9	5.5	5.4	5.8	7.6	9.9	10.7	7.1	4.9	3.4	2.7	2.1	1.5
15	3	3	1.1	0.6	0.4	0.6	0.7	1.9	5.4	8.8	8.1	5.5	4.5	4.7	4.7	5.2	5.3	6.2	7.3	7.9	5.9	4.2	3.7	3.3	2.4	1.6
15	5	1	0.8	0.6	0.6	0.7	1.3	3.0	6.6	9.4	7.9	6.1	6.0	5.6	5.4	5.5	5.4	5.5	5.7	5.1	4.9	4.1	3.3	2.6	2.3	1.4
15	5	2	1.2	0.7	0.6	0.6	0.9	2.2	5.4	6.5	5.5	5.9	4.8	4.8	5.4	5.4	6.1	6.4	8.9	8.4	6.3	4.7	2.7	2.7	2.4	1.6
15	5	3	0.3	0.2	0.1	0.3	0.4	1.3	3.6	9.7	8.2	6.0	6.1	5.7	5.6	6.5	7.4	9.1	8.8	7.5	5.2	2.5	2.2	1.2	1.0	1.0
15	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
15	7	2	1.2	0.6	0.5	0.4	0.5	1.1	4.9	5.5	4.9	4.0	4.7	5.9	6.1	5.6	6.2	8.2	11.4	9.1	5.4	3.6	3.1	2.8	2.0	2.0
15	7	3	1.0	0.4	0.3	0.3	0.5	0.7	3.9	10.2	8.8	5.6	5.1	6.2	6.6	5.4	5.8	9.0	7.9	5.9	4.3	3.5	2.5	2.6	2.0	1.6
17	1	1	1.0	0.7	0.6	0.7	1.1	2.8	8.0	12.1	11.1	6.4	4.6	4.2	4.0	3.9	4.3	5.0	6.5	7.1	5.0	3.3	2.4	2.1	1.8	1.4
17	1	2	1.2	0.6	0.4	0.3	0.3	0.8	2.0	4.4	4.8	4.1	4.3	4.9	5.6	5.9	6.4	8.0	8.9	8.5	7.9	6.4	5.1	4.2	2.9	2.1
17	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
17	3	1	0.7	0.4	0.3	0.3	0.6	1.8	5.2	8.4	8.1	5.8	5.1	5.3	5.7	5.6	5.7	6.2	6.6	6.9	5.9	4.9	3.7	3.1	2.3	1.5
17	3	2	1.4	0.8	0.7	0.4	0.5	1.2	2.9	4.7	5.2	4.7	5.1	5.6	6.1	6.1	6.4	7.3	8.1	7.9	6.7	5.5	4.4	3.5	2.7	2.1
17	3	3	1.0	0.5	0.4	0.3	0.6	1.6	4.2	7.2	7.6	5.6	5.1	5.4	5.7	5.6	6.0	6.8	7.3	7.1	6.0	5.0	3.9	3.2	2.4	1.8
17	5	1	1.8	0.7	0.8	0.5	1.0	2.3	6.9	10.2	12.6	7.5	4.5	5.2	5.0	5.4	6.4	5.7	6.0	5.3	3.8	2.6	1.9	1.4	1.4	1.1
17	5	2	1.2	0.7	0.4	0.3	0.3	0.7	1.7	3.4	4.5	5.1	5.4	6.1	6.7	7.0	7.0	7.1	7.5	7.7	7.1	6.0	5.1	4.2	2.8	1.9
17	5	3	1.1	0.6	0.4	0.3	0.4	1.3	3.6	6.0	6.8	5.6	5.4	5.6	6.1	5.8	6.1	6.7	7.0	7.3	6.3	5.4	4.2	3.5	2.7	1.9
17	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
17	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
17	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4

Hourly Traffic Percentages
by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19	1	1	1.3	1.2	1.3	1.6	2.6	5.7	12.2	13.5	7.9	4.6	3.9	3.8	3.7	3.9	4.5	4.2	4.0	4.4	3.6	2.7	2.6	2.5	2.4	1.7
19	1	2	1.5	1.2	0.8	0.7	0.9	1.2	1.8	3.1	3.2	3.5	4.2	4.5	4.9	4.7	5.6	8.1	10.3	9.8	8.6	6.4	4.8	4.3	3.4	2.5
19	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
19	3	1	0.4	0.2	0.3	0.5	1.1	6.0	11.7	11.3	9.2	6.6	5.3	5.1	4.9	4.6	4.6	5.1	5.0	4.9	4.0	3.0	2.0	1.8	1.5	0.9
19	3	2	0.8	0.5	0.3	0.3	0.5	1.3	2.4	2.9	3.1	3.3	4.0	4.6	4.8	5.5	7.5	9.9	11.5	10.6	7.8	5.8	4.8	3.7	2.5	1.6
19	3	3	0.9	0.4	0.3	0.3	0.6	1.7	5.1	7.5	7.1	5.5	5.1	5.5	5.7	5.6	5.8	6.5	7.3	7.4	6.2	4.8	3.7	3.1	2.3	1.6
19	5	1	0.9	0.7	0.8	1.0	1.9	4.6	8.5	9.3	6.3	5.2	5.2	5.2	5.5	5.4	5.2	5.1	5.2	5.3	4.5	3.9	3.4	2.8	2.5	1.6
19	5	2	1.2	0.8	0.7	0.7	0.7	1.1	2.4	4.1	4.4	4.7	4.7	5.4	5.6	5.4	5.5	7.4	9.2	9.9	7.6	5.6	4.5	3.8	2.5	2.1
19	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
19	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
19	7	2	0.7	0.4	0.3	0.7	0.5	1.8	5.7	7.9	5.2	4.4	4.2	5.0	4.3	4.9	6.0	8.6	12.1	9.2	6.0	4.0	2.6	2.0	1.8	1.7
19	7	3	0.9	0.2	0.2	0.2	0.4	2.3	9.3	9.5	6.1	4.2	4.5	4.6	4.8	5.1	6.6	7.4	9.7	6.3	4.8	3.6	2.5	2.6	2.3	1.7
21	1	1	0.6	0.5	0.4	0.4	0.7	1.7	5.4	10.4	10.6	6.9	5.1	5.1	5.5	5.5	5.6	6.0	6.8	6.9	5.2	3.5	2.3	2.0	1.7	1.1
21	1	2	1.5	0.8	0.6	0.4	0.5	0.9	1.8	3.4	3.8	4.2	5.1	6.0	6.7	6.4	6.5	8.0	9.6	9.4	6.8	5.2	4.5	3.8	2.5	1.7
21	1	3	1.0	0.7	0.6	0.6	0.8	1.9	3.7	6.5	6.9	5.8	5.5	6.0	6.5	6.2	6.4	6.9	7.2	6.9	5.4	4.1	3.3	2.8	2.5	1.8
21	3	1	0.6	0.4	0.4	0.5	0.9	2.3	6.5	10.5	9.3	5.6	5.0	5.3	5.9	5.6	5.6	5.8	6.8	6.8	4.7	3.2	2.7	2.3	2.0	1.3
21	3	2	1.2	0.7	0.6	0.5	0.5	1.3	3.5	5.8	5.6	4.7	4.3	5.0	5.3	5.1	5.6	7.9	11.2	11.4	6.8	4.1	2.8	2.5	2.0	1.4
21	3	3	1.2	0.8	0.6	0.6	0.9	1.8	4.2	7.0	7.6	5.7	4.8	5.1	5.7	5.4	5.7	6.5	7.1	7.7	6.2	4.7	3.5	3.0	2.3	1.7
21	5	1	0.7	0.4	0.3	0.3	0.8	1.8	6.0	10.7	11.7	7.3	6.1	6.6	5.8	5.9	5.3	5.7	5.8	5.4	3.2	2.6	2.3	2.3	1.7	1.1
21	5	2	0.7	0.4	0.2	0.2	0.4	0.9	3.2	5.5	5.8	4.4	4.3	5.2	6.0	5.4	5.9	8.0	12.1	10.5	6.9	5.0	3.0	2.9	1.9	1.3
21	5	3	0.8	0.4	0.4	0.4	0.6	1.2	3.3	6.5	8.6	6.0	5.5	5.8	6.0	5.7	6.3	7.1	7.6	8.0	5.8	4.6	3.2	2.7	2.0	1.5
21	7	1	0.6	0.2	0.1	0.2	0.3	1.2	4.0	8.8	10.0	7.1	5.5	5.3	5.6	5.1	4.5	5.6	8.4	8.3	7.1	4.7	2.8	2.0	1.5	1.0
21	7	2	0.6	0.3	0.2	0.1	0.2	0.6	2.9	7.6	5.5	4.2	4.0	4.5	5.5	5.5	6.0	7.2	9.5	11.2	8.4	5.0	3.7	3.5	2.4	1.2
21	7	3	0.7	0.2	0.2	0.1	0.3	1.2	3.4	7.8	9.9	6.7	5.1	5.3	5.9	5.8	6.2	6.3	9.3	8.3	7.1	4.5	2.5	1.5	1.3	0.7
23	1	1	1.0	0.8	0.9	1.3	2.3	5.7	10.2	10.0	7.4	5.5	4.7	4.6	4.5	4.4	5.2	6.3	6.5	5.0	3.7	2.9	2.5	1.9	1.5	1.1
23	1	2	1.5	0.8	0.6	0.4	0.5	0.9	1.8	3.4	3.8	4.2	5.1	6.0	6.7	6.4	6.5	8.0	9.6	9.4	6.8	5.2	4.5	3.8	2.5	1.7
23	1	3	1.2	0.8	0.6	0.7	1.0	2.3	4.2	5.7	6.8	6.5	5.6	5.4	5.5	5.6	5.7	6.4	6.7	7.1	6.4	4.7	3.7	3.0	2.7	1.7
23	3	1	1.0	0.7	0.7	0.6	0.9	1.9	4.8	8.4	9.2	6.2	4.9	5.1	5.6	5.4	5.2	5.8	6.1	6.5	6.0	4.7	3.3	2.9	2.5	1.7
23	3	2	0.9	0.6	0.5	0.8	1.2	2.1	4.9	5.7	6.0	5.5	4.5	5.2	6.3	6.0	5.5	6.6	7.9	9.0	6.3	4.4	3.3	3.2	2.2	1.5
23	3	3	1.2	0.8	0.6	0.6	0.9	1.8	4.2	7.0	7.6	5.7	4.8	5.1	5.7	5.4	5.7	6.5	7.1	7.7	6.2	4.7	3.5	3.0	2.3	1.7
23	5	1	0.7	0.4	0.3	0.3	0.8	1.8	6.0	10.7	11.7	7.3	6.1	6.6	5.8	5.9	5.3	5.7	5.8	5.4	3.2	2.6	2.3	2.3	1.7	1.1
23	5	2	0.6	0.2	0.2	0.1	0.4	0.9	2.5	4.7	5.2	4.6	4.3	6.5	7.2	6.7	7.1	9.0	10.2	9.4	5.9	4.6	3.4	3.0	2.1	1.4
23	5	3	0.8	0.4	0.4	0.4	0.6	1.2	3.3	6.5	8.6	6.0	5.5	5.8	6.0	5.7	6.3	7.1	7.6	8.0	5.8	4.6	3.2	2.7	2.0	1.5
23	7	1	0.3	0.3	0.4	0.3	0.3	1.2	3.8	10.4	14.0	6.9	4.1	4.0	5.6	4.9	4.5	6.0	7.6	7.5	5.9	4.5	3.0	1.8	1.7	1.0
23	7	2	0.7	0.4	0.2	0.3	0.2	0.7	3.4	7.4	7.1	5.3	3.8	4.2	5.7	5.8	6.2	6.7	9.2	11.6	7.6	4.4	3.3	2.8	1.9	1.0
23	7	3	0.7	0.6	0.4	0.4	0.6	1.6	4.4	6.0	5.3	5.1	5.2	5.7	6.3	6.5	6.4	6.2	6.2	6.3	6.5	6.0	4.6	3.8	2.9	2.3

Hourly Traffic Percentages
by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
25	1	1	1.0	0.8	0.9	1.3	2.3	5.7	10.2	10.0	7.4	5.5	4.7	4.6	4.5	4.4	5.2	6.3	6.5	5.0	3.7	2.9	2.5	1.9	1.5	1.1
25	1	2	1.0	0.5	0.3	0.4	0.4	1.0	3.1	5.9	5.9	3.9	4.1	4.4	4.3	4.6	5.9	8.1	10.4	10.8	8.2	5.2	4.0	3.6	2.4	1.9
25	1	3	1.2	0.8	0.6	0.7	1.0	2.3	4.2	5.7	6.8	6.5	5.6	5.4	5.5	5.6	5.7	6.4	6.7	7.1	6.4	4.7	3.7	3.0	2.7	1.7
25	3	1	0.5	0.4	0.3	0.4	0.8	2.6	7.7	13.3	11.2	5.9	5.0	5.0	5.2	5.4	5.4	6.0	6.1	5.9	3.8	2.5	1.8	2.2	1.5	1.1
25	3	2	1.8	0.8	0.5	0.5	0.5	0.9	1.9	3.8	4.5	4.4	4.6	5.0	5.4	5.6	6.2	7.4	8.5	8.7	7.4	6.4	4.9	4.7	3.2	2.5
25	3	3	0.6	0.4	0.4	0.7	1.7	4.8	5.8	6.4	7.1	5.6	5.1	5.6	5.9	6.5	5.3	4.4	4.6	5.9	6.1	4.9	4.2	3.9	2.4	1.6
25	5	1	0.7	0.4	0.3	0.3	0.8	1.8	6.0	10.7	11.7	7.3	6.1	6.6	5.8	5.9	5.3	5.7	5.8	5.4	3.2	2.6	2.3	2.3	1.7	1.1
25	5	2	0.6	0.2	0.2	0.1	0.4	0.9	2.5	4.7	5.2	4.6	4.3	6.5	7.2	6.7	7.1	9.0	10.2	9.4	5.9	4.6	3.4	3.0	2.1	1.4
25	5	3	0.8	0.4	0.4	0.4	0.6	1.2	3.3	6.5	8.6	6.0	5.5	5.8	6.0	5.7	6.3	7.1	7.6	8.0	5.8	4.6	3.2	2.7	2.0	1.5
25	7	1	0.7	0.5	0.4	0.3	0.6	1.8	5.5	8.3	6.4	5.4	5.2	5.5	6.1	6.3	6.3	6.2	5.8	6.1	6.0	5.3	4.5	3.2	2.2	1.5
25	7	2	1.2	0.6	0.5	0.3	0.4	0.7	1.7	4.0	4.2	4.2	4.6	5.6	6.1	6.0	6.4	8.0	9.1	8.8	7.3	6.0	5.0	4.3	3.0	2.1
25	7	3	0.7	0.6	0.4	0.4	0.6	1.6	4.4	6.0	5.3	5.1	5.2	5.7	6.3	6.5	6.4	6.2	6.2	6.3	6.5	6.0	4.6	3.8	2.9	2.3
27	1	1	0.7	0.4	0.3	0.4	0.9	3.3	8.3	10.7	10.2	6.5	5.2	4.6	4.6	4.4	4.6	5.3	5.9	6.0	4.9	3.8	2.8	2.5	2.1	1.5
27	1	2	1.8	1.2	0.9	0.8	0.9	1.2	2.5	4.3	4.4	4.2	4.5	4.8	5.2	5.4	6.0	7.9	8.2	7.8	7.3	5.7	4.8	4.2	3.4	2.6
27	1	3	2.5	1.6	1.6	1.6	1.9	2.2	4.2	5.6	5.9	4.7	4.6	5.0	4.2	4.8	5.2	6.5	6.8	6.2	5.9	5.4	4.4	3.7	3.1	2.5
27	3	1	0.4	0.2	0.3	0.5	1.1	6.0	11.7	11.3	9.2	6.6	5.3	5.1	4.9	4.6	4.6	5.1	5.0	4.9	4.0	3.0	2.0	1.8	1.5	0.9
27	3	2	0.8	0.5	0.3	0.3	0.5	1.3	2.4	2.9	3.1	3.3	4.0	4.6	4.8	5.5	7.5	9.9	11.5	10.6	7.8	5.8	4.8	3.7	2.5	1.6
27	3	3	0.9	0.6	0.6	0.5	0.6	1.8	3.1	4.1	5.5	6.3	7.0	7.9	7.2	7.3	7.1	6.6	6.7	6.0	5.6	4.6	3.2	2.6	2.3	1.8
27	5	1	0.6	0.3	0.2	0.1	0.2	0.9	4.2	9.6	9.6	6.1	5.3	5.6	5.9	5.7	5.9	6.1	6.0	6.2	5.6	4.9	3.8	3.2	2.4	1.6
27	5	2	0.7	0.3	0.2	0.1	0.2	0.6	2.4	4.8	5.4	4.6	4.6	5.5	6.2	6.0	6.4	7.0	8.1	9.7	9.1	5.6	4.3	3.8	2.6	1.7
27	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
27	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
27	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
27	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4
29	1	1	1.0	0.8	0.9	1.3	2.3	5.7	10.2	10.0	7.4	5.5	4.7	4.6	4.5	4.4	5.2	6.3	6.5	5.0	3.7	2.9	2.5	1.9	1.5	1.1
29	1	2	1.5	0.8	0.6	0.4	0.5	0.9	1.8	3.4	3.8	4.2	5.1	6.0	6.7	6.4	6.5	8.0	9.6	9.4	6.8	5.2	4.5	3.8	2.5	1.7
29	1	3	1.2	0.8	0.6	0.7	1.0	2.3	4.2	5.7	6.8	6.5	5.6	5.4	5.5	5.6	5.7	6.4	6.7	7.1	6.4	4.7	3.7	3.0	2.7	1.7
29	3	1	0.5	0.4	0.3	0.4	0.8	2.6	7.7	13.3	11.2	5.9	5.0	5.0	5.2	5.4	5.4	6.0	6.1	5.9	3.8	2.5	1.8	2.2	1.5	1.1
29	3	2	1.8	0.8	0.5	0.5	0.5	0.9	1.9	3.8	4.5	4.4	4.6	5.0	5.4	5.6	6.2	7.4	8.5	8.7	7.4	6.4	4.9	4.7	3.2	2.5
29	3	3	0.6	0.4	0.4	0.7	1.7	4.8	5.8	6.4	7.1	5.6	5.1	5.6	5.9	6.5	5.3	4.4	4.6	5.9	6.1	4.9	4.2	3.9	2.4	1.6
29	5	1	0.7	0.4	0.3	0.3	0.8	1.8	6.0	10.7	11.7	7.3	6.1	6.6	5.8	5.9	5.3	5.7	5.8	5.4	3.2	2.6	2.3	2.3	1.7	1.1
29	5	2	0.6	0.2	0.2	0.1	0.4	0.9	2.5	4.7	5.2	4.6	4.3	6.5	7.2	6.7	7.1	9.0	10.2	9.4	5.9	4.6	3.4	3.0	2.1	1.4
29	5	3	0.8	0.4	0.4	0.4	0.6	1.2	3.3	6.5	8.6	6.0	5.5	5.8	6.0	5.7	6.3	7.1	7.6	8.0	5.8	4.6	3.2	2.7	2.0	1.5
29	7	1	0.5	0.3	0.3	0.3	0.9	3.7	11.3	14.8	8.7	5.7	5.0	4.5	4.6	4.9	5.4	6.4	6.1	5.7	3.5	2.2	1.4	1.5	1.3	1.0
29	7	2	1.2	0.6	0.5	0.3	0.4	0.7	1.7	4.0	4.2	4.2	4.6	5.6	6.1	6.0	6.4	8.0	9.1	8.8	7.3	6.0	5.0	4.3	3.0	2.1
29	7	3	0.7	0.6	0.4	0.4	0.6	1.6	4.4	6.0	5.3	5.1	5.2	5.7	6.3	6.5	6.4	6.2	6.2	6.3	6.5	6.0	4.6	3.8	2.9	2.3

Hourly Traffic Percentages
by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
31	1	1	0.6	0.3	0.2	0.3	0.7	2.8	7.9	9.2	8.6	6.1	5.2	5.4	5.5	5.2	5.4	5.5	5.8	5.7	5.1	4.5	3.5	2.9	2.1	1.3
31	1	2	1.2	0.6	0.4	0.3	0.3	0.8	2.0	4.4	4.8	4.1	4.3	4.9	5.6	5.9	6.4	8.0	8.9	8.5	7.9	6.4	5.1	4.2	2.9	2.1
31	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
31	3	1	0.9	0.6	0.5	0.5	0.9	2.5	7.4	11.2	10.7	6.1	4.6	4.5	4.9	4.7	4.9	5.4	5.6	6.5	5.2	3.9	2.9	2.4	2.1	1.6
31	3	2	1.4	0.8	0.5	0.4	0.4	0.8	2.6	4.8	5.6	4.1	3.9	4.2	4.7	4.9	5.7	7.5	9.5	10.7	8.1	5.7	4.4	3.9	3.0	2.2
31	3	3	2.5	1.5	0.8	0.5	0.8	0.9	1.6	2.8	4.0	5.6	7.1	7.9	8.3	8.1	7.2	6.1	5.4	5.0	5.1	5.5	4.4	3.6	3.2	2.1
31	5	1	0.6	0.3	0.2	0.1	0.2	0.9	4.2	9.6	9.6	6.1	5.3	5.6	5.9	5.7	5.9	6.1	6.0	6.2	5.6	4.9	3.8	3.2	2.4	1.6
31	5	2	0.7	0.3	0.2	0.1	0.2	0.6	2.4	4.8	5.4	4.6	4.6	5.5	6.2	6.0	6.4	7.0	8.1	9.7	9.1	5.6	4.3	3.8	2.6	1.7
31	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
31	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
31	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
31	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4
33	1	1	1.0	0.7	0.6	0.8	1.1	2.7	7.5	10.9	7.8	5.2	4.6	4.6	4.7	4.7	5.0	6.0	7.0	7.4	5.1	3.6	2.8	2.5	2.0	1.8
33	1	2	1.2	0.8	0.8	0.8	1.1	1.8	4.6	7.6	6.5	4.6	4.1	4.2	4.3	4.4	5.2	7.5	11.8	9.4	6.2	3.8	2.7	2.6	2.5	1.6
33	1	3	1.2	0.9	0.9	0.9	1.0	1.8	4.5	7.9	7.4	4.5	4.1	4.3	4.7	4.5	5.5	7.3	9.6	9.7	6.5	3.4	3.2	2.4	2.1	1.7
33	3	1	1.2	0.6	0.4	0.4	0.5	0.9	2.8	6.1	8.7	6.3	6.2	6.6	5.9	6.3	6.5	7.0	6.4	6.3	5.1	4.8	3.2	2.9	2.6	2.1
33	3	2	2.9	2.0	1.7	1.5	2.2	0.8	1.6	3.2	4.0	3.6	3.7	4.4	4.8	5.1	5.8	7.9	9.5	9.0	6.2	4.9	4.4	3.8	3.8	3.5
33	3	3	1.3	0.6	0.4	0.3	0.4	0.9	2.4	5.1	7.4	5.6	5.0	5.6	5.3	5.5	6.0	7.0	6.1	6.6	5.8	5.9	5.3	4.9	3.6	2.7
33	5	1	1.3	0.6	0.6	0.7	1.1	3.0	6.3	8.6	5.7	5.9	5.6	5.0	5.4	5.9	6.0	6.3	6.5	6.8	5.0	3.8	2.9	2.5	2.5	1.9
33	5	2	0.4	0.2	0.2	0.1	0.3	1.4	6.2	7.2	6.3	5.2	5.1	5.5	5.1	5.8	7.6	10.2	9.1	5.9	5.0	3.3	2.2	2.0	4.3	1.3
33	5	3	0.8	0.4	0.5	0.5	0.6	1.5	4.3	7.0	6.2	5.5	6.1	6.6	6.6	6.7	7.5	7.6	7.4	6.6	4.9	3.9	2.7	2.6	1.9	1.6
33	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
33	7	2	0.7	0.4	0.3	0.7	0.5	1.8	5.7	7.9	5.2	4.4	4.2	5.0	4.3	4.9	6.0	8.6	12.1	9.2	6.0	4.0	2.6	2.0	1.8	1.7
33	7	3	0.9	0.2	0.2	0.2	0.4	2.3	9.3	9.5	6.1	4.2	4.5	4.6	4.8	5.1	6.6	7.4	9.7	6.3	4.8	3.6	2.5	2.6	2.3	1.7
35	1	1	1.0	0.7	0.6	0.7	1.0	2.7	7.6	12.1	10.1	6.0	4.5	4.2	4.1	4.0	4.3	5.3	7.2	7.6	5.1	3.3	2.5	2.3	1.8	1.4
35	1	2	1.1	0.5	0.4	0.4	0.4	0.7	2.8	7.3	6.9	3.6	3.5	3.7	4.2	4.4	5.2	7.6	10.3	11.9	8.8	5.1	3.6	2.8	2.5	2.3
35	1	3	1.0	0.6	0.5	0.6	1.0	2.2	5.9	6.8	7.2	6.7	5.0	4.8	4.9	5.1	5.2	6.2	8.0	8.2	6.2	4.2	3.1	2.9	2.3	1.6
35	3	1	0.6	0.4	0.3	0.3	0.7	1.9	5.6	9.3	8.5	5.7	5.0	4.9	5.4	5.1	5.5	6.3	6.8	7.4	6.1	4.8	3.4	2.6	2.1	1.3
35	3	2	0.9	0.5	0.3	0.2	0.4	0.9	2.6	4.5	4.8	4.1	4.3	4.7	4.9	4.9	5.6	7.2	9.9	11.7	9.3	6.1	4.1	3.6	2.5	2.1
35	3	3	0.9	0.4	0.3	0.3	0.6	1.7	5.1	7.5	7.1	5.5	5.1	5.5	5.7	5.6	5.8	6.5	7.3	7.4	6.2	4.8	3.7	3.1	2.3	1.6
35	5	1	0.6	0.3	0.2	0.1	0.2	0.9	4.2	9.6	9.6	6.1	5.3	5.6	5.9	5.7	5.9	6.1	6.0	6.2	5.6	4.9	3.8	3.2	2.4	1.6
35	5	2	0.7	0.3	0.2	0.1	0.2	0.6	2.4	4.8	5.4	4.6	4.6	5.5	6.2	6.0	6.4	7.0	8.1	9.7	9.1	5.6	4.3	3.8	2.6	1.7
35	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
35	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
35	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
35	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4

Hourly Traffic Percentages
by County from CMS

CC	FT	PT	1AM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
37	1	1	1.3	1.2	1.3	1.6	2.6	5.7	12.2	13.5	7.9	4.6	3.9	3.8	3.7	3.9	4.5	4.2	4.0	4.4	3.6	2.7	2.6	2.5	2.4	1.7
37	1	2	1.5	1.2	0.8	0.7	0.9	1.2	1.8	3.1	3.2	3.5	4.2	4.5	4.9	4.7	5.6	8.1	10.3	9.8	8.6	6.4	4.8	4.3	3.4	2.5
37	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
37	3	1	0.4	0.2	0.3	0.5	1.1	6.0	11.7	11.3	9.2	6.6	5.3	5.1	4.9	4.6	4.6	5.1	5.0	4.9	4.0	3.0	2.0	1.8	1.5	0.9
37	3	2	0.8	0.5	0.3	0.3	0.5	1.3	2.4	2.9	3.1	3.3	4.0	4.6	4.8	5.5	7.5	9.9	11.5	10.6	7.8	5.8	4.8	3.7	2.5	1.6
37	3	3	0.6	0.4	0.4	0.7	1.7	4.8	5.8	6.4	7.1	5.6	5.1	5.6	5.9	6.5	5.3	4.4	4.6	5.9	6.1	4.9	4.2	3.9	2.4	1.6
37	5	1	0.5	0.3	0.2	0.5	0.9	4.3	9.8	9.1	8.4	5.9	5.1	5.3	5.2	4.6	5.1	5.0	5.5	5.8	5.0	3.7	3.8	2.7	2.0	1.3
37	5	2	1.2	0.5	0.3	0.2	0.3	0.6	1.7	3.9	4.9	4.4	4.4	4.5	4.6	4.9	5.6	8.1	9.8	9.7	9.2	6.4	5.1	4.6	3.0	2.2
37	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
37	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
37	7	2	0.7	0.4	0.3	0.7	0.5	1.8	5.7	7.9	5.2	4.4	4.2	5.0	4.3	4.9	6.0	8.6	12.1	9.2	6.0	4.0	2.6	2.0	1.8	1.7
37	7	3	0.9	0.2	0.2	0.2	0.4	2.3	9.3	9.5	6.1	4.2	4.5	4.6	4.8	5.1	6.6	7.4	9.7	6.3	4.8	3.6	2.5	2.6	2.3	1.7
39	1	1	1.0	0.7	0.6	0.7	1.1	2.8	8.0	12.1	11.1	6.4	4.6	4.2	4.0	3.9	4.3	5.0	6.5	7.1	5.0	3.3	2.4	2.1	1.8	1.4
39	1	2	2.1	1.3	0.8	0.4	0.5	0.8	1.6	2.1	2.5	3.7	4.8	5.2	5.3	5.8	6.5	6.5	7.8	8.0	7.7	7.3	6.7	5.5	4.2	2.9
39	1	3	1.6	1.2	0.6	0.7	0.8	1.4	3.3	4.2	5.0	5.7	6.5	6.4	6.1	5.6	6.2	6.1	6.1	6.1	6.0	5.0	4.5	4.1	3.7	3.1
39	3	1	0.7	0.4	0.3	0.3	0.6	1.8	5.2	8.4	8.1	5.8	5.1	5.3	5.7	5.6	5.7	6.2	6.6	6.9	5.9	4.9	3.7	3.1	2.3	1.5
39	3	2	1.4	0.8	0.7	0.4	0.5	1.2	2.9	4.7	5.2	4.7	5.1	5.6	6.1	6.1	6.4	7.3	8.1	7.9	6.7	5.5	4.4	3.5	2.7	2.1
39	3	3	1.0	0.5	0.4	0.3	0.6	1.6	4.2	7.2	7.6	5.6	5.1	5.4	5.7	5.6	6.0	6.8	7.3	7.1	6.0	5.0	3.9	3.2	2.4	1.8
39	5	1	1.8	0.7	0.8	0.5	1.0	2.3	6.9	10.2	12.6	7.5	4.5	5.2	5.0	5.4	6.4	5.7	6.0	5.3	3.8	2.6	1.9	1.4	1.4	1.1
39	5	2	1.2	0.7	0.4	0.3	0.3	0.7	1.7	3.4	4.5	5.1	5.4	6.1	6.7	7.0	7.0	7.1	7.5	7.7	7.1	6.0	5.1	4.2	2.8	1.9
39	5	3	1.1	0.6	0.4	0.3	0.4	1.3	3.6	6.0	6.8	5.6	5.4	5.6	6.1	5.8	6.1	6.7	7.0	7.3	6.3	5.4	4.2	3.5	2.7	1.9
39	7	1	0.8	0.4	0.4	0.3	0.5	1.1	3.9	7.3	9.6	5.0	4.5	4.7	6.1	6.5	6.4	5.8	6.6	7.4	6.0	5.2	4.1	3.0	2.5	1.9
39	7	2	1.2	0.5	0.3	0.1	0.2	0.5	2.3	4.2	5.2	4.5	4.6	5.7	7.4	6.4	6.5	7.1	7.9	9.0	7.2	6.4	5.1	3.6	2.4	1.7
39	7	3	0.6	0.3	0.1	0.1	0.2	0.6	2.8	6.5	7.9	5.6	4.3	5.0	5.6	6.0	5.9	7.4	7.9	8.3	7.4	5.7	4.3	3.5	2.4	1.4
41	1	1	1.3	1.2	1.3	1.6	2.6	5.7	12.2	13.5	7.9	4.6	3.9	3.8	3.7	3.9	4.5	4.2	4.0	4.4	3.6	2.7	2.6	2.5	2.4	1.7
41	1	2	1.5	1.2	0.8	0.7	0.9	1.2	1.8	3.1	3.2	3.5	4.2	4.5	4.9	4.7	5.6	8.1	10.3	9.8	8.6	6.4	4.8	4.3	3.4	2.5
41	1	3	0.9	0.5	0.4	0.4	0.7	1.9	6.1	7.7	6.9	5.1	4.3	4.5	4.8	4.8	5.1	6.2	7.4	7.6	6.1	5.1	4.2	4.2	3.1	1.9
41	3	1	0.4	0.2	0.3	0.5	1.1	6.0	11.7	11.3	9.2	6.6	5.3	5.1	4.9	4.6	4.6	5.1	5.0	4.9	4.0	3.0	2.0	1.8	1.5	0.9
41	3	2	0.8	0.5	0.3	0.3	0.5	1.3	2.4	2.9	3.1	3.3	4.0	4.6	4.8	5.5	7.5	9.9	11.5	10.6	7.8	5.8	4.8	3.7	2.5	1.6
41	3	3	0.9	0.4	0.3	0.3	0.6	1.7	5.1	7.5	7.1	5.5	5.1	5.5	5.7	5.6	5.8	6.5	7.3	7.4	6.2	4.8	3.7	3.1	2.3	1.6
41	5	1	0.9	0.7	0.8	1.0	1.9	4.6	8.5	9.3	6.3	5.2	5.2	5.2	5.5	5.4	5.2	5.1	5.2	5.3	4.5	3.9	3.4	2.8	2.5	1.6
41	5	2	1.2	0.8	0.7	0.7	0.7	1.1	2.4	4.1	4.4	4.7	4.7	5.4	5.6	5.4	5.5	7.4	9.2	9.9	7.6	5.6	4.5	3.8	2.5	2.1
41	5	3	0.6	0.3	0.1	0.1	0.3	0.8	3.4	5.7	6.6	6.1	5.6	6.2	6.6	6.4	6.8	6.8	6.8	6.9	6.5	5.8	4.0	3.6	2.5	1.4
41	7	1	0.9	0.3	0.3	0.4	0.5	0.8	4.0	11.3	9.2	5.9	5.2	6.0	6.4	5.2	5.9	8.6	7.5	6.1	4.6	3.0	2.9	2.3	1.6	1.2
41	7	2	0.7	0.4	0.3	0.7	0.5	1.8	5.7	7.9	5.2	4.4	4.2	5.0	4.3	4.9	6.0	8.6	12.1	9.2	6.0	4.0	2.6	2.0	1.8	1.7
41	7	3	0.9	0.2	0.2	0.2	0.4	2.3	9.3	9.5	6.1	4.2	4.5	4.6	4.8	5.1	6.6	7.4	9.7	6.3	4.8	3.6	2.5	2.6	2.3	1.7

APPENDIX C

Computation Worksheets

Worksheet 3.1: Analysis of the Work Zone

Work Zone: ____________________ **Normal Capacity:** ________
Percent Trucks: ________ **Percent Cars:** ________ **Work Zone/Detour Capacity:** ________
Directional ADT: ________ **Year:** ________ **Lanes Under Normal Operation:** ________

3.1(A)	3.1(B)	3.1(C)	3.1(D)	3.1(E)	3.1(F)	3.1(G)	3.1(H)	3.1(I)	3.1(J)	3.1(K)
Time Period (hour)	Hourly Traffic (%)	Vehicle Demand (vph)	Lanes Open (#)	Roadway Capacity (vph)	Queue Rate (vph)	Queued Vehicles (vph)	Average Queued Vehicles (vph)	Vehicles that Travel Work Zone (vph)	Vehicles that Travel Detour (vph)	Vehicles that Travel Queue (vph)
12-1 AM										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12 PM										
12-1										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7										
7-8										
8-9										
9-10										
10-11										
11-12										
TOTALS										

Project: ______________________________ **Date:** ____________
Description: ______________________________

Worksheet 3.2: Queue Delay

	3.2(A)	3.2(B)	3.2(C)	3.2(D)	3.2(E)	3.2(F)	3.2(G)	3.2(H)
	Queue Period (hour)	Queue Volume (veh/hr)	Normal Capacity (veh/hr)	V/C Ratio	Average Queue Speed (mph)	Unrestricted Speed (mph)	Average Queued Vehicles per Queue Period (#)	Queue Lanes (#)
1								
2								
3								
4								
5								

	3.2(I)	3.2(J)	3.2(K)	3.2(L)	3.2(M)	3.2(N)	3.2(O)
	Average Vehicle Length (feet/veh)	Average Queue Length (mile)	Queue Travel Time at Unrestricted Speed (hr/veh)	Queue Travel Time at Queue Speed (hr/veh)	Added Time to Travel Queue (hr/veh)	Affected Vehicles per Queue Period (#)	Added Time per Queue Period (hour)
1							
2							
3							
4							
5							
			Totals				
			Added Time Weighted Average				hr/veh

Project: ______________________________ **Date:** ______________

Description: ____

Worksheet 3.3: Work Zone and Circuity (Detour) Delays

Work Zone Delay

3.3(A)	3.3(B)	3.3(C)	3.3(D)	3.3(E)	3.3(F)
Work Zone Length (mile)	Work Zone Speed (mph)	Unrestricted Speed (mph)	Work Zone Travel Time at Unrestricted Speed (hr/veh)	Work Zone Travel Time at Work Zone Speed (hr/veh)	Added Time to Travel Work Zone (hr/veh)

Circuity (Detour) Delay

3.3(G)	3.3(H)	3.3(I)	3.3(J)	3.3(K)	3.3(L)
Travel Length without Detour (mile)	Travel Length with Detour (mile)	Added Travel Length (mile)	Travel Time without Detour (hr/veh)	Travel Time with Detour (hr/veh)	Added Time to Travel Detour (hr/veh)

Alternating Traffic (Flagging) Delay

Flagging Zone Length (mile)	Flagging Zone Speed (mph)	Unrestricted Speed (mph)	Flagging Zone Travel Time at Unrestricted Speed (hr/veh)	Flagging Zone Travel Time at Flagging Zone Speed (hr/veh)	Added Time to Travel Flagging Zone (hr/veh)	Approach Vehicle Wait Time (hr/veh)

Project: ______________________________ **Date:** ____________

Description: ______________________________

Worksheet 3.4: Escalation Factors and Cost Rates

Escalation Factors

3.4(A)	3.4(B)	3.4(C)	3.4(D)
Cost Factors	1970 (CPI-U)	Current (CPI-U)*	Escalation Factor
IDLING and VOC (transportation component)	37.5		
TIME VALUE (all components)	38.8		

* CPI-U = Unadjusted Consumer Price Index for all Urban Consumers, US City Average

Cost Rates

3.4(E)	3.4(F)	3.4(G)	3.4(H)	3.4(I)	3.4(J)	3.4(K)
Vehicle Class	1970 Time Value Cost Rate ($/veh-hr)	1970 Idling Cost Rate ($/veh-hr)	1970 VOC Cost Rate ($/mile)	Current Time Value Cost Rate ($/veh-hr)	Current Idling Cost Rate ($/veh-hr)	Current VOC Cost Rate ($/mile)
CAR	3.00	0.1819	0.06			
TRUCK	5.00	0.2092	0.12			

Project: ______________________________ **Date:** ______________

Description: ______________________________

Worksheet 3.5: Road User Costs

3.5(A)	3.5(B)	3.5(C)	3.5(D)	3.5(E)	3.5(F)	3.5(G)	3.5(H)
Road User Cost Component	**Vehicle Class**	**Percent Class (%)**	**Total Vehicles (#)**	**Added Travel Length (mile/veh)**	**Added Time (hr/veh)**	**Cost Rate ($/veh-hr, $/mile)**	**Road User Cost ($)**
Queue Delay (Added Time)	CAR						
	TRUCK						
Queue Idling VOC (Added Cost)	CAR						
	TRUCK						
Work Zone Delay (Added Time)	CAR						
	TRUCK						
Circuity Delay (Added Time)	CAR						
	TRUCK						
Circuity VOC (Added Cost)	CAR						
	TRUCK						

Total Vehicles that Travel Queue: ___________

Total Vehicles that Travel Work Zone: ___________

Total Vehicles that Travel Detour: ___________

Percent Passenger Cars: ___________

Percent Trucks: ___________

Daily Road User Cost	
Calculated Road User Cost (CRUC)	
Number of Work Zone Days	
Total Road User Cost	

Project: ______________________________ **Date:** ______________

Description: ______________________________